Aggregate Gradation
Important Properties

Gradation
Relative density and absorption
Hardness (resistance to wear)
Durability (resistance to weathering)
Shape and surface texture
Deleterious substances
Crushing strength
Soft and lightweight particles
Chemical stability
Gradation Analysis

A gradation analysis (or sieve analysis) is a procedure used to assess the particle size distribution (gradation) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass. The size distribution is often of critical importance to the way the material performs in use.
Gradation Analysis

percent coarser
or
percent retained

percent finer
or
percent passing

Percentages are calculated by mass
Gradation Chart
(typically used for soil)

Percent Passing

Opening Size (mm)

Total mass percent passing each sieve

0
20
40
60
80
100

100
40
20
0

100
0.1
0.01

4.75
Gradation Chart

(typically used for aggregate)

<table>
<thead>
<tr>
<th>Percent Passing</th>
<th>Opening Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>20</td>
<td>0.1</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>60</td>
<td>4.75</td>
</tr>
<tr>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Total mass percent passing each sieve

0.01 0.1 1 10 100
Sieve Shakers

Mary Ann Shaker
Screen Shakers

Gilson Shaker
### Sieve Sizes Used in Construction

<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Traditional</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 in.</td>
<td>75</td>
<td>mm</td>
</tr>
<tr>
<td>2½ in.</td>
<td>63</td>
<td>mm</td>
</tr>
<tr>
<td>2 in.</td>
<td>50</td>
<td>mm</td>
</tr>
<tr>
<td>1½ in.</td>
<td>37.5</td>
<td>mm</td>
</tr>
<tr>
<td>1 in.</td>
<td>25.0</td>
<td>mm</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>19.0</td>
<td>mm</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>12.5</td>
<td>mm</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>9.5</td>
<td>mm</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.75</td>
<td>mm</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.36</td>
<td>mm</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18</td>
<td>mm</td>
</tr>
<tr>
<td>No. 30</td>
<td>600</td>
<td>µm</td>
</tr>
<tr>
<td>No. 50</td>
<td>300</td>
<td>µm</td>
</tr>
<tr>
<td>No. 100</td>
<td>150</td>
<td>µm</td>
</tr>
<tr>
<td>No. 200</td>
<td>75</td>
<td>µm</td>
</tr>
</tbody>
</table>
Sieve Sizes Used in Construction

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<td>37.5 mm</td>
</tr>
<tr>
<td>3/4 in.</td>
<td></td>
<td>19.0 mm</td>
</tr>
<tr>
<td>3/8 in. No. 4</td>
<td></td>
<td>9.5 mm</td>
</tr>
<tr>
<td>No. 8</td>
<td></td>
<td>4.75 mm</td>
</tr>
<tr>
<td>No. 16</td>
<td></td>
<td>2.36 mm</td>
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<tr>
<td>No. 30</td>
<td></td>
<td>1.18 mm</td>
</tr>
<tr>
<td>No. 50</td>
<td></td>
<td>0.60 mm</td>
</tr>
<tr>
<td>No. 100</td>
<td></td>
<td>0.30 mm</td>
</tr>
<tr>
<td>No. 200</td>
<td></td>
<td>0.075 mm</td>
</tr>
</tbody>
</table>

Openings vary by a factor of two.
Gradation Chart

Percent Passing (%)

Opening Size (mm)

1½" ¾" ⅜" 4 8 16 30 50 100 200
Gradation Example

<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Cumulative Weight Retained (g)</th>
<th>Cumulative Percent Retained (g)</th>
<th>Cumulative Percent Passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8 in.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8 in.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cumulative Weight Retained in Pan must be within 0.3% of the Initial Weight
**Gradation Example**

