Lecture outcomes

- **Light weight concrete**
  - Light weight aggregate concrete
  - Aerated concrete
  - No – fines concrete

- **Colored concrete**

- **Polymer concretes**
  - Impregnated polymer concretes
  - Polymer binder concrete
  - Cement polymer concretes
Introduction:

- Light weight concrete is a special concrete which weighs lighter than conventional concrete.

- Density of this concrete is considerably low (300 kg/m3 to 1850 kg/m3) when compared to normal concrete (2200 kg/m3 to 2600 kg/m3).

- Three types of LWC:
  1) Light weight aggregate concrete
  2) Aerated concrete
  3) No – fines concrete
**Advantages:**

- Reduces the dead load of the building
- Easy to handle and hence reduces the cost of transportation and handling
- Improves the workability
- Relatively low thermal conductivity
- Comparatively more durable, but less resistant to abrasion
- Has applications in pre-stressed concrete, high rise buildings & shell roofs
- Good resistance to freezing & thawing action when compared to conventional concrete.
- Helps in disposal of industrial wastes like fly ash, clinker, slag etc.

**Disadvantages**

- Very sensitive with water content in the mixtures.
- Difficult to place and finish because of the porosity and angularity of the aggregate.
- Mixing time is longer than conventional concrete to assure proper mixing.
**Principle behind LWC:**

The basic principle behind the making of light weight concrete is by inducing the air in concrete.

To achieve the above principle practically, there are 3 different ways:

1) By replacing the conventional mineral aggregates by cellular porous aggregates (Light weight aggregate concrete)

2) By incorporating the air or gas bubbles in concrete (Aerated concrete).

3) By omitting the sand from the concrete (No- fines concrete).

**Light weight aggregate concrete:**

Basically two types of light weight aggregates

- Natural aggregates
- Artificial aggregates

**Natural light weight aggregates**

- Less preferred over artificial aggregates.
- Important natural aggregates – Pumice & Scoria

**Artificial aggregates**

- usually produced by expanding the rocks such as Shale, Slate, Perlite, Vermiculite, etc.,
### Properties of light weight aggregates:

- Pumice and Scoria are volcanic rocks having densities between 500kg/m³ to 800kg/m³.

- Natural aggregates have good insulating properties but subjected to high absorption and shrinkage.

<table>
<thead>
<tr>
<th>Natural light-weight aggregate</th>
<th>Artificial light-weight aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Pumice</td>
<td>(a) Artificial cinders</td>
</tr>
<tr>
<td>(b) Diatomite</td>
<td>(b) Coke breeze</td>
</tr>
<tr>
<td>(c) Scoria</td>
<td>(c) Foamed slag</td>
</tr>
<tr>
<td>(d) Volcanic cinders</td>
<td>(d) Bloated clay</td>
</tr>
<tr>
<td>(e) Sawdust</td>
<td>(e) Expanded shales and slate</td>
</tr>
<tr>
<td>(f) Rice husk</td>
<td>(f) Sintered fly ash</td>
</tr>
<tr>
<td></td>
<td>(g) Exfoliated vermiculite</td>
</tr>
<tr>
<td></td>
<td>(h) Expanded perlite</td>
</tr>
<tr>
<td></td>
<td>(i) Thermocole beads.</td>
</tr>
</tbody>
</table>

### Natural aggregates

**Pumice:**
- These are rocks of volcanic origin.
- They are light colored or nearly white and has a fairly even texture of interconnected voids.
- Its bulk density is 500 – 800 kg/ m³.

**Scoria:**
- Scoria is light weight aggregate of volcanic origin.
- They are dark in colour It is slightly weaker than pumice.
Perlite & Vermiculite gives lowest possible dense concrete. (Perlite – 30kg/m$^3$ to 240 kg/m$^3$ and Vermiculite 60kg/m$^3$ to 130kg/m$^3$).

