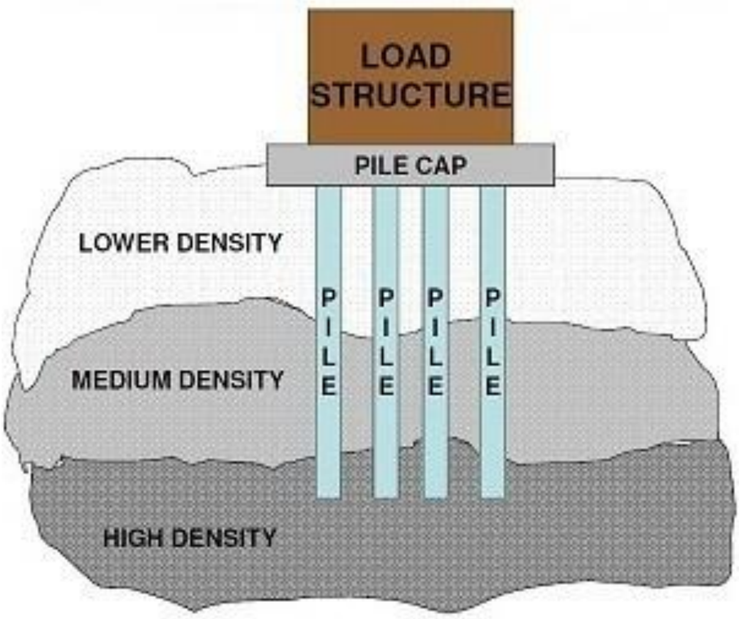
Pile Foundation

Pile Foundation. Pile foundations are deep foundations used when the site has a weak shallow bearing strata making it necessary to transfer load to a deeper stratum either by friction or end bearing principles. Foundations provide support for structures by transferring the load to the rock or layers of soil that have sufficient bearing capacity and suitable settlement characteristics. There are a very wide range of foundation types available which are suitable for different applications. Foundations are classified as Shallow foundations and Deep foundations.



pile foundation

Shallow foundations are used where the load imposed by a structure are low relative to bearing capacity of surface soils. Deep foundations are necessary where the bearing capacity of the surface soils is insufficient to support loads imposed on it and hence, they are transferred to deeper layers with high bearing capacity.

Pile foundations are deep foundations which are formed by long slender columnar elements. They consist of two components: Pile cap and single or group of piles. Pile foundations are principally used to transfer the loads from super structure, through weak compressible strata or water on to stronger, more compact, less compressible, and stiffer soil or rock. This type of foundation is used for large structures and in situations where the soil is not suitable to prevent excessive settlement.

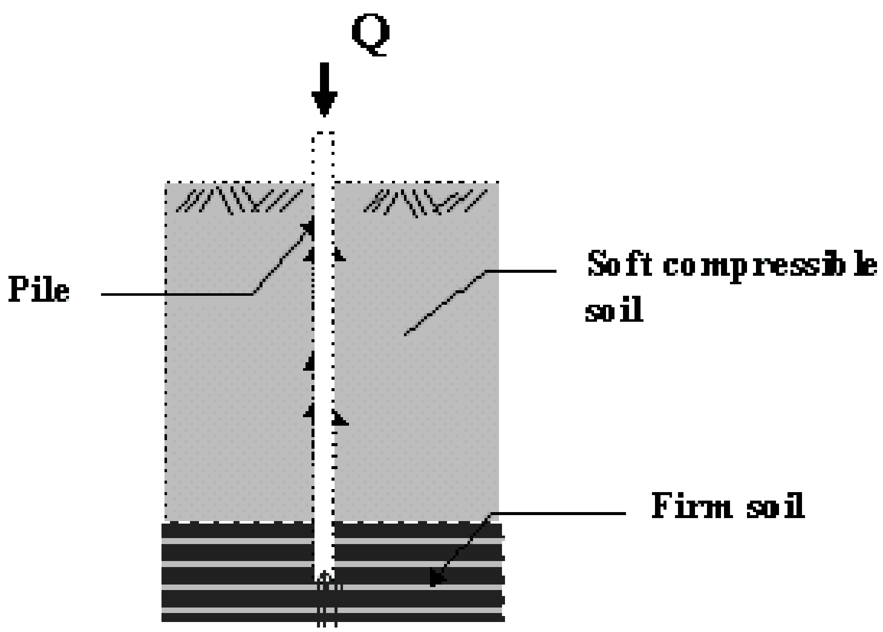
Classification of Pile foundations:

The pile foundations are classified based on load carrying characteristic of piles, material of pile construction and type of soil.

