CEMENT AND CONCRETE:

Concrete - composite material (cement + water + aggregates + additives)

Cement - CaO (calcareous material) + Al₂O₃, Fe₂O₃ (argillaceous material) + gypsum (set regulator)

Specific gravity = 3.15

Components in cement -
- calcium silicate hydrate - primary strength giving component
- calcium hydroxide - susceptible to chemical attack
- calcium sulpho-aluminate - early stiffening of concrete

BIS classification of cement:
1) OPC - Ordinary Portland cement - 33, 43, 53 grade depending on the strength achieved at the end of 28 days. (IS 269-1989).
2) Portland cement, low heat
3) Rapid hardening Portland cement
4) Portland - Pozzolana cement
5) Portland - slag cement

Aggregates: coarse - 4.75 - 40 mm, fine - sand - well graded (4.75 mm - 0.075 mm)

→ rounded vs. angular - rounded provide better packing & compaction
→ smooth vs. rough - rough has better bond strength with paste
→ Flaky & elongated aggregates may break - not preferred.

→ Normal concrete - aggregate strength > concrete strength,
→ High strength concrete - aggregate strength < concrete strength

→ Aggregates should be strong, clean, resistant to freeze-thaw deterioration, chemically stable, & properly graded for size distribution.

→ The maximum aggregate size should not be greater than three-fourths of the clear spacing between reinforcement bars (BRE) or one-third the depth of a slab.
Admixtures: additive to the concrete mixture that enhances the properties of concrete in fresh or hardened state.

Chemical admixtures:
(i) Air entrainers - create microscopic air bubbles to provide space for water to freeze, shrinks down, strengthens the concrete.
(ii) Water reducers (plasticizers & superplasticizers) - reduce the amount of water to be added, facilitate placement of concrete.
(iii) Set controllers - to speed up (accelerators) / delay (retarders) setting process.

Mineral admixtures:
Help in increasing the strength, reduction of water demand, impermeability, low heat of hydration etc. Result in low cost and energy savings, minimization of environmental damage & greenhouse emissions. Ex: Flyash, slag, silica fume, meta kaolin etc.

Workability of concrete:
Ease of mixing, placing, compacting and finishing of concrete.
Test for fresh concrete workability - Slump test.

Good slump: 80 - 120mm

* Concrete should be poured directly into the desired location (making & pushing should be avoided).
* Chutes should pour concrete vertically down into the formwork (avoid angled pours, if unavoidable, use baffles).
* Loss of workability while pumping should be accounted for.

Segregation: separation of paste and aggregates, caused by lack of fine particles, poor gradation of aggregates, excessively wet mix or improper construction practices.

Bleeding: water layers accumulate under the aggregates. Helpful sometimes in reduction of plastic shrinkage but can affect bond with paste.

Consolidation: Increases packing of aggregates, entrapped air gets expelled.

Curing: ensures proper hydration, prevents early age cracks due to thermal & shrinkage effects, keeps the concrete moist.

Ponding, spraying, fogging, wet burlap (jute bags) curing, steam curing, membrane forming compounds.
Hardened concrete:

- Compressive strength - depends on w/c ratio, amount of cement, age, curing, aggregate etc.
- Tensile strength, $f_t = \frac{1}{10} \sigma_c = \frac{1}{7} f_c$. 
  
  Direct tension, split tension & flexure tests used to test Tensile strength
- Modulus of elasticity - $E(MPa) = 5000 (f_{cu})^{0.5}$. For most concrete, 
  $15 GPa < E < 45 GPa$. 
- Poisson's ratio - For most concrete, $0.15 < \nu < 0.22$.

Durability - ability to resist weathering action, chemical attack, abrasion, or any process of deterioration. Related to water tightness or permeability. Common problems of durability: 

(i) Corrosion of steel in concrete - The rebar is stable in alkaline condition. Corrosion occurs when pH drops. Rust is formed which is 5 to 7 times greater in volume than steel.

(ii) Chemical attack - Cement paste gets attacked, forms expansive compounds, reduction of pH leading to lossy strength & corrosion of rebar

(iii) Alkali aggregate reaction

(iv) Freezing and thawing damage

Creep: Deformations due to sustained loading. Only the paste is susceptible to creep due to its high porosity & water within it gets driven slowly under load.