Vermiculite
- hydrated laminar minerals which are aluminium-iron-magnesium silicates, resembling mica in appearance

Expanded Perlite:
- siliceous volcanic rock
- This expansion is due to the presence of two to six percent combined water in the crude perlite rock.
- When quickly heated to above (870°C) the crude rock pops in a manner similar to popcorn
### Table 12.2. Typical Properties of Common Light-weight Concretes

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Type of Concretes</th>
<th>Bulk density of aggregates kg/m³</th>
<th>Dry density of kg/m³</th>
<th>Compressive strength of 28 days</th>
<th>Drying Shrinkage 10⁻⁶</th>
<th>Thermal conductivity J/m² K⁰ C⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sintered fly ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fine</td>
<td>1050</td>
<td>1500</td>
<td>25</td>
<td>300</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Coarse</td>
<td>800</td>
<td>1540</td>
<td>30</td>
<td>350</td>
<td>–</td>
</tr>
<tr>
<td>2.</td>
<td>Sintered fly ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>with natural sand</td>
<td>800</td>
<td>1700</td>
<td>25</td>
<td>300</td>
<td>–</td>
</tr>
<tr>
<td>3.</td>
<td>Pumice</td>
<td>500–800</td>
<td>1200</td>
<td>15</td>
<td>1200</td>
<td>0.14</td>
</tr>
<tr>
<td>4.</td>
<td>Perlite</td>
<td>40–200</td>
<td>400–500</td>
<td>1.2–3.0</td>
<td>2000</td>
<td>0.05</td>
</tr>
<tr>
<td>5.</td>
<td>Vermiculite</td>
<td>60–200</td>
<td>300–700</td>
<td>0.3–3.0</td>
<td>3000</td>
<td>0.10</td>
</tr>
<tr>
<td>6.</td>
<td>Cellular (Fly ash)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>950</td>
<td>750</td>
<td>3.0</td>
<td>700</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1600</td>
<td>900</td>
<td>6.0</td>
<td>–</td>
<td>0.22</td>
</tr>
<tr>
<td>7.</td>
<td>Autoelaved aerated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>–</td>
<td>800</td>
<td>4.0</td>
<td>800</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Structural light weight concrete:**

- Concrete which is light weight and has sufficient compressive strength.
- 28 days compressive strength of more than 17Mpa and 28 days dry density not exceeding 1850 kg/m³.
- Generally has normal fine aggregates and lighter coarse aggregates.
- Workability is less due to water absorption by the aggregates.
**Structural light weight concrete:**

- Drying shrinkage is more and less thermal expansion than normal concrete.
- Is good in sound proofing, sound absorption & thermal insulation.
- Economical when compared to normal weight concrete.
- Has good fire resistance property than conventional concrete.

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**Light weight concrete mix proportioning**

1. **Start**
   - Choice of slump

2. **Step 2**
   - Choice of nominal maximum size of coarse aggregate

3. **Step 3**
   - Estimation of mixing water and air content
   - Method of Mix Design

4. **Weight Method**
   - Step 4: Selection of appropriate w/c ratio
   - Step 5: Calculation of cement content
   - Step 6: Estimation of lightweight coarse aggregate content
   - Step 7: Estimation of fine aggregate content

5. **Volume Method**
   - Step 4: Estimation of cement content
   - Step 5: Estimation of total volume of aggregate
   - Step 6: Estimation of weight of fine aggregate
   - Step 7: Estimation of weight of coarse aggregate

6. **Step 8**
   - Trial mixtures
Light weight concrete mix proportioning

**Step 1:** choice of concrete slump

<table>
<thead>
<tr>
<th>Types of construction</th>
<th>Slump, (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Beams and reinforced walls</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>Building columns</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>Floor slabs</td>
<td>75</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3.1—Recommended slumps for various types of construction

Light weight concrete mix proportioning

**Step 2:** choice of nominal maximum size of course aggregate

- Generally, the nominal maximum size of aggregate should be the largest that is economically available and consistent with the dimensions of the structure.
  - the nominal maximum size should not exceed:
    - **one-fifth** of the narrowest dimension between sides of forms,
    - **one-third** the depth of slabs,
    - **three-quarters** of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pre-tensioning strands.
**Light weight concrete mix proportioning**

