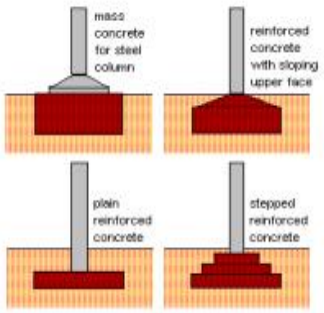

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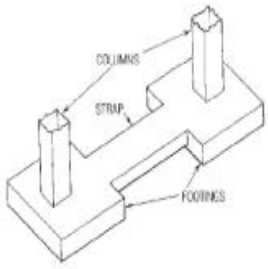
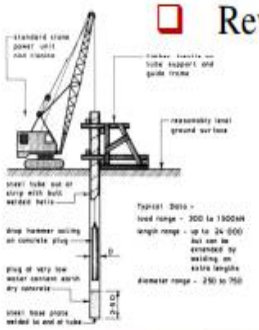
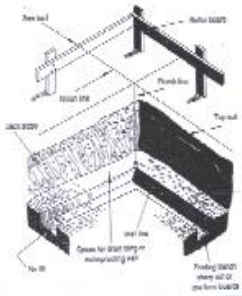


Fig. 7.8 Cantilever footing.



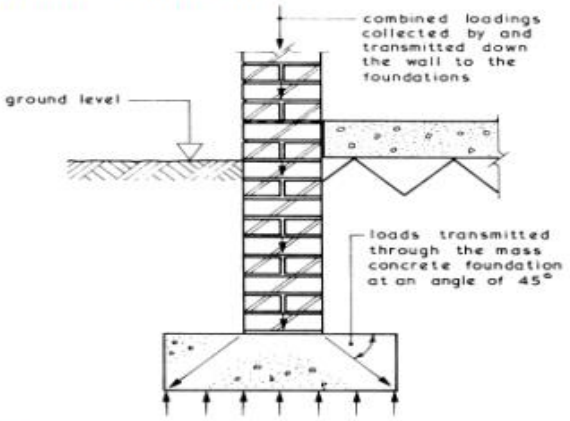


1. INTRODUCTION (CONT...)

- A foundation should be sufficiently strong to prevent **excessive settlement** as well as **unequal settlement**.
- Unequal settlement or differential settlement may be caused by:
  - Weak sub-soils, such as made up ground,
  - Shrinkable and expansive soil (such as clay),
  - Frost action,
  - Movement of ground water, and uplift pressure
  - Excessive vibrations, due to traffic, machinery etc.,
  - Slow consolidation of saturated clays, and
  - Slipping of strata on sloping sites.

1. INTRODUCTION

- Every building consists of two basic parts: The **Super-structure** and **Sub-structure** (foundation).
- Foundation is that part of the structure which is in direct contact with the ground to which the loads are transmitted.
- The function of a foundation is to distribute the load of super-structure over a larger area, in such a way that;
  - settlements are with in permissible limit and
  - The soil does not fail.



2. FUNCTIONS OF FOUNDATION

- Foundations serve the following purposes:
  1. **Reduction of load intensity**: Foundation distribute the loads of superstructure, to a larger area so that the intensity of the load at its base does not exceed the safe bearing capacity of the sub-soil.
  2. **Even distribution of load**: foundations distribute the non-uniform load of the superstructure evenly to the sub soil.
  3. **Provision of level surface**: foundations provide levelled and hard surface over which the superstructure can be built.
  4. **Lateral stability**: it anchors the superstructure to the ground, thus imparting lateral stability to the superstructure.
  5. **Safety against undermining**: it provides safety against scouring due to burrowing animal and flood water.
  6. **Protection against soil movements**: minimises the distress on the superstructure due to expansion or contraction of sub-soil because of moisture movement in some problematic soil.

3. ESSENTIAL REQUIREMENTS OF A FOUNDATION

- Foundations should be constructed to satisfy the following requirements:

1. The foundations shall be constructed to sustain all loads and transmit them to the sub soil with out causing settlement which would impair the stability of the building or adjoining structure.
2. Foundation base should be rigid so that differential settlements are minimised, specially for the case when super-imposed loads are not evenly distributed.
3. Foundation should be taken sufficiently deep to guard the building against damage or distress caused by swelling or shrinkage of sub-soil.
4. Foundations should be so located that its performance may not be affected due to any unexpected future influence.

4. TYPES OF FOUNDATIONS

- Foundations may be broadly classified under two heads:

1. **Shallow Foundations**
2. **Deep Foundations**

4.1 SHALLOW FOUNDATIONS

- Shallow foundations are those founded near to the finished ground surface. generally where the founding depth (D_f) is less than the width of the footing and less than 3m.
  - Shallows foundations are used when surface soils are sufficiently strong and stiff to support the imposed loads.
  - They are generally unsuitable in weak or highly compressible soils, such as poorly-compacted fill, peat, alluvial deposits, etc.

TYPES OF FOUNDATIONS (CONT...)

