Objectives

• Describe the Superpave mixture requirements for a highway-class dense-graded asphalt paving mixture
  • AASHTO M 323

• Summarize the Superpave mix design process
  • AASHTO R 35
### Standard Practice for

**Superpave Volumetric Design for Hot-Mix Asphalt (HMA)**

**AASHTO Designation:** R 35-04

1. **SCOPE**
   
   1.1. This standard for mix design evaluation uses aggregate and mixture properties to produce a hot-mix asphalt (HMA) job-mix formula. The mix design is based on the volumetric properties of the HMA in terms of the air voids, voids in the mineral aggregate (VMA), and voids filled with asphalt (VFA).
   
   1.2. This standard may also be used to provide a preliminary selection of mix parameters as a starting point for mix analysis and performance prediction analyses that primarily use T 320 and T 322.
   
   1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. **REFERENCED DOCUMENTS**

   2.1. AASHTO Standards:
   
   - M 320, Performance-Graded Asphalt Binder
   - M 323, Superpave Volumetric Mix Design
   - R 30, Mixture Conditioning of Hot-Mix Asphalt (HMA)
   - T 2, Sampling of Aggregates
   - T 11, Material Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
   - T 27, Sieve Analysis of Fine and Coarse Aggregates
   - T 164, Quantitative Extraction of Asphalt Binder from Hot-Mix Asphalt (HMA)
   - T 178, Recovery of Asphalt from Solution by Absorb Method
   - T 176, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
   - T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
   - T 304, Uncompacted Void Content of Fine Aggregate
   - T 308, Determining the Asphalt Binder Content of Hot-Mix Asphalt (HMA) by the Ignition Method
   - T 312, Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

### Standard Specification for

**Superpave Volumetric Mix Design**

**AASHTO Designation:** M 323-07

1. **SCOPE**

   1.1. This specification for Superpave volumetric mix design uses aggregate and mixture properties to produce a hot-mix asphalt (HMA) job-mix formula.
   
   1.2. This standard specifies minimum quality requirements for binder, aggregate, and HMA for Superpave volumetric mix designs.
   
   1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. **REFERENCED DOCUMENTS**

   2.1. **AASHTO Standards:**
   
   - M 320, Performance-Graded Asphalt Binder
   - R 35, Superpave Volumetric Design for Hot-Mix Asphalts (HMA)
   - T 11, Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
   - T 27, Sieve Analysis of Fine and Coarse Aggregates
   - T 164, Quantitative Extraction of Asphalt Binder from Hot-Mix Asphalt (HMA)
   - T 178, Recovery of Asphalt from Solution by Absorb Method
   - T 176, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
   - T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
   - T 304, Uncompacted Void Content of Fine Aggregate
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   - T 312, Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
Mix Type Selection

- Select the right mix type for the pavement application
  - type of traffic/loads
  - layer-specific needs

NAPA Publication IS-128
4 Steps of Superpave Mix Design

1. Materials selection
2. Design aggregate structure
3. Design binder content
4. Moisture sensitivity
Pre-Mix Design
Selection of Mixture Requirements

- Project traffic
  - 20-year design-lane ESALs
- Project pavement cross-section
  - Layer thicknesses
- Pavement layer asphalt binder selection
  or project location
Goals of Laboratory Compaction

- Simulate field densification
  - Construction
  - Traffic – affected by binder grade and pavement temperature
- Assess the mixture’s compactability
In-Place HMA Density Change over Time/Traffic

After construction

After about three years, there is typically no further increase in density unless traffic loads increase.
Superpave Gyratory Compactor

- 150 mm diameter mold accommodates up to 37.5 mm NMAS
- Heights recorded through compaction process

ram pressure
600 kPa

150 mm diameter

1.16 degrees

30 gyrations per minute
SGC Makes & Models

- Troxler 4141
- Troxler 5850
- Pine AFGB1
- Pine AFG2
- IPC Servopac
Gyratory Compaction

- Density of mixtures is evaluated at three points:
  1. $N_{\text{initial}}$
  2. $N_{\text{design}}$
  3. $N_{\text{maximum}}$

- The density at $N_{\text{design}}$ ($%G_{mm@N_{\text{design}}}$) is the most important of these three points. It is where volumetric properties are determined.

