Structural System in Architecture

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Lecture No -37

Building Foundaion

Welcome to the NPTEL online certification course on structural systems in architecture. This is the 37thlecture and this is the second lecture of the module 8 or the week 8. And this lecture's topic is Building Foundation.

Concepts Covered

- Introduction of foundation
- Soil Bearing Capacity
- Types of Foundation
- Shallow Foundation
- Deep Foundation
- Reasons for Foundation Failure

Learning Objectives

- To discuss the fundamentals of soil Bearing Capacity.
- Outlining the shallow and deep foundation for building.
- Discussing the reasons for foundation failure.

Introduction of foundation

A specific field in Civil Engineering deals with building foundation and its design. It involves two major area of study:

i. Soil Mechanics
ii. Foundation Engineering

Soil Mechanics deals with properties and parameters of soil to investigate the safe bearing capacity, settlement analysis, consolidation etc.

Foundation Engineering deals with the design of different types of foundation system of building and structures.

Soil Bearing Capacity

- The Bearing Capacity is defined as the capacity of the soil to support the imposed load.
- It is the maximum contact pressure that the soil can bear before it fails due to shear.
- It is expressed in t/m2 or KN/m2

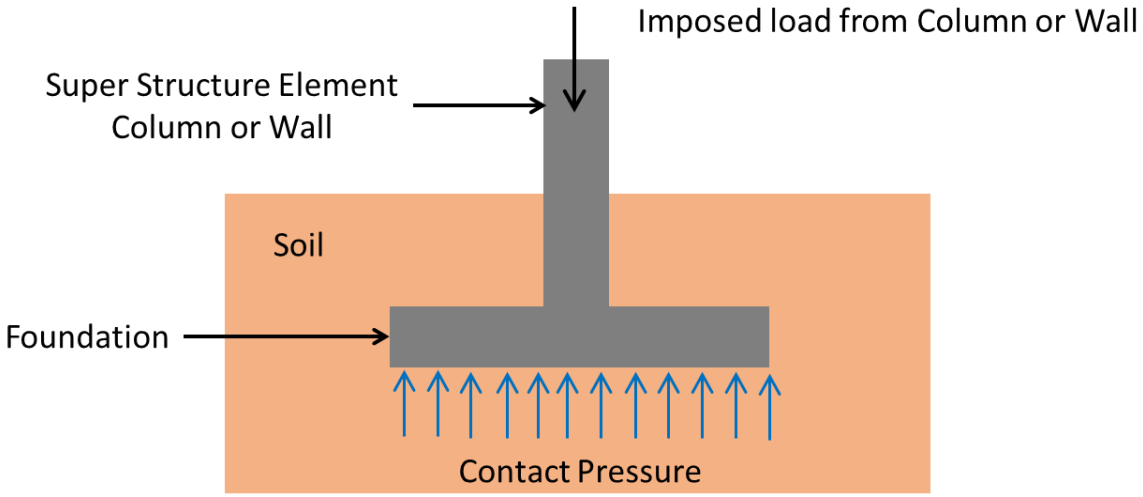


Figure 1 Concept of load transfer in foundaion

The design of foundation is based on the fundamental of load transfer, in which the load which in transferred from superstructure to the ground and from ground it is transferred to the foundation where it follows the Newton's Third Law of motion in order to balance out the contact pressure. Hence to lower the intensity of the pressure the area of the pad is increased to provide stability to the foundation.