**Step 3:** estimation of mixing water and Air Content → based on slump and the maximum aggregate size

<table>
<thead>
<tr>
<th>Slump, (mm)</th>
<th>Mixing Water (kg/m³) of concrete for indicated nominal maximum sizes of aggregates</th>
<th>9.5 mm</th>
<th>12.7 mm</th>
<th>19.0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air-entrained concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 to 50</td>
<td></td>
<td>181</td>
<td>175</td>
<td>166</td>
</tr>
<tr>
<td>75 to 100</td>
<td></td>
<td>202</td>
<td>193</td>
<td>181</td>
</tr>
<tr>
<td>125 to 150</td>
<td></td>
<td>211</td>
<td>199</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>Recommended average total air content, percent, for level of exposure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild exposure</td>
<td></td>
<td>4.5</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Moderate exposure</td>
<td></td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Extreme exposure</td>
<td></td>
<td>7.5</td>
<td>7.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Non Air-Entrained Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 to 50</td>
<td></td>
<td>208</td>
<td>199</td>
<td>187</td>
</tr>
<tr>
<td>75 to 100</td>
<td></td>
<td>228</td>
<td>217</td>
<td>202</td>
</tr>
<tr>
<td>125 to 150</td>
<td></td>
<td>237</td>
<td>222</td>
<td>208</td>
</tr>
<tr>
<td>Approximate amount of entrapped air in non-air-entrained concrete, percent</td>
<td></td>
<td>3</td>
<td>2.5</td>
<td>2</td>
</tr>
</tbody>
</table>

**Light weight concrete mix proportioning**

**Step 4:** Selection of approximate water-cementitious ratio or minimum cementitious material content

<table>
<thead>
<tr>
<th>Compressive strength at 28 days, (MPa)</th>
<th>Approximate water-cement ratio, by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nonair-entrained concrete</td>
</tr>
<tr>
<td></td>
<td>41.4</td>
</tr>
<tr>
<td></td>
<td>34.5</td>
</tr>
<tr>
<td></td>
<td>27.6</td>
</tr>
<tr>
<td></td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>13.8</td>
</tr>
</tbody>
</table>

**Step 5:** Calculation of Cement Content
LWC mix proportioning: ACI 211.2

Step 6: Estimation of lightweight coarse aggregate content

The volume is converted to dry weight of coarse aggregate required in a unit volume of concrete by multiplying it by the oven-dry loose weight per (m$^3$) of the lightweight coarse aggregate.

- Example: Sand (Moduli 2.8) for 19mm max. agg size = 1*0.7*800 kg/m$^3$

<table>
<thead>
<tr>
<th>Maximum size of aggregate, (mm)</th>
<th>Volume of oven-dry loose coarse aggregates per unit volume of concrete for different fineness moduli of sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5</td>
<td>0.58 0.56 0.54 0.52</td>
</tr>
<tr>
<td>12.7</td>
<td>0.67 0.65 0.63 0.61</td>
</tr>
<tr>
<td>19.0</td>
<td>0.74 0.72 0.70 0.68</td>
</tr>
</tbody>
</table>

Type of Sand  Fineness Modulus Range
Fine Sand  2.2 – 2.6
Medium Sand  2.6 – 2.9
Coarse Sand  2.9 – 3.2

LWC mix proportioning: ACI 211.2

Step 7: Estimation of fine aggregate

- With the quantities of water, cement, and coarse aggregate established, the remaining material comprising the m$^3$ of concrete must consist of sand and the total air used.

<table>
<thead>
<tr>
<th>Specific gravity factor</th>
<th>First estimate of lightweight concrete weight, (kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air-entrained concrete</td>
</tr>
<tr>
<td></td>
<td>4% 6% 8%</td>
</tr>
<tr>
<td>1.00</td>
<td>1596 1561 1519</td>
</tr>
<tr>
<td>1.20</td>
<td>1680 1644 1608</td>
</tr>
<tr>
<td>1.40</td>
<td>1769 1727 1691</td>
</tr>
<tr>
<td>1.60</td>
<td>1852 1810 1775</td>
</tr>
<tr>
<td>1.80</td>
<td>1935 1899 1858</td>
</tr>
<tr>
<td>2.00</td>
<td>2024 1982 1941</td>
</tr>
</tbody>
</table>

specific gravity factor
Is: The ratio of the weight of aggregates, including all moisture, as introduced into the mixer to the effective volume displaced by the aggregates.
# LWC mix proportioning: ACI 211.2

