Course Outline

2. SUBSTRUCTURE/FOUNDATION
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Definition of Sub-Structure

- The supporting part of a structure; the foundation. (i.e.: footing / piling, pile cap, column stump)
- Sub-structure will include ground beams, ground floor column and ground floor slab.

Introduction

- The lowest artificially built part of a structure which transmits the load of the structure to the soil lying underneath is called foundation.
Foundation

- Structure who support the weight of the upper structure and applied loads.
- Designed to transmit building load to the supportive soils or rock.

Foundation Anatomy

[Diagram showing different parts of a building and foundation design, including roof, walls, floor, and foundation design considerations.]
Foundation

- Types of foundation include *footings, piles and piers.*
Purposes of foundation:

1. To distribute loads of the structure over a large bearing area so as to bring intensity of loading within the safe bearing capacity of the soil lying underneath.
2. To load the bearing surface at a uniform rate so as to prevent unequal settlement.
3. To prevent the lateral movement of the supporting material.
4. To secure the level and firm bed for building operations.
5. To increase the stability of the structure as a whole.

Factors affecting selection of foundations.

1. Types and intensity of loads acting on various parts of the structure which may be dead load, live load, wind load, snow load, etc.
2. Nature and bearing capacity of the soil on which the structure directly rests.
Foundation

- Design and selection of foundation depends on:
  - Total load of building
  - Nature and **bearing capacity** of soil

Causes of settlement are;
1. Deformation of soils causing by an imposed load
2. Volume changes of soil cause by seasonal conditions.
3. Mass movements of ground in an unstable areas.

Foundation failure: collapse or excessive *settlement* of a building supporting structure resulting from soil movement.

Source: http://grees.usc.edu/GEES/RecentEQ/Turkey/Report/day2rep.htm
Foundations can be considered under two groups:

- **Shallow Foundations**
- **Deep Foundations**

**Shallow Foundations**

1. *Spread Foundations / Footings*
   - Pad @ Isolated Foundations, Strip Foundations and Combine Both
2. *Raft Foundation*

**Deep Foundations**

- Pile, Pier and Caissons

Shallow foundations are those founded near to the finished ground surface; generally where the founding depth (Df) is less than the width of the footing and less than 3m.
The principal types of RC Foundation for buildings are:

1. Strip Foundation
2. Pad @ Isolated Foundation
3. Raft Foundation
4. Combination of 1, 2 and 3
5. Piled Foundation
Foundations – Strip Foundation

- Strip foundations are used to **support a line of loads**, either due to a load-bearing wall, or if a line of columns need supporting where column positions are so close that individual pad foundations would be inappropriate.
Foundations – Pad @ Isolated Foundation

-Pad foundations are *used to support an individual point load such as that due to a structural column*. They may be circular, square or rectangular.

They usually consist of a block or slab of uniform thickness, but they may be stepped or hunched if they are required to spread the load from a heavy column. Pad foundations are usually shallow, but deep pad foundations can also be used.
Foundations – Raft Foundation

- Raft foundations are used to spread the load from a structure over a large area, normally the entire area of the structure.

- where the **ground conditions are very poor** and **bearing power of the soil is low** that the individual spread footing cannot be provided.

Raft foundation

**Method of construction.** The whole area is dug at a specified depth. The bed is compacted, then a layer of concrete or lean concrete is laid to a suitable thickness to act as a bottom cover. After this, reinforcements are laid as in figure. Then the cement concrete (1:2:4) is laid and compacted to the required thickness. The concrete slab so laid is then properly cured.
Foundations – Raft Foundation

Deep Foundations

- Deep foundations are those founding too deeply below the finished ground surface for their base bearing capacity to be affected by surface conditions,
- this is usually at depths >3 m below finished ground level
Deep foundations.

- The foundations constructed below ground level with some arrangements such as piles, wells, etc. at their base are called deep foundations.
- Deep foundations are classified into the following types:
  - Pile foundation
  - Well foundation
  - Caisson foundation
Foundations –
Pile Foundation

Suitability.
Pile foundation is suitable under the following situations:
i. When the soil is very soft and solid bed is not available at a reasonable depth to keep the bearing power within safe limits.
ii. When provision of pad and raft foundations becomes very expensive.
iii. When the structure carries heavy concentrated loads.
iv. When it is necessary to construct a building along the sea-shore or river bed.

Piles are generally classified into two categories:
1. According to function, e.g. bearing piles, friction piles, friction-cum-bearing piles, batter piles, guide piles, sheet piles, etc.
2. According to composition or material of construction, e.g. timber piles, concrete piles, sand piles, steel piles, etc.
Foundations – Pile Foundation

- Structures place on top of the piles.
- Piles + Pile Cap = Pile foundation
- Function: Distributes load to the individual piles.
- Pile Cap will connect the pile together and distributes the superstructure loads to the layer beneath.
Foundations – Pile Foundation (Pile Cap)

Pile Foundation

- Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface.

