Cihan University Sulaymaniya
Faculty of Engineering
Architectural Engineering Department

Building Materials

Chapter Three

(Footing and Foundation)

1st Grade- Fall Semester 2022-2023

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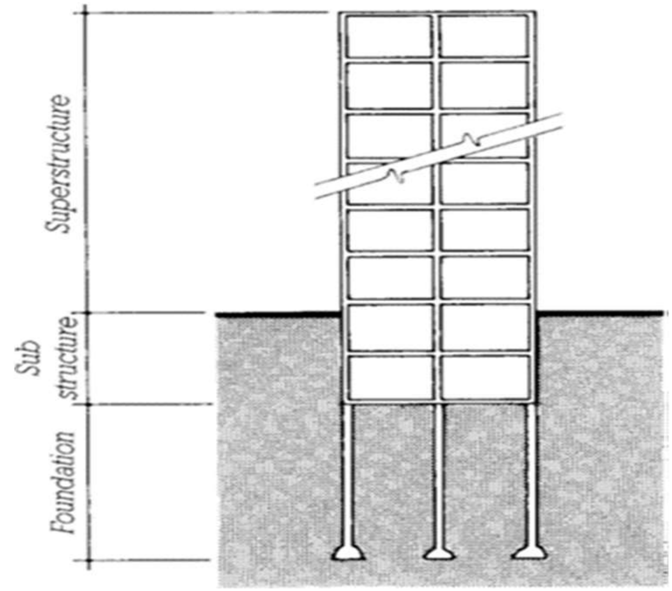
Footing and Foundation

It is convenient to think of a building as consisting of three major parts:

The superstructure, which is the aboveground portion of the building; **the substructure**, which is the habitable below-ground portion; and **the foundations**, which are the components of the building that transfer its loads into the soil.

In the Figure 4.1 below: Superstructure, substructure, and foundation. The substructure in this example contains two levels of basements, and the foundation consists of bell caissons. (In some buildings, the substructure and foundation may be partly or wholly the same.)

Footing and Foundation



Footing and Foundation

There are two basic types of foundations:

A. Shallow foundation

B. Deep foundation

Shallow foundations are those that transfer the load to the earth at the base of the column or wall of the substructure.

Deep foundations, either piles or caissons, penetrate through upper layers of incompetent soil in order to transfer the load to competent bearing soil or rock deeper within the earth. Shallow foundations are generally less expensive than deep ones and can be used where suitable soil is found at the level of the bottom of the substructure, whether this be several feet or several stories below the ground surface.

Footing and Foundation

A. Shallow Foundations

Most shallow foundations are simple concrete footings. A column footing is a square block of concrete, with or without steel reinforcing, that accepts the concentrated load placed on it from above by a building column and spreads this load across an area of soil large enough that the allowable bearing stress of the soil is not exceeded.

Depth of footing depends on:

1- Type of soil and its strength (Bearing capacity).

2- Depth of frost action.

3- Level of ground water.

4- Present of basement and services.

5- Present of adjacent building.

6- Problem of clay soil swelling and shrinkage.

Footing and Foundation

Footings are made from:

1- Plain concrete.

2- Reinforced concrete.

3- Steel grillage.

The primary factors that affect the choice of a foundation type for a building are:

- Subsurface soil and groundwater conditions
- Structural requirements, including foundation loads, building configurations, and depth

Footing and Foundation

Secondary factors that may be important include:

- Construction methods, including access and working space
- Environmental factors, including noise, traffic, and disposal of earth and water
- Building codes and regulations
- Proximity of adjacent property and potential impacts on that property
- Time available for construction
- Construction risks

Footing and Foundation

Types of footing

1- Wall footing

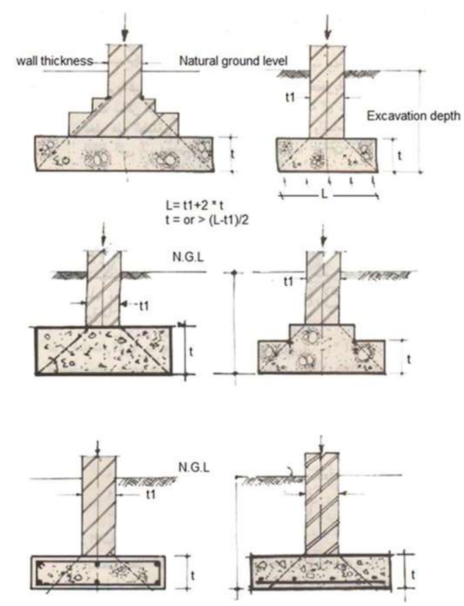
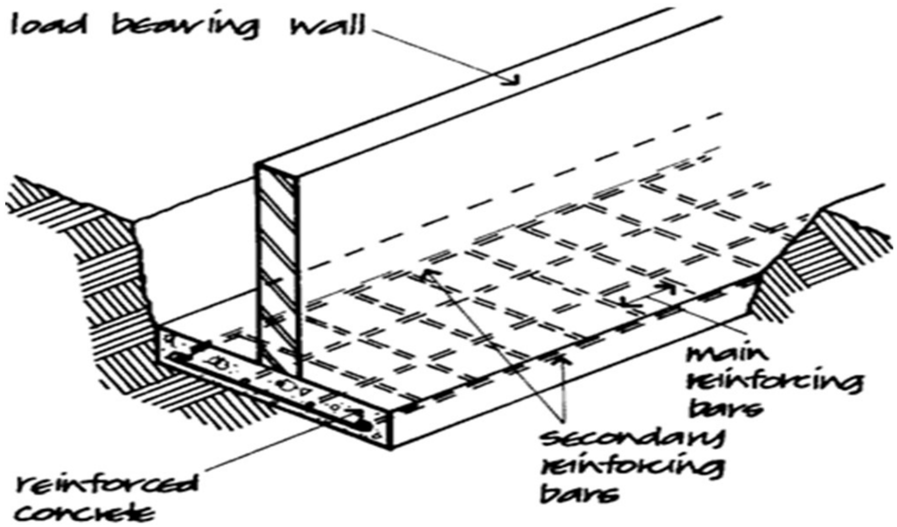


Fig.4.2: A wall footing or strip footing is a continuous strip of concrete that serves the same function for a loadbearing wall

Footing and Foundation

Fig. 4.3: Wall footing



Footing and Foundation

Stepped footing

Use this type of footing when the site of project sloped, and it cause the large depth of excavation and filling. When building on slopes, it is often necessary to step the footings to maintain the required depth of footing at all points around the building (Fig.4.4-4.6).

Footing and Foundation

Fig. 4.4: Longitudinal section for stepped footing

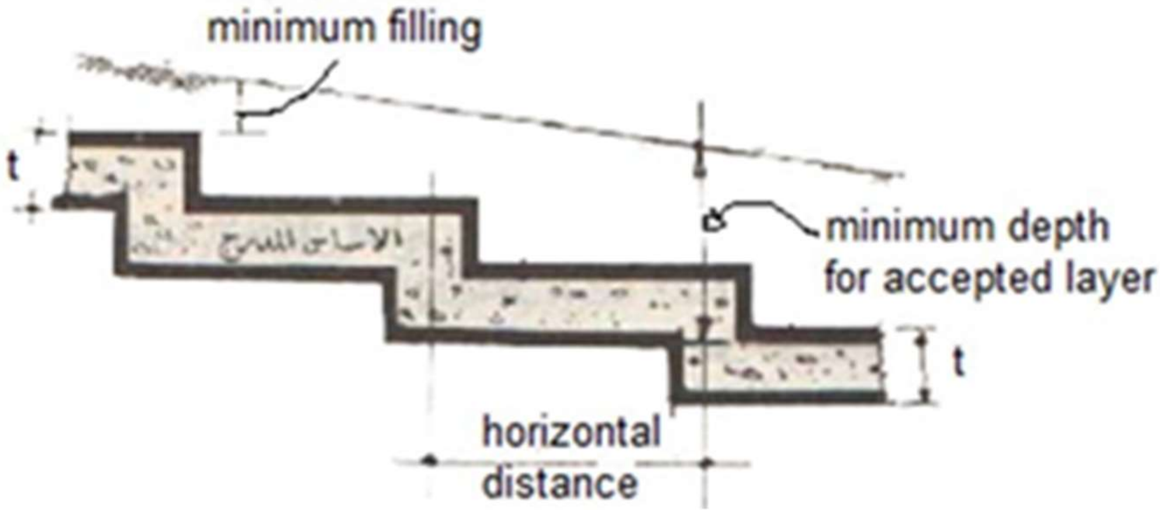


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Fig. 4.5: Detail of the stepped in stepped footing