Factors affecting the Bearing Capacity of Soil

- Type of Soil and its properties

a. Cohesive soils : Clay

b. Non-cohesive Soils: Sand

- Depth of water table
- Depth of Foundation

- Type of Foundation

Category	Types of rocks and soils	Presumed bearing value
Non-cohesive soils	Dense gravel or dense sand and gravel	>600 kN/m²
	Medium dense gravel, or medium dense sand and gravel	<200 to 600 kN/m²
	Loose gravel, or loose sand and gravel	<200 kN/m²
	Compact sand	>300 kN/m²
	Medium dense sand	100 to 300 kN/m²
	Loose sand	<100 kN/m²
Cohesive soils	Very stiff bolder clays & hard clays	300 to 600 kN/m²
	Stiff clays	150 to 300 kN/m²
	Firm clay	75 to 150 kN/m²
	Soft clays and silts	< 75 kN/m²
	Very soft clay	Not applicable

Table 1 Soils types and their Bearing Capacities

Classification of foundation

Foundation can be basically classified into two types:

i. Shallow Foundation
   - When depth (D) of the foundation is less than or equals to the width of the foundation than it is classified into the shallow foundation.
   - Wall footings, Isolated Column Footing, Combine Footing (Rectangular Footing, Strap Footing, Grid Footing and Raft Foundation) are the general types.

ii. Deep Foundation

- When depth (D) of the foundation is very much high than the width of the foundation than it is classified into the deep foundation.
- Pile Foundation, Well Foundation and Pier Foundation are its general types.

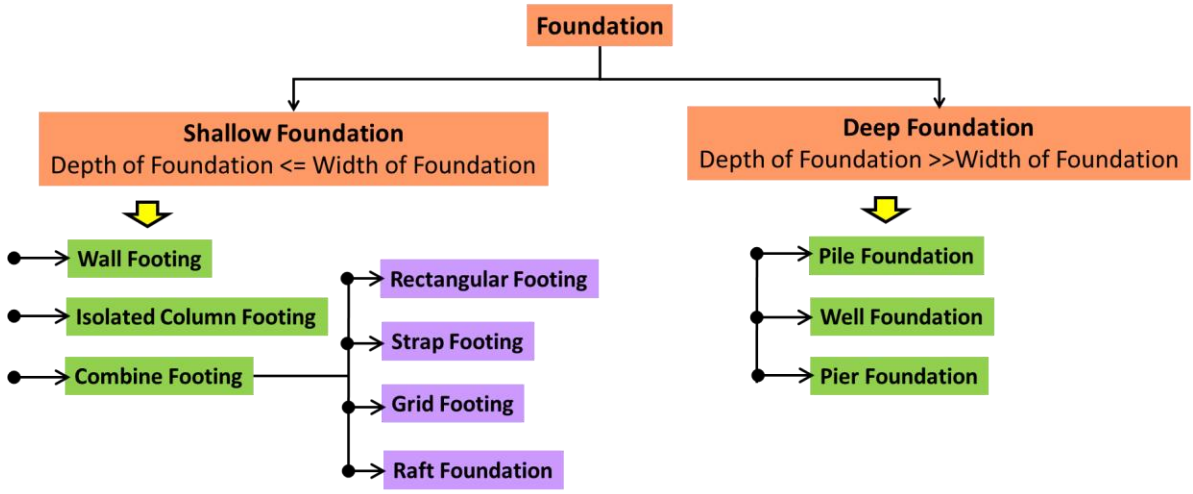


Figure 2 Classification of Foundation

Shallow Foundation

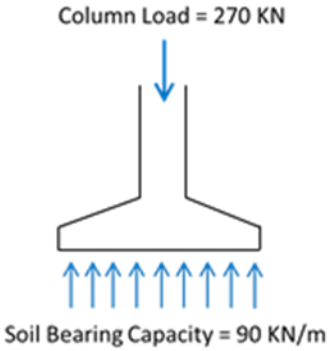
In general, the depth of a shallow foundation is less than its width. Shallow foundations are commonly used as they are the most economical foundation system and are relatively easy to construct.

