Learning Objective

- Develop a basic understanding of aggregates and aggregate properties.
Aggregates

• Fine
  ▪ Consists of natural sand, manufactured sand or crushed stone
  ▪ <3/8”
  ▪ Fine aggregate will pass the # 4 sieve
• Coarse
  ▪ Natural or crushed stone
  ▪ 3/8” to 1 ½” (or more)
  ▪ Coarse aggregate is larger than a #4 sieve

Mineralogy

• Igneous (Latin - “Fire”)
  ▪ Formed from volcanic processes and the heating and cooling of magma
    • Example: granite
• Sedimentary (Latin - “Settling”)
  ▪ Formed by the layering of sediments due to the action of wind or water
    • Example: sandstone
• Metamorphic (Greek - “Change”)
  ▪ Result from long-term high temperature and pressure on igneous and sedimentary rocks
    • Example: marble
Aggregates

Important Properties

- Durability, Freeze - Thaw and Chemical Resistance
- Hardness, Toughness, Abrasion
- Texture & Shape
- Strength
- Unit Weight / Density
- Cleanliness

Aggregate Specifications

- ASTM C33 - Normal Weight Aggregates
- ASTM C330 - Lightweight Aggregates
- ASTM C637 - Radiation Shielding Aggregates (Heavyweight)
Aggregate Specifications

- ASTM C33 - Normal Weight Aggregates
  - Durability requirements
Deleterious Substances C 33

7. Deleterious Substances

7.1 The amount of deleterious substances in fine aggregate shall not exceed the limits prescribed in Table 1.

7.2 Organic Impurities:

7.2.1 Fine aggregate shall be free of injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for organic impurities and producing a color darker than the standard shall be rejected.

7.2.2 Use of a fine aggregate failing in the test is not prohibited, provided that the discoloration is due principally to the presence of small quantities of coal, lignite, or similar discrete particles.

7.2.3 Use of a fine aggregate failing in the test is not prohibited, provided that, when tested for the effect of organic impurities on strength of mortar, the relative strength at 7 days, calculated in accordance with Test Method C 87, is not less than 95%.

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass % of Total Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay lumps and friable particles</td>
<td>3.0</td>
</tr>
<tr>
<td>Material finer than 75 micron (No. 200)</td>
<td>3.0*</td>
</tr>
<tr>
<td>sieve:</td>
<td></td>
</tr>
<tr>
<td>Concrete subject to abrasion</td>
<td>3.0*</td>
</tr>
<tr>
<td>All other concrete</td>
<td>5.0*</td>
</tr>
<tr>
<td>Coal and lignite:</td>
<td></td>
</tr>
<tr>
<td>Where surface appearance of concrete</td>
<td>0.5</td>
</tr>
<tr>
<td>is of importance</td>
<td></td>
</tr>
<tr>
<td>All other concrete</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Table 1 Limits for Deleterious Substances in Fine Aggregate for Concrete, ASTM C 33.

* In the case of manufactured sand, if the material finer than the 75-micron (No. 200) sieve consists of the dust or fracture, essentially free of clay or shale, these limits are permitted to be increased to 5 and 7%, respectively.

Lignite is sometimes found in natural sand. The amount varies, depending on the quarry and the particular deposit. When sand containing lignite is used in making concrete, lignite particles near the surface can expand and cause the pop outs. Lignite is often referred to as brown coal, it is the lowest rank of coal quality.
Deleterious Substances C 33

7. Deleterious Substances

7.1 The amount of deleterious substances in fine aggregate shall not exceed the limits prescribed in Table 1.

### 7.2 Organic Impurities:

7.2.1 Fine aggregate shall be free of injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for organic impurities and producing a color darker than the standard shall be rejected.

7.2.2 Use of a fine aggregate failing in the test is not prohibited, provided that the discoloration is due principally to the presence of small quantities of coal, lignite, or similar discrete particles.

7.2.3 Use of a fine aggregate failing in the test is not prohibited, provided that, when tested for the effect of organic impurities on strength of mortar, the relative strength at 7 days, calculated in accordance with Test Method C 87, is not less than 95%.