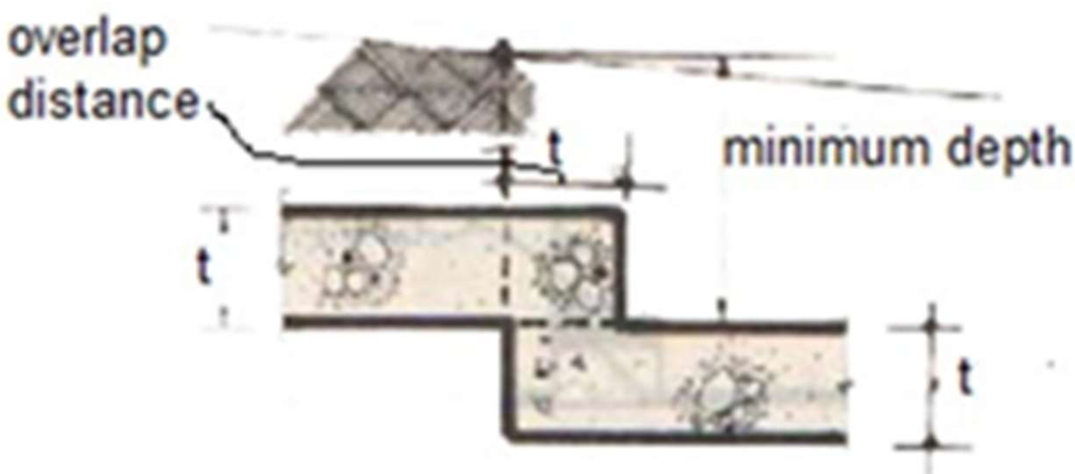

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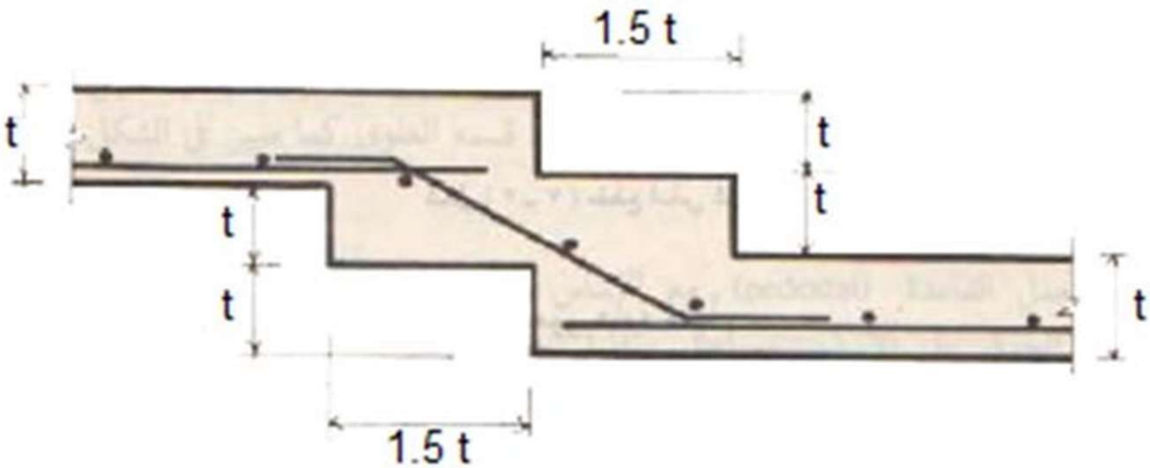
Fig. 4.6: Stepped footing in very sloped site



Footing and Foundation

2-Strip footing (Trench footing)

Use the strip footing as an alternative for wall footing in those sites which has high shear strength, and loaded the weight by surface friction between the footing sides and cohesive soil by which and soil bearing capacity in bottom of footing. Usually use plain concrete (i.e.: without reinforcement) for strip footing.

Advantage of strip footing:

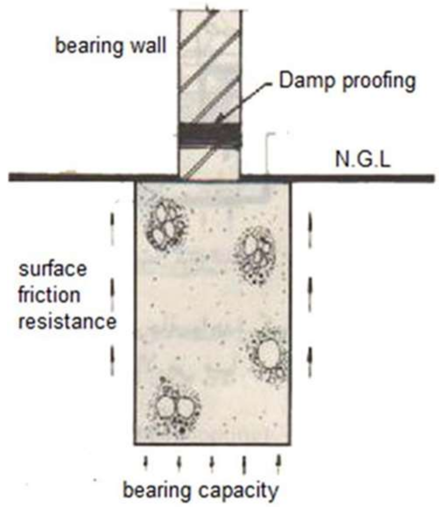
1-Fast construction

2-Prevent of moving ground water from sides of footing and it work as damp proofing.

3-Use as deep beam to reduce the differential settlement and resistance the bending moment which exist in large void and concentrated load, for this purpose add the small amount of steel bar.

Footing and Foundation

Fig. 4.7: Section of strip footing



Footing and Foundation

3-Isolated footing (Single footing)

Use this type of footing to transfer concentrated load from column or pier to the earth (Fig. 4.8), it's make from plain concrete or reinforced concrete or steel section (grillage foundation) (Fig. 4.12), usually in square or rectangular form . Pedestal use with isolated footing when has large area, to distribute the load on footing by stages and reduce thickness of footing (4.11).

Tie beams are in the same elevation with the footing or on it, better than other elevation (Fig. 4.10)

Footing and Foundation

Fig. 4.8: Isolated footing

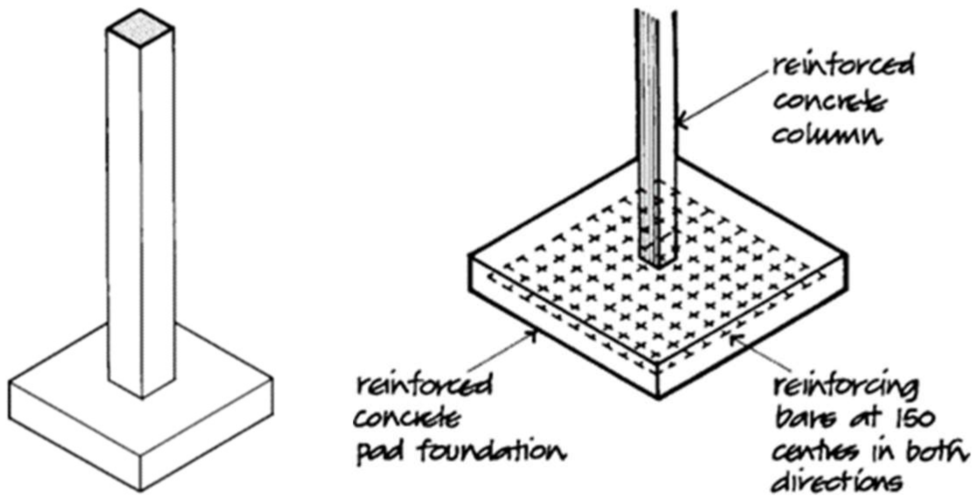


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Figure 4.9: Plan and section of isolated footing and reinforced concrete tie

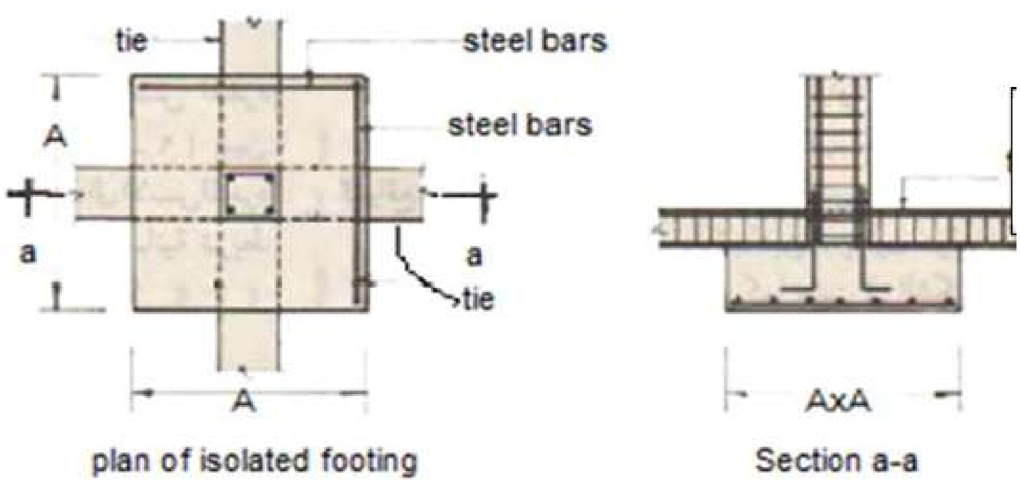

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Fig. 4.10: Form of tie with isolated footing

