Concrete Technology

Brief Recap
Manufacturing Process of Portland Cement

- **Raw material for cement**
  - **Calcareous Materials**
    - e.g. limestone
    - Chalk
    - marl
  - **Argillaceous materials**
    - e.g.
    - Clay
    - Shale

**Calcarius**: Composed of or containing calcium or calcium carbonate.

**Argillaceous minerals**: are minerals containing substantial amounts of clay-like components. Argillaceous components are aluminosilicates, and more particularly clay minerals such as kaolinite, montmorillonite-smectite, illite, and chlorite. Claystone and shales are thus predominantly argillaceous
Processes of Manufacturing

- Wet Process
- Dry Process
- Semi-Dry Process
Wet Process

FIG. 1.1: FLOW CHART FOR WET PROCESS OF CEMENT MANUFACTURING
Dry Process

**Flow Chart for Dry Process of Cement Manufacturing**

1. **Calcareous Material Lime Stone**
   - Crushing
   - Fine Grinding in Ball mills & Tube mills
   - Storage basin
   - Mixing in correct proportions
   - Preheating @ 800° by exhaust gases
   - Storage tank for raw mix
   - Fuel fed from lower end (coal, oil or natural gas.)
   - Fed to rotary kiln
   - Clinkers are formed
   - Addition of 2 to 3% of gypsum
   - Clinkers are ground in Ball mill
   - Cement silos
   - Packing plant

2. **Argillaceous Material Clay**
   - Crushing
   - Fine Grinding in Ball mills & Tube mills
   - Storage basin
   - Channel

**FIG. 1.3 : FLOW CHART FOR DRY-PROCESS OF CEMENT MANUFACTURING**
Semi-Dry Process

In the semi-dry process raw materials are crushed and fed to a grinding mill to convert it into fine powder. The dry powder called raw mix is pumped in a blending silo where the correct proportions are adjusted and intimately mixed by compressed air. This blended meal is now sieved and fed into a rotating dish called granulator and about 10-14 percent water is added at the same time. In this way the meal is converted into hard pallets of about 15 mm diameter. The pallets are baked by means of hot gases available from the kiln. These baked pallets are fed into the kiln. The subsequent operations are same as in wet process.

<table>
<thead>
<tr>
<th>Number of large cement factories in India (March 1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet process</td>
</tr>
<tr>
<td>49 plants</td>
</tr>
<tr>
<td>Dry process</td>
</tr>
<tr>
<td>115 plants</td>
</tr>
<tr>
<td>Semi-dry process</td>
</tr>
<tr>
<td>9 plants</td>
</tr>
<tr>
<td>Total 173 plants</td>
</tr>
</tbody>
</table>
Composition of Concrete

• Concrete is composed of,
• Concrete = Cement + Sand + aggregate + water + admixtures + air
• Cement: The function of cement is to bind the aggregates. It also fills the void between sand and aggregate.
• Aggregate:
  • The aggregate occupy about 75% of the volume and hence their influence on various properties of concrete is considerable. Aggregates are generally cheaper than cement and impart greater volume, stability, and durability to concrete. The aggregate generally provides bulk to the concrete.
• Water: Water is required for carrying out chemical reactions in cement. If the water content is less the heat of hydration is not possible, hence the strength of concrete will be reduced. If water content is in excess water will cause undesirable capillary cavities and concrete becomes porous.
• Admixtures: Admixtures is defined as a material other than the basic ingredient of concrete mixed immediately before or during mixing to modify some properties of concrete in the fresh or hardened state.
• The use of admixtures like accelerators, retarders, air-entraining agents, pozzolanic material, water proofing admixtures etc.
Cement
Aggregate
Composition of Concrete

• The properties commonly modified using admixtures are setting time, workability, air entrainment, dispersion etc. The admixtures are generally added in small quantity from 0.005 to 2 % by cement weight. Overuse of admixtures have detrimental effect on the properties of concrete.