---

Organic Impurities C 40 (fine aggregate)

**Lovibond AF347 Test Kit**

Organic Impurities in Fine Aggregates, according to ASTM C 40

- Compact, robust and easily portable for site use
- No need to prepare a standard solution
- Simple, straightforward test procedure
- Glass dependent measurements that are easily intergraded
- Includes stable coloured glass standards for long-term use

The Lovibond AF347 kit employs a test method for organic impurities in fine aggregates, conforming to the alternate procedure specified in ASTM C 40. Organic impurities, mostly in the form of amine and amine derivatives, are typically present in fine aggregates such as sand. These impurities, when in the presence of hydrated lime, may affect the strength of the cement, mortar or concrete where the aggregate is being used. The results given by the kit are designed to serve as a warning that unacceptable levels of organic impurities may be present.

What is the effect on Concrete if negative result?

3.0% Sodium Hydroxide Solution

---

Meets the following standards:

- ASTM C-40
- BS EN 12620 T-21
Larger Aggregate Test

• Check for silt or clay
• Mason jar test is not an official test, but only an indication of how much fine material is present.
• Check ASTM C33 and FDOT Sections 901 and 902 for amount and type of allowable fine material.
• Use a “Mason jar”

Durability of Materials…Soundness ASTM C 88

Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

1. Scope

1.1 This test method covers the testing of aggregates to estimate their soundness when subjected to weathering action in concrete or other applications. This is accomplished by repeated immersion in saturated solutions of sodium or magnesium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the rehydration of the salt upon re-immersion, simulates the expansion of water on freezing. This test method furnishes information helpful in judging the soundness of aggregates when adequate information is not available from service records of the material exposed to actual weathering conditions.
Soundness

- Resistance to weathering action
- Standard Test
  - ASTM C 88, Sodium or Magnesium Sulfate Soundness
  - Intended to simulate wet/dry and freezing/thawing conditions
- Reproducibility of results is sometimes difficult

Soundness

- Test consists of 5 cycles of soaking in sulfate solution followed by drying. After the 5 cycles any breakdown of the aggregate is removed and the loss in weight calculated.
  - This value is reported as the “Soundness Loss”
  - Typical Specification Limits are between 8-18% depending on which salt is used
  - Magnesium salt gives higher losses than Sodium
L.A. Abrasion Test

• Purpose
  ▪ To evaluate the aggregate’s resistance to degradation during processing, mixing, placing, and later while in service

• Standard Test Methods
  ▪ ASTM C 131 (aggregates < 1-1/2")
  ▪ ASTM C 535 (larger aggregates)
  ▪ ASTM C33 50% maximum loss

\[
\text{Loss} = \frac{W_{\text{initial}} - W_{\text{final}}}{W_{\text{initial}}} \times 100
\]

Aggregate Specifications

ASTM C33 - Normal Weight Aggregates
  ▪ Size and Gradation
Always read Materials section of an ASTM

6. Materials

6.1 The aggregate shall be so sized, graded, proportioned and mixed with such proportions of Portland cement, blended hydraulic cement, or Portland cement and supplementary cementing materials, or admixtures, if used, or a combination thereof, and water to produce a homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of the specification. In no case, however, shall the proportion of Portland cement, blended hydraulic cement, or a

Aggregates—Aggregates shall conform to Specification C 33 except that the requirement for gradation shall not apply.

Aggregate Size

- Maximum Size:
  - The smallest sieve opening through which the entire amount of aggregate is required to pass.
- Nominal Maximum Size:
  - The smallest sieve opening through which the entire amount of aggregate is permitted to pass.
- Example: ASTM C33 requires that 100% of a # 57 coarse aggregate MUST pass the 1.5” sieve but 95 - 100% MAY pass the 1” sieve, therefore # 57 aggregate is considered to have a Maximum size of 1.5” and an Nominal Maximum size of 1”.
Aggregate Gradation

- Also known as “sieve analysis”
- It is the distribution of particle sizes
- “Well-graded” aggregates:
  - particles evenly distributed among sieve sizes
  - require less cement and water than “poorly graded” aggregates
- Careful choice of aggregates provides for optimization of cement, water and admixtures

