Superstructure & Formwork
Learning Objective 1

- identify the structural concept of a building
- discuss generally the structural forces
Forces acting onto a building ...
Structural Concept

3 Basic Structural Concepts

• Skeletal structure
• Solid structure
• Surface structure

What are their characteristic, loading, uses?
Skeletal Structure
Solid Structure

- Wall / Column Beam loading bearing
- Masonry / concrete

- Cross wall structure
- Cellular structure
- Transfer of loads
Solid Structure
Surface Structure

- Thin plates of material / flexible sheet membranes suspended or stretched over supporting members
Learning Objective 2

• Discuss the characteristics, advantages and disadvantages of different types of framed structure:
  1. in-situ reinforced concrete
  2. precast concrete
  3. steel
In-situ RC Frame

- Can cast into any shape or size
- Cast on site
- Reinforcement is required to take tension
- Wet concrete is poured after reinforcement is placed
- Requires formwork
- Need to wait for concrete to cure before constructing the next stage
In-situ RC Frame

Main Components

- RC Beam
- RC Column
- RC Slab
In-situ RC Frame

RC Beam
- varying in complexity

Diagram:
- Load on simply supported plain concrete beam
- Compression in upper fibres
- Tension in lower fibres
- Tension cracks occur at low loading due to inherent tensile weakness of concrete
- Plain concrete
- Shear bars and/or stirrups to provide extra resistance to diagonal tension
- Reinforcement to give member extra tensile strength
- Tension cracks will occur if tensile strength of RC beam is exceeded

Additional notes:
- Top bar (to keep stirrup in position during concreting)
- Stirrup (to take care of shear stress)
- Main bar (to take the main loading)
In-situ RC Frame

RC Column

- Mainly under compression
- However, rebar is needed as columns are subjected to bending in the following conditions

![Diagram](image-url)
RC Columns
In-situ RC Frame

RC Slab

- Simply supported slab – tension at bottom edge at center of span
In-situ RC Frame

RC Slab
- Continuous slab – tension over supports at top edge
- Reinforcement needed at tension zone
- Fabric/mesh reinforcement are usually used
In-situ RC Frame

Advantages

1. Higher fire resistance compared to steel structure
2. Regular maintenance not required
3. Greater flexibility in layouts and design – any shape for aesthetic purposes
4. Cheaper than steel structure
In-situ RC Frame

Disadvantage:
1. Wet process requiring formwork
2. Construction affected by weather
3. Supervision required to ensure quality and workmanship
4. More site space required for formwork and steel fabrications
5. Slower construction speed as time is required for concrete to gain sufficient strength before going to the next stage
6. Problem of shrinkage
Precast Concrete Frame

- Structural components are cast off site
- Precast components transported to site and installed into their final position
- Requires proper connections
Precast Concrete Frame

Advantages

1. A closer control of the concrete - saving in materials and improvement in quality
2. Less site space needed
3. Site is less obstructed
4. Repetitive standard units reduce costs
5. Formwork is greatly reduced
6. The casting operation is not at the mercy of the weather
7. Difficulties arising from the shrinkage of fresh concrete are eliminated
8. Less site labour is required
9. Satisfactory surface finishes can be produced
Precast Concrete Frame

Disadvantages

1. Less flexible in its design concept
2. The continuity and rigidity of structure are more difficult to achieve
3. Economical if mass produced
4. Larger mechanical lifting plant needed to position units
Disadvantages

5. Work program may be restricted by controls on delivery and unloading times laid down by the authority.

6. Structural connections between the precast concrete units can present design problems.

7. Components to be simple in form.

8. Transportation problems – permitted sizes in region of 18 to 21 m by 2.4 m overall.

Steel Building Frame

Characteristics

• Consists of horizontal beams in both directions and vertical columns called stanchions
• Standard rolled sections
• Joined together by welding and/or bolts
Steel Building Frame

Characteristics

• Sometimes encased in concrete
• Steel beams can carry in-situ precast or precast concrete floors
Steel Building Frame

Basic elements

- Universal beams : f
- Universal column : c
- Joist : a
- Channels : b
- Angle : d
- Tee- sections : e
Steel Building Frame

Advantages
1. Simple in construction procedure and fast in construction speed
2. Immediately strong
3. Better construction accuracy can be achieved
4. Less site space needed
5. Not weather dependent
6. Better quality, less supervision
7. No shrinkage problem
8. Less obstruction on site
9. Easy extension of structural elements
10. Suitable for very high rise building
11. Salvage value upon demolition
Steel Building Frame

Disadvantages
1. Rust requiring protection (painting)
2. Requires fire protection (strength reduces sharply when subjected to high temperature)
3. Expensive
4. Transportation
5. Lifting equipment required
6. Requires regular maintenance
Steel Building Frame

Fire protection

a) Encase in concrete
b) Plaster board encasement
c) Spray vermiculite
Learning Objective 3

• Briefly describe the constituent materials of concrete
• Describe basic concrete operation and concrete tests
• Explain the principles of reinforced concrete
Basics of Concrete

Concrete
- Has good compressive strength
- Can form any shapes and sizes

Materials (AWCA)
- Aggregates
- Water
- Cement
- Admixtures
Basics of Concrete

• Aggregates:
  – 60-80% of concrete is made up of aggregates
  – Low cost
  – Fine aggregates (sand) size < 4.76mm
  – Coarse aggregates (granite) size from 4.76 mm to 20 or 40 mm

• Requirements:
  • Clean, free from impurities
  • Hard
  • Strong
  • Well graded
  • Angular in shape
Basics of Concrete

