PHYSICAL PROPERTIES OF AGGREGATES
4 Steps of Superpave Mix Design

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

Physical Properties of Aggregates
Aggregate Properties

- **Consensus Properties** - *required*
  - coarse aggregate angularity (CAA)
  - fine aggregate angularity (FAA)
  - flat, elongated particles
  - clay content

- **Source Properties** - *agency option*
  - toughness
  - soundness
  - deleterious materials
Coarse Aggregate Angularity

- Measured on + 4.75 mm material
- Based on fractured faces
  - fractured surface larger than 25% of aspect ratio
- ASTM D 5821
- Specification requirements depend on:
  - depth of layer within pavement
  - traffic level
## Coarse Aggregate Angularity

<table>
<thead>
<tr>
<th>Traffic ESALs</th>
<th>Depth from Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>&lt; 100 mm</td>
</tr>
<tr>
<td></td>
<td>&gt; 100 mm</td>
</tr>
<tr>
<td>95% one fractured face</td>
<td>95/90</td>
</tr>
<tr>
<td>90% two+ fractured faces</td>
<td>80/75 Minimum</td>
</tr>
</tbody>
</table>
Contrasting Stone Skeletons

Cubical Aggregate

Rounded Aggregate
Shearing Behavior of Aggregate

Before Load

After Load

shear plane
Fine Aggregate Angularity

• Measured on - 2.36 mm material
• Based on air voids in loosely compacted sample
• AASHTO T 304, Method A
  – Standard Grading: +1.18 mm to +0.150 mm
• Requirements depend on
  – depth of layer within pavement
  – traffic level
Fine Aggregate Angularity

funnel
fine aggregate sample
cylinder of known volume \( (V) \)
measured mass

uncompacted voids =
\[
\frac{V - \frac{M}{G_{sb}}}{V} \times 100\%
\]
## Fine Aggregate Angularity

<table>
<thead>
<tr>
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<th>Depth from Surface</th>
<th>&lt; 100 mm</th>
<th>&gt; 100 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x $10^6$</td>
<td></td>
<td>45</td>
<td>40</td>
</tr>
</tbody>
</table>

Minimum<br>

> Rounded particles pack tighter together -- less air

*% air voids in loose sample*
What Affect Does FAA Have on Performance?

- FAA and restricted zone used to limit the amount of rounded natural sands

- National Rutting Study initiated in 1987 by NCAT evaluated 42 pavements in 14 states. The study identified a minimum FAA value of 43.3% to resist rutting.
Flat, Elongated Particles

- Measured on + 4.75 mm material
- Based on dimensional ratio of particles
  - ratio of max to min dimension < 5
- ASTM D 4791
- Requirements depend on traffic level
Flat, Elongated Particles

1:5 pivot point

fixed post (B)

fixed post (A)

swinging arm
## Flat & Elongated Particles

<table>
<thead>
<tr>
<th>Traffic ESALs</th>
<th>Percent</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

**percentage of flat and elongated particles**
What Affect Does F&E Have on Performance?

• Tend to break under the roller exposing uncoated faces which may lead to stripping of the asphalt film off the aggregate in the presence of moisture
• Particles tend to orient flat under traffic, reducing pavement voids. May lead to flushing
• Change in shape affects mixture volumetrics
Clay Content

- Measured on - 4.75 mm material
- Based on sand equivalent value
- AASHTO T176
- Requirements depend on traffic level

> How dirty is the sand?
Clay Content

- Graduated cylinder
- Clay reading
- Sand reading
- Flocculating solution
- Suspended clay
- Sedimented aggregate

Physical Properties of Aggregates
## Clay Content

<table>
<thead>
<tr>
<th>Traffic</th>
<th>ESALs</th>
<th>Percent</th>
<th>Minimum</th>
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<td></td>
<td>10 - 30 x 10^6</td>
<td>45</td>
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</table>

- More sand - Less clay
- Clay on aggregate particles reduces binder adhesion

sand equivalent value
Aggregate Source Properties

- Toughness
  - AASHTO T96 (LA abrasion)
- Soundness
  - AASHTO T104 (Na or Mg sulfate soundness)
- Deleterious materials
  - AASHTO T112 (clay lumps and friable particles)
- Others selected by agency
  - Used in Mix Design or for Acceptance Control
Superpave Aggregate Specifications

- Required on total aggregate blend
- Not individual aggregate stockpiles
4 Steps of Superpave Mix Design

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Physical Properties of Aggregates
Superpave Aggregate Gradation

• Use 0.45 power gradation chart
• Blend size definitions
  – maximum size
  – nominal maximum size
• Gradation limits
  – control points
  – restricted zone
Example:

4.75 mm sieve plots at \((4.75)^{0.45} = 2.02\)
Standard Aggregate Sieves

- 50 mm
- 37.5 mm
- 25 mm
- 19 mm
- 12.5 mm
- 9.5 mm
- 4.75 mm

- 2.36 mm
- 1.18 mm
- 0.6 mm
- 0.3 mm
- 0.15 mm
- 0.075 mm
0.45 Power Grading Chart

Percent Passing

Sieve Size (mm) Raised to 0.45 Power

max size

maximum density line
Aggregate Size 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
Percent Passing

max density line

restricted zone

control point

Sieve Size (mm) Raised to 0.45 Power

Physical Properties of Aggregates
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
  - Permeability varies
Superpave Aggregate Gradation

Sieve Size (mm) Raised to 0.45 Power

Percent Passing

Design Aggregate Structure

Physical Properties of Aggregates
# 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>37.5 mm</td>
<td>37.5</td>
<td>50</td>
</tr>
<tr>
<td>25 mm</td>
<td>25</td>
<td>37.5</td>
</tr>
<tr>
<td>19 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>
Superpave Aggregate Tests and Blend Selection

• Aggregate tests
  – Consensus properties - required
  – Source properties - optional
• Aggregate criteria
  – Based on aggregate blend
  – Based on traffic and depth into pavement
• Design aggregate structure
  – 0.45 power chart
  – Controls points and restricted zone
Effect of Physical Properties on Performance

• Size

• Higher size
  – greater bearing capacity
  – toughness critical to performance
  – poor packing characteristics
Effect of Physical Properties on Performance

• Shape and Texture

• Flat and elongated versus cubical
  – Cubical: better interlocking and stability

• Rounded versus angular
  – Rounded: poor shear resistance, poor interlocking
  – Angular: low workability
Questions – does it all make sense?