Most Common Sieve Series

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Metric Size</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2&quot;</td>
<td>38 mm</td>
<td>37.5 mm</td>
</tr>
<tr>
<td>1&quot;</td>
<td>25 mm</td>
<td>---</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>20 mm</td>
<td>19 mm</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>12.5 mm</td>
<td>---</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>10 mm</td>
<td>9.5 mm</td>
</tr>
<tr>
<td>#4</td>
<td>4.75 mm</td>
<td>4.75 mm</td>
</tr>
<tr>
<td>#8</td>
<td>2.50 mm</td>
<td>2.36 mm</td>
</tr>
<tr>
<td>#16</td>
<td>1.12 mm</td>
<td>1.18 mm</td>
</tr>
<tr>
<td>#30</td>
<td>0.6 mm</td>
<td>0.6 mm</td>
</tr>
<tr>
<td>#50</td>
<td>0.3 mm</td>
<td>0.3 mm</td>
</tr>
<tr>
<td>#100</td>
<td>0.15 mm</td>
<td>0.15 mm</td>
</tr>
<tr>
<td>#200</td>
<td>0.075 mm</td>
<td>0.075 mm</td>
</tr>
</tbody>
</table>

Not used in FM Calculation
Aggregate Size Effects:

- As the maximum size aggregate increases, the amount of paste needed for a given slump decreases.
- The maximum aggregate size used in a concrete mix is dictated by the size of the structural member and the spacing between reinforcing steel.


Graded Aggregate

- Sand
- Stone
- Well Graded Blend
Gradation

- Distribution of particle sizes
- Grading is determined by ASTM C 136
- Well graded concrete aggregates will result in fewer voids between particles = less cement paste demand

Aggregate Gradation Affects:

- Workability
- Pumpability
- Economy
- Porosity
- Shrinkage
- Durability
Fineness Modulus (FM)

- A single number system used to express the fineness or coarseness of an aggregate
- Higher values indicate coarser grading
- Sum of cumulative % retained on the standard sieves
- Certain sieves are NOT counted (even if used)
- Can be helpful in calculating blends of two materials
- FM of coarse aggregate can also be calculated and can aid in blending coarse and medium size materials

FM & Gradation are NOT the SAME

Fine Aggregate Gradation

- Fineness Modulus (FM) should be between 2.3 and 3.1
- FM is empirical # determined by dividing the sum of percent retained on a standard series of sieves by 100 (No. 4, 8, 16, 30, 50, 100)
- Coarser fine aggregate has a higher FM

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 in</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>95-100</td>
</tr>
<tr>
<td>No. 8</td>
<td>80-100</td>
</tr>
<tr>
<td>No. 16</td>
<td>50-85</td>
</tr>
<tr>
<td>No. 30</td>
<td>25-60</td>
</tr>
<tr>
<td>No. 50</td>
<td>5-30</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-10</td>
</tr>
</tbody>
</table>

ASTM C 33 Grading for Fine Agg
Percent Passing the No. 200 Sieve

- Very fine material such as silt, clay, or dust of fracture can increase the water demand in concrete
- Fines limit is 3% in ASTM C 33 for concrete subject to abrasion
- Manufactured sands 5% and 7%
- Coarse aggregate limit is 1% (1.5% for crushed stone)

Gradation & Fineness Modulus:

<table>
<thead>
<tr>
<th>Dry Sample Wt.</th>
<th>Sample:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Retained</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size, (mm)</th>
<th>Sieve Size, (US)</th>
<th>Mass, (g)</th>
<th>Ind. % Retained</th>
<th>Cum % Retained</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.18</td>
<td>#16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td>#30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>#50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>#100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve Loss Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Gradation & Fineness Modulus:

<table>
<thead>
<tr>
<th>Sieve Size, (mm)</th>
<th>Sieve Size, (US)</th>
<th>Mass, (g)</th>
<th>Ind. % Retained</th>
<th>Cum % Retained</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1 1/2”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>75</td>
<td>1”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>37.5</td>
<td>3/4”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>3/2”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4.75</td>
<td># 4</td>
<td>25</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>2.36</td>
<td># 8</td>
<td>163</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>1.18</td>
<td># 16</td>
<td>228</td>
<td>18.0</td>
<td>18.0</td>
<td>18.0</td>
</tr>
<tr>
<td>0.6</td>
<td># 30</td>
<td>278</td>
<td>22.0</td>
<td>22.0</td>
<td>22.0</td>
</tr>
<tr>
<td>0.3</td>
<td># 50</td>
<td>355</td>
<td>28.1</td>
<td>28.1</td>
<td>28.1</td>
</tr>
<tr>
<td>0.15</td>
<td># 100</td>
<td>177</td>
<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td>38</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1264</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Sieve Loss Check: 0.24%