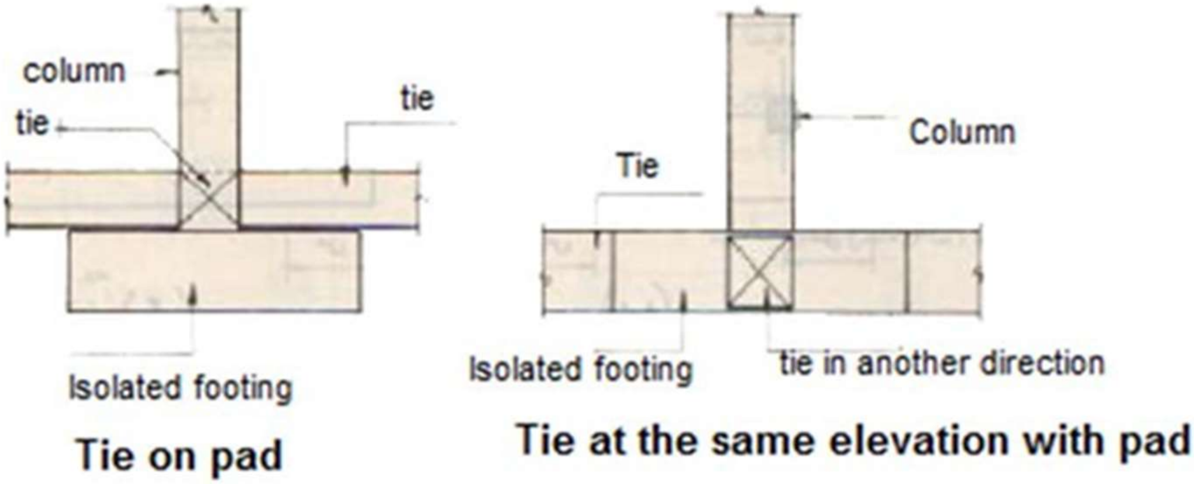

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Fig. 4.11: Isolated footing with pedestal

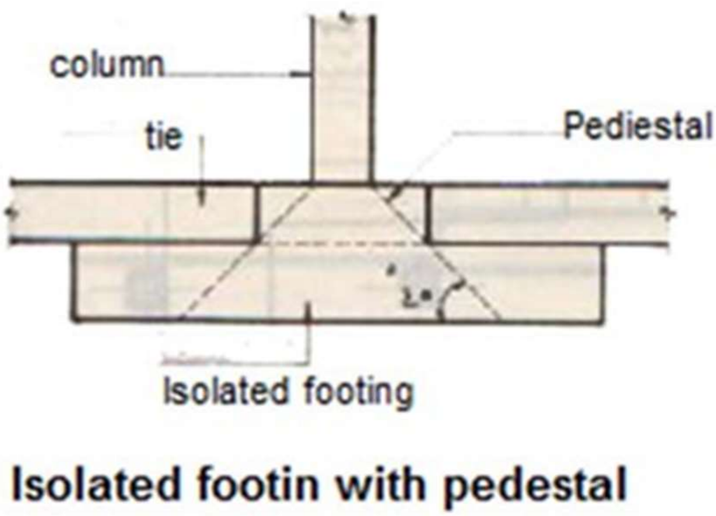

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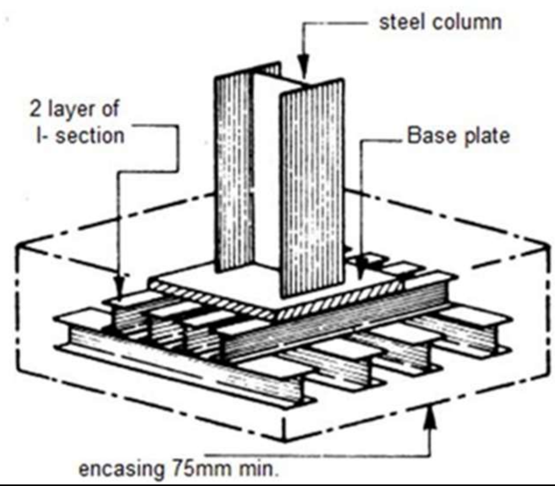
Fig. 4.12: Isolated grillage footing, constructed from steel section covered by concrete



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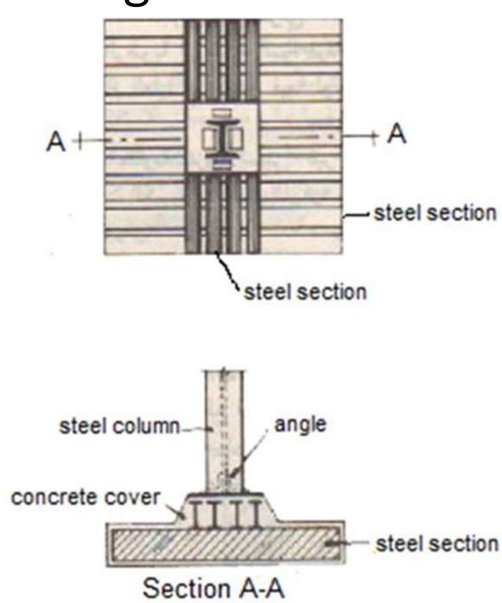


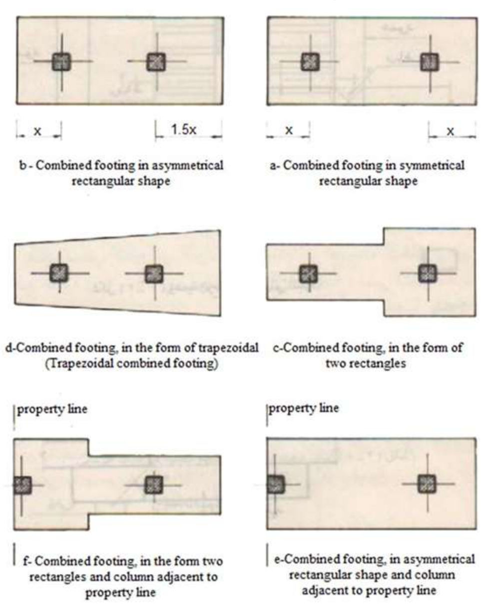
Footing and Foundation

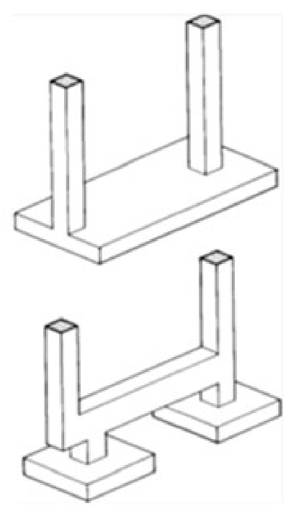
4-Combined footing

Footings cannot legally extend beyond a property line, even for a building built tightly against it. If the outer toe of the footing were simply cut off at the property line, the footing would not be symmetrically loaded by the column or wall and would tend to rotate and fail. Combined footings and cantilever footings solve this problem by tying the footings for the outside row of columns to those of the next row in such a way that any rotational tendency is neutralized.

Fig.4.13: a-Footing under two columns loaded by two equal loads. b, c, d-Footing under two columns loaded by two unequal loads. e, f-Footing under two columns loaded by two loads and adjacent to property line

Footing and Foundation





Illustrated combined footing and cantilever footing

Footing and Foundation

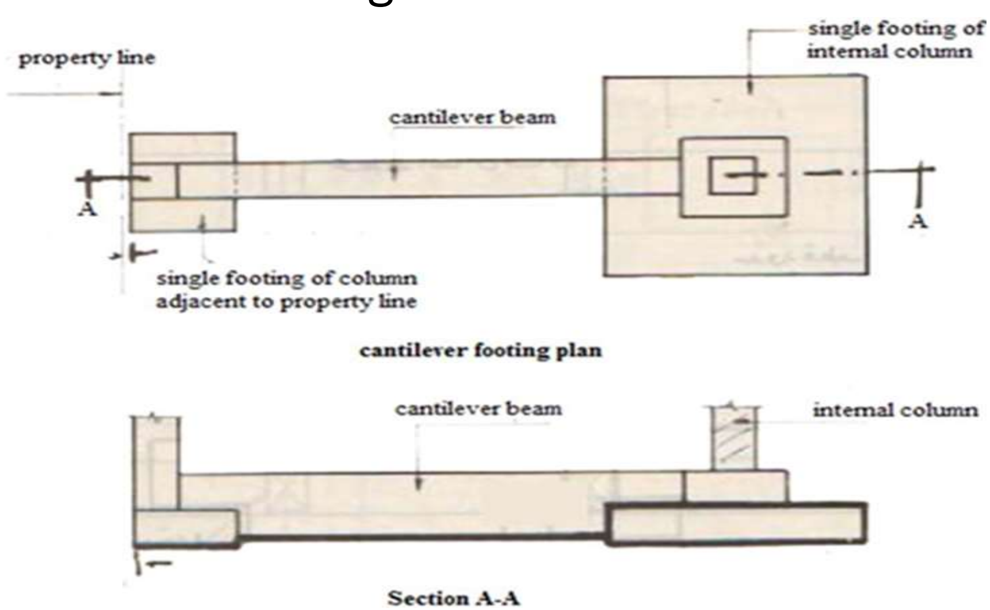
5-Cantilever footing

Cantilever footing constructed from two "single footings" tied by reinforced concrete cantilever beam. The loads transfer from external column which has asymmetrical "single footing" by cantilever beam to the base of internal column which has symmetrical single footing (fig. 4.14).