4.2 DEEP FOUNDATIONS

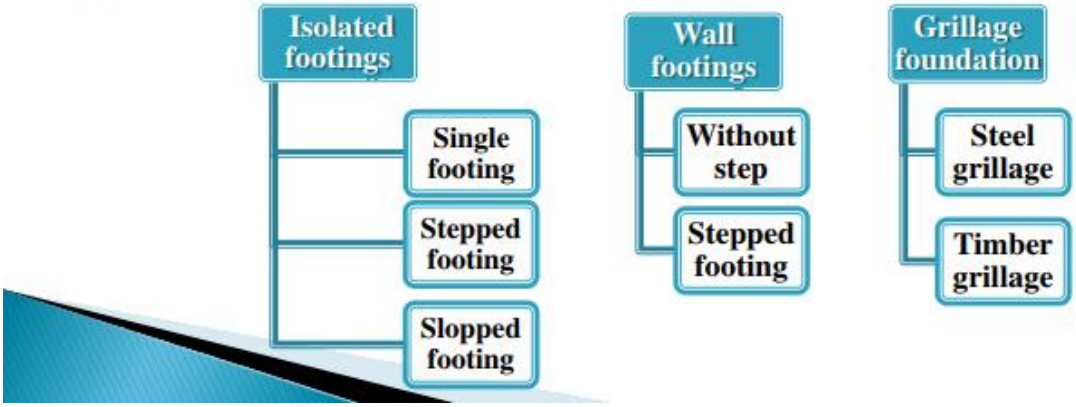
- Deep foundations are those founding too deeply below the finished ground surface for their base bearing capacity to be affected by surface conditions,
  - this is usually at depths >3 m below finished ground level.
  - Deep foundations can be used to transfer the loading to a deeper, more competent strata at depth if unsuitable soils are present near the surface.

Shallow foundation	Deep foundation
• Spread footings • Combined footings • Strap footings • Mat foundation	• Pile foundation • Pier foundation • Well or caissons foundation

4.1 SHALLOW FOUNDATIONS

4.1.1 SPREAD FOOTINGS

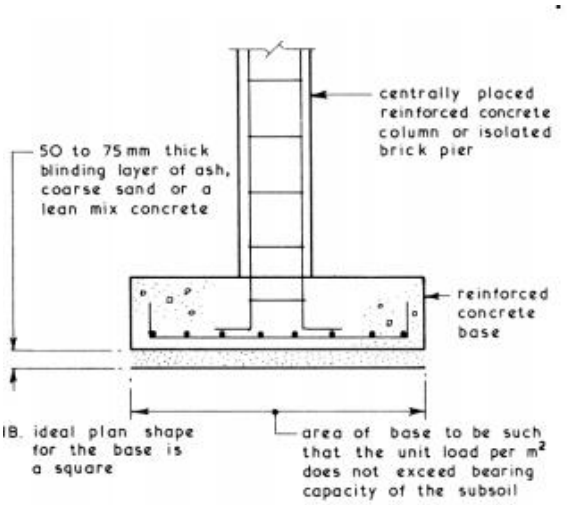
- Spread footings are those which spread the super-imposed load of wall or column over large area.
- Spread footings support either a column or wall.
- They are most widely used foundation types since they do not require special equipment and skill for construction and are usually economical.
- Spread footings may be of the following types:

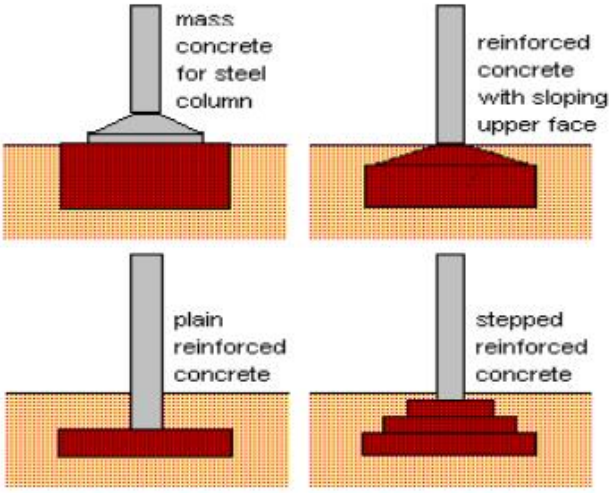


4.1 SHALLOW FOUNDATIONS (CONT...)

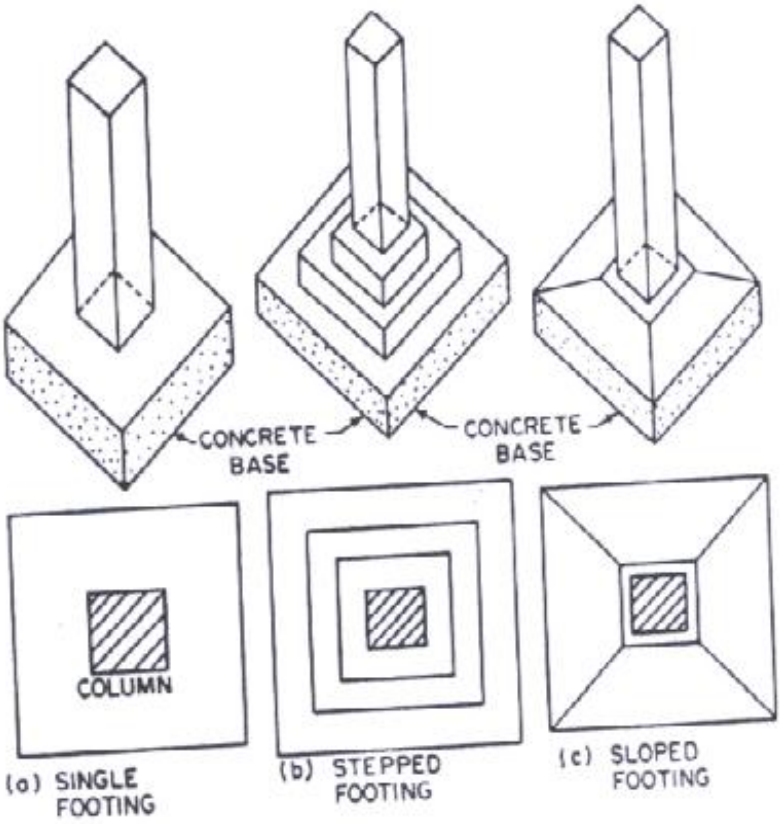
I. ISOLATED FOOTINGS

- These footings are sometimes known as column footings and are used to support the individual columns, piers or other concentrated load.
- Most column footings are slab footings with two-way reinforcements and constant depth.





