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, $G_{sb}$

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

Surface Voids

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

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

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

- **Surface Voids**
- **Solid Agg. Particle**
- **Vol. of water-perm. voids not filled with asphalt**
- **Absorbed asphalt**
Water Absorption

Surface Voids

SSD weight - Oven dry weight

Solid Agg. Particle

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 % = $\left[\frac{(B - A)}{A}\right] \times 100$
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** - $G_{sa}$
  \[
  \frac{A}{(A - C)}
  \]
- **Bulk Specific Gravity** - $G_{sb}$
  \[
  \frac{A}{(B - C)}
  \]
- **Absorption, %**
  \[
  \frac{(B - A)}{A}
  \]
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 % = $\frac{[(S - A) / A] * 100}{ }$
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 = \( [(S - A) / A] \times 100 = \) 
  \( (500.1-498.9)/498.9 = 0.24 \% \)
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
Superpave Aggregate Gradation

Percent Passing

Design Aggregate Structure

max density line

control points

Sieve Size (mm) Raised to 0.45 Power

Aggregate Blending, Absorption & Specific Gravity
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>
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</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

9.5 mm
12.5 mm
19.0 mm
Blending of Aggregates

• Reasons for blending
  – Obtain desirable gradation
  – Single natural or quarried material not enough
  – Economical to combine natural and process materials
Blend ofing 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
    - $a, b, c, \ldots = \text{Proportions (decimal fractions)}$ of aggregates to be used in blend
## Blending of Aggregates

P = Aa + Bb + ...

<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 100</td>
<td>B 100</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>30.0%</td>
<td>30.0%</td>
<td>100.0%</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>90</td>
<td>100</td>
<td>70.0%</td>
<td>97.0%</td>
</tr>
<tr>
<td>No. 8</td>
<td>30</td>
<td>100</td>
<td>70.0%</td>
<td>79.0%</td>
</tr>
<tr>
<td>No. 16</td>
<td>7</td>
<td>88</td>
<td>61.6%</td>
<td>63.7%</td>
</tr>
<tr>
<td>No. 30</td>
<td>3</td>
<td>47</td>
<td>32.9%</td>
<td>33.8%</td>
</tr>
<tr>
<td>No. 50</td>
<td>1</td>
<td>32</td>
<td>22.4%</td>
<td>22.7%</td>
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<tr>
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<td>0</td>
<td>24</td>
<td>16.8%</td>
<td>16.8%</td>
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<tr>
<td>No. 200</td>
<td>0</td>
<td>10</td>
<td>7.0%</td>
<td>7.0%</td>
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</tbody>
</table>
### Blending of Aggregates

P = Aa + Bb + ... 

<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></td>
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</tr>
<tr>
<td>Sieve</td>
<td>% Passing % Batch</td>
<td>% Passing % Batch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8</td>
<td>A 100 50.0% A 100 50.0%</td>
<td>B 100 50.0% B 100 50.0%</td>
<td>100.0%</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>90 45.0% 90 45.0%</td>
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<td>No. 8</td>
<td>30 15.0% 30 15.0%</td>
<td>100 50.0% 100 50.0%</td>
<td>65.0%</td>
<td>36 to 76</td>
</tr>
<tr>
<td>No. 16</td>
<td>7 3.5% 7 3.5%</td>
<td>88 44.0% 88 44.0%</td>
<td>47.5%</td>
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</tr>
<tr>
<td>No. 30</td>
<td>3 1.5% 3 1.5%</td>
<td>47 23.5% 47 23.5%</td>
<td>25.0%</td>
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<tr>
<td>No. 50</td>
<td>1 0.5% 1 0.5%</td>
<td>32 16.0% 32 16.0%</td>
<td>16.5%</td>
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<tr>
<td>No. 100</td>
<td>0 0.0% 0 0.0%</td>
<td>24 12.0% 24 12.0%</td>
<td>12.0%</td>
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<tr>
<td>No. 200</td>
<td>0 0.0% 0 0.0%</td>
<td>10 5.0% 10 5.0%</td>
<td>5.0%</td>
<td>2 to 10</td>
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Classroom Problem
## Blending of Aggregates

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

Mass of 1.18 mm material = 0.230 * 0.300 * 4000 = 276.0 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>#1</td>
<td>#2</td>
</tr>
<tr>
<td>Sieve</td>
<td>%</td>
<td>%</td>
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<td>%</td>
</tr>
<tr>
<td></td>
<td>Passing</td>
<td>Retained</td>
<td>Passing</td>
<td>Retained</td>
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<tr>
<td>3/8</td>
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<td>0.0</td>
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<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>
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<tr>
<td>No. 16</td>
<td>7.0</td>
<td>23.0</td>
<td>88.0</td>
<td>12.0</td>
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<td>4.0</td>
<td>47.0</td>
<td>41.0</td>
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<tr>
<td>Total Mass</td>
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<td></td>
<td>2300.0</td>
<td>2300.0</td>
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Classroom Problem
Batcing 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>
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</thead>
<tbody>
<tr>
<td>% Used</td>
<td>30.0%</td>
<td>70.0%</td>
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<td></td>
</tr>
<tr>
<td>Sieve</td>
<td>% Passing</td>
<td>% Retained</td>
<td>% Passing</td>
<td>% Retained</td>
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<td>3/8</td>
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<td>No. 4</td>
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<td>100.0</td>
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<td>No. 8</td>
<td>30.0</td>
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<tr>
<td>Passing 200</td>
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<td></td>
<td>0.0</td>
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</tbody>
</table>

Total Mass

Aggregate Blending, Absorption & Specific Gravity
Combined 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: \( P_A, P_B, \) and \( P_C \) = percent by mass of each aggregate in blend

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

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

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:

\begin{align*}
P_A &= 50\% & G_A &= 2.695 \\
P_B &= 25\% & G_B &= 2.711 \\
P_C &= 25\% & G_C &= 2.721
\end{align*}

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