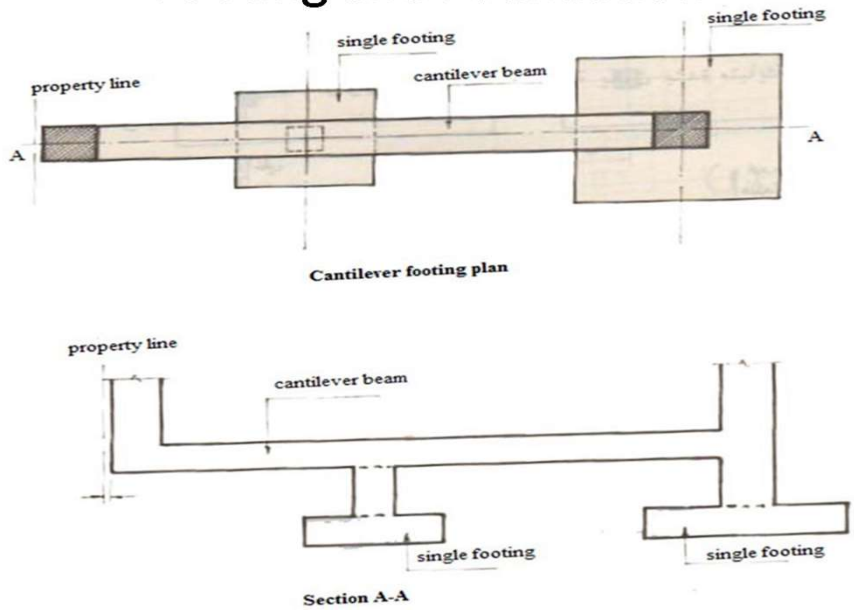
Used cantilever beam which connected by two single footings to transfer the load from external column to this two single footings (fig.4.15).

Next two slide is plan and section of cantilever footing (**fig.4.14** and **fig.4.15**).

Footing and Foundation



Footing and Foundation



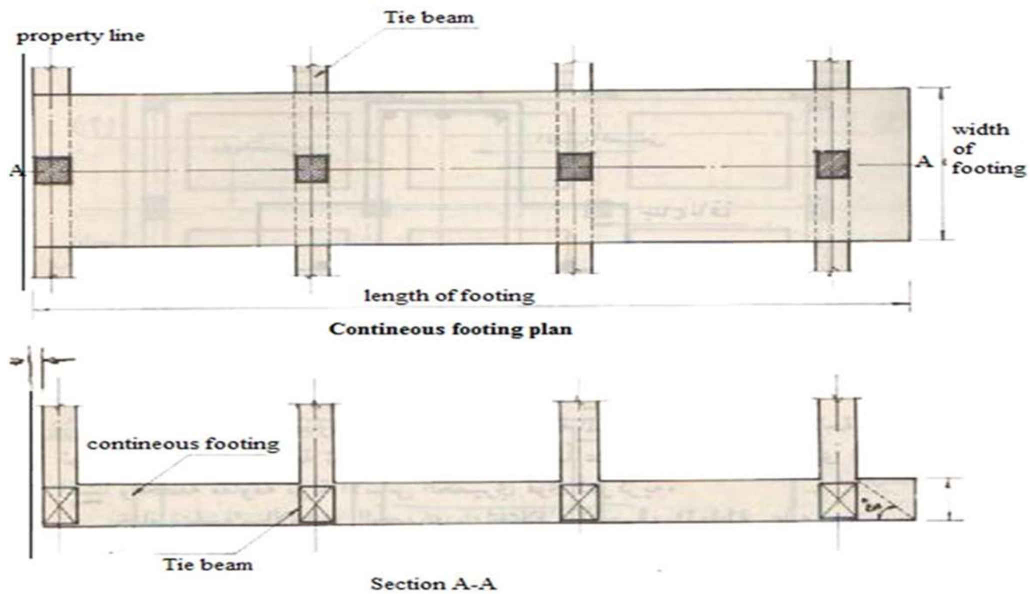
Footing and Foundation

6-Contineous footing

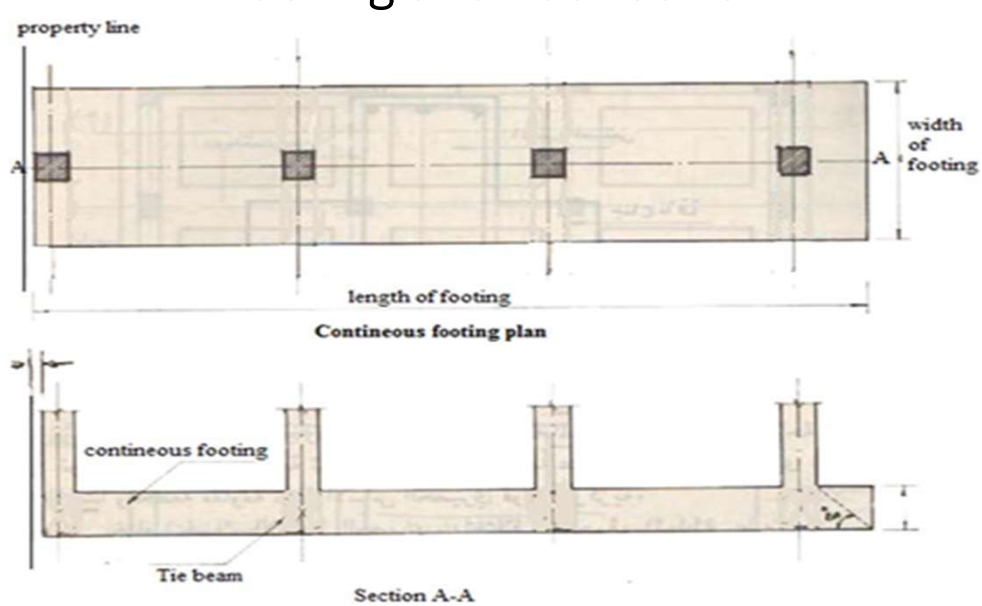
Where there is a wide spread of pad foundations to a framed building due to the low bearing capacity of the subsoil or the close spacing of columns, such that the edge of adjacent separate foundations would be close together, it may be economical and convenient to form one continuous column foundation, as illustrated in (Fig. 4.16 and Fig 4.17). This in effect is a reinforced concrete strip foundation supporting concentrated loads.

Next two slide is plan and section of Continuous footing and tie beam (**fig.4.16** and **fig.4.17**).

Footing and Foundation



Footing and Foundation



Footing and Foundation

7-Mat (raft) foundation

A raft foundation is continuous in two directions, usually covering an area equal to or greater than the base of a building or structure. Raft foundations are used for lightly loaded structures on soils with poor bearing capacity or where variations in soil conditions necessitate a considerable spread of the load, for heavier loads in place of isolated foundations, where differential settlements are significant and where mining subsidence is likely.

Footing and Foundation

The three types of reinforced concrete raft foundations are:

1-Solid slab raft

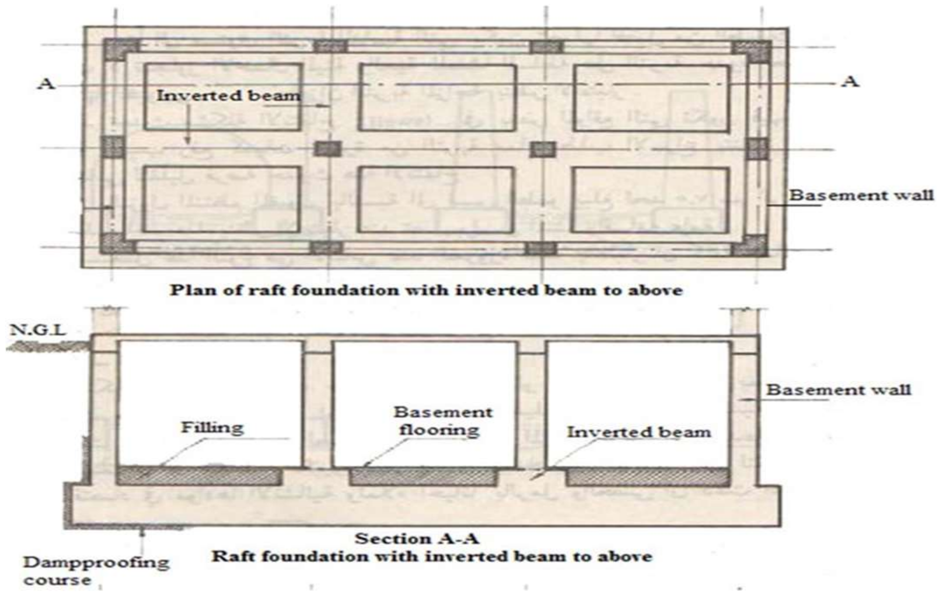
2-Beam and slab raft

3-Cellular raft

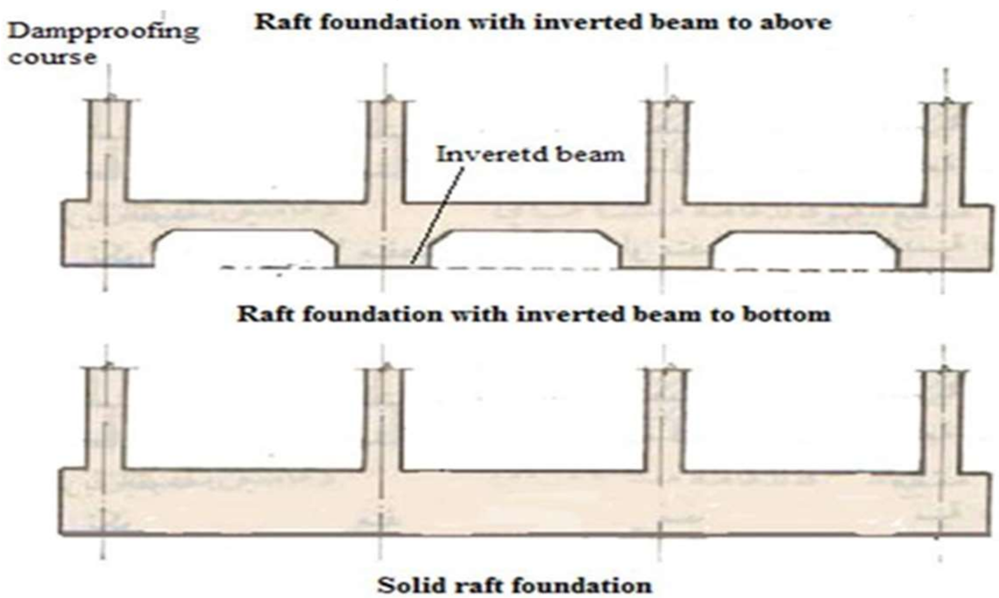
Fig. 4.18 in next two slide is:

- Beam and slab raft foundation
- Solid slab raft foundation

Footing and Foundation



Footing and Foundation



Footing and Foundation

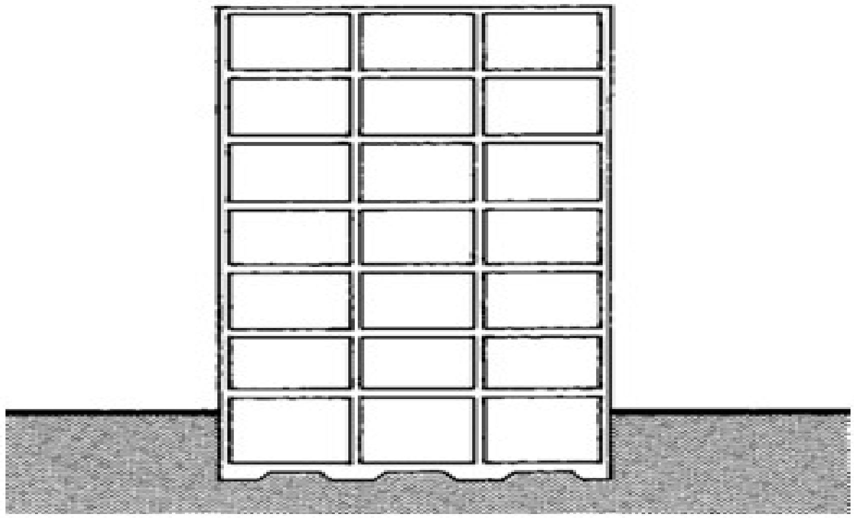
8-Buoyancy foundation

Where the bearing capacity of the soil is low and settlement must be carefully controlled, a floating foundation is sometimes used. A floating foundation is similar to a mat foundation, but is placed beneath a building at a depth such that the weight of the soil removed from the excavation is equal to the weight of the building above. One story of excavated soil weighs about the same as five to eight stories of superstructure, depending on the density of the soil and the construction of the building (fig. 4.19).

Footing and Foundation

Fig.4.19: A cross section through a building with a floating foundation. The building weighs approximately the same as the soil excavated for the substructure, so the stress in the soil beneath the building is the same after construction as it was before.

Footing and Foundation



Footing and Foundation

B. Deep foundation

They are used when:

1. The soil is weak, cannot bearing the loads by using the other types of footing.
2. Clay soil which has seasonal swell and shrinkage.
3. The structure at water level.
4. Deep excavation cannot be achieved for other types of footing because of adjacent building.
5. Required for balance tensile and lateral force.
6. Used for earthquake if stiff foundation required.
7. Ground water level is too high. Other type of foundation cannot be excavated.
8. Resistance for lateral force caused by pushing of soil or water, usually used steel sheet pile.

Footing and Foundation

Types of deep foundation

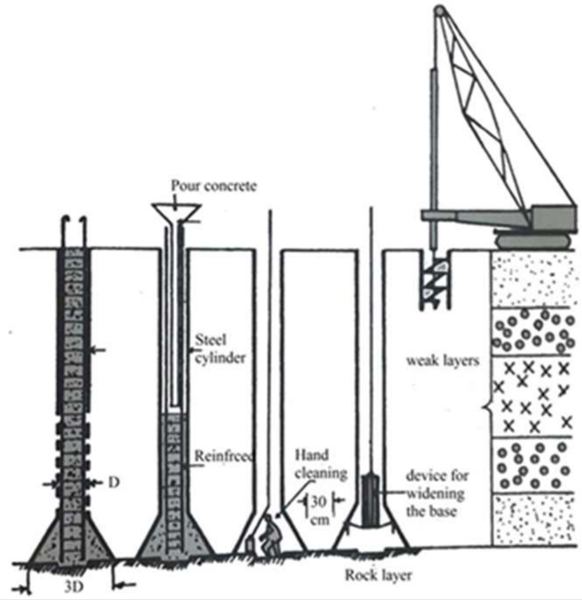
1- Piers, and Caissons foundation

2- Piles foundation

Pier Foundation	Caisson	Pile Foundation
Pier foundation is a type of deep foundation, which consists of a cylindrical column of large diameter to support and transfer large superimposed loads to firm strata below.	Caissons are watertight structures made up of wood, steel or reinforced concrete built above the ground level and then sunken into the ground.	Pile foundation is a type of deep foundation, in which the loads are taken to a low level by means of vertical timber, concrete or steel.
The types of pier foundations are masonry or concrete piers and drilled caissons.	The types of caissons are box, open, pneumatic, monolithic, floating, excavated etc.	The types of pile foundation are end-bearing piles, friction piles, compaction piles, anchor piles, tension or uplift piles, sheet and batter piles etc.
Pier is inserted down to the bedrock.	Caisson is putting a box into underwater and pouring it with concrete.	Pile is a column of material driven by a piledriver.
Pier has a footing.	Caisson doesn't have a footing.	Pile doesn't have a footing.
Pier is typically dug out and cast in place using forms.	Caissons are driven into surface condition.	Piles are driven into surface condition.

Footing and Foundation

Fig.4.20
Construction steps for "end bearing caisson" which has large diameter



Footing and Foundation

Fig.4.21: Large auger drills are used for drilling caissons

Footing and Foundation

Fig.4.22: Deep foundations,

Caissons are concrete cylinders poured into drilled holes.

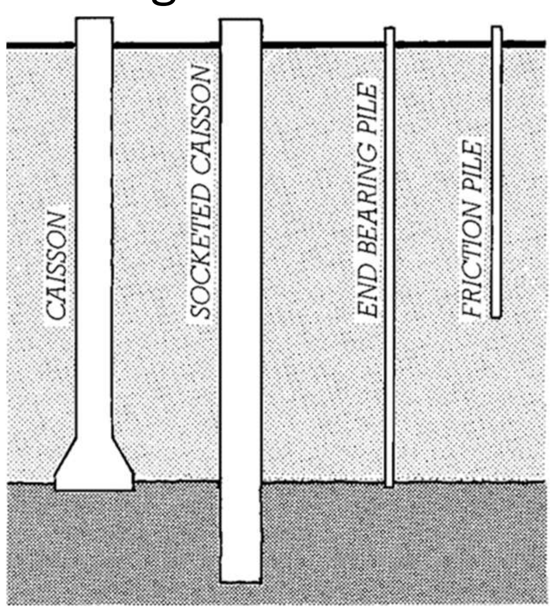
The end bearing caisson at the left is belled as shown when additional bearing capacity is required.

The socketed caisson is drilled into a hard stratum and transfers its load primarily by friction between the soil or rock and the sides of the caisson.