• **Air:** The voids in the mass of concrete can be classified into two groups
  - Entrapped air
  - Entrained air
Composition of Concrete

• **Entrapped air:** The entrapped air is the void present in the concrete due to insufficient compaction

• **Entrained air:** The entrained air is the intentionally incorporated minute spherical bubbles
Entrapped Air
Entrained Air
Ingredients of Concrete
Strength Mechanism

• When water is added to cement, ingredients of cement react chemically with water and form various complicated chemical compounds. The chemical reaction that takes place between cement and water is referred as hydration of cement.

• Anhydrous cement does not bind fine and course aggregates. It acquire adhesive property only when water is mixed.

• The silicates ($C_3S$, $C_2S$) and aluminates of cement react with water and form hydro silicates and hydro aluminates. These products are thick and sticky. It is called gel. Gel posses adhesive property and binds aggregate and sand togeather. It also fill the voids between sand and aggregate.
Oxide Composition of Cement

- The raw material used for the manufacturing of Ordinary Portland cement contains mainly lime, silica, alumina, and iron oxide. These oxides interact with one another in the kiln at high temperature to form more complex compounds. The relative proportions of these oxide compounds are responsible for various physical properties of cement. Rate of cooling and fineness of grinding also affect the property of cement.
# Oxide Composition of cement

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime, CaO</td>
<td>60-67 %</td>
</tr>
<tr>
<td>Silica, SiO₂</td>
<td>17-25 %</td>
</tr>
<tr>
<td>Alumina, Al₂O₃</td>
<td>3-8 %</td>
</tr>
<tr>
<td>Iron Oxide, Fe₂O₃</td>
<td>0.5-6 %</td>
</tr>
<tr>
<td>Magnesia, MgO</td>
<td>0.5-4 %</td>
</tr>
<tr>
<td>Alkalies, K₂O, Na₂O</td>
<td>0.3-1.2 %</td>
</tr>
<tr>
<td>Sulphates, SO₃</td>
<td>1.0 – 3.0 %</td>
</tr>
</tbody>
</table>
Bogue’s Compounds

- As stated earlier the oxides present in the raw materials interact with one another in the kiln at high temperature to form more complex compounds. The identification of the major compound is largely based on the work of R.H.Bogue. And other and so it is often referred as ‘Bogue’s Compounds’ or Bogue’s Composition’.
# Bogue’s Compounds

<table>
<thead>
<tr>
<th>Name of Compound</th>
<th>Formula</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricalcium silicate</td>
<td>3 CaOSiO(_2)</td>
<td>C(_3)S</td>
</tr>
<tr>
<td>Dicalcium Silicate</td>
<td>2CaOSiO(_2)</td>
<td>C(_2)S</td>
</tr>
<tr>
<td>Tricalcium aluminate</td>
<td>3CaOAl(_2)O(_3)</td>
<td>C(_3)A</td>
</tr>
<tr>
<td>Tetracalcium aluminoferrite</td>
<td>4CaO.Al(_2)O(_3).Fe(_2)O(_3)</td>
<td>C(_4)AF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bogue’s Compound</th>
<th>Percentage by mass in cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(_3)S</td>
<td>30-50</td>
</tr>
<tr>
<td>C(_2)S</td>
<td>20-45</td>
</tr>
<tr>
<td>C(_3)A</td>
<td>08-12</td>
</tr>
<tr>
<td>C(_4)AF</td>
<td>06-10</td>
</tr>
</tbody>
</table>
Bogue’s Compounds

• In addition to four major compound there exists minor compounds, such as MgO, TiO$_2$, Mn$_2$O$_3$, K$_2$O, Na$_2$O.

• Two of the minor compounds of interest are K$_2$O, Na$_2$O, known as alkalies. They have been found to react with some aggregates, the product of this reaction causing disintegration of concrete, and also have been found to affect strength of cement.
Properties of Bogue’s Compounds

- The properties of Bouge’s are as under:

  - $C_3S$:
    - It is responsible for early strength
    - First 7 days strength is due to $C_3S$
    - It Produces more heat of Hydration
    - A cement with more $C_3S$ content is better for cold weather concreting.