- The density at $N_{\text{initial}}$ ($%G_{mm@N_{\text{initial}}}$) is used to assess the strength of the aggregate structure.

- The density at $N_{\text{maximum}}$ ($%G_{mm@N_{\text{maximum}}}$) is used to determine if the mix may tend to continue to densify under long-term heavy traffic.
## Current AASHTO R35 $N_{\text{design}}$ Table

<table>
<thead>
<tr>
<th>Traffic Level Million ESALs</th>
<th>Compaction Level</th>
<th>$N_{\text{initial}}$</th>
<th>$N_{\text{design}}$</th>
<th>$N_{\text{maximum}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td></td>
<td>6</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>0.3 to &lt; 3.0</td>
<td></td>
<td>7</td>
<td>75</td>
<td>115</td>
</tr>
<tr>
<td>3.0 to &lt; 30.0</td>
<td></td>
<td>8</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>&gt; 30.0</td>
<td></td>
<td>9</td>
<td>125</td>
<td>205</td>
</tr>
</tbody>
</table>

**Note:** Most states use different $N_{\text{design}}$ levels
4 Steps of Superpave Mix Design

1. Materials selection
2. Design aggregate structure
3. Design binder content
4. Moisture sensitivity
Step 1: Materials Selection

• Binder selection
  • The binder grade is specified in nearly all cases
  • Selecting binder supplier usually based on cost

• Aggregates selection
  • Must comply with specified criteria
  • Choice of aggregates usually limited to locally available materials
  • NMAS is typically selected based on layer thickness
Example Project

- Project on I-43
- Milwaukee, Wisconsin
- 18,000,000 ESAL Design
- Asphalt overlay - 120 mm total thickness
  - 40 mm - wearing course (12.5 mm NMAS)
  - 80 mm - intermediate course (19.0 mm NMAS)
Asphalt Binder Grades
Milwaukee, Wisc.
Climate Based Selection

Pavement Temperature (°C), Milwaukee, Wisc.
Binder Selection: Milwaukee, Wisc.

<table>
<thead>
<tr>
<th></th>
<th>PG 52-28</th>
<th>PG 58-34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability (%)</td>
<td>50</td>
<td>74.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>99.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>99.6</td>
</tr>
</tbody>
</table>

Selected PG 58-34

http://www.tfhrc.gov/pavement/ltpp/ltppbind.htm
Adjusting the virgin binder grade

• Increase the high PG by one grade when:
  • traffic speed is slow (e.g. between 20 and 70 km/h (12 to 43 mph))

• Increase the high PG by two grades when:
  • traffic speed is standing (e.g. less than 20 km/h (12 mph))

• Decrease the high and low PG by one grade when:
  • RAP content is more than 25 percent (RAP binder ratio > 0.25)
Mixing and Compaction Temperatures

Mixing Range: 165-172°C
Compaction Range: 151-157°C
Available Aggregates

Available stockpiles
- #56
- #67
- #8
- #10
- Natural sand
4 Steps of Superpave Mix Design

1. Materials selection

2. Design aggregate structure

3. Design binder content

4. Moisture sensitivity

TSR
Step 2: Design the Aggregate Structure

- Establish trial blends
- Check aggregate consensus properties
- Compact specimens
- Evaluate volumetric properties of trial blends
- Select design aggregate structure
Consensus Aggregate Properties

See criteria in AASHTO M 323
## Consensus Aggregate Requirements

<table>
<thead>
<tr>
<th>Design EASLs Millions</th>
<th>Fracture Faces Coarse Agg. Min. %</th>
<th>Uncomp. Voids Fine Agg. Min. %</th>
<th>Sand Equiv. Min. %</th>
<th>Flat &amp; Elong. Max. %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth from Surface</td>
<td>Depth from Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 100 mm</td>
<td>&gt; 100 mm</td>
<td>≤ 100 mm</td>
<td>&gt; 100 mm</td>
<td></td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>55/–</td>
<td>–</td>
<td>40</td>
<td>–</td>
</tr>
<tr>
<td>0.3 to &lt;3</td>
<td>75/–</td>
<td>50/–</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>3 to &lt;10</td>
<td>85/80</td>
<td>60/–</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>10 to &lt;30</td>
<td>95/90</td>
<td>80/75</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>≥30</td>
<td>100/100</td>
<td>100/100</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

All consensus aggregate requirements apply to the blend, not the individual components.