**ASTM 136**

If the amounts differ by more than 0.3%, based on the original dry sample mass, results should not be used.

\[
\frac{(163 - 1267)}{1267} \times 100 = 0.24\%
\]

Use original dry mass

\[
\frac{25}{1267} \times 100 = 2.0
\]

\[
\frac{163}{1267} \times 100 = 12.9
\]
Gradation & Fineness Modulus:

<table>
<thead>
<tr>
<th>Dry Sample Wt.</th>
<th>1267 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample:</td>
<td></td>
</tr>
<tr>
<td>Retained</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size, (mm)</th>
<th>Sieve Size, (US)</th>
<th>Mass, (g)</th>
<th>Ind. % Retained</th>
<th>Cum % Retained</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1 1/2&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>75</td>
<td>1&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>3/4&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>1/2&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>4.75</td>
<td># 4</td>
<td>25</td>
<td>2.0</td>
<td>2.0</td>
<td>85.1</td>
</tr>
<tr>
<td>2.36</td>
<td># 8</td>
<td>163</td>
<td>12.9</td>
<td>14.9</td>
<td>85.1</td>
</tr>
<tr>
<td>1.18</td>
<td>#16</td>
<td>226</td>
<td>18.0</td>
<td>32.9</td>
<td>67.1</td>
</tr>
<tr>
<td>0.6</td>
<td># 30</td>
<td>278</td>
<td>22.0</td>
<td>54.9</td>
<td>45.1</td>
</tr>
<tr>
<td>0.3</td>
<td># 50</td>
<td>355</td>
<td>28.1</td>
<td>83.0</td>
<td>17.0</td>
</tr>
<tr>
<td>0.15</td>
<td># 100</td>
<td>177</td>
<td>14.0</td>
<td>97.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td>38</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1264</td>
<td>100</td>
<td>2.85 FM</td>
<td></td>
</tr>
</tbody>
</table>

**Sieve Loss Check:** 0.24%

**Gradation & Fineness Modulus:**

<table>
<thead>
<tr>
<th>Dry Sample Wt.</th>
<th>1267 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample:</td>
<td></td>
</tr>
<tr>
<td>Retained</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size, (mm)</th>
<th>Sieve Size, (US)</th>
<th>Mass, (g)</th>
<th>Ind. % Retained</th>
<th>Cum % Retained</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1 1/2&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>75</td>
<td>1&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>3/4&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>1/2&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>4.75</td>
<td># 4</td>
<td>25</td>
<td>2.0</td>
<td>2.0</td>
<td>85.1</td>
</tr>
<tr>
<td>2.36</td>
<td># 8</td>
<td>163</td>
<td>12.9</td>
<td>14.9</td>
<td>85.1</td>
</tr>
<tr>
<td>1.18</td>
<td>#16</td>
<td>226</td>
<td>18.0</td>
<td>32.9</td>
<td>67.1</td>
</tr>
<tr>
<td>0.6</td>
<td># 30</td>
<td>278</td>
<td>22.0</td>
<td>54.9</td>
<td>45.1</td>
</tr>
<tr>
<td>0.3</td>
<td># 50</td>
<td>355</td>
<td>28.1</td>
<td>83.0</td>
<td>17.0</td>
</tr>
<tr>
<td>0.15</td>
<td># 100</td>
<td>177</td>
<td>14.0</td>
<td>97.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td>38</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1264</td>
<td>100</td>
<td>2.85 FM</td>
<td></td>
</tr>
</tbody>
</table>

**Sieve Loss Check:** 0.24%

1" & 1/2" sieve are NOT used to calculate FM

Never include the Pan when calculating the FM

Σ Cum% retained/100
Gradation & Fineness Modulus:

<table>
<thead>
<tr>
<th>Sieve Size, (mm)</th>
<th>Sieve Size, (US)</th>
<th>Mass, (g)</th>
<th>Ind. % Retained</th>
<th>Cum % Retained</th>
<th>% Passing</th>
<th>ASTM C33 6.1 Fine Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1 1/2”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>75</td>
<td>1”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>3/4”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>3/8”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td># 4</td>
<td>25</td>
<td>2.0</td>
<td>98.0</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>4.75</td>
<td># 8</td>
<td>163</td>
<td>12.9</td>
<td>14.9</td>
<td>85.1</td>
<td>80</td>
</tr>
<tr>
<td>2.36</td>
<td># 16</td>
<td>228</td>
<td>18.0</td>
<td>32.9</td>
<td>67.1</td>
<td>50</td>
</tr>
<tr>
<td>1.18</td>
<td># 30</td>
<td>278</td>
<td>22.0</td>
<td>54.9</td>
<td>45.1</td>
<td>25</td>
</tr>
<tr>
<td>0.6</td>
<td># 50</td>
<td>355</td>
<td>28.1</td>
<td>83.0</td>
<td>17.0</td>
<td>5</td>
</tr>
<tr>
<td>0.3</td>
<td># 100</td>
<td>177</td>
<td>14.0</td>
<td>97.0</td>
<td>3.0</td>
<td>0</td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td>38</td>
<td>3.0</td>
<td>100</td>
<td>0.24%</td>
<td>2.85 FM</td>
</tr>
</tbody>
</table>

FM = 2.85

Can you use this SAND to manufacture Pipe under C76?
Gradation High Fineness Modulus:

<table>
<thead>
<tr>
<th>Dry Sample Wt.</th>
<th>1091</th>
<th>g</th>
</tr>
</thead>
</table>

**Sample:**

<table>
<thead>
<tr>
<th>Sieve Size, (mm)</th>
<th>Sieve Size, (US)</th>
<th>Mass, (g)</th>
<th>Ind. % Retained</th>
<th>Cum % Retained</th>
<th>% Passing</th>
<th>ASTM C33 6.1 Fine Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1 1/2&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100 100</td>
</tr>
<tr>
<td>75</td>
<td>1&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100 100</td>
</tr>
<tr>
<td>37.5</td>
<td>3/4&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100 100</td>
</tr>
<tr>
<td>19</td>
<td>1/2&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100 100</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100 100</td>
</tr>
<tr>
<td>4.75</td>
<td># 4</td>
<td>90</td>
<td>8.3</td>
<td>8.3</td>
<td>91.7</td>
<td>95 100</td>
</tr>
<tr>
<td>2.36</td>
<td># 8</td>
<td>251</td>
<td>23.1</td>
<td>31.4</td>
<td>68.6</td>
<td>80 100</td>
</tr>
<tr>
<td>1.18</td>
<td># 16</td>
<td>230</td>
<td>21.1</td>
<td>52.5</td>
<td>47.5</td>
<td>50 85</td>
</tr>
<tr>
<td>0.6</td>
<td># 30</td>
<td>190</td>
<td>17.5</td>
<td>70.0</td>
<td>30</td>
<td>25 60</td>
</tr>
<tr>
<td>0.3</td>
<td># 50</td>
<td>140</td>
<td>22.1</td>
<td>92.1</td>
<td>7.9</td>
<td>5 30</td>
</tr>
<tr>
<td>0.15</td>
<td># 100</td>
<td>77</td>
<td>7.1</td>
<td>99.2</td>
<td>0.8</td>
<td>0 10</td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td>10</td>
<td>0.9</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1088</td>
<td>100</td>
<td>3.54</td>
<td></td>
<td>FM 2.3 FM 3.1</td>
</tr>
</tbody>
</table>

Sieve Loss Check: 0.275%
Fine Aggregates: Greatest Affect on Water Demand

Fine aggregates have between 25 and 40 times more surface area than coarse aggregates of same weight and volume.
Why Aggregates Affect Water Demand

Small boxes have equal volume, but twice the surface area.

### 2 Units
- **Volume:** $2 \times 2 \times 2 = 8$
- **Surface Area:** $6 \times (2 \times 2) = 24$

### 1 Unit
- **Volume:** $8 \times (1 \times 1 \times 1) = 8$
- **Surface Area:** $8 \times (6 \times 1) = 48$

Aggregates Critical to the Water Demand

- Aggregates take up the largest amount of volume in concrete.
- Aggregate particle size, distribution, shape, and texture affect the amount of water needed in concrete.
- Therefore, more than any other material, aggregates have the greatest affect on the water needed for a given concrete workability.
Absorption and Moisture Content

- Bone Dry or Oven Dry
- Air Dry
- Saturated and Surface Dry
- Moist

Absorbed moisture (absorption)