Shrinkage: Reduction of volume of concrete. When restraint to volume contraction is present, cracks occur - not a structural problem but affects long term durability by providing easy access to water & other aggressive species into concrete.

How to produce durable concrete?

- Low permeability (with low w/c) and adequate depth of cover, keep water away!!!

- Good quality control and curing

- Proper material selection
STEEL

Alloy of iron + steel + other components. Carbon increases strength & decreases ductility.

Weld steel: carbon < 0.25%.

![Stress-strain curve]

- Ultimate tensile strength
- 0.0025 strain
- Yield strength
- 0.014 strain (strain hardening strain)
- ~10-15% strain
- 0.75 strain (strain at ultimate stress)
- ~125% strain
- 0.85 strain (fracture strain)

- Ductility = $\frac{\Delta \text{max}}{\Delta \gamma}$
- Deformability = $\Delta \text{max}$

Toughness = $\int_{0}^{\Delta \gamma} \sigma \, d\epsilon$ [Area under the stress-strain curve]

(Always material property)

Stiffness - Force required to produce unit deformation in the direction of force applied. (Always structural property).

High strength steel

![Stress-strain curve]

- 0.2% proof strength - for steels which do not have definite yield plateau.
Three basic forms:
- Structural sections: 7250 to 7450 MPa
- Reinforcement bars: 7250 to 750 MPa
- Wires: 600–700 to 71500 MPa

Steel bars
- For reinforcement in concrete
- Provides tensile strength to the member
- Mild steel bars have maximum elongation
- High yield strength bars – less elongation (due to carbon content)

Properties:

<table>
<thead>
<tr>
<th></th>
<th>Yield stress</th>
<th>UTS (Ultimate tensile strength)</th>
<th>Ultimate elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild steel</td>
<td>250</td>
<td>400</td>
<td>25–30%</td>
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<tr>
<td>HYS D</td>
<td>415</td>
<td>480</td>
<td>14.5%</td>
</tr>
<tr>
<td>Fe 415</td>
<td></td>
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<tr>
<td>TMT</td>
<td>415</td>
<td>550–660</td>
<td>25.1%</td>
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<tr>
<td>Fe 500</td>
<td>500</td>
<td></td>
<td>12.1%</td>
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* Steel as a material is excellent in tension & compression but steel structures are poor in compression.
* No steel bars should touch the surface of concrete to avoid corrosion.
* Steel can be joined to steel by: lapping, welding, splicing.
* Reinforcement in columns & beams
  - Spiral - better confinement of concrete
  - Column stiffeners - prevent local buckling
  - Stirrups in beams - take care of the shear pit in beam, ends - horizontal force

PRE-STRESSING:
(i) The tensioning: High strength steel strands are stretched tightly between abutments in a precasting plant and the concrete member is cast around the stretched steel. After the concrete has cured to minimum compressive strength, the strands are cut off at either end of each member. This releases the external tension on steel, allowing it to recoil slightly, which squeezes all of the concrete into compression. Useful
Only for precast mom concrete members.

Post-tensioning: High strength steel strands (tendons) are covered with a steel or plastic tube to prevent them from bonding to the concrete. Each tendon is anchored to a steel plate embedded in one end of beam or slab. A hydraulic jack is inserted between the other end of the tendon and a similar steel plate in the other end of the member, and large tensile force is applied while compressing the concrete with an equal but opposite force applied through the plate. The stretched tendon is anchored to the plate before the jack is removed.

Concrete not allowed to bond to the steel strands during curing.

After the concrete has cured, the tendons are tensioned with a hydraulic jack anchored to the ends of the beam.

Pre-tensioning

MASONRY

- consists of units and mortar.

MORTAR TYPES:

- Lime (lime, sand, water)
- Cement (cement, sand, water)
- Cement: Lime

Bonds individual units together, provides strength.
stone, burnt clay bricks, cement blocks are used as units in masonry.

→ Masonry - brittle material
  without reinforcement - compression only cases
  with reinforcement - compression & partial tension

→ burnt clay bricks: 1-10 Mla compressive strength.
  Concrete blocks: 15-25 Mla & higher
  Burnt clay bricks
  → Tensile strength - 3-5% of compressive strength.
  → Specific gravity > 2.7
  → Water absorption < 0.6% acceptable
  → Weight - 19 kN/m³
  → Compressive strength of masonry wall
  \[ f_{\text{maw}} = \sqrt{f_b \times f_{\text{maw}}} \]
  \( f_b \) - compressive strength of brick, \( f_{\text{maw}} \) - compressive strength of mortar.