• Water
  – Needed for hydration and improve workability
  – Normal drinking or potable water
Basics of Concrete

• Cement
  – Ordinary Portland Cement (OPC)
  – Other types
    • Rapid hardening
    • Sulphate resisting
    • Low heat
    • Early strength
Basics of Concrete

• Admixture
  – Added to concrete mix to change or improve its properties. Eg
  – Retarder – prolong the setting time
  – Superplasticizer – reduce water and cement used but maintain the same concrete strength and improve its workability
Concreting Operation

Before Actual Concreting

a) Storage
   - Prevent deterioration
   - Cement – kept dry, not to be stacked > 10 bags high
   - Aggregates – on clean surface, not directly on ground to avoid contamination

b) Batching
   - Accurate quantities
   - Batch by volume, weight
Concreting Operation

Before Actual Concreting (cont’d)

c) Mixing
   – Ready Mixed Concrete for structural concrete
   – Water to be added last
   – Mixing time – at least 2 mins.

d) Transporting
   – By truck
   – No water to be added
   – Avoid segregation
Concreting Operation

Actual Concreting

e) Placing
   - Not to fall freely > 1 m to prevent segregation and air pockets being formed
   - Buckets or concrete pump
Concreting Operation

Actual Concreting (cont’d)

f) Compaction
   – To release the entrapped air in concrete so that concrete can achieve its desired strength and density
   – Use poke vibrator

g) Finishing
   – To give a satisfactory uniform concrete surface
   – Screed board, steel trowel, wood float
Concreting Operation

Post Concreting

h) Curing
   – To prevent moisture loss and allow concrete to complete hydration process
   – Methods:
     • Spray water, cover with gunny sacks or plastic for 3-7 days
     • Spray curing compound
     • Immerse in water

i) Removal of formwork
   – Formwork is left in position until concrete has gained sufficient strength
   – Stripping to be done carefully to avoid damage for reuse
Concreting Operation

How do we know if the concreting is acceptable?
Concrete Tests

1. Slump Test
   - Fresh concrete
   - Check consistency and workability
   - Too high slump – too wet
   - Too low slump – too dry
   - Use slump cone and tamping roda
Concrete Tests

2. Compressive strength test

– Hardened concrete
– Cube specimens are made and cured
– Poured in 3 layers, each layer compacted with rod or vibrating table
– Tested on 3, 7 and 28 days
– Cube sizes:
  • 150 x 150 x 150 mm
  • 100 x 100 x 100 mm
Concrete Tests

Compressive Strength Gain over Time
Principles of Reinforced Concrete

- Concrete is good in compression
- But weak in tension
- Therefore, it has to be reinforced with steel bars/reinforcement in areas of tension and shear
Principles of Reinforced Concrete

- At midspan
  - Sagging in middle
  - Tension at the lower edge at midspan
  - Cracks if unreinforced
Principles of Reinforced Concrete

- At interior support
  - Hogging at interior supports
  - Tension at top edge
  - Reinforcement required at top edge
Principles of Reinforced Concrete

- Near supports
  - Shear forces are greatest
  - Stirrups or bent-up bars to add strength and to resist shear failure
  - Potential shear crack at 45 degree sloping towards supports
Principles of Reinforced Concrete

- Typical RC beam detailing
Principles of Reinforced Concrete

Reinforcement

- Steel bars are usually used in reinforced concrete
- Mild steel (R) and high tensile steel (T)
- Fabric/mesh reinforcement are used for floors
- Diameter: 6 mm to 40 mm
Principles of Reinforced Concrete

Concrete Cover

• Reinforcement must be surrounded by concrete
• To protect steel bars against corrosion & fire
• To allow the bar to develop its correct force
• Nominal cover:

<table>
<thead>
<tr>
<th>Conditions of exposure</th>
<th>Nominal cover (mm) for concrete grade of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Mild</td>
<td>20</td>
</tr>
<tr>
<td>Moderate</td>
<td>40</td>
</tr>
<tr>
<td>Severe</td>
<td>50</td>
</tr>
</tbody>
</table>
Learning Objective 4

- Understand the use and types of formwork
Formwork
Formwork

• Definition
• Reasons for formwork
• Functional requirements
• Materials
• Types
Formwork

• Reasons:
  – To withstand the pressure of wet concrete
  – To form concrete to the required shape, dimension and appearance
  – To support the weight of concrete
Formwork

• Functional requirements
  – Strong enough to carry the loads
  – Sufficiently rigid to avoid deformation
  – Accurately set out
  – Joints must be grout-tight
  – Can be easily handled
  – Formwork material should not contaminate the concrete
  – Able to achieve the desired surface finish requirement
  – Permit easy erection and stripping
  – Prevent members being trapped when striking
  – Work should be pre-planned
  – Able to be re-used after stripping
Formwork

Types of loads

- Hydrostatic pressure on edge form
- Dead load of concrete
- Horizontal load
- Wind load
- Self-weight of formwork
- Imposed load
- Prop
Formwork

• Materials used for formwork
  – Timber
  – Metal
  – Special plastic
Formwork

• Types
  – Foundation Formwork
Formwork

- Types

- Beam Formwork
Formwork

• Types
  – Column Formwork

Typical Timber Yoke

Typical Metal Clamp
Formwork

• Types
  – Column Formwork
Formwork

• Types
  – Beam & Slab Formwork
Formwork

• Types
  – Beam & Slab Formwork
Formwork

• Types
  – Wall Formwork
Formwork

• Types
  – Wall Formwork
    i. Traditional wall formwork
Formwork

• Types
  – Wall Formwork
    ii. Climbing formwork