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a.</td>
<td>Estimate free (net) water requirements. Compute absolute volume of water.</td>
<td>(W&lt;sub&gt;W&lt;/sub&gt;) (V&lt;sub&gt;W&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>b.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>a.</td>
<td>Based upon specification requirements (maximum, water/cementitious ratio, or minimum cement content) compute weight of cementitious materials.</td>
<td>(W&lt;sub&gt;CM&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>b.</td>
<td>Compute absolute volume of cementitious materials.</td>
<td>(V&lt;sub&gt;CM&lt;/sub&gt;)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Based upon specification requirements or durability exposure determine volume of air.</td>
<td>(V&lt;sub&gt;A&lt;/sub&gt;)</td>
</tr>
<tr>
<td>4</td>
<td>a.</td>
<td>Based upon current practice (usually related to density requirements for structural loads) establish weight of coarse lightweight aggregate.</td>
<td>(W&lt;sub&gt;CA&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>b.</td>
<td>Compute absolute volume of coarse aggregate.</td>
<td>(V&lt;sub&gt;CA&lt;/sub&gt;)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Sum up absolute volumes of water (V&lt;sub&gt;W&lt;/sub&gt;) cementitious materials (V&lt;sub&gt;CM&lt;/sub&gt;), air (V&lt;sub&gt;A&lt;/sub&gt;) and coarse lightweight aggregate (V&lt;sub&gt;CA&lt;/sub&gt;).</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Calculate volume (V&lt;sub&gt;FA&lt;/sub&gt;) and weight (W&lt;sub&gt;FA&lt;/sub&gt;) of fine aggregate necessary to make one cubic meter (cubic yard).</td>
<td>(V&lt;sub&gt;FA&lt;/sub&gt;) (W&lt;sub&gt;FA&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>V = volume (m&lt;sup&gt;3&lt;/sup&gt;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W = weight (kg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D = Density (kg/m&lt;sup&gt;3&lt;/sup&gt;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CM = Cement, A = Air</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CA = Coarse aggregate, FA = Fine aggregate</td>
</tr>
</tbody>
</table>

## Aerated concrete

Cellular structure of Hebel AAC
Aerated concrete:

- Produced by introducing air into the concrete.
- It is also called cellular concrete having voids between 0.1mm to 1mm size.
- Two ways are there to induce the air in concrete.
  - Gas concrete
  - Foamed concrete

- **Gas concrete** is produced by chemical reaction in which gas is produced in the concrete.
- Finely divided aluminum powder is generally used as gas producing agent.
- Its quantity is about 0.2% of weight of cement.
- Aluminum powder reacts with Ca(OH)2 to liberate hydrogen bubbles.

Aerated concrete

- Powdered zinc, aluminum alloy or hydrogen peroxide can also be used as gas producing agents.
- **Foamed concrete** is produced by adding foaming agent, usually hydrolyzed protein or resin soaps, during mixing
- In some cases, stable preformed foam is also added during mixing.
- Concrete of densities 300kg/m$^3$ to 1100kg/m$^3$ can be obtained.
- Compressive strength varies from 12MPa to 14MPa for a concrete of density 500kg/m$^3$.
- Generally autoclaved aerated concrete is used.
- Aerated concrete has higher thermal movement, higher shrinkage and higher moisture movement compared to light weight aggregate concrete of same strength.
No – fines concrete:

- It is a type of light weight concrete produced by omitting the fine aggregates from conventional concrete.
- This concrete has only cement, coarse aggregate and water.
- Due to absence of fine aggregates, concrete will have large voids, resulting in light weight.
- Even though there is reduction in strength, there is no capillary movement of water, resulting in low permeability and consequently more durable.
- No – fines concrete with lighter coarse aggregates, can get density as low as 640 kg/m3.
**No – fines concrete:**

- Very often only single size of coarse aggregate, of size passing through 20mm and retain on 10mm is used.
- By using single size aggregate, voids can be increased.
- The actual void content may vary between 30 to 40% depending upon the degree of consolidation of concrete.
- No-fines concrete is generally made with the aggregate/cement ratio from 6 : 1 to 10 : 1.
- The water/cement ratio for satisfactory consistency will vary between 0.38 to 0.50.
- The strength of no fine concrete is depended on water/cement ratio, aggregate/cement ratio and unit weight of concrete.

![Diagram of no-fines concrete components](image)

- 0% Fine Aggregate
- Voids-15% to 35%
- Water and Admixture
- Cement + Pozzoluna (Fly Ash)
- 100% Coarse Aggregate with maximum size of 12.5 mm
No – fines concrete

<table>
<thead>
<tr>
<th>Aggregate/cement ratio by volume</th>
<th>Water/cement ratio by mass</th>
<th>Density (kg/m³)</th>
<th>28-day compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.38</td>
<td>2020</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>0.40</td>
<td>1970</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>0.41</td>
<td>1940</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>0.45</td>
<td>1870</td>
<td>7</td>
</tr>
</tbody>
</table>

**Properties**

**Density**

- It depends on the properties and proportion of the material used, and on the compaction procedures used in placement. In place density on the order of 1600kg/m³ to 2000kg/m³ are common, which is in upper range of lightweight concretes.