See M323 for other notes

one face/two faces
# Example Coarse Agg. Angularity

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>1+ Frac Faces</th>
<th>Criterion</th>
<th>2+ Frac Faces</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>#56</td>
<td>92%</td>
<td></td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>#67</td>
<td>97%</td>
<td>95% min</td>
<td>94%</td>
<td>90% min</td>
</tr>
<tr>
<td>#8</td>
<td>99%</td>
<td></td>
<td>95%</td>
<td></td>
</tr>
</tbody>
</table>

ASTM D 5821 Determining the Percentage of Fractured Particles in Coarse Aggregate
### Example Flat & Elongated Particles

#### TEST RESULTS

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>% Flat &amp; Elongated</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>#56</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>#67</td>
<td>0%</td>
<td>10% max</td>
</tr>
<tr>
<td>#8</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

ASTM D 4791 Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
### Example Fine Aggregate Angularity

#### TEST RESULTS

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>%Uncomp. Voids</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>48%</td>
<td>45% min</td>
</tr>
<tr>
<td>Natural sand</td>
<td>43%</td>
<td></td>
</tr>
</tbody>
</table>

AASHTO T 304 Uncompacted Void Content of Fine Aggregate
## Example Sand Equivalent

### TEST RESULTS

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Sand Equivalent</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>47</td>
<td>45 min</td>
</tr>
<tr>
<td>Nat. sand</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

AASHTO T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
## Example Trial Blends

<table>
<thead>
<tr>
<th></th>
<th>Trial blend 1</th>
<th>Trial blend 2</th>
<th>Trial blend 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>#56</td>
<td>25%</td>
<td>30%</td>
<td>10%</td>
</tr>
<tr>
<td>#67</td>
<td>15%</td>
<td>20%</td>
<td>15%</td>
</tr>
<tr>
<td>#8</td>
<td>17%</td>
<td>13%</td>
<td>20%</td>
</tr>
<tr>
<td>#10</td>
<td>18%</td>
<td>10%</td>
<td>26%</td>
</tr>
<tr>
<td>Nat. sand</td>
<td>10%</td>
<td>12%</td>
<td>14%</td>
</tr>
<tr>
<td>RAP</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>
I-43 Trial Blend Gradations

19.0 mm NMAS Mixture

Trial blend 1

Trial blend 2

Trial blend 3
Choosing a Gradation

- Finer Gradations
- More Compactable
- More Workable
- Less Permeable
BLENDED AGGREGATE PROPERTIES ARE DETERMINED

<table>
<thead>
<tr>
<th>Property</th>
<th>Criteria</th>
<th>Blend 1</th>
<th>Blend 2</th>
<th>Blend 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Ang.</td>
<td>95%/90% min.</td>
<td>96%/92%</td>
<td>95%/92%</td>
<td>97%/93%</td>
</tr>
<tr>
<td>Fine Ang.</td>
<td>45% min.</td>
<td>46%</td>
<td>46%</td>
<td>48%</td>
</tr>
<tr>
<td>Flat/Elongated</td>
<td>10% max.</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Sand Equiv.</td>
<td>45 min.</td>
<td>59</td>
<td>58</td>
<td>54</td>
</tr>
<tr>
<td>Combined $G_{sb}$</td>
<td>n/a</td>
<td>2.699</td>
<td>2.697</td>
<td>2.701</td>
</tr>
<tr>
<td>Combined $G_{sa}$</td>
<td>n/a</td>
<td>2.768</td>
<td>2.769</td>
<td>2.767</td>
</tr>
</tbody>
</table>
Compact Specimens (Trial Blends)

- Establish a trial asphalt binder content
- Establish trial aggregate weights
- Batch, mix, and compact specimens
- Determine $N_{ini}$ and $N_{des}$
- Calculate mixture properties
Specimen Preparation