Isolated Foundation

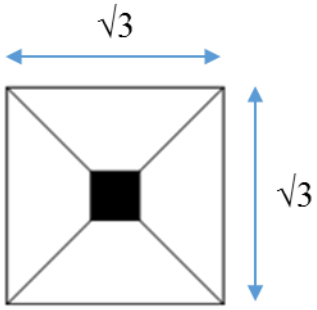
- Single foundation dedicated to a single column.
- Square or Rectangular in shape.
- Area of foundation should be such that the load should be safely distributed over the soil.

$$\text{Area of Foundation} = \frac{\text{Column Load}}{\text{Soil Bearing Capacity}}$$

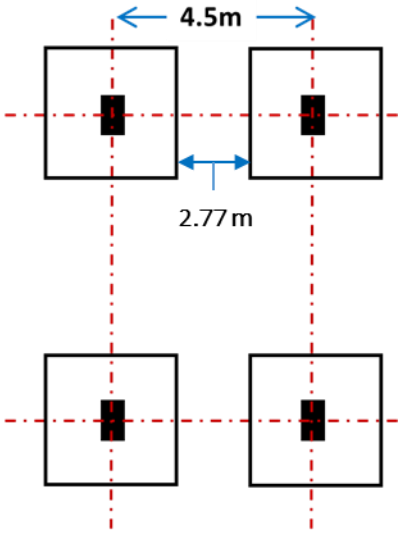
Example- If a column have a loading of 270KN and he soil has the bearing capacity of 90KN/m, the area of the foundation can be given by further calculation.



$$\text{Area of Foundation} = \frac{\text{Column Load}}{\text{Siol Bearing Capacity}} = \frac{270}{90} = 3m^2$$



- For a span of 4.5m these columns can be arranged in such a manner that, the gapbetween the Foundation is (4.5-1.73) = 2.77m

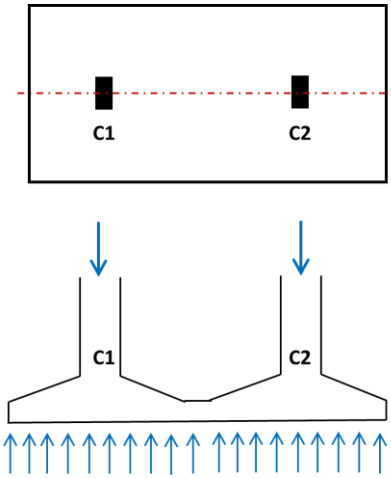


If loading of the column is increased so in that case:

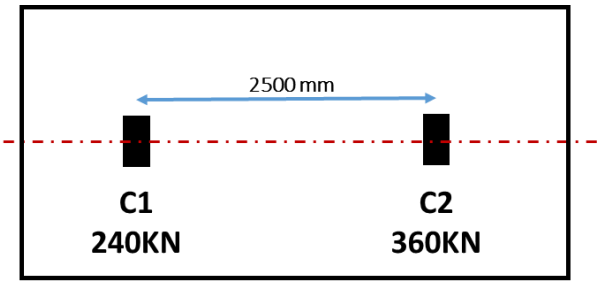
- Area of the foundation = 800/ 90 = 8.89 sq. m and the gap between the Foundation = (4.5-3.0) = 1.5m.
- Which is too narrow Gap or there may be a case where foundations may overlap.
- So in such cases combined footing is created.

Combine Foundation or Rectangular Footing

- Combine Foundation or combined footing is provided when two columns are very close enough to each other such that their footing overlap.
- When the load-bearing capacity of the soil is low, the requirement of more area under the individual footing.



Example: Rectangular Foundation with two columns having differential loads and the soil Bearing Capacity = 75KN/m2



So, 600x = 360 X2.5; x = 1.5m.

