AGGREGATE BLENDING, ABSORPTION, & SPECIFIC GRAVITY
Topics to be Covered

- Aggregate Specific Gravities
- Gradations
- Blending Stockpiles
- Batching
- Combined Specific Gravities
Specific Gravity Tests for Aggregates

• Two tests are needed
  – Coarse aggregate (retained on the 4.75 mm sieve)
  – Fine aggregate (passing the 4.75 mm sieve)
Apparent Specific Gravity, $G_{sa}$

$G_{sa} = \frac{\text{Mass of Aggregate, oven dry}}{\text{Volume of aggregate}}$
Bulk Specific Gravity, $G_{sb}$

$G_{sb} = \frac{\text{Mass of aggregate, oven dry}}{\text{Vol of agg, } + \text{ surface voids}}$

Surface Voids

Vol. of water-perm. voids
Effective Specific Gravity, $G_{se}$

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

Surface Voids

Solid Agg. Particle

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

Absorbed asphalt

Effective volume = volume of solid aggregate particle + volume of surface voids not filled with asphalt
Water Absorption

Surface Voids

Solid Agg. Particle

SSD weight - Oven dry weight

Oven dry weight
Coarse Aggregate Specific Gravity

- ASTM C127
  - Dry aggregate
  - Soak in water for 24 hours
  - Decant water
  - Use pre-dampened towel to get SSD condition
  - Determine mass of SSD aggregate in air
  - Determine mass of SSD aggregate in water
  - Dry to constant mass
  - Determine oven dry mass
Coarse Aggregate Specific Gravity
Coarse Aggregate Specific Gravity
Coarse Aggregate Specific Gravity

Calculations

- \( G_{sb} = \frac{A}{(B - C)} \)
  - \( A \) = mass oven dry
  - \( B \) = mass SSD
  - \( C \) = mass under water

- \( G_{s,SSD} = \frac{B}{(B - C)} \)

- \( G_{sa} = \frac{A}{(A - C)} \)

- Water absorption capacity, %
  - Absorption % = \( \frac{(B - A)}{A} \times 100 \)
Coarse Aggregate Specific Gravity

Calculations - Example Problem

- Given:
  - Mass oven dry - 3625.5 (A)
  - Mass SSD - 3650.3 (B)
  - Mass under Water - 2293.0 (C)
Coarse Aggregate Specific Gravity

*Calculations - Example Problem*

- **Apparent Specific Gravity** - \( G_{sa} \)
  \[
  A / (A - C)
  \]
- **Bulk Specific Gravity** - \( G_{sb} \)
  \[
  A / (B - C)
  \]
- **Absorption, %**
  \[
  (B - A) / A
  \]
Coarse Aggregate Specific Gravity

*Calculations - Example Problem*

- **Apparent Specific Gravity -** $G_{sa}$
  
  \[
  \frac{3625.5}{(3625.5 - 2293.0)} = 2.721
  \]

- **Bulk Specific Gravity -** $G_{sb}$
  
  \[
  \frac{3625.5}{(3650.3 - 2293.0)} = 2.671
  \]

- **Absorption, %**
  
  \[
  \frac{(3650.3 - 3625.5)}{2293.0} = 0.68 \%
  \]
Fine Aggregate Specific Gravity

- ASTM C128
  - Dry aggregate
  - Soak in water for 24 hours
  - Spread out and dry to SSD
  - Add 500 g of SSD aggregate to pycnometer of known volume
    - Pre-filled with some water
  - Add more water and agitate until air bubbles have been removed
  - Fill to calibration line and determine the mass of the pycnometer, aggregate and water
  - Empty aggregate into pan and dry to constant mass
  - Determine oven dry mass
Fine Aggregate Specific Gravity
Fine Aggregate Specific Gravity
Fine Aggregate Specific Gravity
Fine Aggregate Specific Gravity

Calculations

- $G_{sb} = \frac{A}{B + S - C}$
  - $A =$ mass oven dry
  - $B =$ mass of pycnometer filled with water
  - $C =$ mass pycnometer, SSD aggregate and water
  - $S =$ mass SSD aggregate