• Specimen height
  • Compacted $N_{des}$ specimens: 115±5 mm (~4700 g)

• Loose specimen for $G_{mm}$ (Rice)
  • Varies with nominal max size
    • 19.0 mm (2500 g)
    • 12.5 mm (1500 g)
Batching Samples of Trial Blends
Mix Conditioning

Two hours at the compaction temperature
Set SGC to Design
Number of Gyrations
<table>
<thead>
<tr>
<th>Traffic Level Million ESALs</th>
<th>Compaction Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N_{\text{initial}}$</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>6</td>
</tr>
<tr>
<td>0.3 to &lt; 3.0</td>
<td>7</td>
</tr>
<tr>
<td>3.0 to &lt; 30.0</td>
<td>8</td>
</tr>
<tr>
<td>&gt; 30.0</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: Most states use different $N_{\text{design}}$ levels
Compact samples, then extrude immediately.
Remove paper immediately and label samples
Measure $G_{mb}$, $G_{mm}$ and Calculate Volumetric Properties
Superpave Mixture Requirements

• Mixture volumetric properties
  • Air voids
  • Voids in the mineral aggregate (VMA)
  • Voids filled with asphalt (VFA)
• Dust to Binder Ratio
• \%G_{mm} @ N_{ini}
Air Voids ($V_a$)

Calculated using bulk specific gravity ($G_{mb}$) and maximum specific gravity ($G_{mm}$) of the mix

$$V_a = 100 \times \frac{G_{mm} - G_{mb}}{G_{mm}}$$

$$\%G_{mm} = 100 - V_a$$
Voids in Mineral Aggregate (VMA)

\[ VMA = 100 - \frac{G_{mb} \times (1-P_b)}{G_{sb}} \]

\[ VMA = V_a + V_{be} \]

\( V_{be} = \) volume of effective binder

It is the most important parameter to ensure mix durability
Voids Filled with Asphalt

VFA = 100 x \( \frac{VMA - V_a}{VMA} \)

VFA is the percentage of VMA that is filled with asphalt binder

If Va is fixed at 4.0% and a min. VMA is given, then and the min. VFA is redundant.
Calculation of $\%G_{mm} @ N_{ini}$

To calculate the $\%G_{mm} @ N_{ini}$, you need the $\%G_{mm} @ N_{des}$ and the heights from the SGC at $N_{des}$ and $N_{initial}$

$$\%G_{mm} @ N_{ini} = (\%G_{mm} @ N_{des}) \times \frac{Ht. @ N_{ini}}{Ht. @ N_{des}}$$
### Superpave Volumetric Criteria

**AASHTO M323**

<table>
<thead>
<tr>
<th>Traffic Million ESALs</th>
<th>SGC Compaction % of $G_{mm}$</th>
<th>VMA (%)</th>
<th>VFA (%)</th>
<th>Dust to Binder Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N_{ini}$</td>
<td>$N_{des}$</td>
<td>$N_{max}$</td>
<td>see next slide</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>$\leq 91.5$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 3</td>
<td>$\leq 90.5$</td>
<td>= 96.0</td>
<td>$\leq 98.0$</td>
<td></td>
</tr>
<tr>
<td>&gt; 3</td>
<td>$\leq 89.5$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$N_{max}$ is not evaluated for the trial blends. It is checked later.

See M323 Table 6 for footnotes.
Superpave VMA Requirements

<table>
<thead>
<tr>
<th>Nominal Max Size (mm)</th>
<th>Minimum VMA %</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>16.0</td>
</tr>
<tr>
<td>9.5</td>
<td>15.0</td>
</tr>
<tr>
<td>12.5</td>
<td>14.0</td>
</tr>
<tr>
<td>19.0</td>
<td>13.0</td>
</tr>
<tr>
<td>25.0</td>
<td>12.0</td>
</tr>
<tr>
<td>37.5</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Some agencies set higher VMA criteria
### Trial Blend Results