And,

Area of Foundation:

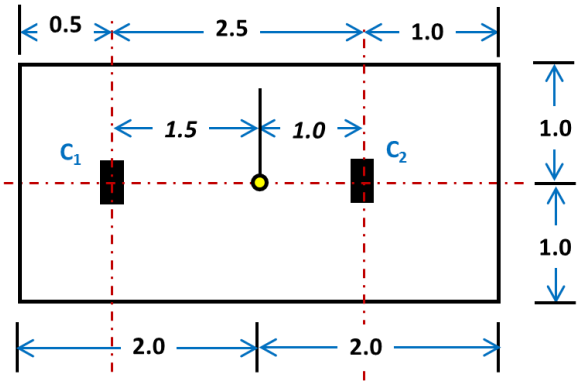
(600/75) = 8 m2

Keeping L: B=2:1

2B2= 8

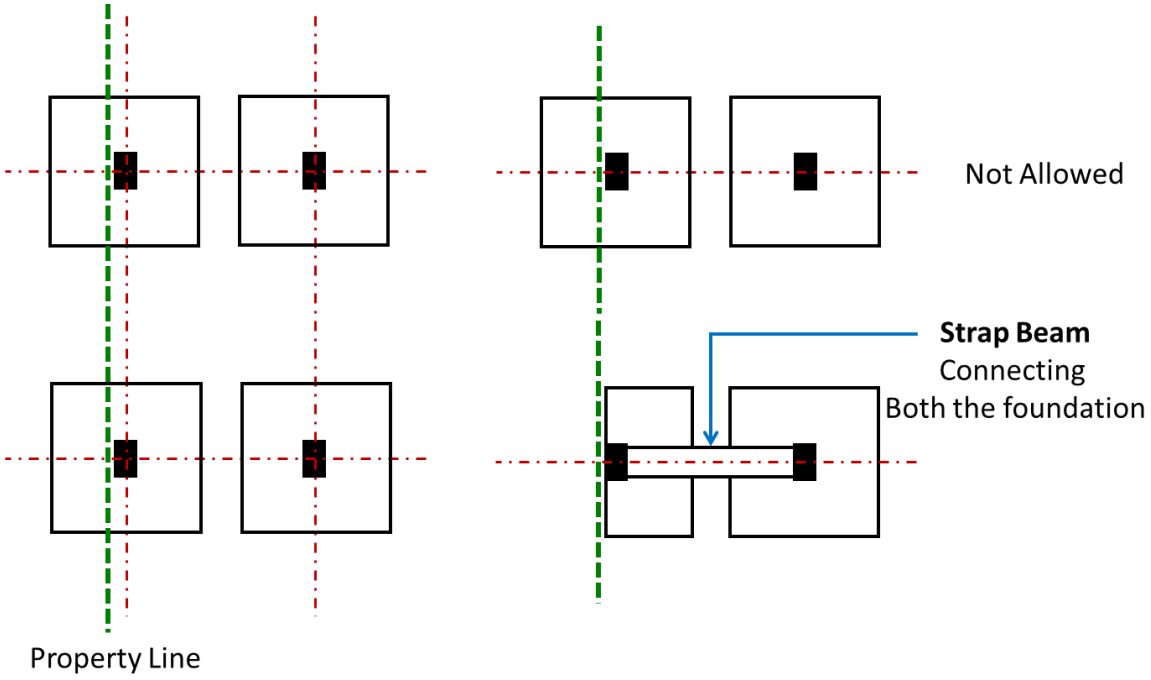
B=2m, L=4m

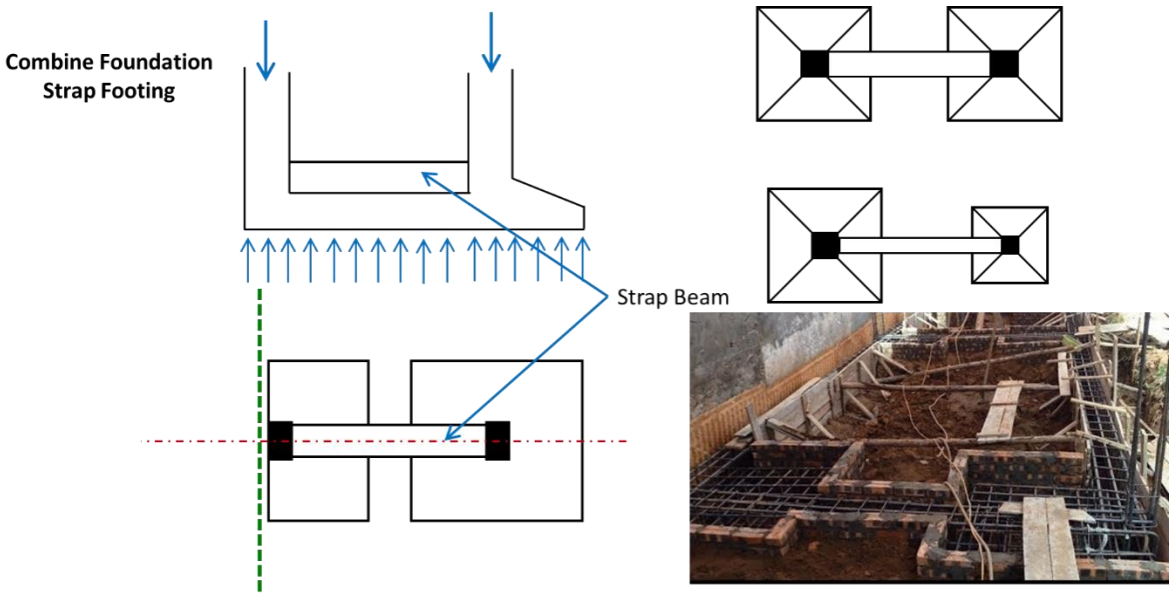
And we also know that CG of the loading should coincide with CG of the footing. Therefore,



In another case,

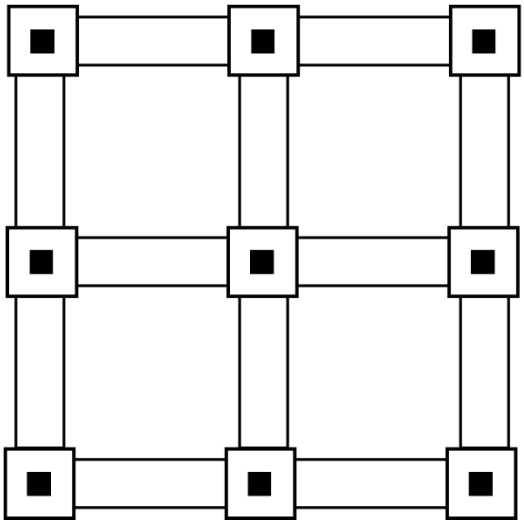
If there is a limit of property line in the foundation, so there combined footings can be casted withthe cantilever beam.





- And when the strata is uneven and there are so many undulations on site, so at that place we can use an array of combined footings which are called Combine Foundation Grid Footing.