I. ISOLATED FOOTINGS (CONT...)

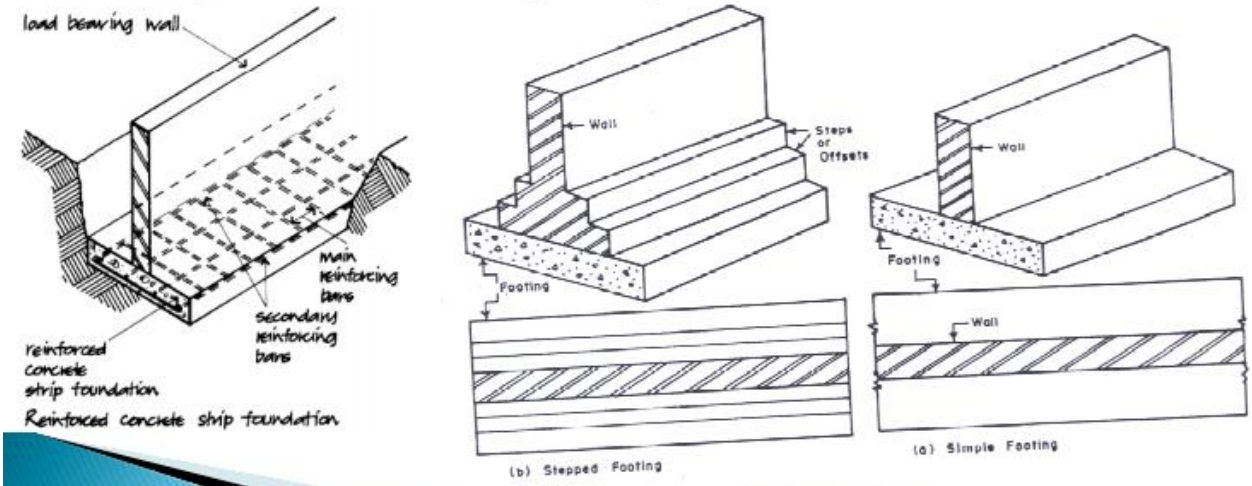


Spread footings for column

4.1 SHALLOW FOUNDATIONS (CONT...)

II. WALL FOOTINGS (STRIP FOOTINGS)

- 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.
- A wall footing may have a base course of concrete may be entirely built up of one material , e.g. bricks or stones.

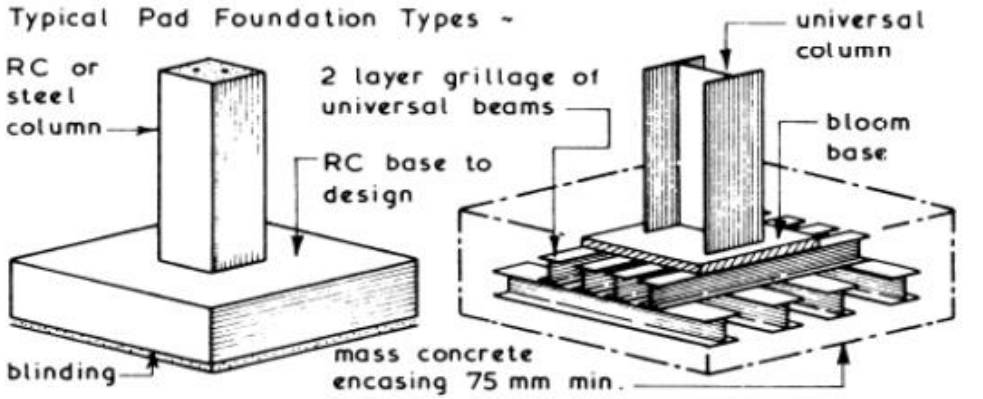


Strip footing

4.1 SHALLOW FOUNDATIONS (CONT...)

III. GRILLAGE FOUNDATIONS

- They consist of steel beams arranged in layers at right angles to one another and embedded in concrete.
- They are generally provided for heavily loaded steel column and used in locations where bearing capacity of soil is poor.



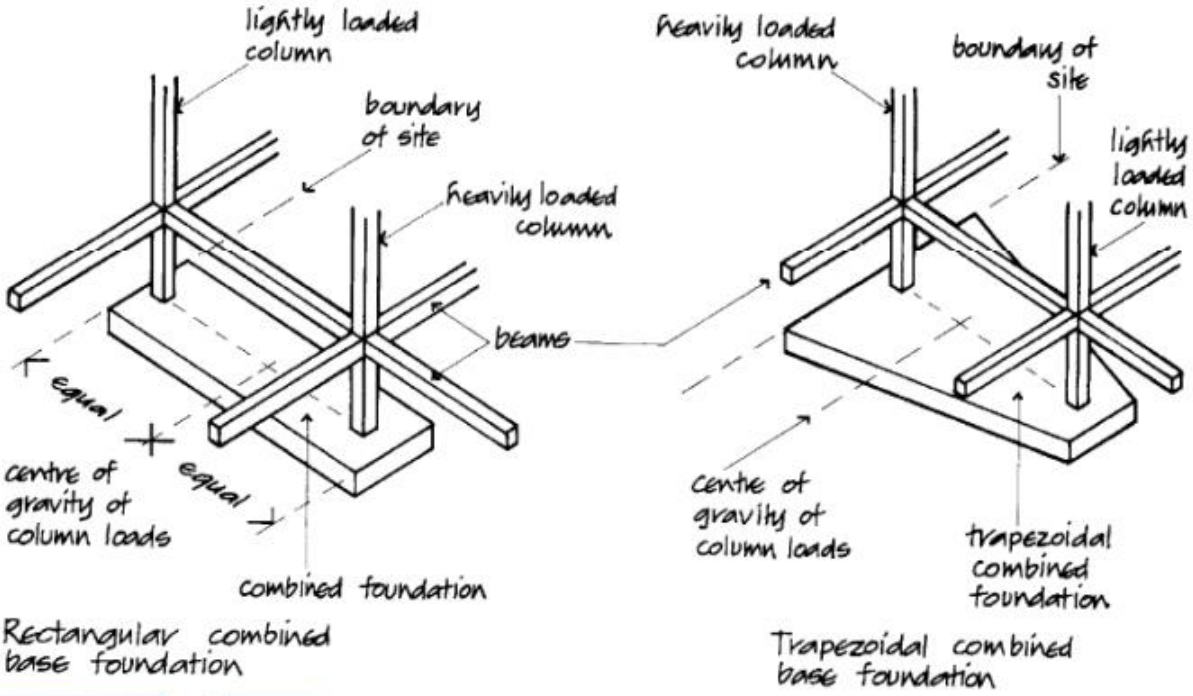
4.1 SHALLOW FOUNDATIONS (CONT...)