→ Efflorescence - soluble salts (Ca, Mg, K, Na salts) migrate to surface.
  → not desirable.
  → Different sizes of bricks.

半砖

Four closure

→ Normal size of brick - 230x115x75 mm.
→ Perforated brick used in reinforced masonry.
→ Mortar strength should be less than unit strength.

Mortar strength < unit strength
Mortar strength > unit strength.

Mode of failure
Zig-Zag bond - used for paving brick floor

FOUNDATIONS

- Safely transfer the building load to the ground without exceeding bearing capacity of soil.
- Foundation loads: dead load, live load, wind load, seismic load.

Types of foundation settlements:
- No settlement
- Uniform: all columns settle at same rate.
- Differential: each column settles at different rate, due to diff in soil condition.

Foundation on bedrock settles a negligible amount.

Soil gets stronger only when it is confined.

- Soil type & particle size important in predicting:
  1. Load bearing capacity
  2. Soil stability
  3. Drainage characteristics

Soil investigation:
- Test pits: useful when foundation is not deeper than about 8 feet (2.5 m).
- Soil borings with penetration tests: give direct indication of bearing capacity & extends the possible range of exploration much deeper than the test pits.

Excavation: removal of soil for various purposes like foundation, basement, etc.

Backfilling: filling back the excavated soil into the space left.

Common problems:
- Water table
- Rock/boulders
- Unsuitable material

Unrestricted site - bench excavation or slope of excavation (angle of repose) is less expensive.
6. Restricted site:
   (i) Girder beams & lagging
   (ii) Sheet piling: wood, steel, precast - temporary
       Slurry wall - permanent. Bentonite slurry stabilizes
       the sides of the soil.

7. Rock excavation: sheeting not required, grout injection & rock anchors
    generally used.

8. Soil nailing:
   (1) Holes drilled
   (2) Anchors installed & grouted
   (3) Cementitious coating installed.

1. Types of foundation:
   (1) Shallow foundation - isolated, combined, mat or raft, wall, continuous
       → depth ≤ width
       → wall footing - simple & stepped
          (simple) (stepped)

   → isolated footing - slab, stepped, sloped.
      (slab) (stepped) (sloped)

   → combined footing - trapezoidal shape for the uniform distribution of load and
      to coincide the C.G. of the trapezoid with the C.G. of the load (when
      columns are unequally loaded).

   → continuous footing - avoids differential settlement, suitable to locations
      subjected to earthquakes

   → Hat or raft footing - a combined footing covering the entire area below the
      structure. Used when soil bearing capacity is low, offsets avoids differential
      settlement.
Deep foundation - used for tall buildings.
- depth > width
- Types:
  - (a) caisson drilled pile - used to resist horizontal loads.
  - (b) socketed caisson
  - (c) end bearing pile - load transfer occurs at the end of the pile.
  - (d) friction pile - load transfer occurs through the pile surface.
- Materials used for piles - steel, precast concrete, wood.
- Caisson installation sequence
  - (i) Hole drilled with a large drill rig
  - (ii) casing installed
  - (iii) Bell or tip enlargement
  - (iv) Bottom tested & inspected
  - (v) Reinforcement placed
  - (vi) Concrete placement and casing removal.

CONSTRUCTION EQUIPMENT

1) Excavation  2) Loading & Hauling  3) Lifting  4) Concrete equipment
5) Compaction equipment  6) Pumps  7) Construction equipment.

EXCAVATION EQUIPMENT:

- Dozers
  - Bulldozers
  - Angle dozers
  - Rippers

Bulldozers - blades mounted perpendicular to the direction of travel.
Angle dozers - blades at an angle with the direction of travel.

Used in backfilling.

Dozers are versatile machine - (i) spread earth, fill; (ii) clearing land by
 timber & stumps; (iii) opening up roads through mountain and rocky
terrain.