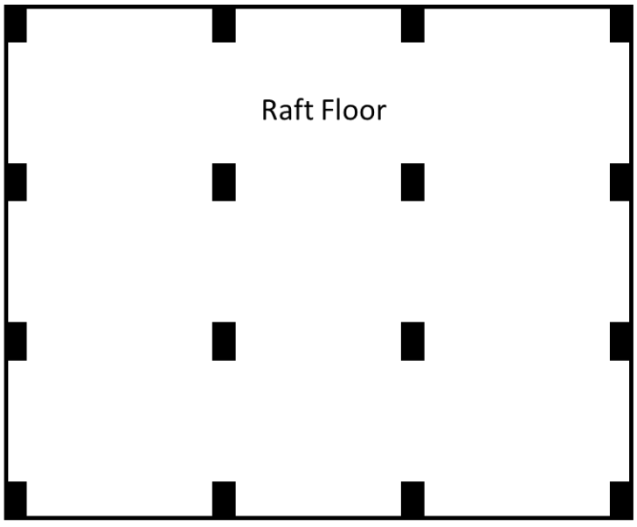
Combine Foundation
Grid Footing



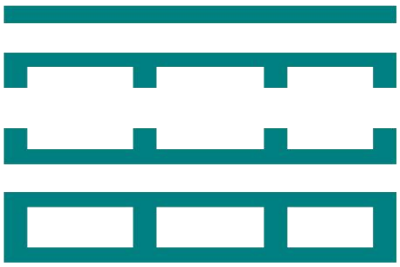
Raft Foundation

Raft foundations or Mat foundations are basically slabs of concrete that sit on a firm, level bed of soil and extend across the largest part or even the entire footprint of the build. Whilst these are shallow foundations, they can provide much better stress distribution than conventional trench footings. Because the weight of the building is spread across a much larger surface area than with traditional trench footings or pile footings, the stress acting on the soil below is greatly reduced.