- $G_{sb,SSD} = \frac{S}{B + S - C}$

- $G_{sa} = \frac{A}{B + A - C}$

- Water absorption capacity, %
  - Absorption % = $\left(\frac{S - A}{A}\right) \times 100$
Fine Aggregate Specific Gravity

Calculations - Example Problem

Given

A = mass oven dry = 489.3
B = mass of pycnometer filled with water = 666.5
C = mass pycnometer, SSD aggregate and water = 982.3
S = mass SSD aggregate = 500.1
Fine Aggregate Specific Gravity

Calculations - Example Problem

- \( G_{sb} = \frac{A}{B + S - C} = \frac{498.9}{(666.5+500.1-982.3)} \)
  = 2.707

- \( G_{sb,SSD} = \frac{S}{B + S - C} = \frac{500.1}{(666.5+500.1-982.3)} \)
  = 2.714

- \( G_{sa} = \frac{A}{B + A - C} = \frac{498.9}{(666.5+498.9-982.3)} \)
  = 2.725

- Water absorption = \[ \frac{(S - A)}{A} \times 100 = \]
  \( \frac{(500.1-498.9)}{498.9} = 0.24 \% \)
Aggregate Gradation

- Distribution of particle sizes expressed as percent of total weight
- Determined by sieve analysis
Types Of Gradations

* Open graded
  - Few points of contact
  - Stone on Stone contact
  - High permeability

* Well graded
  - Good interlock
  - Low permeability

* Gap graded
  - Lacks intermediate sizes
  - Good interlock
  - Low permeability
Definitions

- **Nominal Maximum Aggregate Size**
  - one size larger than the first sieve to retain more than 10%

- **Maximum Aggregate Size**
  - one size larger than nominal maximum size
## Superpave Mix Size Designations

<table>
<thead>
<tr>
<th>Superpave Designation</th>
<th>Nom Max Size (mm)</th>
<th>Max Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0 mm</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>12.5</td>
<td>19</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>9.5</td>
<td>12.5</td>
</tr>
</tbody>
</table>
Aggregate Blending, Absorption & Specific Gravity
Blending of Aggregates

• Reasons for blending
  – Obtain desirable gradation
  – Single natural or quarried material not enough
  – Economical to combine natural and process materials
Blending of Aggregates

• Numerical method
  – Trial and error
  – Basic formula
Blending of Aggregates

- \( P = Aa + Bb + Cc + \ldots \)

- Where:
  - \( P = \) % of material passing a given sieve for the blended aggregates
  - \( A, B, C, \ldots = \) % material passing a given sieve for each aggregate
  - \( a, b, c, \ldots = \) Proportions (decimal fractions) of aggregates to be used in blend
## Blending of Aggregates

\[ P = Aa + Bb + \ldots \]

<table>
<thead>
<tr>
<th>Material</th>
<th>Aggregate No. 1</th>
<th>Aggregate No. 2</th>
<th>Blend</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Used</td>
<td>a 30.0%</td>
<td>b 70.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve</td>
<td>% Passing</td>
<td>% Batch</td>
<td>% Passing</td>
<td>% Batch</td>
</tr>
<tr>
<td>3/8</td>
<td>A 100 30.0%</td>
<td>B 100 70.0%</td>
<td>100.0%</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>90 27.0%</td>
<td>100 70.0%</td>
<td>97.0%</td>
<td>90 to 100</td>
</tr>
<tr>
<td>No. 8</td>
<td>30 9.0%</td>
<td>100 70.0%</td>
<td>79.0%</td>
<td>36 to 76</td>
</tr>
<tr>
<td>No. 16</td>
<td>7 2.1%</td>
<td>88 61.6%</td>
<td>63.7%</td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td>3 0.9%</td>
<td>47 32.9%</td>
<td>33.8%</td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td>1 0.3%</td>
<td>32 22.4%</td>
<td>22.7%</td>
<td></td>
</tr>
<tr>
<td>No. 100</td>
<td>0 0.0%</td>
<td>24 16.8%</td>
<td>16.8%</td>
<td></td>
</tr>
<tr>
<td>No. 200</td>
<td>0 0.0%</td>
<td>10 7.0%</td>
<td>7.0%</td>
<td>2 to 10</td>
</tr>
</tbody>
</table>
**Blending of Aggregates**

\[ P = Aa + Bb + \ldots \]