<table>
<thead>
<tr>
<th>Sample:</th>
<th>5/8&quot; Gravel</th>
<th>Initial Weight:</th>
<th>Date:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Cumulative Weight Retained (g)</th>
<th>Cumulative Percent Retained (g)</th>
<th>Cumulative Percent Passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 in.</td>
<td>0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>49</td>
<td>4.9</td>
<td>95.1</td>
</tr>
<tr>
<td>No. 4</td>
<td>204</td>
<td>20.5</td>
<td>79.5</td>
</tr>
<tr>
<td>No. 8</td>
<td>439</td>
<td>44.2</td>
<td>55.8</td>
</tr>
<tr>
<td>No. 16</td>
<td>573</td>
<td>57.6</td>
<td>42.4</td>
</tr>
<tr>
<td>No. 30</td>
<td>743</td>
<td>74.7</td>
<td>25.3</td>
</tr>
<tr>
<td>No. 50</td>
<td>819</td>
<td>82.4</td>
<td>17.6</td>
</tr>
<tr>
<td>No. 100</td>
<td>894</td>
<td>89.9</td>
<td>10.1</td>
</tr>
<tr>
<td>Pan</td>
<td>994</td>
<td>100.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Cumulative Weight Retained in Pan must be within 0.3% of the Initial Weight
Typical Aggregate Gradations

Uniformly graded aggregate
All of the particles are approximately the same size

Open-graded aggregate
Very little fine aggregate thus lots of void space between particles

Gap-graded aggregate
Very little aggregate in the medium size range

Dense-graded aggregate
Lots of different particle sizes thus very little void space
Uniformly Graded Aggregate

Opening Size (mm)

Percent Passing

“clear” gravel
uniform sand

1½” ¾” 3/8” 4 8 16 30 50 100 200

0 10 20 30 40 50 60 70 80 90 100

100 10 1 0.1 0.01
Uniformly Graded Aggregate

Narrow range of sizes
Grain-to-grain contact
High void content
High permeability
Low stability
Difficult to compact
Open-Graded Aggregate

Decent range of sizes
Very few fine particles
Grain-to-grain contact
High void content
High permeability
High stability
Difficult to compact
Gap-Graded Aggregate

- Open graded gravel
- Gap graded blend
- Missing sizes
- Open graded sand
Gap-Graded Aggregate

- Wide range of sizes
- Missing middle sizes
- No grain-to-grain contact
- Moderate void content
- Moderate permeability
- Low stability
- Easy to compact
Dense-Graded Aggregate

Percent Passing

Opening Size (mm)

Dense graded gravel
Dense-Graded Aggregate

Wide range of sizes
Grain-to-grain contact
Low void content
Low permeability
High stability
Difficult to compact
Fuller’s Curve


\[ p_i = \left( \frac{d_i}{D} \right)^{0.50} \]

- \( p_i \) = percent passing \( i^{th} \) sieve
- \( d_i \) = opening size of \( i^{th} \) sieve
- \( D \) = maximum particle size

Produces the highest density and lowest void content
Aggregate gradation curves: (a) maximum density gradations for 37.5 and 4.75 mm sizes based on the Fuller relationship; (b) a uniform aggregate; (c) a gap-graded aggregate; (d) screenings.
FHWA Maximum Density Curve

In 1962 FHWA published a modified version of Fuller’s equation with a different exponent.

\[ p_i = \left( \frac{d_i}{D} \right)^{0.45} \]

- \( p_i \) = percent passing \( i^{th} \) sieve
- \( d_i \) = opening size of \( i^{th} \) sieve
- \( D \) = maximum particle size

Produces the highest density and lowest void content
Maximum density curves on Federal Highway Administration 0.45 power gradation chart.
Dense-Graded Aggregate

TDOT 411-D

Maximum Density Curve

Percent Passing

Opening Size (mm)
Dense-Graded Aggregate

Opening Size (mm) Raised to the 0.45 Power

Percent Passing

Maximum Density Curve

TDOT 411-D

0 1 2 3 4 5

0 20 40 60 80 100

1/2" 5/8"