  - $C_2S$:
    - The hydration of $C_2S$ starts after 7 days. Hence, it gives strength after 7 days.
    - $C_2S$ hydrates and hardens slowly and provides much of the ultimate strength.
    - It is responsible for the later strength of concrete.
    - It produces less heat of hydration.
Properties of Bogue’s Compounds

• **C₃A:**
  - The reaction of C₃A with water is very fast and may lead to an immediate stiffening of paste, and this process is termed as flash set.
  - To prevent this flash set, 2 to 3 % gypsum is added at the time of grinding the cement clinkers.
  - The hydrate C₃A do not contribute to the strength of concrete.

• **C₄AF:**
  - C₄AF hydrates rapidly.
  - It does not contribute to the strength of concrete.
  - The hydrates of C₄AF show a comparatively higher resistance to sulphate attack than the hydrates of C₃A
Hydration of Cement

• When water is added to cement, ingredients of cement react chemically with water and form various complicated chemical compounds. The chemical reaction that takes place between cement and water is referred as hydration of cement.

• Anhydrous cement does not bind fine and course aggregates. It requires adhesive property only when mixed with water.

• The silicates (C₃S, C₂S) and aluminates (C₃A) aluminates of cement react with water and form hydro silicates and hydro aluminates. These products are thick and sticky. It is called gel. Gel posses adhesive property and binds aggregate and sand togeather. It also fill voids between sand and aggregate.
Hydration of Cement

• The hydration process is not an instantaneous one. The reaction is faster in the early stage and continuous indefinitely at a decreasing rate. Complete hydration cannot be obtained under a period of one year or more unless the cement is very finely ground.
Hydration of Cement

Raw Materials for Cement

- Calcareous materials - limestone, chalk
- Argillaecous materials - clay, shale

Component Elements

- O₂
- Si
- Ca
- Al
- Fe

Component Oxides

- CaO
- SiO₂
- Al₂O₃
- Fe₂O₃

Cement Compounds

- C₃S
- C₂S
- C₃A
- C₄AF

Portland Cement

Various types of Portland cement

Hydration Products

- C–S–H gel and Ca (OH)₂
- Schematic diagram of hydration of cement
Hydration of Cement

[Graph showing the hydration of different cement compounds over time, with compressive strength values in MPa and psi as the y-axis and time in days on the x-axis.]
Ordinary Portland Cement

• The raw materials required for manufacture of portland cement are calcareous materials, such as limestone or chalk, and argillaceous material such as shale or clay. The process of manufacturing of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon purity and composition and burning them in a kiln at temperature of about 1300 to 1500 °C at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinkers is cooled and grounded to a fine powder with addition of about 2 to 3 % of gypsum. The product formed by using this procedure is Portland cement.
Ordinary Portland Cement
Portland Pozzolana Cement

- The portland Pozzolana Cement is manufactured by the intergrinding of OPC clinker with 15 to 35% of pozzolanic material. The pozzolanic material generally used for the manufacturing of Portland Pozzolana Cement (PPC) are flyash and calcined clay. The pozzolanic material are essentially a silicious or aluminious material which itself possessing no cementitious properties, which will in finely divided form and in the presence of water, reacts with calcium hydroxide, liberated in the hydration process, to form compounds possessing cementitious properties.

- The hydration of C₃S and C₂S produce considerable quantity of calcium hydroxide (Ca(OH)₂) which is by large a useless material from the point of view of strength and durability. If such useless mass could be converted into a useful cementitious product, it considerable improves quality of concrete.

- \[ \text{Ca(OH)}_2 + \text{flyash or calcined clay} + \text{Water} \rightarrow \text{C-S-H gel (gel)} \]

- It is important to note that addition of pozzolana does not contribute to the strength at early ages, but gives later strengths similar to those of OPC.
Thanks