<table>
<thead>
<tr>
<th>Material</th>
<th>Aggregate No. 1</th>
<th>Aggregate No. 2</th>
<th>Blend</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Used</td>
<td>% Passing</td>
<td>% Batch</td>
<td>% Passing</td>
<td>% Batch</td>
</tr>
<tr>
<td>3/8</td>
<td>A 100</td>
<td>50.0%</td>
<td>B 100</td>
<td>50.0%</td>
</tr>
<tr>
<td>No. 4</td>
<td>90</td>
<td>45.0%</td>
<td>100</td>
<td>50.0%</td>
</tr>
<tr>
<td>No. 8</td>
<td>30</td>
<td>15.0%</td>
<td>100</td>
<td>50.0%</td>
</tr>
<tr>
<td>No. 16</td>
<td>7</td>
<td>3.5%</td>
<td>88</td>
<td>44.0%</td>
</tr>
<tr>
<td>No. 30</td>
<td>3</td>
<td>1.5%</td>
<td>47</td>
<td>23.5%</td>
</tr>
<tr>
<td>No. 50</td>
<td>1</td>
<td>0.5%</td>
<td>32</td>
<td>16.0%</td>
</tr>
<tr>
<td>No. 100</td>
<td>0</td>
<td>0.0%</td>
<td>24</td>
<td>12.0%</td>
</tr>
<tr>
<td>No. 200</td>
<td>0</td>
<td>0.0%</td>
<td>10</td>
<td>5.0%</td>
</tr>
</tbody>
</table>
Classroom Problem
## Blending of Aggregates

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Pass Aggregate 1</th>
<th>% Batch Aggregate 1</th>
<th>% Pass Aggregate 2</th>
<th>% Batch Aggregate 2</th>
<th>% Pass Aggregate 3</th>
<th>% Batch Aggregate 3</th>
<th>Blend</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td>87</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td>90 to 100</td>
<td></td>
</tr>
<tr>
<td>No. 8</td>
<td>63</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td>36 to 76</td>
<td></td>
</tr>
<tr>
<td>No. 16</td>
<td>19</td>
<td>93</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td>8</td>
<td>88</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td>5</td>
<td>55</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 100</td>
<td>3</td>
<td>36</td>
<td>97</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 200</td>
<td>2</td>
<td>3</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 to 10</td>
</tr>
</tbody>
</table>
Batching of Aggregate Blends

• Why Batch?
  – We Want To Reproduce the Desired Gradation for Mix Design
Batching

• Things We Need To Know To Batch
  – % of Each Stockpile in Blend
  – % Retained For Each Sieve of Each Stockpile
Batching

\[
M_{\text{per sieve}} = \%\text{Ret} \times \%\text{Agg} \times M_{\text{batch}}
\]

- \(M_{\text{per sieve}}\) = Mass of one aggregate in the blend for one sieve size
- \(\%\text{Ret}\) = Percent retained on the sieve expressed in *decimal* form
- \(\%\text{Agg}\) = The percent of the stock pile to being used in the blend in *decimal* form

**EXAMPLE:**

How much 1.18 mm material do I need from Aggregate #1 for a 4,000 gram batch given the following:

- % Retained on 1.18 mm sieve = 23.0 %
- % Agg. #1 Used in Blend = 30.0 %
- Total Batch wt. = 4000 grams

\[
\text{Mass of 1.18 mm material} = 0.230 \times 0.300 \times 4000 = 276.0 \text{ grams}
\]
Example
Problem
## Batching of Aggregates