4.1.2 COMBINED FOOTINGS

- A spread footing which supports two or more columns is termed as combined footing.
- Footings of this type are most frequently used to support walls and columns, which are close to the property line.
- Combined footings are essential whenever:
  - the projections of columns are not possible on one side due to limited available space and
  - when the spacing of two consecutive columns are close for isolated footing.
- The combined footing for columns will be rectangular in shape if they carry equal load or trapezoidal shape for unequal loads.

4.1 SHALLOW FOUNDATIONS (CONT...)

4.1.2 COMBINED FOOTINGS (CONT...)



Rectangular combined base foundation

Trapezoidal combined base foundation

4.1 SHALLOW FOUNDATIONS (CONT...)

4.1.3 STRAP FOOTINGS (CANTILEVER FOOTING)

- If the independent footing of two columns are connected by a beam, it is called a strap footing.
- They serve the same function as combined footings by permitting a column load to be placed near the edge of the footing.
- It is used where a large spacing between two columns create a situation where a continuous footing is uneconomical due to the usage of large quantity of concrete.
- A rigid beam connects the two pads to transmit the unbalanced shear and moment from the statically unbalanced footing to the second footing.

4.1.3 STRAP FOOTINGS (CONT...)

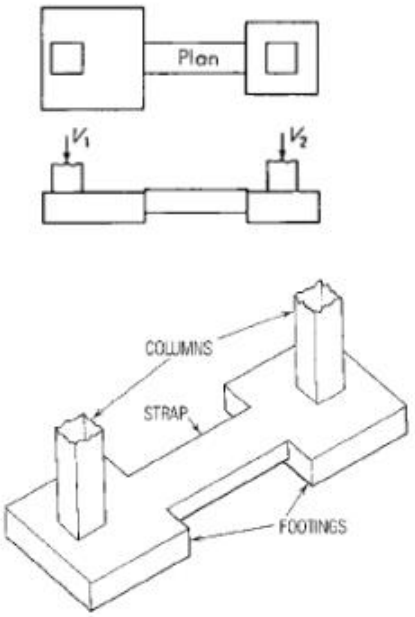
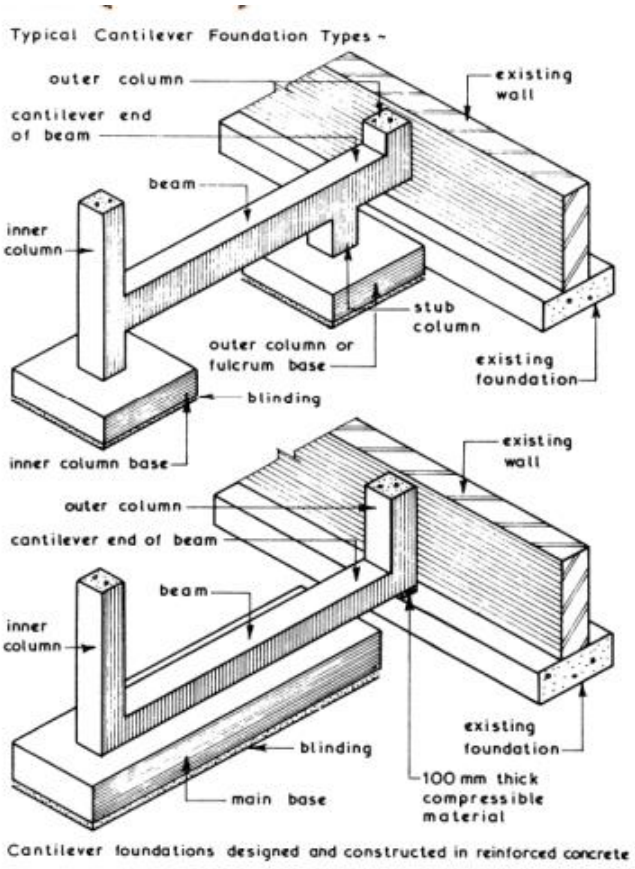


Fig. 7.8 Cantilever footing.