<table>
<thead>
<tr>
<th>Property</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial binder content</td>
<td>4.4%</td>
<td>4.4%</td>
<td>4.4%</td>
</tr>
<tr>
<td>$%G_{mm} @ N_{des}$</td>
<td>96.2%</td>
<td>95.7%</td>
<td>95.2%</td>
</tr>
<tr>
<td>$%G_{mm} @ N_{ini}$</td>
<td>87.1%</td>
<td>85.6%</td>
<td>86.3%</td>
</tr>
<tr>
<td>%Air voids</td>
<td>3.8%</td>
<td>4.3%</td>
<td>4.8%</td>
</tr>
<tr>
<td>%VMA</td>
<td>12.7%</td>
<td>13.0%</td>
<td>13.5%</td>
</tr>
<tr>
<td>%VFA</td>
<td>68.5%</td>
<td>69.2%</td>
<td>70.1%</td>
</tr>
<tr>
<td>Dust/Binder Ratio</td>
<td>0.9</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Estimating $P_b$ to get 4.0% $V_a$ for the Trial Blends

Determine the difference in avg. air void content at $N_{des}$ ($\Delta V_a$) for each trial blend from the target of 4.0%:

$$\Delta V_a = 4.0 - V_a$$

Example (Blend 1) \hspace{0.5cm} \Delta V_a = 4.0 - 3.8 = 0.2\%$

Estimate the change in binder content ($\Delta P_b$) needed to change the air void content to 4.0%:

$$\Delta P_b = -0.4 \times \Delta V_a$$

Example (Blend 1) \hspace{0.5cm} \Delta P_b = -0.4 \times 0.2\% = -0.08\%$
Adjusting the VMA

Estimate the change in VMA

$$\Delta VMA = 0.2 \times \Delta Va \quad \text{if } V_{a_{trial}} > 4.0$$
$$\Delta VMA = -0.1 \times \Delta Va \quad \text{if } V_{a_{trial}} < 4.0$$

$$VMA_{est} = VMA_{trial} + \Delta VMA$$

Example (Blend 1)

$$\Delta VMA = -0.1 \times 0.2 = -0.02\%$$
$$VMA_{est} = 12.7\% + (-0.02\%) = 12.7\%$$
Adjusting $\%G_{mm@N_{ini}}$

Estimate the change in $\%G_{mm@N_{ini}}$

$$\%G_{mm@N_{ini}}^{est} = \%G_{mm@N_{ini}}^{trial} - \Delta V_a$$

Example (Blend 1)

$$\%G_{mm@N_{ini}}^{est} = 87.1\% - 0.2\% = 86.9\%$$
Adjusting Dust to Binder Ratio

Estimate the change in DP

\[ P_{be\text{est}} = P_{be\text{trial}} + \Delta Pb \]

\[ D/B \text{ Ratio}_{est} = P_{0.075} / P_{be\text{est}} \]

Example (Blend 1)

\[ P_{be\text{est}} = 4.4\% + (-0.08\%) = 4.3\% \]

\[ D/B \text{ Ratio}_{est} = P_{0.075} / P_{be\text{est}} = 3.9/4.3\% = 0.9 \]
### Compare Adjusted Trial Blend Results to Mixture Criteria

<table>
<thead>
<tr>
<th>Property</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial binder content</td>
<td>4.3%</td>
<td>4.5%</td>
<td>4.7%</td>
<td></td>
</tr>
<tr>
<td>$% G_{mm} @ N_{ini}$</td>
<td>86.9%</td>
<td>85.9%</td>
<td>87.1%</td>
<td>&lt; 89%</td>
</tr>
<tr>
<td>%Air voids</td>
<td>4.0%</td>
<td>4.0%</td>
<td>4.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>%VMA</td>
<td>12.7%</td>
<td>13.0%</td>
<td>13.3%</td>
<td>≥ 13.0%</td>
</tr>
<tr>
<td>%VFA</td>
<td>68.5%</td>
<td>69.2%</td>
<td>70.1%</td>
<td>65-75%</td>
</tr>
<tr>
<td>Dust/Binder Ratio</td>
<td>0.9</td>
<td>0.8</td>
<td>0.9</td>
<td>0.6-1.2</td>
</tr>
</tbody>
</table>
Select the Design Aggregate Structure

