Concrete Physical & Mechanical Properties

**Introduction**

- Composition.
- Physical Properties.
- Mechanical Properties.
- Defects & Deterioration.

**Composition**

- Portland Cement.
- Aggregate.
- Mixing Water.
- Entrapped Air.
- Admixtures.
- Supplementary Cementing Materials.

**Proportions of Materials in Concrete**
Cross-section of Concrete

Portland Cement
- It was invented in 18th century and called Portland cement.
- Chemical compound which reacts with water to form a stone like mass (hydration).

Portland Cement
- 73% Limestone
- 23% Clay
- 2% Iron
- 3% Sand

Cement Manufacture
Cement Manufacture

Types of Cement

- Type “GU” – General use.
- Type “HE” – High early strength.
- Type “MS” – Moderate sulfate resistance.
- Type “HS” – High sulfate resistance.
- Type “MH” – Moderate heat of hydration.
- Type “LH” – Low heat of hydration.

Water

Impurities cause:
- abnormal set
- decreased strength
- volume change
- efflorescence
- corrosion of reinforcement
Characteristics of Aggregate

- Clean & sound.
- Abrasion resistance
- Freeze & thaw resistance
- Wetting & drying properties
- Chemical stability
- Alkali aggregate reactivity
- Shape and surface texture
- Aggregate grading

Grading Limits

<table>
<thead>
<tr>
<th>Sieve sizes - nominal opening</th>
<th>Percent Passing by Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td>100</td>
</tr>
<tr>
<td>140</td>
<td>90</td>
</tr>
<tr>
<td>125</td>
<td>70</td>
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<tr>
<td>112</td>
<td>50</td>
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<td>100</td>
<td>30</td>
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<tr>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>80</td>
<td>0</td>
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</table>
### Fineness Modulus

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage Retained by Mass</th>
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<tbody>
<tr>
<td>16 mm</td>
<td>0</td>
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<tr>
<td>5 mm</td>
<td>2</td>
</tr>
<tr>
<td>2.5 mm</td>
<td>15</td>
</tr>
<tr>
<td>1.25 mm</td>
<td>35</td>
</tr>
<tr>
<td>630 µm</td>
<td>55</td>
</tr>
<tr>
<td>315 µm</td>
<td>79</td>
</tr>
<tr>
<td>160 µm</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td>283</td>
</tr>
</tbody>
</table>

Fineness Modulus $= \frac{283}{100} = 2.83$

### Air-Entrained Concrete

- Freeze-thaw resistance
- Improves workability
- Finishes sooner
- Reduces water
- Reduces segregation and bleeding
- Improves sulfate resistance
- Entrained air 5% to 8%

### Thermal Expansion

- Concrete: $9.9 \times 10^{-6}/°\text{C}$
- Steel: $12.0 \times 10^{-6}/°\text{C}$

### Volume Change due to Moisture

- Swelling
- Shrinkage

### Physical Properties

- Thermal expansion:
  - Concrete: $9.9 \times 10^{-6}/°\text{C}$
  - Steel: $12.0 \times 10^{-6}/°\text{C}$
**Swelling/Shrinkage**

- Stored in water
- Stored in air

**W/C Ratio & Shrinkage of Paste**

<table>
<thead>
<tr>
<th>Age (Days)</th>
<th>W/C = 0.26</th>
<th>W/C = 0.45</th>
<th>W/C = 0.55</th>
<th>W/C = 0.65</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.8</td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td>28</td>
<td>0.8</td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td>90</td>
<td>0.8</td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td>180</td>
<td>0.8</td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td>270</td>
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<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td>360</td>
<td>0.8</td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
</tr>
</tbody>
</table>

**Mechanical Properties**

- Strength
  - Compressive (28 day – f’c)
  - Tensile (10% of f’c)
  - Shear (12% to 13% of f’c)
  - Flexural (14% of f’c)
- Abrasion resistance
- Creep
- Fire resistance
- Durability
- Permeability

**W/C Ratio vs. Strength**

- Non air-entrained concrete
- Air-entrained concrete

**Concrete Physical & Mechanical Properties**

- Swelling/Shrinkage
- W/C Ratio & Shrinkage of Paste
- Mechanical Properties
- W/C Ratio vs. Strength
Effect of Curing on Strength

Compressive Strength & Air Content

Wear vs. Strength

Concrete Strength & Creep
**Concrete Physical & Mechanical Properties**

**Curing Method & Creep**

- **7 days moist cured**
- **Atmospheric steam cured**
- **High-pressure steam cured**

Time after loading (Days) vs. Creep Deflection

**Age of Loading & Creep**

- **Age of loading 28 days**
- **90 days**
- **180 days**

Age (Days) vs. Creep Strain

**Freeze/Thaw Resistance, Air & W/C Ratio**

- Fog cured 16 days
- Dried 76 days at 50% RH
- Air entrained concrete
- Non-air entrained concrete
- Fog cured 28 days
- No drying

Cycles of freezing & thawing vs. % loss in mass

**Permeability, W/C Ratio & Curing**

- Non-air entrained concrete
  - 1 day moist, 90 days in air
  - 7 days moist, 90 days in air

Permeability (cm/sec) vs. W/C Ratio
Deterioration Stains

Staining, Efflorescence & Corrosion

Deck Ponding

Surface Durability
Freeze-Thaw Damage

Light Scaling

Medium Scaling

Heavy Scaling
Concrete Physical & Mechanical Properties

Sound Concrete Deck

Surface Abrasion

Concrete Stress-Strain Relationship

\[
\text{Strain} = \frac{\Delta L}{L} \\
\Delta L = 0.003 \times 300 = 0.9 \text{ mm}
\]
High-Performance Concrete

- High strength.
- High modulus of elasticity.
- High abrasion resistance.
- Low permeability and diffusion.
- Resistance to chemical attack.
- High resistance to frost.
- Ease of placement

Self-Compacting Concrete

- Able to flow and consolidate on its own.
- Must be cohesive to fill spaces without segregation.
- Useful wherever placing is difficult.
- SCC reduces the need for vibration.
- It is based on increasing the amount of fine material without changing the water content.

Shrinkage Cracks

Map Cracking
Concrete Physical & Mechanical Properties

**Flexural Cracks**

**Construction Joint**

**Corrosion Spalls & Pop-outs**

**Corrosion Spall**
Questions??