SSD (ideal)

Free moisture (moisture content)

Total water content

Absorption

- Aggregate particles are not solid...they contain pores that absorb water.
- Concrete mixes are designed based on aggregates being in the saturated surface-dry (SSD) condition.
- Aggregate in the SSD condition is in a state of equilibrium...it will neither absorb water from nor give up water to a concrete mix.
- In reality, this state is not achievable in production concrete.
Aggregate Absorption * Aggregate Total Moisture

Aggregate absorption
\[ A = \text{absorption of an aggregate} \]
\[ A = \frac{\text{SSD Wt} - \text{Dry Wt}}{\text{Dry Wt}} \times 100\% \]

Aggregate total moisture
\[ MC = \text{Moisture content} \]
\[ MC = \frac{\text{Wet Wt} - \text{Dry Wt}}{\text{Dry Wt}} \times 100\% \]

Wet Wt is the field weight of the aggregate with moisture

Example:
\[ \text{Wet Wt} = 1000 \text{ g} \]
\[ \text{Dry Wt} = 980 \text{ g} \]
\[ \frac{1000 - 980}{980} \times 100 = 2.4\% \]

Never include the weight of the pan!

Aggregate Moisture

Total Moisture = Free moisture + Aggregate absorbed moisture

\[ \% \text{Total Moisture Content} = \frac{\text{(Wet Wt - Dry Wt)}}{\text{Dry Wt}} \times 100 \]

Example:
\[ \text{Wet Wt} = 1000 \text{ g} \]
\[ \text{Dry Wt} = 980 \text{ g} \]
\[ \frac{1000 - 980}{980} \times 100 = 2.4\% \]

Never include the weight of the pan!

\[ \% \text{Free Moisture} = \text{Total Moisture} - \text{Absorbed Moisture} \]
How do we measure moisture in aggregates

Cook out method

Stove top or microwave

Chapman Flask

“Speedy” moisture meter

Total Moisture = Free moisture + Aggregate absorbed moisture

Chapman Flask - Moisture Determination

- Fill Chapman flask to 200 ml mark with water
- 500.0 gram sample of damp aggregate
- Add aggregate sample to flask
- Agitate flask with sample to remove entrapped air
- Obtain reading from flask
- Using SSD specific gravity of sand look up free moisture on chart
Moisture Compensation

Concrete Mix designs are most often based on SSD conditions for the aggregates, these conditions seldom exist in reality. A mix containing 1400 pounds of sand with a free moisture of 5% will carry 70 pounds of addition water into the mix. This water must be adjusted out of the design water.

Mix design calls for:
- Sand (ssd) 1400 lb.
- Water 300 lb.

**Batch Weights**

<table>
<thead>
<tr>
<th>SAND:</th>
<th>1400 lb X 5% (free) = 70.00 pounds of water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Batch out (1400 + 70) = 1470</td>
</tr>
</tbody>
</table>

**WATER:**

300 - 70 = 230 net water

All aggregates must be adjusted.
Moisture Adjustment

<table>
<thead>
<tr>
<th>Materials</th>
<th>Pounds of Material</th>
<th>S.G.</th>
<th>Abs Volume</th>
<th>SSD</th>
<th>Moisture Adjustment</th>
<th>Batch Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>400</td>
<td>3.15</td>
<td>2.04</td>
<td>400</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Type F Ash</td>
<td>100</td>
<td>2.48</td>
<td>0.65</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Miller Stone</td>
<td>1873</td>
<td>2.85</td>
<td>10.53</td>
<td>1873</td>
<td>37</td>
<td>1910</td>
</tr>
<tr>
<td>Evert Sand</td>
<td>1247</td>
<td>2.62</td>
<td>7.63</td>
<td>1247</td>
<td>50</td>
<td>1297</td>
</tr>
<tr>
<td>Water</td>
<td>300</td>
<td>1.00</td>
<td>4.81</td>
<td>300</td>
<td>87</td>
<td>213</td>
</tr>
<tr>
<td>Air</td>
<td>5%</td>
<td>1.35</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3920</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3920</td>
</tr>
</tbody>
</table>

Density: 145.2

Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Total Moisture %</th>
<th>Absorption %</th>
<th>Free Moisture %</th>
<th>Moisture Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miller Stone</td>
<td>3.00</td>
<td>1.00</td>
<td>2.00</td>
<td>37</td>
</tr>
<tr>
<td>Evert Sand</td>
<td>5.50</td>
<td>1.50</td>
<td>4.00</td>
<td>50</td>
</tr>
</tbody>
</table>