Combine Foundation
Raft Foundation



Types of Raft Foundation Floor



Deep Foundation

When depth (D) of the foundation is very much high than the width of the foundation than it is classified into the deep foundation. Pile Foundation, Well Foundation and Pier Foundation are its general types.

Pile Foundation

- Pile is the common type of deep foundation.
- It is narrower in cross section and longer in length.
- It is inserted into the soil strata up to a required depth to transmit the load of the super structure to soil.
- Pile foundations are also capable of providing stability against upliftment.

Pile foundation is proposed for the following conditions:

- Top soil having low bearing capacity.
- Foundation subjected to very high concentrated load.
- Building over marshy land.
- When raft foundation is not economical.

Types of Pile Foundations

There are various classifications of pile foundation.

Based on primary load transmission

i. End Bearing Pile
ii. Friction Pile

Based on Material

i. Concrete Pile
ii. Sand Pile
iii. Steel Pile
iv. Timber Pile

v. Composite Pile

Based on Function

i. Load Bearing Pile
ii. Sheet Pile
iii. Compaction Pile
iv. Anchor Pile

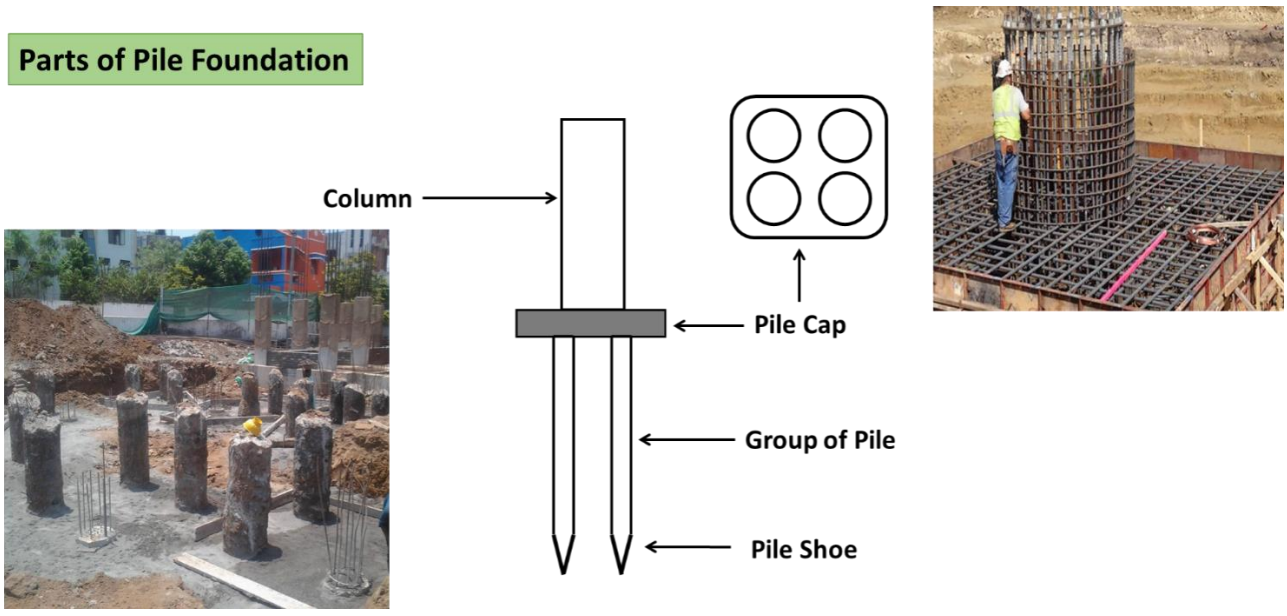
Based on Construction Method

i. Pre-cast Pile
ii. Cast-in-situ Pile