**Total Batch Size: 4600.0 grams**

<table>
<thead>
<tr>
<th>Material</th>
<th>Aggregate No. 1</th>
<th>Aggregate No. 2</th>
<th>Mass of Agg #1</th>
<th>Mass of Agg #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Used</td>
<td>50.0%</td>
<td>50.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>Passing</td>
<td>Retained</td>
<td>Passing</td>
<td>Retained</td>
</tr>
<tr>
<td>3/8</td>
<td>100.0</td>
<td>0.0</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>No. 4</td>
<td>90.0</td>
<td>10.0</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>No. 8</td>
<td>30.0</td>
<td>60.0</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>No. 16</td>
<td>7.0</td>
<td>23.0</td>
<td>88.0</td>
<td>12.0</td>
</tr>
<tr>
<td>No. 30</td>
<td>3.0</td>
<td>4.0</td>
<td>47.0</td>
<td>41.0</td>
</tr>
<tr>
<td>No. 50</td>
<td>1.0</td>
<td>2.0</td>
<td>32.0</td>
<td>15.0</td>
</tr>
<tr>
<td>No. 100</td>
<td>0.0</td>
<td>1.0</td>
<td>24.0</td>
<td>8.0</td>
</tr>
<tr>
<td>No. 200</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Passing 200</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Total Mass</td>
<td>2300.0</td>
<td>2300.0</td>
<td>2300.0</td>
<td>2300.0</td>
</tr>
</tbody>
</table>
Classroom Problem
### Batching of Aggregates

**Total Batch Size: 4600.0 grams**

<table>
<thead>
<tr>
<th>Material</th>
<th>Aggregate No. 1</th>
<th>Aggregate No. 2</th>
<th>Mass of Agg #1</th>
<th>Mass of Agg #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Used</td>
<td>30.0%</td>
<td>70.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve</td>
<td>% Passing</td>
<td>% Retained</td>
<td>% Passing</td>
<td>% Retained</td>
</tr>
<tr>
<td>3/8</td>
<td>100.0</td>
<td></td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td>90.0</td>
<td></td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>No. 8</td>
<td>30.0</td>
<td></td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>No. 16</td>
<td>7.0</td>
<td></td>
<td>88.0</td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td>3.0</td>
<td></td>
<td>47.0</td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td>1.0</td>
<td></td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>No. 100</td>
<td>0.0</td>
<td></td>
<td>24.0</td>
<td></td>
</tr>
<tr>
<td>No. 200</td>
<td>0.0</td>
<td></td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Passing 200</td>
<td>0.0</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total Mass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Combined Specific Gravity

\[ G_{sb} = \left( \frac{P_A}{G_A} + \frac{P_B}{G_B} + \frac{P_C}{G_C} \right) \left( P_A + P_B + P_C \right) \]

Where:  
\( P_A, P_B \) & \( P_C \) = percent by mass of each aggregate in blend 

\( G_A, G_B \) & \( G_C \) = Bulk Specific Gravity of each aggregate
**Example Problem**

Aggregate Blending, Absorption & Specific Gravity

\[
G_{sb} = \frac{(P_A + P_B + P_C)}{\left(\frac{P_A}{G_A} + \frac{P_B}{G_B} + \frac{P_C}{G_C}\right)}
\]

Where:  
- \(P_A, P_B, P_C\) = percent by mass of each aggregate in blend  
- \(G_A, G_B, G_C\) = Bulk Specific Gravity of each aggregate

Based on the information given:

- \(P_A = 50\%\)  
- \(G_A = 2.695\)

- \(P_B = 25\%\)  
- \(G_B = 2.711\)

- \(P_C = 25\%\)  
- \(G_C = 2.721\)

\[
G_{sb} = \frac{(50 + 25 + 25)}{\left(\frac{50}{2.695} + \frac{25}{2.711} + \frac{25}{2.721}\right)} = 2.705
\]
Questions – does it all make sense?