Total moisture = Free moisture + Aggregate absorption

Moisture Probes

- Used in batching
- Installed per manufactures recommendations
- Must be calibrated
- There is a difference between a mixer probe and a bin probe

www.concrete-pipe.org
Concrete Properties Influenced by Aggregates

- **Strength**
  - Compressive or Flexural
  - Bonding Properties
  - Surface texture, mineralogy, cleanliness
  - Particle shape, max size, and grading
  - Compatibility

- **Finishability**
  - In general, the more rounded (especially in sand) the particle shape = better finishability

- **Water Requirements**
  - Grading, particle shape, mineralogy, and absorption
Concrete Properties Influenced by Aggregates

- **Workability**
  - **Grading**
    - Particle size and distribution
    - Affects economy of mix design
    - Should be graded up to the largest size practical for job conditions
    - Affects workability and placeability
  - **Nature of particles**
    - Shape, porosity, surface texture

- **Durability**
  - Freeze-thaw resistance, potential for cracking, abrasion, wet/dry, heat/cool, ASR
  - Air entrainment will not protect against concrete made with non-durable aggregates

- **Volume Change**
  - Larger the volume fraction of aggregate, the lower the drying shrinkage of concrete
  - Use largest nominal max size of coarse aggregate to reduce potential of drying shrinkage
Fine Aggregates in Concrete

- Coarse sand or under-sanded mixes:
  - hard to pump
  - hard to consolidate
  - bleed excessively
  - segregate
  - hard to get accurate slump

- Fine sand or over-sanded mixes:
  - increase water demand
  - sticky, hard to finish surface
  - reduced strength
  - blister
  - bugholes
  - scaling

Aggregate Texture and Shape

- Affect the properties of fresh concrete:
  - rough textured, angular, elongated particles have greater surface area and require more cement paste than do smooth rounded particles
  - angular and poorly graded aggregates are harder to finish

- Generally:
  - rounded gravel makes stronger and more finishable lean mixes
  - angular crushed stone is better suited for high strength, richer cement paste mixes
Particle Shape

(a) Rounded
(b) Angular
(c) Flaky
(d) Elongate
(e) Elongate and Flaky

Specific Gravity

Stone: Specific Gravity = 2.70

Water: Specific Gravity = 1.00

Same Volume, but 2.70 Times More Mass
Specific Gravity

- The relative density of a material compared to water
- The ratio of a material's weight to the weight of an equal volume of water
- Bulk specific gravity (SSD):
  - Used to determine the "solid volume" (absolute volume) of a material going into concrete
  - It is determined by submerging the material in water for 24 hours in order to fill any permeable voids
- Absorption is the penetration liquid into aggregate particles
- Test Procedures: ASTM C 127 for CA and C 128 for FA
- Not a measure of quality
- Ensures proper yield
- SG of normal weight aggregates vary from 2.40 to 2.80

Sampling Aggregate for Testing

- Obtain truly representative sample
  - Critical to any standardized testing of concrete materials.
- Every time aggregate is moved, handled or stored they tend to segregate.
  - As particles tend to segregate (fines vs. coarse) samples obtained may not represent the pile.
Reducing Field Samples

- ASTM D75 Collecting Sample from Stockpile
- ASTM C702 Reducing Samples of Aggregate to Testing Size
- Sample Splitter Method
  - Each sample must be representative of total product (i.e., sampled correctly)
  - Sample Splitter
    - Must have equal width chutes
    - Must have two receptacles
  - Place sample in hopper
  - Distribute Evenly
  - Allow to Freely Flow
  - Repeat as many times as necessary.

Sample Splitter
Reducing Field Samples (stockpile method)

- Mix Sample
- Place in Single Pile
- Divide Into Equal Quarters
- Collect Opposite Quarters

Reducing Field Samples

Cone sample on hard, clean surface
Mix by forming new cone
Quarter after flattening cone

Sample divided into quarters
Retain opposite corners, reject other two corners

Quartering on a Hard, Clean Surface
Aggregate Quality Control

• Critical to obtain predictable and consistent concrete properties
• QC Program

QUESTIONS?