Piles are driven into the earth.

End bearing piles act in the same way as caissons. The friction pile derives its load-carrying capacity from friction between the soil and the sides of the pile.

Footing and Foundation



Footing and Foundation

Types of pile according to load transfer:

1- End bearing pile: It is a pile driven until its tip encounters firm resistance from a suitable bearing stratum such as rock, dense sands, or gravels.

End bearing piles work essentially the same as caissons and are used on sites where a firm bearing stratum can be reached by the piles, sometimes at depths of 150 feet (45 m) or more. Each pile is driven “to refusal,” the point at which little additional penetration is made with continuing blows of the hammer, indicating that the pile is firmly embedded in the bearing layer.

Footing and Foundation

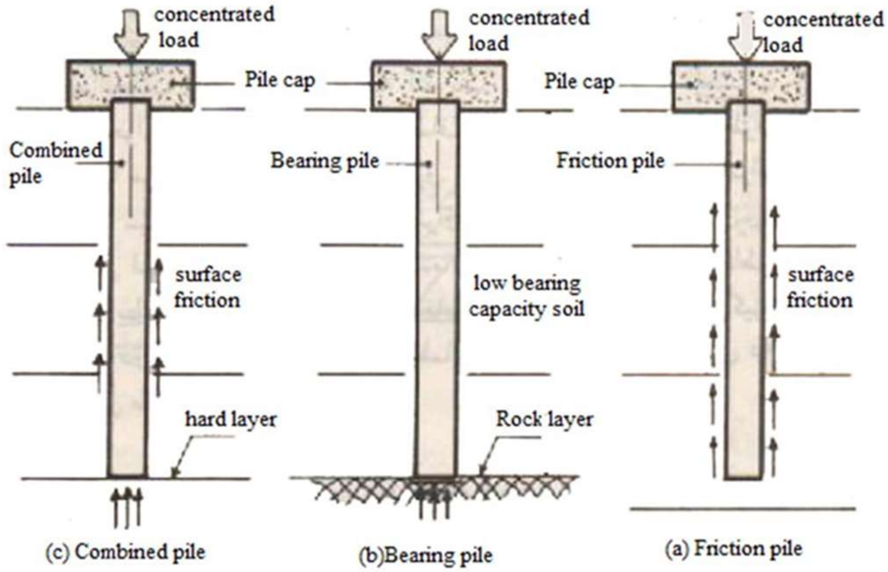
2- Friction pile: It is a pile driven only into softer material, without encountering a firm bearing layer, it may still develop a considerable load-carrying capacity through frictional resistance between the sides of the pile and the soil through which it is driven.

Friction piles work best in silty, clayey, and sandy soils. They are driven either to a predetermined depth or until a certain level of resistance to hammer blows is encountered, rather than to refusal as with end bearing piles.

3- Combined pile: it is a pile which rely on a combination of end bearing and friction for their strength.

Fig.4.23: (a) Friction pile, (b) Bearing pile, and(c) Combined pile.

Footing and Foundation



Footing and Foundation

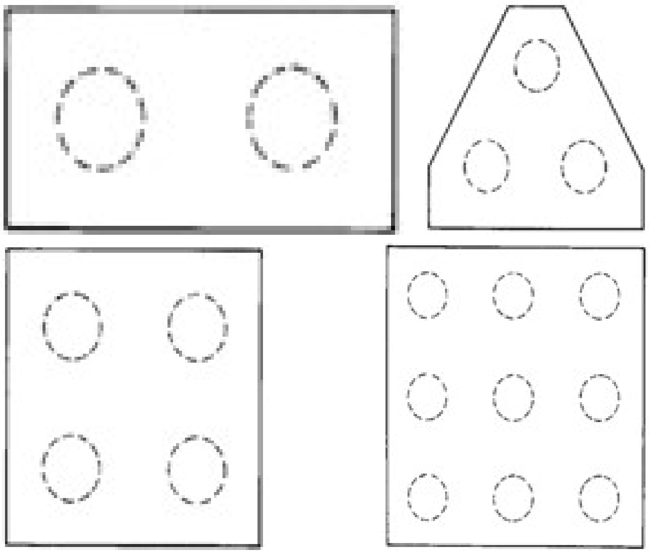
Piles are usually driven closely together in clusters that contain 2 to 25 piles each. The piles in each cluster are later joined at the top by a reinforced concrete pile cap, which distributes the load of the column or wall above among the piles.

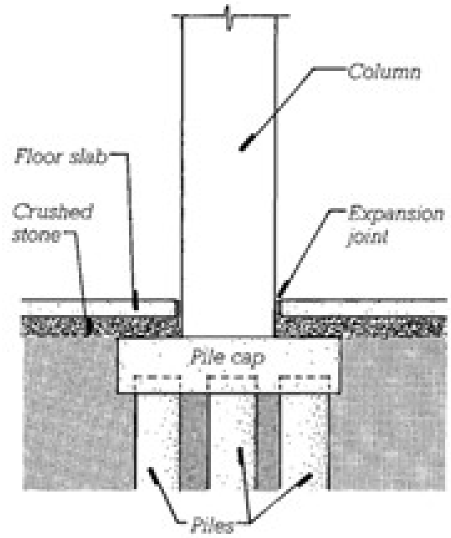
Fig.3.24:

Clusters of two, three, four, and nine piles with their concrete caps, viewed from above. The caps are reinforced to transmit column loads equally into all the piles in the cluster, but the reinforcing steel has been omitted here for the sake of clarity.

And an elevation view of a pile cap, column, and floor slab.

Footing and Foundation



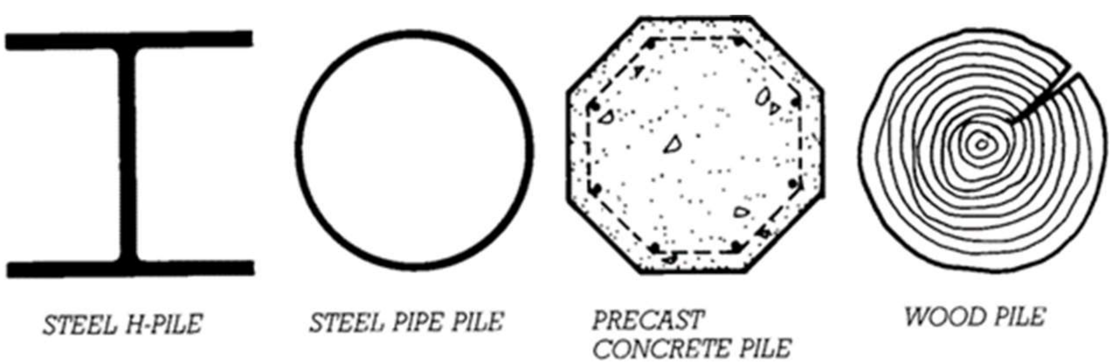


Footing and Foundation

Types of pile according to Material:

Piles may be made of:

Timber, steel, concrete, and various combinations of these materials



Footing and Foundation

1-Steel pile

Two forms of steel piles are used, H-piles and pipe piles.

H-piles are special hot-rolled, wide-flange sections, 8 to 14 inches (200 to 355 mm) deep, which are approximately square in cross section. They are used mostly in end bearing applications.

Steel pipe piles have diameters of 8 to 16 inches (200 to 400 mm). They may be driven with the lower end either open or closed with a heavy steel plate. An open pile is easier to drive than a closed one, but its interior must be cleaned of soil and inspected before being filled with concrete, where as a closed pile can be inspected and concreted immediately after driving.

Footing and Foundation

2-Concrete pile

Precast concrete piles are square, octagonal, or round in section, and in large sizes often have open cores to allow inspection. Most are pre stressed, but some for smaller buildings are merely reinforced. Typical cross-sectional dimensions range from 10 to 16 inches (250 to 400 mm).

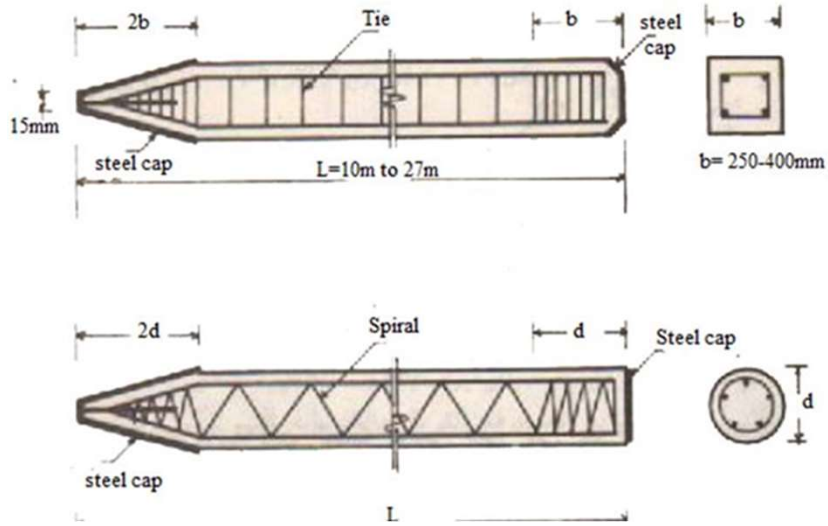
Advantages of precast piles include

- high load capacity,
- an absence of corrosion or decay problems,
- In most situations, a relative economy of cost.