• What if none of the trial blends are acceptable?
  • Recombine existing aggregates to form additional blends (i.e., blend 4, blend 5, etc.)
  • Add one or more new aggregate materials and make new blends
  • Repeat step 2 of the process
I-43 Trial Blend Gradations

19.0 mm NMAS Mixture

Sieve size (mm)

% Passing

Trial blend 4

% Passing

0 10 20 30 40 50 60 70 80 90 100

0.075 2.36 9.5 19.0

NAPA Webinars
4 Steps of Superpave Mix Design

1. Materials selection
2. Design aggregate structure
3. Design binder content
4. Moisture sensitivity
Step 3: Design Binder Content

• The selected trial blend becomes the design aggregate structure
• Batch, mix, and compact more samples with this gradation with four asphalt contents
• Determine volumetric properties
• Select Pb at 4.0% air voids and check other volumetric properties
• Compact an additional set to $N_{\text{max}}$ for check
## Design Binder Content Samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Binder content (4.2%)</th>
<th>4.7%</th>
<th>5.2%</th>
<th>5.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{mm} @ N_{ini}$</td>
<td>85.7%</td>
<td>87.1%</td>
<td>87.4%</td>
<td>88.6%</td>
</tr>
<tr>
<td>$G_{mm} @ N_{des}$</td>
<td>94.6%</td>
<td>96.1%</td>
<td>97.1%</td>
<td>98.2%</td>
</tr>
<tr>
<td>%Air voids</td>
<td>5.4%</td>
<td>3.9%</td>
<td>2.9%</td>
<td>1.8%</td>
</tr>
<tr>
<td>%VMA</td>
<td>13.3%</td>
<td>13.1%</td>
<td>13.3%</td>
<td>13.5%</td>
</tr>
<tr>
<td>%VFA</td>
<td>59.4%</td>
<td>70.2%</td>
<td>78.2%</td>
<td>86.7%</td>
</tr>
<tr>
<td>Dust/Binder Ratio</td>
<td>1.0</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>
Mix Air Voids Requirement

4.0 % at $N_{des}$

Regardless of the Traffic Level

Some agencies target lower air void contents for some or all mixes
Air Voids: Example Mix Design

I-43 Binder, Blend 3

% ASPHALT BINDER

Air Voids = 4.0 %
Mix VMA Requirements
Voids in the Mineral Aggregate

<table>
<thead>
<tr>
<th>Nom Max Size (mm)</th>
<th>Minimum VMA %</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>16.0</td>
</tr>
<tr>
<td>9.5</td>
<td>15.0</td>
</tr>
<tr>
<td>12.5</td>
<td>14.0</td>
</tr>
<tr>
<td>19.0</td>
<td>13.0</td>
</tr>
<tr>
<td>25.0</td>
<td>12.0</td>
</tr>
<tr>
<td>37.5</td>
<td>11.0</td>
</tr>
</tbody>
</table>

% binder

VMA
**VMA: Example Mix Design**

I-43 Binder, Blend 3

<table>
<thead>
<tr>
<th>% Asphalt Binder</th>
<th>VMA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7</td>
<td>14.5</td>
</tr>
<tr>
<td>4.2</td>
<td>13.5</td>
</tr>
<tr>
<td>4.7</td>
<td>13.1</td>
</tr>
<tr>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>

VMA = 13.1%
Mix VFA Requirement
Voids Filled with Asphalt

<table>
<thead>
<tr>
<th>Traffic 10^6 ESALs</th>
<th>Range of VFA %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>70 - 80</td>
</tr>
<tr>
<td>0.3 to ≤ 3</td>
<td>65 - 78</td>
</tr>
<tr>
<td>&gt; 3</td>
<td>65 - 75</td>
</tr>
</tbody>
</table>
VFA: Example Mix Design

I-43 Binder, Blend 3

% ASPHALT BINDER

VFA = 70%
Criteria for Dust/Binder Ratio

\[
\frac{\% \text{ mass of } -0.075 \text{ material}}{\% \text{ mass of effective asphalt}} \leq 1.2
\]