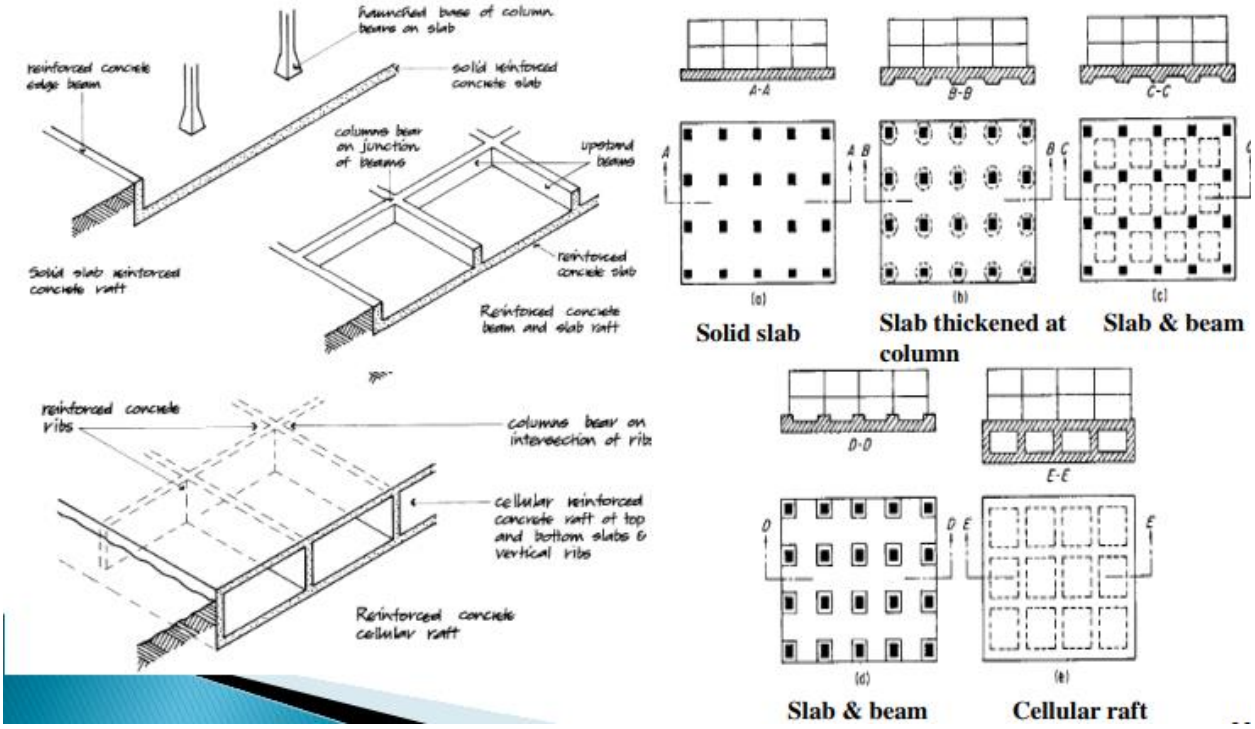


4.1 SHALLOW FOUNDATIONS (CONT...)

4.1.4 MAT (RAFT) FOUNDATION

- A raft or mat is a combined footing that covers the entire area beneath the structure and supports all the walls and columns.
- It is used where:
  - ✓ The allowable soil pressure is low,
  - ✓ The building loads are heavy,
  - ✓ The use of spread footings would cover more than half the area,
  - ✓ The soil mass contains compressible lenses,
  - ✓ The soil is sufficiently erratic so that differential settlement would be difficult to control.
- Raft foundation is also used to reduce settlement above highly compressible soils, by making the weight of the structure and raft approximately equal to the weight of the soil excavated (**Floating**).
- Raft foundation is not suitable:
  - ✓ For steeply sloping sites where excavation would be excessive,
  - ✓ To framed buildings with heavy concentrated loads where raft thickness and reinforcement would be excessive.
- Rafts may be divided into three types, based on their design and construction
  - i. **Solid slab system**: is a solid reinforced concrete slab generally uniform thickness.
  - ii. **Beam slab system**: consists of up-stand or down-stand beams that take the loads of the walls or columns and spread them.
  - iii. **Cellular system**: consists of top and bottom slab separated by and reinforced with vertical cross ribs in both direction.

4.1.4 MAT (RAFT) FOUNDATION (CONT…)



4.2 DEEP FOUNDATIONS

4.2.1 PILE FOUNDATION

- This is an element of a construction placed in the ground either vertically or slightly inclined to increase the load carrying capacity of the soil.
- Pile foundations may be adopted:
  - i. Instead of raft foundation where no firm bearing strata exists at any reasonable depth and the loading is uneven.
  - ii. When a firm bearing strata does not exist but at a depth such as to make strip or spread footing uneconomical
  - iii. When pumping of sub-soil water would be too costly or timbering to excavations too difficult.
- Based on **basic design function** Piles may be of four types:
  - i. End bearing pile
  - ii. Friction pile
  - iii. Combined end bearing and friction pile
  - iv. Compaction pile

End bearing piles: Transfer load through water or soft soil to a suitable bearing stratum.

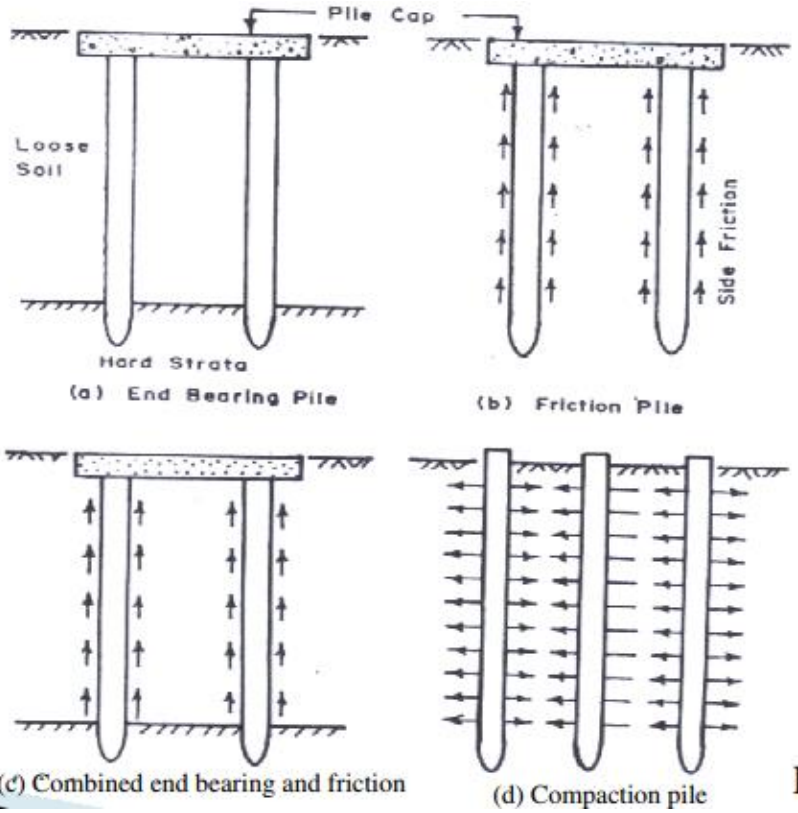
- Such piles are used to carry heavy loads safely to hard strata.
- Multi-storied buildings are invariably founded on end bearing piles, so that the settlements are minimised.