Precast piles must be handled carefully to avoid bending and cracking before installation. Splices between lengths of precast piling can be made effectively with mechanical fastening devices that are cast into the ends of the sections.

Footing and Foundation

Fig.4.26: Precast concrete piles have square and round cross section



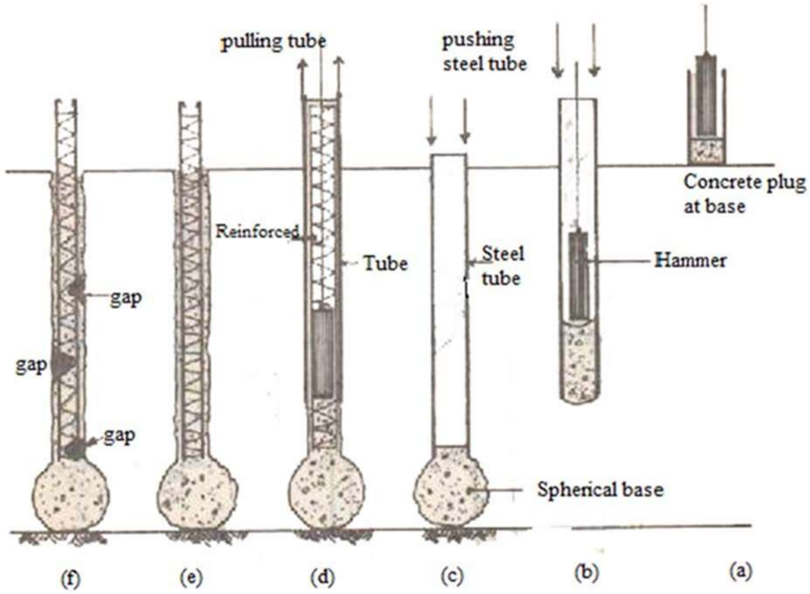
Footing and Foundation

<u>Site cast concrete pile</u> is made by driving a hollow steel shell into the ground and filling it with concrete. The primary reason to use site cast concrete piles is their economy.

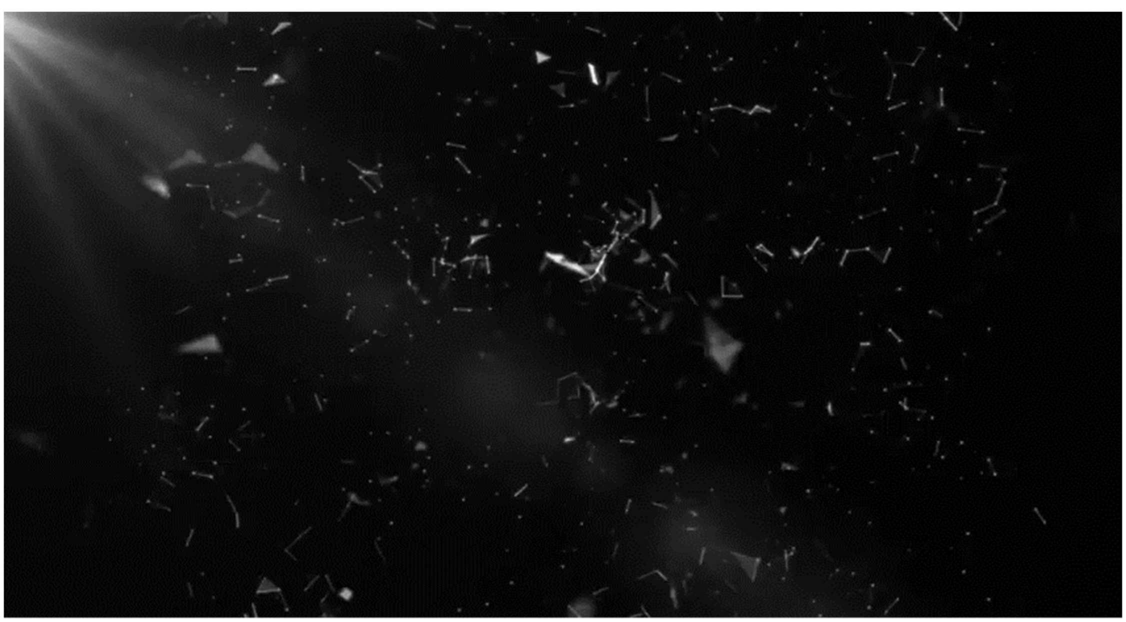
Fig.4.27:

Steps in the construction "Site-cast concrete pile", method of driven from the bottom of the tube is using by concrete plug.

Footing and Foundation



Pile Foundation Construction Process



Footing and Foundation

Applications of using deep foundation:

Building construction begins at the base. In ancient times, pyramidal structures were often used to distribute the weight of tall buildings over a large area.

In modern times, the advancement of technology and soaring land costs in cities have led engineers to consider the size of a building's footprint while continuing to think vertically.

Creating a large amount of real estate out of a relatively small amount of ground area is very appealing to developers in large cities.

Like the roots of a tree, a skyscraper's foundation is laid below ground to create the most stability. To lay the most stable foundation possible, the bedrock (solid rock underneath the ground's soil) must be reached. Accessing the bedrock, in most cases, requires significant excavation of soils (sand, clay, etc.) to reach the bedrock.

Burj Alkhalifa

The foundation system for the Burj Alkhalifa is comprised of 192 bored piles (drilled shafts) 1.5-m (approximately 5-ft) in diameter and approximately 50-m deep (164- ft). A 3.7-m (12-ft) thick raft foundation sits on top of the piles under the full footprint of the structure.

Burj Alkhalifa

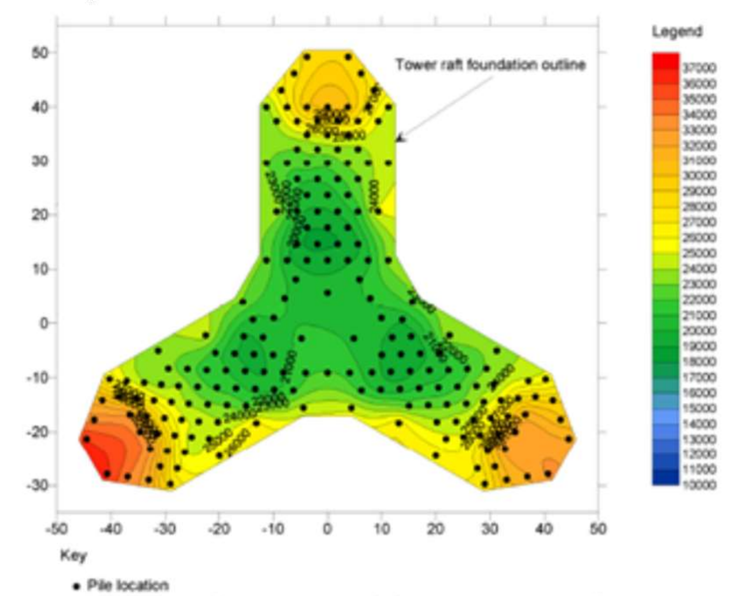
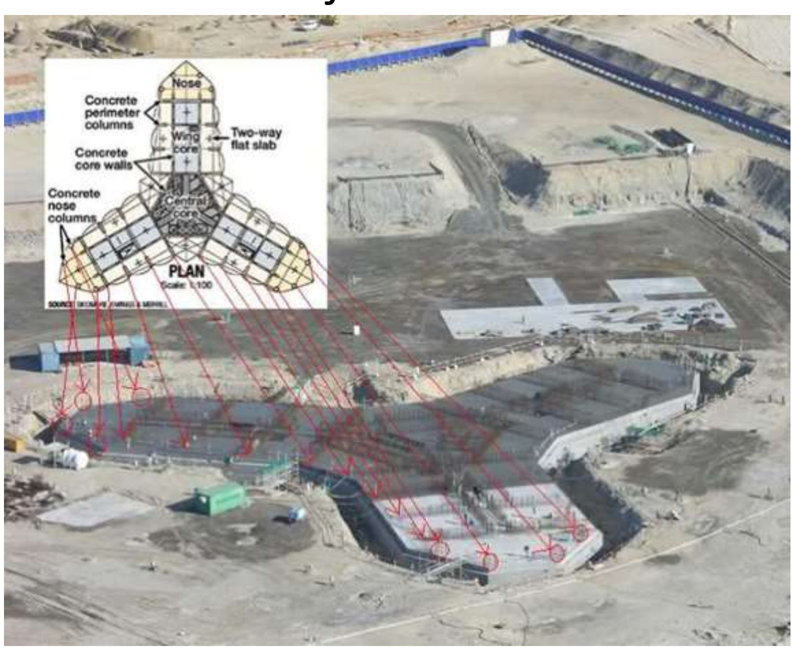
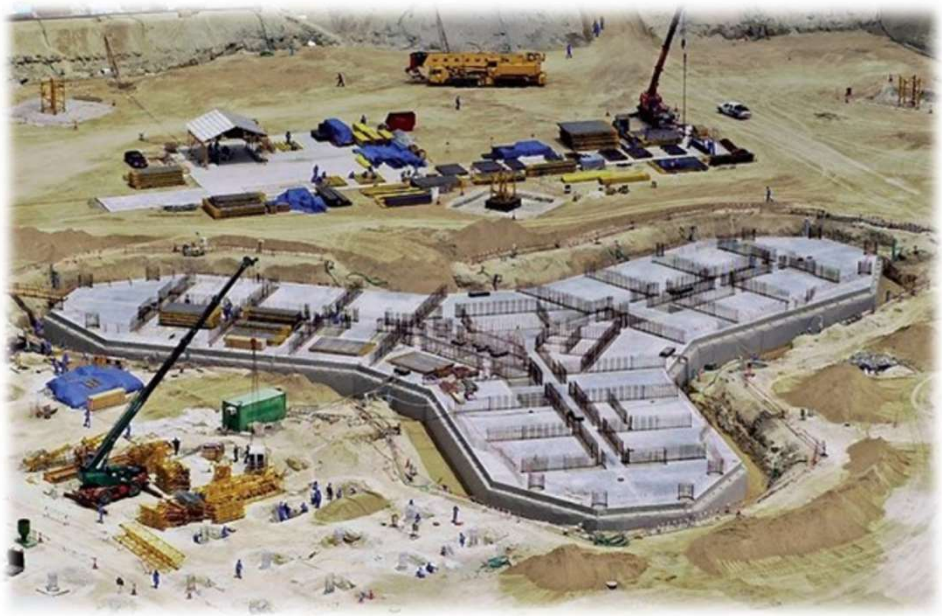