- The main components of the foundation are the pile cap and the piles.

- Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity.

- The main types of materials used for piles are Wood, steel and concrete.
Pile Foundation

Functions of Piles
- to transmit a foundation load to a solid ground
- to resist vertical, lateral and uplift load

Classifications of Piles

Classifications of piles with respect to load transmission and functional behaviors

1. End Bearing Piles (point bearing piles)
2. Friction piles (cohesion piles)
3. Combination of friction and cohesion piles
- Pile Foundation

Classifications of Piles – End Bearing

- End bearing piles are those which **terminate in hard**, relatively impenetrable material such as **rock** or very dense sand and gravel.

- These piles **transfer their load** on to a **firm stratum**

- The pile **behaves** as an **ordinary column** and should be designed as such
Pile Foundation

Classifications of Piles – Skin Friction

- Friction piles obtain a greater part of their carrying capacity by skin friction or adhesion.

- This tends to occur when piles do not reach an impenetrable stratum.

- These piles transmit most of their load to the soil through skin friction.
Pile Foundation

Classifications of Piles – Combination of friction and end bearing

Classification of piles according to their composition or material of construction

1. Timber
2. Concrete
3. Steel
4. Composite piles
Timber Piles

- The piles made of wood, should be free from defects, decay, etc and it should be well seasoned.
- The piles can be circular or square in cross-section. Top of these piles is provided with an iron ring to prevent it from splitting under blows of hammer.
- The bottom is fitted with an iron shoe to facilitate sinking of piles.
- These piles are driven by blows of hammer of a pile driving machine.
- Used for buildings, bridges and cofferdams but is not recommended to be used in sea water.
**Timber piles.**

- **Advantages of timber piles:**
  
  i. Less expensive as timber available can be used after suitable treatment.
  
  ii. Can be made longer in lengths by joining the individual pieces easily.
  
  iii. Cutting of these piles is easy.
  
  iv. Can be driven easily with lighter machinery.

- **Disadvantages:**
  
  i. The piles deteriorate by action of water and insects.
  
  ii. Lesser load bearing capacity.
  
  iii. A number of small individual units require to construct long piles; this entails lot of joining work as such the cost becomes high in constructing the piles.

**Pile Foundation**

Classifications of Piles – Concrete Piles

![Concrete Piles Diagram](image-url)
Concrete piles

- The piles are made of cement concrete, strong, durable and can bear more load than timber piles. They are free from defects and cannot be attacked by insect, white-ant, etc.
- The piles are fire-proof and water-proof.
- Concrete piles are classified into two types:
  1. Pre-cast piles.
  2. Cast-in-situ piles.

Pre-cast piles

These are R.C.C piles which are square, circular or octagonal in cross-section. It’s the heaviest, brittle and lack of tensile strength. The construction requires care in handling and driving to prevent pile damage.

- **Advantages of Pre-cast Concrete Piles:**
  1. Best concrete can be prepared by proper workmanship. Any defect can be repaired immediately.
  2. The reinforcement remains in proper position and does not displaced.
  3. The concrete only withstands loads after complete curing has taken place. They can be cast beforehand and quick driving progress can be ensured.
  4. More convenient when driven through wet conditions.
  5. Suitable when part of their length is to remain exposed.
  6. Not affected by other additional forces which act on the piles while adjacent piles are driven.

- **Disadvantages:**
  1. Heavy and difficult to transport.
  2. Lapping of additional length means extra cost, labour and energy.
  3. Heavier in section to withstand holding stresses.
  4. The shocks of driving make the weaker.
This type of piles is constructed in its location in a bore hole prepared for this field. The operation consists of boring a hole, filling it with concrete or steel reinforcement and concrete. Examples are simplex pile, pedestal or bulb pile, Frankie pile, Raymond concrete pile, etc.

- **Advantages of Cast-in-situ piles:**
  i. Less wastage of material as exact length of pile is cast.
  ii. Time spent on curing is saved.
  iii. Can bear heavier loads by improving their X-sectional profile, e.g., pedestal pile.

- **Disadvantages:**
  i. Good quality concrete cannot be easily obtained due to unusual height of dumping.
  ii. The reinforcements are liable to get displaced.
  iii. They cannot be used under water.
  iv. The green concrete loses strength after coming in contact with the soil.
  v. The shells are affected by casting additional piles adjacent to them.
Sand piles. The piles consisting of sand filled in bore holes, formed by digging holes which are then filled with sand and compacted. Top of the pile is covered with concrete. Cheap, easily constructed and only for light loads.

- **Steel piles are of steel section.** Useful where driving conditions are difficult and other types of piles are not suitable. Usually used for building and bridge foundations. The piles are in form of I, U, H sections.
- **Steel piles** are available in the following forms.
  i. Steel pin piles
  ii. Sheet piles
  iii. Disc piles
  iv. Screw piles.