Friction piles: are used to transfer loads to a depth of a friction-load-carrying material by means of skin friction along the length of the pile.

- Such piles are generally used in granular soil where the depth of hard stratum is very great.

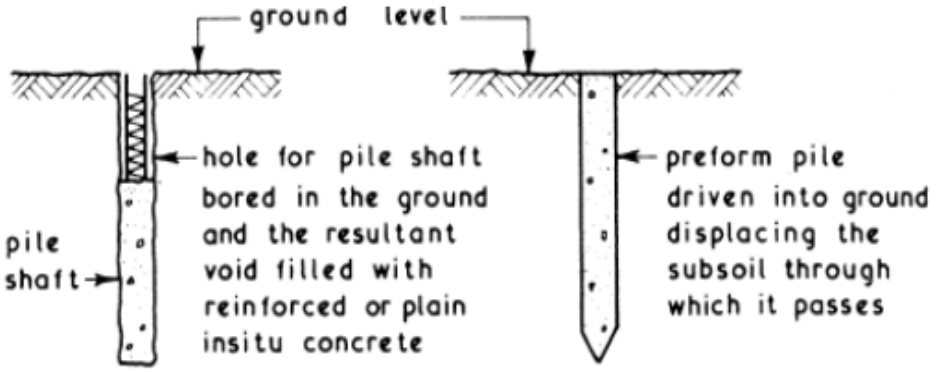
Combined end bearing and friction piles: Transfer the superimposed load both through side friction as well as end bearing.

Compaction piles: are used to compact loose granular soils, thus increasing bearing capacity.



Pile foundations

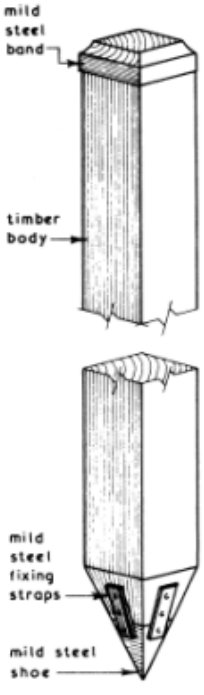
- Based on the method of construction piles may be classified as:
  - **i. Replacement piles**: these are often called **bored piles** since the removal of the soil to form the hole for the pile is always carried out by a boring technique.
  - **ii. Displacement piles**: these are often called **driven piles** since they are usually driven into the ground displacing the earth around the pile shaft.



- Depending upon the materials used in their production, piles can be broadly classified as: Timber piles, reinforced concrete piles, steel piles and composite piles.

Timber piles

Advantages	Disadvantages
• Less expensive • Can be made longer by joining individual piles • Cutting of piles is very easy • Can be driven quickly with lighter machine	• Deteriorate by different actions • Have lesser loading capacity • Possibility of damage due to over driving • Joining work is time taking and expensive



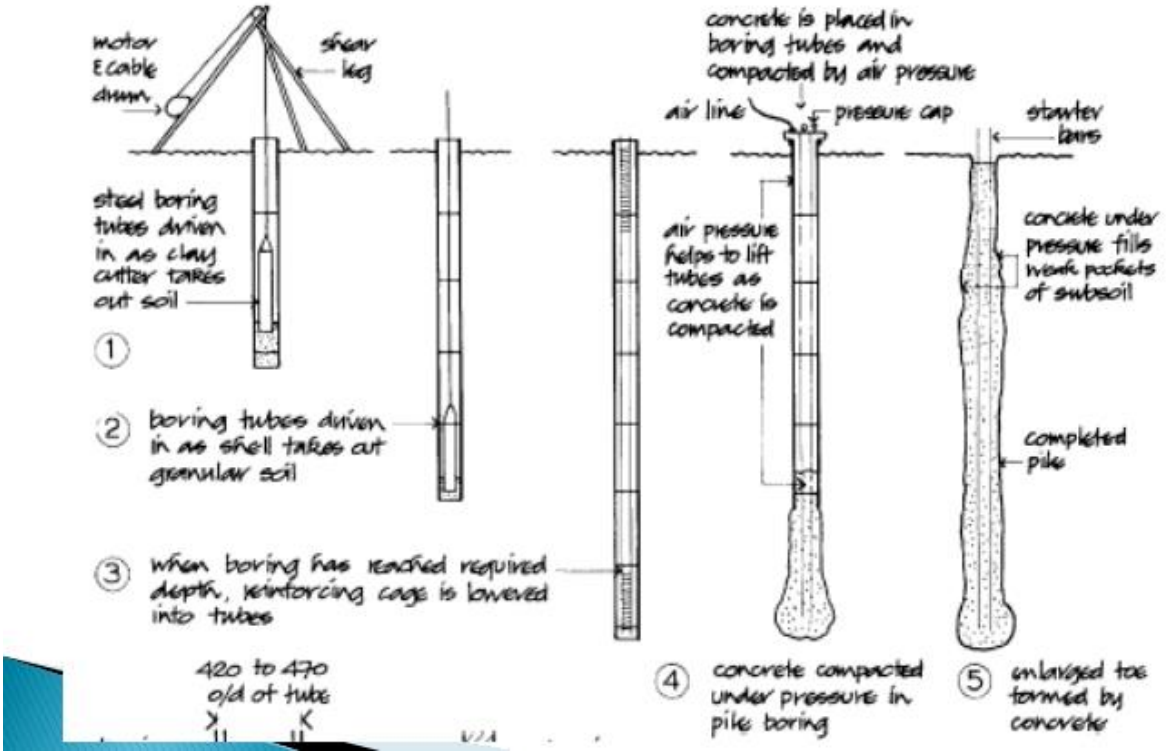
Precast concrete piles

Advantages	Disadvantages
• Best concrete quality • Reinforcement bars remain in position • Concrete withstand loads after complete curing • Convenient when driven through wet soil • More suitable where part of length remain exposed	• Heavy and difficult to transport • Shocks of driving make them weaker • Trimming is difficult

Cast in situ concrete pile: is a concrete pile built in permanent location within a hole made for this purpose.