**Permeability**

- It depends on the materials and placing operation. Typical flow rates for water through previous concrete are 120L/m²/min to 320L/m²/min.
**Compressive strength**

- No-Fines concrete mixture develop compressive strength in the range 3.5 MPa to 28 MPa, which is suitable for a wide range of application
- Typical Values are about 17 MPa.

**Shrinkage**

- Drying shrinkage of no-fines concrete develops sooner, but is much less than conventional concrete.
- Roughly 50% to 80% of shrinkage occurs in first 10 days, compared to 20 to 30% in the same period for conventional concrete.
- Because of this lower shrinkage and the surface texture, many no-fines concrete are made without control joints and allowed to crack randomly.

**Properties**

**No – fines applications**

1. Its high porosity provides insulating (i.e in walls of buildings)
2. It has good acoustical properties (for sound barrier walls).

<table>
<thead>
<tr>
<th>Low-volume pavements</th>
<th>Well linings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential roads, alleys, and driveways</td>
<td>Tree grates in sidewalks</td>
</tr>
<tr>
<td>Sidewalks and pathways</td>
<td>Foundations / floors for greenhouses, fish hatcheries,</td>
</tr>
<tr>
<td>Parking areas</td>
<td>aquatic amusement centers, and zoos</td>
</tr>
<tr>
<td>Low water crossings</td>
<td>Hydraulic structures</td>
</tr>
<tr>
<td>Tennis courts</td>
<td>Swimming pool decks</td>
</tr>
<tr>
<td>Subbase for conventional concrete pavements</td>
<td>Pavement edge drains</td>
</tr>
<tr>
<td>Patios</td>
<td>Groins and seawalls</td>
</tr>
<tr>
<td>Artificial reefs</td>
<td>Noise barriers</td>
</tr>
<tr>
<td>Slope stabilization</td>
<td>Walls (including load-bearing)</td>
</tr>
</tbody>
</table>
No – fines applications

Walkways

Parking Lots

Pavements

COLORED CONCRETES
Colored concrete

- Coloured concrete can be produced by using coloured aggregates or by adding colour pigments (ASTM C 979) or both.
- If surfaces are to be washed with acid, a delay of approximately two weeks after casting is necessary.
- Coloured aggregates may be natural rock such as quartz, marble, and granite, or they may be ceramic materials.
- Synthetic pigments generally give more uniform results.
- The amount of colour pigments added to a concrete mixture should not be more than 10% of the mass of the cement.

Colored concrete

- For example, a dose of pigment equal to 1.5% by mass of cement may produce a pleasing pastel colour, but 7% may be needed to produce a deep colour.
- Use of white portland cement with a pigment will produce cleaner, brighter colours and is recommended in preference to gray cement, except for black or dark gray colours.
Colored concrete

• Colored concrete is produced by adding pigmented metal oxides (mainly iron oxide).
• The pigments are in the form of powder, fine, low dust granulates or liquid.
• The dosage is normally 0.5 – 5.0% of the cement weight.
• Higher dosages do not enhance the color intensity but may adversely affect the concrete quality.
• Typical primary colors are:
  − Synthetic iron oxide yellow and red
  − Synthetic iron oxide black (note: carbon black may adversely affect the creation of air voids)
  − White (titanium dioxide; general brightener)

Colored concrete

When use Liquid Pigments:

− Faster more efficient loading (higher volumes)
− Clean and easy use of liquid color
− Greater technological accuracy - less chance of mistakes
− Reduced complexity

When use Powder Pigments:

− Smaller applications (lower volumes)
− No need to store powders frost protected
− Automation not explicitly necessary
Colored concrete application
Colored concrete application

POLYMER CONCRETE
Polymer concrete

Polymer

Aggregates

with or without cement and water

Polymer concrete

CLASSIFICATION OF POLYMERS

Monomers

(Group of monomers)

Polymers

Synthetic (derived from petrol, oil)

Thermosetting (high temperature)

Thermoplastic (not suitable for high temperature)

Natural (available naturally source)

Organic (without carbon)

Cellulose, nucleic acids

Inorganic (carbon)