Fig 4: Contours of Maximum Axial Load

Burj Alkhalifa



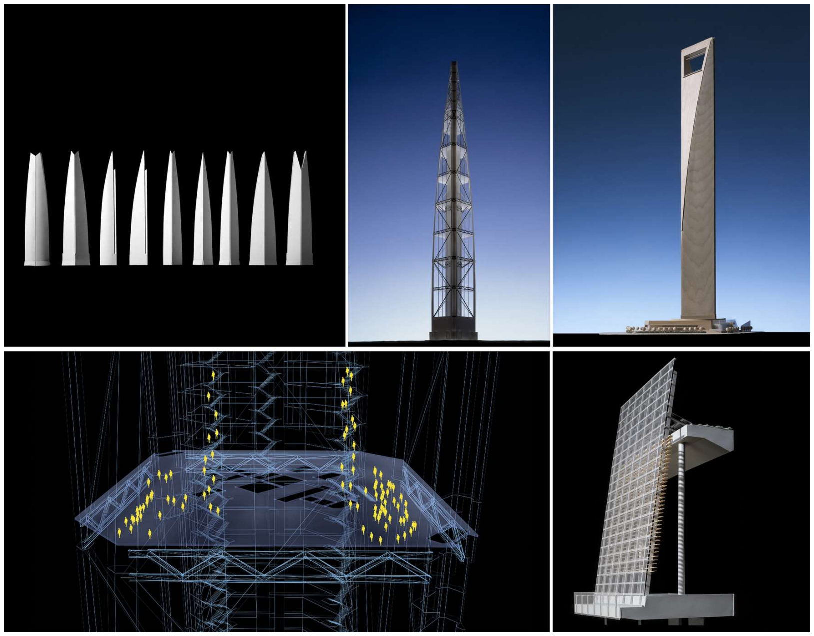
Burj Alkhalifa



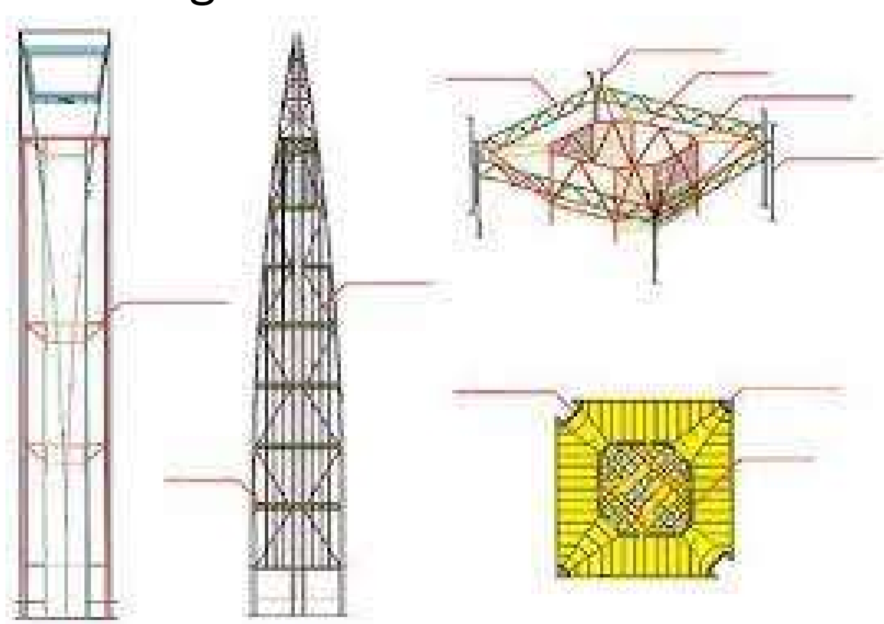
Shanghai World Financial Center

- Contrary to popular myth, skyscrapers do not need to bear on bedrock. They do require a foundation system that distributes their weight to the soil below and can resist the upward pull from high winds. Shanghai's waterlogged soil has little bearing capacity, so an economical construction method is friction piles, which support gravity loads, resist wind loads, and gain additional capacity from resting on the stiff sand below.
- At the Shanghai World Financial Center, a thick reinforced-concrete mat transfers the building loads to piles that extend 275 ft. (84 m.) below the surface to a layer of stiff sand. The tower uses approximately 2,200 friction piles made up of steel pipes filled with concrete.

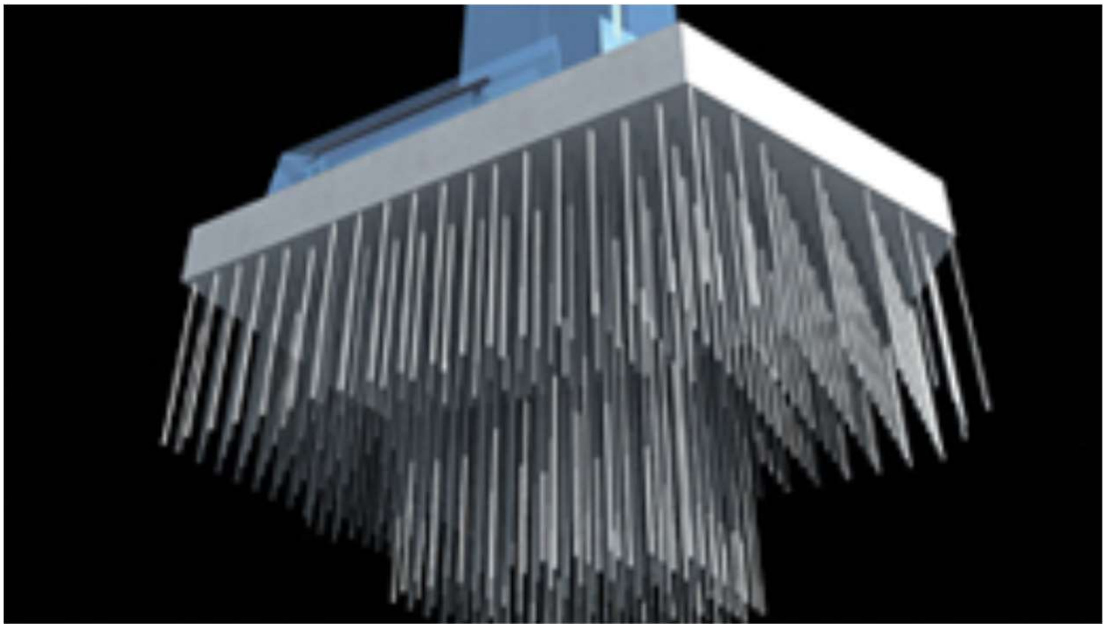
Shanghai World Financial Center



Shanghai World Financial Center



Shanghai World Financial Center



Thank You