Unabsorbed binder in mix

See M323 Table 6 for exceptions
Dust/Binder Ratio: Example Mix Design

I-43 Binder, Blend 3

D/B Ratio = 0.9
I-43 Binder, Blend 3

%G_{mm} @ N_{ini}

\% G_{mm} @ N_{ini} = 87.1\%
Mixture Compaction Checks

% $G_{mm}$ vs. Gyrations

Limit for $N_{max}$

Limit for $N_{ini}$
### Select Design Asphalt Binder Content

#### SUMMARY OF MIXTURE PROPERTIES @ 4.7% AC

<table>
<thead>
<tr>
<th>Property</th>
<th>Result</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Air voids</td>
<td>4.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>%VMA</td>
<td>13.1%</td>
<td>&gt;13.0%</td>
</tr>
<tr>
<td>%VFA</td>
<td>70%</td>
<td>65-75%</td>
</tr>
<tr>
<td>D/A ratio</td>
<td>0.9</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>$%G_{mm} @ N_{ini}$</td>
<td>87.1%</td>
<td>&lt;89%</td>
</tr>
<tr>
<td>$%G_{mm} @ N_{max}$</td>
<td>97.5%</td>
<td>&lt;98%</td>
</tr>
</tbody>
</table>
4 Steps of Superpave Mix Design

1. Materials selection
2. Design aggregate structure
3. Design binder content
4. Moisture sensitivity
Definition

Moisture susceptibility: loss of adhesion between the aggregate surface and the asphalt binder in the presence of water.
Step 4: Moisture Sensitivity
AASHTO T 283

Conducted on the proposed mix design

- Three Conditioned Specimens
- Three Dry Specimens
- Tensile Strength Ratio

Minimum Tensile Strength Ratio: 80%
AASHTO T 283 Conditioning

• Conditioning
  • After mixing, cool to room temp. for 2 hrs.
  • Condition loose mix 16 hrs @ 60°C
  • Compact specimens, then set aside for 24 hrs @ 25°C

• Two subsets with equal voids
  • Unconditioned (dry) subset
  • Conditioned subset

7 ± 0.5% air voids
Dry

7 ± 0.5% air voids
70 to 80 % saturation
AASHTO T 283 Conditioning

- Freeze-thaw cycle
  - 16 hours @ -18°C

- 24 hour hot water soak
  - 24 hours @ 60°C
AASHTO T 283 Test Procedure

50 mm / min @ 25°C

Average **dry** tensile strength

Average **wet** tensile strength

\[ \text{TSR} = \frac{\text{wet}}{\text{dry}} \geq 0.80 \]
Calculate TSR

$$TSR = \frac{\text{Wet Strength}}{\text{Dry Strength}}$$

$$TSR = \frac{721 \text{ kPa}}{872 \text{ kPa}} = 0.83$$

Criterion is 0.80 minimum.

The mix design exceeds the minimum requirement.
## Final Asphalt Mix Design

### Job Mix Formula

<table>
<thead>
<tr>
<th>Aggregate Blend</th>
<th></th>
<th>Aggregate gradation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% #56 stone</td>
<td></td>
<td>25 mm 100%</td>
</tr>
<tr>
<td>15% #67 stone</td>
<td></td>
<td>19.0 mm 97%</td>
</tr>
<tr>
<td>20% #8 stone</td>
<td></td>
<td>12.5 mm 89%</td>
</tr>
<tr>
<td>26% #10 mfg. sand</td>
<td></td>
<td>9.5 mm 77%</td>
</tr>
<tr>
<td>14% Nat. Sand</td>
<td></td>
<td>4.75 mm 44%</td>
</tr>
<tr>
<td>15% RAP</td>
<td></td>
<td>2.36 mm 32%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.18 mm 22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 mm 15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3 mm 8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15 mm 5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.075 mm 3.9%</td>
</tr>
</tbody>
</table>

Asphalt binder: 4.7% PG 58-34
Mix Design verification during Production

• Mixtures must be verified from plant samples to ensure the mix properties are within the given specification limits.

• Differences in lab prepared mix design and plant produced mix should be expected.

• Take care so that adjustments don’t result in a poor quality mix
Thank you!
Questions?

Type question here

Select Organizer Only