- Shovels (dig soil above grade level)
- Excavators
  - Backhoes (excavation below grade)
  - Loaders (transport & load bulk materials like gravel, earth).
- Scrapers - to excavate, load, haul & dump loose materials.
dragline & clamshells -
  dragline - used when earth is to be removed from a ditch, canal or pit containing water.
  output depends on type of soil, depth of cut, angle of swing.
  clamshell - used to remove materials from cofferdams, pile foundations, sewer manholes & sheet-lined trenches.

→ Finishing equipment
  → grader - to bring earthwork to the desired shape & elevation
    → graderall - combines features of backhoe, dragline, & grader.

(2) HAULING AND COMPACTION EQUIPMENT

Hauling

→ Trucks:
  L. rear dump truck
  L. side dump truck
  L. bottom dump or belly dump truck.

→ Wagons.

Compaction - Pass heavy equipment and compact soil layers.

depending on the way energy is applied, types of compaction equipment -

i) Kneading action - rollers
   L. Tamping rollers - for clay soil
   L. smooth-wheeled roller - granular soils
   L. pneumatic tined roller - all types of soils

ii) Vibration
    L. vibratory rollers - pressure & vibration
    L. vibratory plate compactor
    L. vibro compaction

iii) Dynamic compaction
(3) **LIFTING EQUIPMENT**:

- Hoists
- Cranes: consist of base (mobile/static) and boom (telescopic/lattice)

![Diagram of hoisting, swinging, and travelling]

- **Lattice boom**
- **Telescopic boom**

- Tower cranes - increased coverage of work area within the project site
- Derrick cranes
- Gantry cranes

- Freedom systems

(4) **CONCRETE**

i. Production (batching & mixing) - batching plant - all components mixed
   - Concrete mixer
   - Pan mixer

ii. Transportation
   - Ready mix concrete lorry
   - Hand buggies, power buggies, conveyors, pump, crane & bucket (within site)

iii. Compaction
   - Needle vibrators - internal vibration
   - Screed - external vibration

iv. Finishing
   - Laser screed

* **FORMWORK**: provides shape to wet concrete,
  - should support weight of the wet concrete
  - should be easy to remove, no leakage of water from concrete
1. Precast concrete -
   - Better quality control
   - Less material use
   - Accelerated construction schedule

2. Detailing - Arrangement of steel in the column.
   Buildings having ductile detailing withstand earthquake.

3. **Dutch**
   - Extradose
   - Depth
   - Rise
   - Abutment

4. In truss,
   - Stent - member in compression

   ![King post](image1)
   ![Queen post](image2)

   Queen post is used for longer spans.
   King post is used for smaller spans.

5. High strength column - 53 grade cement used
   - Compound pin/column - 33 grade

   Quick setting - low heat of hydration
   Quick target - high early age strength cement.

6. Shallow beams are proposed when there is height restriction.

7. One way slab
   - Beam

   Two way slab
   - Beam
Bay spacing - distance between the columns in x/y direction

5) Camber - amount of upward displacement in a beam.

6) Framing - process of erection of columns and beams.

7) Lateral stability - stability against horizontal forces.
   Shear wall - to take horizontal load.

Beam coping - cutting the top or a flange of a beam to allow another beam to pass through.

Building Process:

1) Building Life cycle:
   → Planning (assess the uses requirements)
   → Design
   → Feasibility and cost estimation
   → Technology and economic feasibility of each alternate building plan
   → Construction
   → Use
   → Maintenance and repair
   → End-of-life

2) Participants:
   → Owner
   → Architect
   → Structural designers
   → General contractor
   → Subcontractors - mechanical, electrical, plumbing, structural steel
   → Material suppliers - concrete, steel, hardware
   → Equipment suppliers
Project life cycle

Market demands or perceived needs → definition of project objectives and scope

Conceptual planning & feasibility study → conceptual plan or preliminary design

Design & engineering → construction plans and specifications

Procurement & construction → completion of construction

Startup for occupancy → acceptance of facility

Operation & maintenance → fulfillment of useful life

Disposal of facility

1. In-site, 3 setbacks are to be provided:
   - Front open space
   - Side open space
   - Rear open space

2. Binhth area - Total area of the building (Carpet area + wall area)
   Binhth - portion of the structure b/w ground & the floor.

3. LEED - Leadership in Energy & Environmental Design.