Parts of Pile Foundation

Pile consist of four main parts

i. Column – The member which transfer the load from superstructure to the ground.
ii. Pile Cap – It houses numbers of pile and connect the pile with the columns to the pile.
iii. Group of Pile – These are the group of pile (min. 3) which transfers he load to the ground.
iv. Pile Shoe – It is the end of the pile which is sharp in nature.

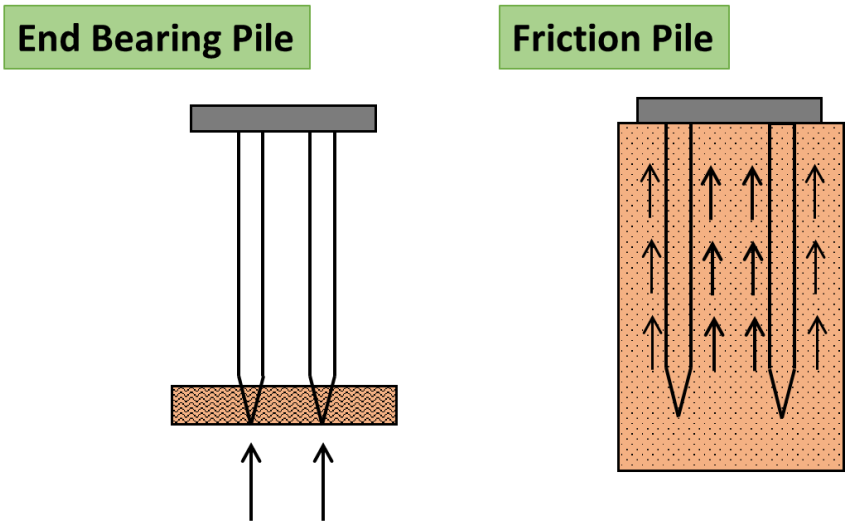


End Bearing Pile

- The tip of the pile reaches to the hard strata and load transfer occurs at the tip of the pile only.

Friction Pile

- The friction generated between the pile surface and the surrounding soil transfers the load.



.**Calculation**

To calculate the depth of penetration 'H' in the bottom layer of a pile.

Given,

- Column Load 1200KN (4nos of Pile Group)
- Skin Friction (above layer): 20KN/m2
- Depth of the above layer of the soil – 5m
- Depth of the above layer of the soil – H (unknown)
- Skin Friction: 25KN/m2

Since there are 4 no. of pile so:

- Design load of One pile = 1200/4 = 300KN
- Let Diameter (d) of pile be 300mm

Formula

- Support load = $\boldsymbol{\pi}$dL X Skin Friction

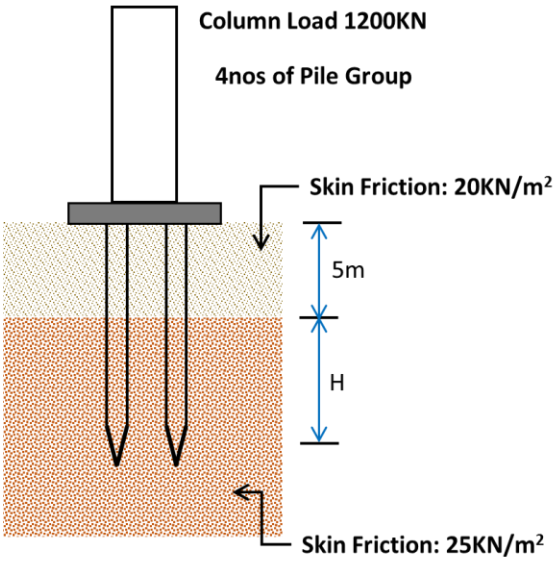
For top soil

- Support load = ($\boldsymbol{\pi}\times\mathbf{0.3}\times\mathbf{5}$) X 20 = 94.5 KN