Advantages	Disadvantages
• Avoid vibration caused by driving • Underlying soil can be explored during the process • Less wastage of material • No time spent on curing • Lighter equipment is required than driven piles	• Quality of concrete may be compromised due to height • Possible displacement of reinforcement • Difficult to use under water

Cast in situ concrete pile



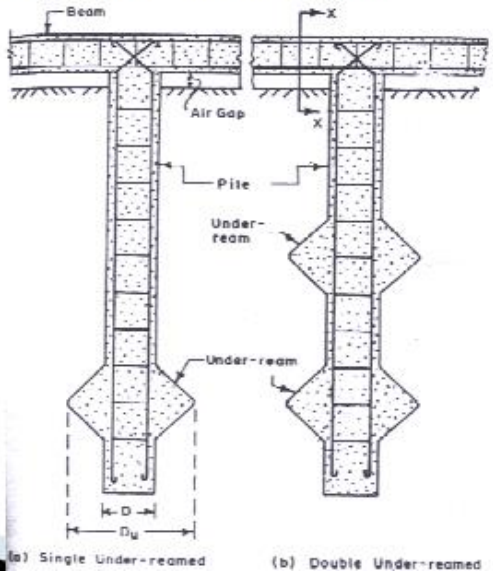
4.2.1 PILE FOUNDATION (CONT...)

Steel piles: may be of I-section or hollow pipe section.

- Because of small sectional area, steel piles are easy to drive.
- They are mostly used as bearing piles.
- It is usual to fill the tube with mass concrete to form a composite pile.

UNDER-REAMED PILES

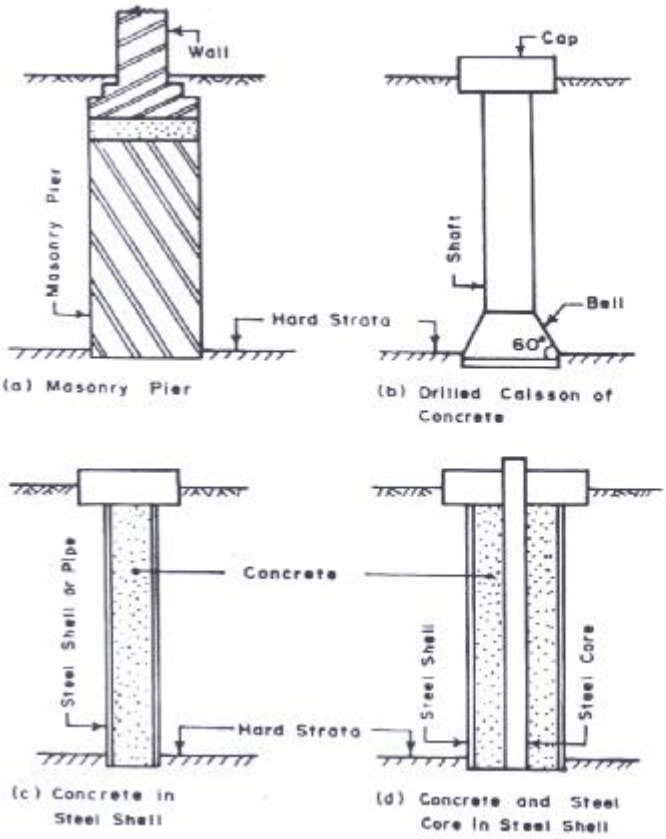
- Under reamed piles are bored and cast in situ concrete piles having **bulb shaped** arrangement near base.
- The principle of this type of foundation is to anchor the structure at a depth where ground movements due to changes in moisture content or consolidation of the poor strata is negligible.