Diamond, graphite
Types of polymer concrete

Polymer concrete

- Polymer mix concrete
- Polymer concrete
- Polymer impregnated concrete
- Geo polymer cement

Production methods

Three production methods

i. Impregnated polymer concretes
ii. whole binder consists of polymer = polymer concrete
iii. Monomer or polymer is mixed into fresh concrete mix = cement polymer concretes
i) Impregnated polymer concretes

1. First a common concrete structure or product is cast
2. Drying
3. Vacuum treatment
4. Monomer is pressed into concrete at 3.5 atm pressure caused by nitrogen

Partial impregnation
- Drying of the surface of the structure at 150 °C, for example, by infra red heaters
- Monomer is spread on the surface (5 hours causes 4 cm penetration)
- Polymerizing by heat treatment

i) Impregnated polymer concretes

Most common polymer materials
- 95 % methyl meth acrylate (MMA)
- below 5 % tri methyl propane tri methyl acrylate (TMPTMA)
- to excite the polymerization below 1 % iso butyro nitrine
- The treatment improves freeze-thaw durability, water tightness and friction properties of the structure surface

Applications
- bridges, concrete dams, and repair of corrosion damages
ii) Polymer binder concretes (whole binder is polymer)
- aggregates of normal concretes 90-95 %
- large number of different monomer variations
  - methyl meth acrylate + TMPTMA + benzoil peroxide
  - polyester resins
  - vinyl ester resins
  - epoxy resins
- the hardening time is remarkably shorter compared to normal concretes
- no need for outside heating
- consistency and color similar as with normal concretes,
- sometimes color pigments are needed
- good bond to normal concrete

Applications
- repair of concrete bridges
- precast units
- preservation of radioactive waste materials
- as frame structures for heavy-duty machine tools
- products of mechanical engineering
iii) Cement polymer concretes

Several monomers such as methyl methacrylate (MMA) are insoluble into water and, hence, are not suitable.

**Raw materials**
- latex polymers
- epoxies
- elastomers
- polyester and acryl resins

**Production methods**
- addition directly during mixing or after one hour of the original mixing time

**Applications**
- repair and coating of concrete structures

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### Concrete Properties

<table>
<thead>
<tr>
<th>Concrete</th>
<th>Compressive strength [MPa]</th>
<th>Tensional strength [MPa]</th>
<th>Ec [GPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal concrete</td>
<td>20 - 50</td>
<td>2 - 4</td>
<td>20 - 30</td>
</tr>
<tr>
<td>High-strength concrete</td>
<td>50 - 120</td>
<td>4 - 12</td>
<td>30 - 40</td>
</tr>
<tr>
<td>Impregnated polymer concrete</td>
<td>100 - 150</td>
<td>9 - 12</td>
<td>35 - 40</td>
</tr>
<tr>
<td>Polymer concrete</td>
<td>40 - 150</td>
<td>7 - 14</td>
<td>7 - 35</td>
</tr>
<tr>
<td>Cement polymer concretes</td>
<td>20 - 60</td>
<td>4 - 7</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Cast iron</td>
<td>100 - 350</td>
<td>100 - 350</td>
<td>90 - 130</td>
</tr>
<tr>
<td>Steel</td>
<td>200 - 500</td>
<td>200 - 500</td>
<td>210</td>
</tr>
<tr>
<td>Concrete</td>
<td>Water suction %</td>
<td>Freeze-thaw Cycles/ % w. loss</td>
<td>Acid durability Improvement/ comparison</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------</td>
<td>-------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Normal concrete</td>
<td>5 - 6</td>
<td>700 / 25</td>
<td>1</td>
</tr>
<tr>
<td>High-strength concrete</td>
<td>1 - 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impregnated polymer concrete</td>
<td>0.3 - 0.6</td>
<td>3000 / 0-2</td>
<td>5 - 10</td>
</tr>
<tr>
<td>Polymer concrete</td>
<td>-</td>
<td>1500 / 0-1</td>
<td>8 - 10</td>
</tr>
<tr>
<td>Cement polymer concretes</td>
<td>-</td>
<td>-</td>
<td>1 - 6</td>
</tr>
<tr>
<td>Cast iron</td>
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<tr>
<td>Steel</td>
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</tbody>
</table>

References

1. ACI 213R-03. “Guide for Structural Lightweight-Aggregate Concrete Reported by ACI Committee 213