For bottom soil

Support load = ($\pi \times 0.3 \times$H) X 25 = (300 – 94.5)

H=8.7m



Design load of One pile = 300KN

Let Diameter of pile be 300mm

For Top 5m:

Support load = $(\pi \times 0.3 \times 5) \times 20 = 94.5KN$

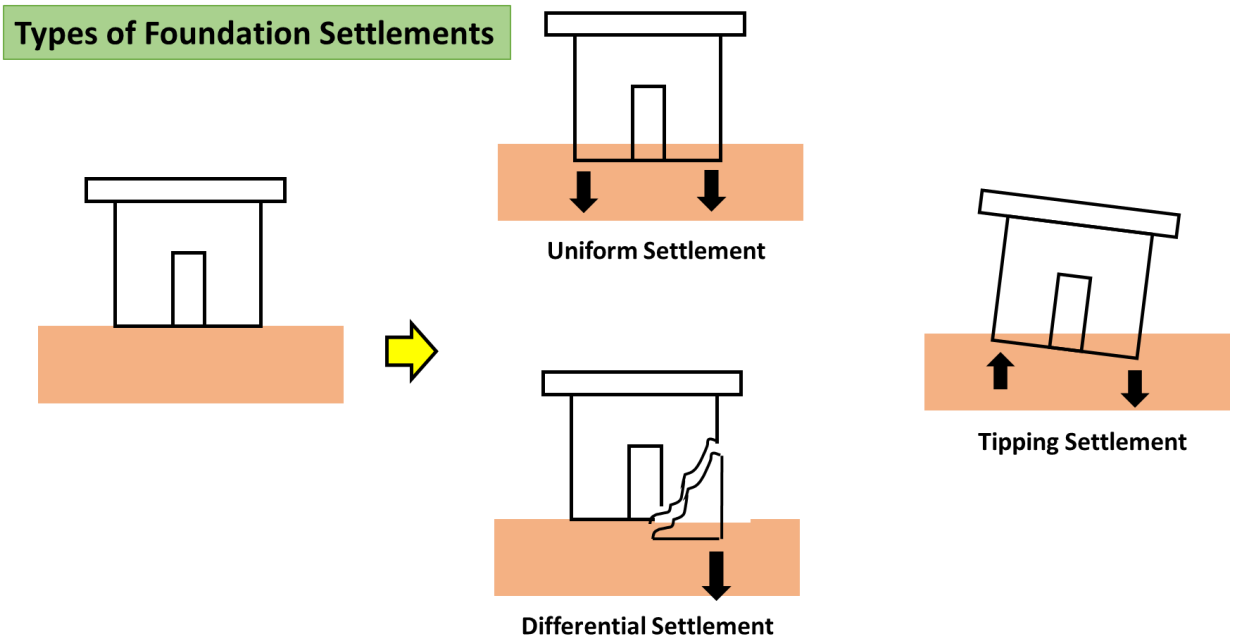
Let the required depth of penetration in the bottom layer be 'H'

$(\pi \times 0.3 \times H) \times 25 = (300 - 94.5)$

Solving, H=8.7m

Reasons for Foundation Failure

- Unequal Settlement
- Presence of Expansive Soil
- Rising of Water table
- Foundation damage by tree roots
- Foundation damage by rat holes
- Soil liquefaction due to earthquake



References

- **Building Structure Illustrated** by Francis D.K. Ching, Willy
- **Soil Mechanics and Foundation Engineering** by K.R. Arora, Standard Publisher

Conclusion

- Bearing capacity of soil plays a key role about the foundation system of any structure.
- Shallow and deep are the two types of foundations generally used in buildings.