Under-reamed piles

4.2.2 PIER FOUNDATION

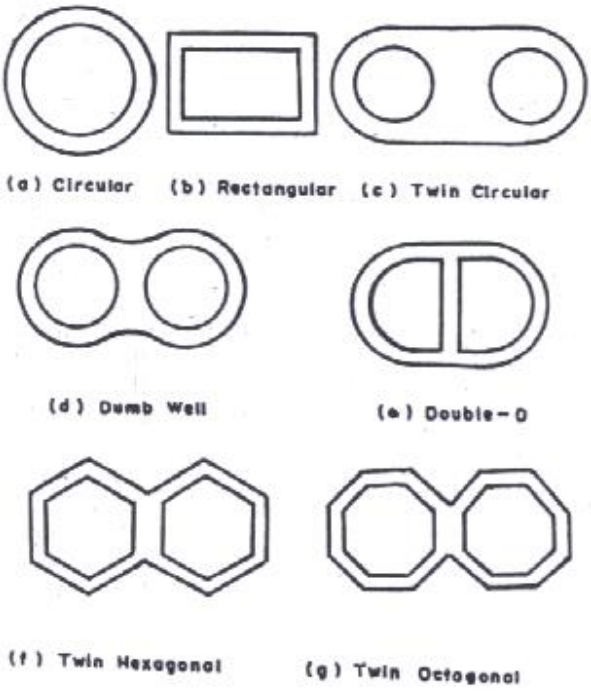
- Consists of cylindrical column of large diameter to support and transfer large super imposed loads to the firm strata below.
- The difference between pile foundation and pier foundation lies in the method of construction. The major differences are:
  i. Pier foundation transfer load only through bearing
  ii. Pier foundation are shallower in depth than pile foundation.
  iii. Pier foundation is preferred where the top strata consists of decomposed rock overlaying a strata of hard rock.
  iv. Pier foundations are preferred in case of stiff clays, which offer large resistance to the driving of a bearing pile.
  v. In case of piers, the excavation can be carried to the desired depth easily.
- Pier foundations may be of the following types:
  i. Masonry concrete pier, or
  ii. Drilled caissons
- When a good bearing stratum exists up to 5m below ground level, brick, masonry or concrete foundation piers in excavated pits may be used.
- A drilled caisson is largely a compressed member subjected to an axial load at the top and reaction at the bottom.
- Drilled caissons are generally drilled with the mechanical means.
- Drilled caissons may be of three types:
  i. Concrete caisson with enlarged bottom
  ii. Caisson of steel pipe with concrete filled in the pipe
  iii. Caisson with concrete and steel core in steel pipe
- There are various methods of driving the piers:
  i. Open caisson method
  ii. Compressed air (Caisson method)
  iii. Ordinary excavation method
  iv. Use of sheeting and sheet pile



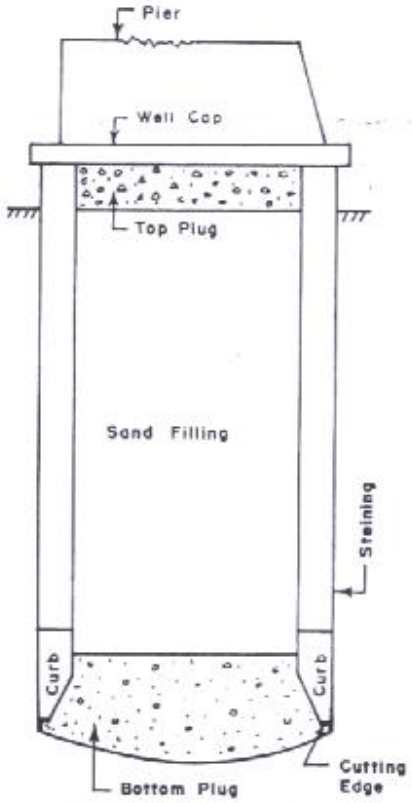
Pier foundations

4.2.3 WELL FOUNDATION (CAISSONS)

- They are box like structure- circular or rectangular- which are sunk from the surface of either land or water to the desired depth.
- They are much large in diameter than the pier foundation or drilled caissons.
- Well foundations are used for major foundation works, such as for:
  - Bridge piers and abutments in rivers, lakes etc.
  - Break waters and other structures for shore protection
  - Large water front structures such as pump houses.
- Well foundations or caissons are hollow from inside, which may be filled with sand and are plugged at the bottom.
- The load is transferred through the perimeter wall.
- Well foundations are not used for building.



Shapes of wells



Well foundation

5. FOUNDATION FAILURE

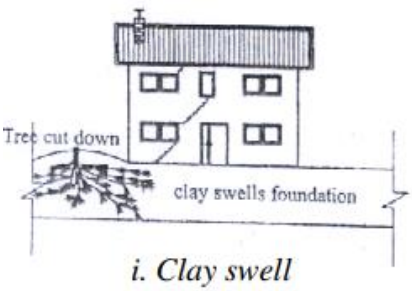
A. Causes of foundation failure

- Foundations may fail due to the following reasons:
  - i. Unequal settlement of subsoil
  - ii. Unequal settlement of masonry
  - iii. Sub-soil moisture movement
  - iv. Lateral pressure on the walls
  - v. Lateral movement of sub soil
  - vi. Weathering of sub-soil due to trees
  - vii. Atmospheric action

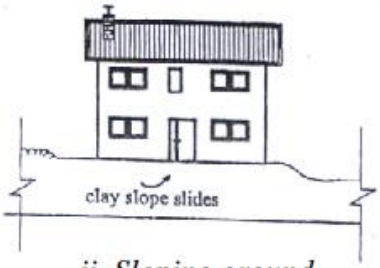
B. Sites with potential hazards

- i. Clay of high shrinkage or swelling potential
- ii. Sloping ground
- iii. Deep fill
- iv. Mining areas
- v. Peat or other soft soils
- vi. Old building foundations and basements
- vii. Ground waters

B. Sites with potential hazards (Cont...)

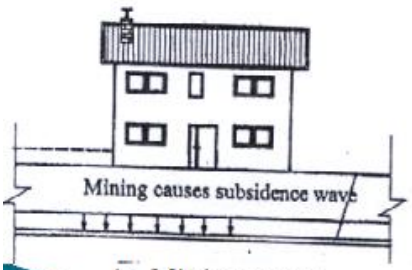


i. Clay swell

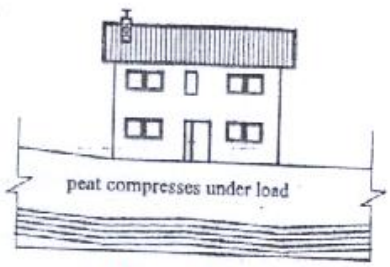


ii. Sloping ground

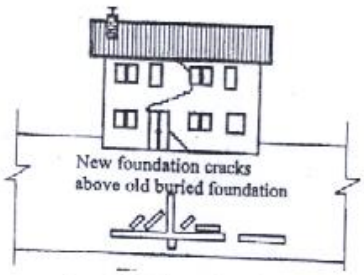
iii. Deep fill



iv. Mining areas



v. Peat or soft soil



vi. Old foundation