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>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>&lt; 100 mm</td>
<td>95/90</td>
</tr>
<tr>
<td></td>
<td>&gt; 100 mm</td>
<td>80/75 Minimum</td>
</tr>
</tbody>
</table>

95% one fractured face

90% two+ fractured faces

Physical Properties of Aggregates
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>
<th>Traffic ESALs</th>
<th>Depth from Surface</th>
<th>% air voids in loose sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>45, 40 (Minimum)</td>
<td></td>
</tr>
</tbody>
</table>

> Rounded particles pack tighter together -- less air
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

Physical Properties of Aggregates
Flat & Elongated Particles

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

Maximum 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

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

Minimum

- 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

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

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  2.36 mm
37.5 mm  1.18 mm
25 mm  0.6 mm
19 mm  0.3 mm
12.5 mm  0.15 mm
9.5 mm  0.075 mm
4.75 mm
0.45 Power Grading Chart

Percent Passing

Sieve Size (mm) Raised to 0.45 Power

maximum density line

max size
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
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

Percent Passing

Sieve Size (mm) Raised to 0.45 Power

Design Aggregate Structure
### 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?