Classification based on load transmission:

End bearing piles (Point bearing)

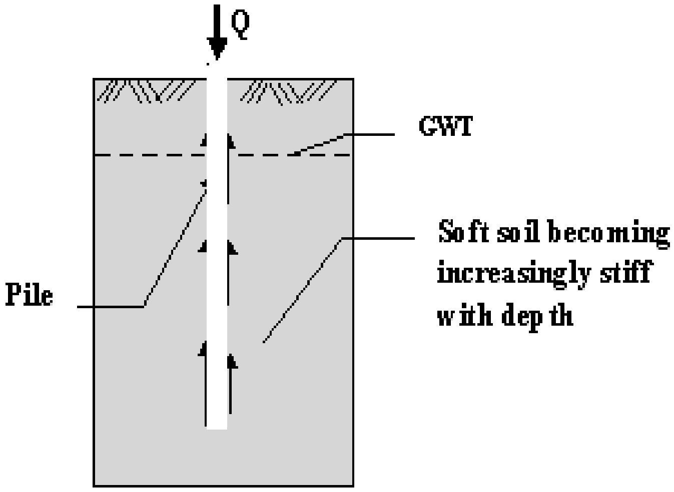
These transmit most of their loads to the load bearing layer (which can be dense sand or rock). Most of the pile capacity is inferred from the end bearing point.



End-bearing pile

Friction piles :

These transmit their load through the layers through which the piles pass which is mostly through the surface friction (skin friction) with the surrounding soils. Here the piles are driven to such a depth that the frictional resistance which is developed at the side of the piles equals to the load coming on the piles.



Friction pile

Classification based on Material of Piles Construction:

Timber piles:

Timber can be used for manufacture of temporary piles and for permanent ones in regions where timber is readily and economically available. It is most suitable for long cohesion piling and piling under embankments.

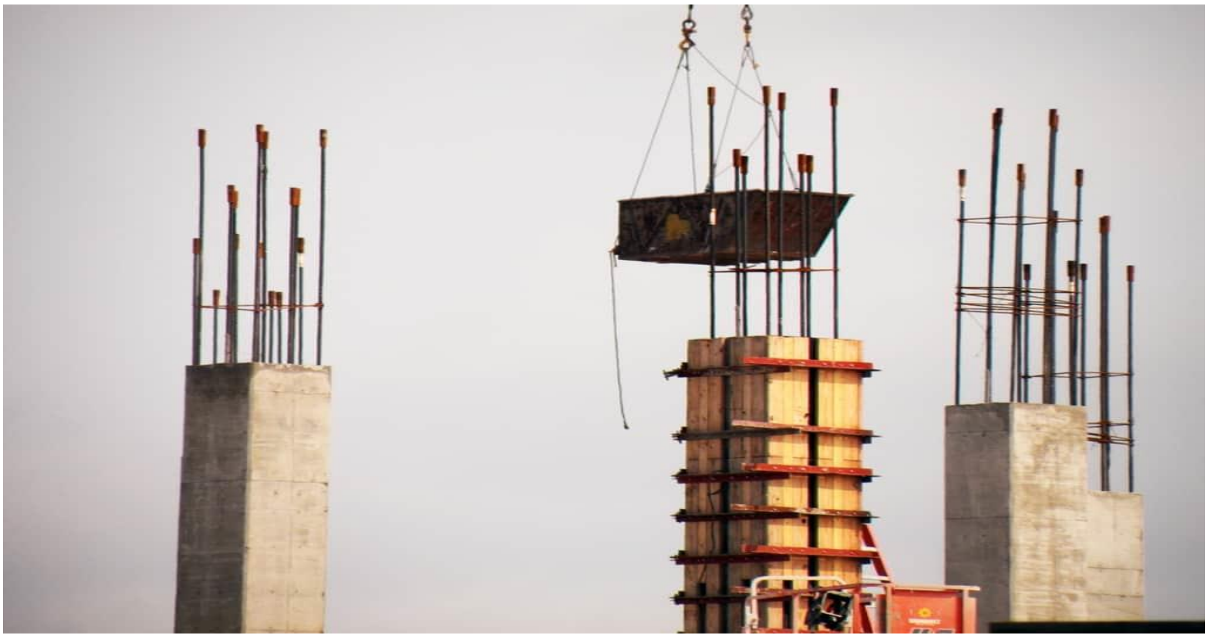
Steel piles:

Steel can be used for both temporary and permanent works. They are suitable for handling and driving for piles with prolonged lengths. Their small cross-sectional area along with the high strength makes penetration easier in firm soil. If it's driven in to a soil with low Ph value, there may occur a risk of corrosion which can be eliminated by tar coating or cathodic protection.

Installation of steel piles

Concrete piles:

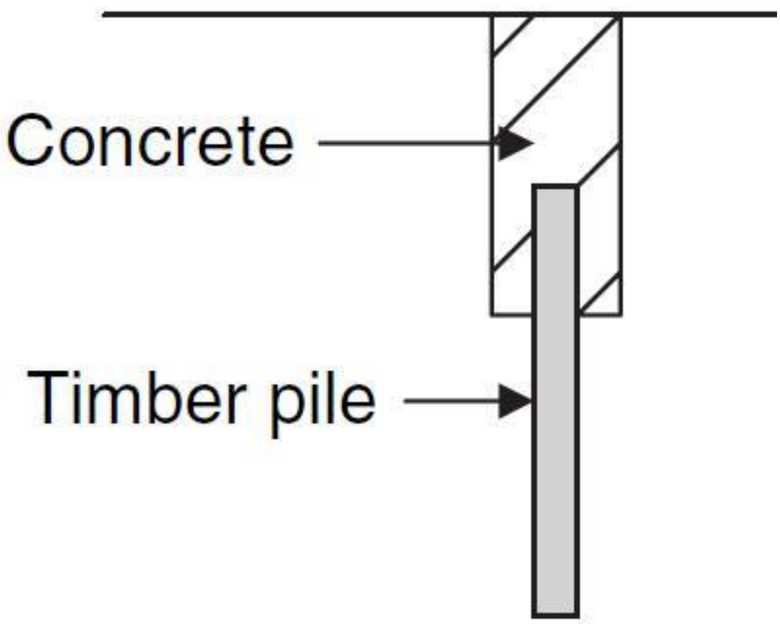
Concrete is used to manufacture of precast concrete piles, cast in place and pre-stressed concrete piles. Pre-stressed concrete piles are becoming more approved than the ordinary pre-cast as less reinforcement is required.



concrete piles

Composite piles:

When a pile consists of a combination of varied materials in the same pile, it is called as Composite pile. For example, part of timber pile which is installed above ground water could be endangered to insect attack and decay. So, to avoid this, concrete or steel pile is used above ground water level whilst timber is installed under the ground water level.

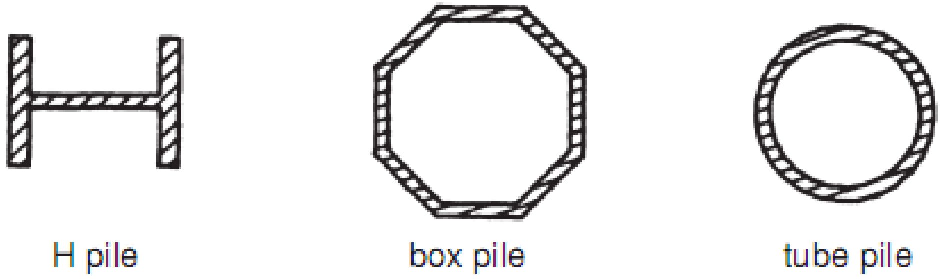


Composite pile of concrete and timber

Classification based on the effect of soil:

Driven piles:

In this process of driving of pile into the ground, soil is moved radially when the pile shaft enters the ground. There may exist a component of movement of the soil in the vertical direction. Hence driven piles are considered as displacement piles.



Different cross sections used for steel piles

Bored piles:

In this process, a void is formed by boring or excavation before pile is introduced into the ground. Piles can be produced by casting concrete in the void. Boring piles are considered as non-displacement piles.

Piling foundation: Advantages

- Pile foundation benefits include the ability to pre-prepare heaps based on length.
- Pre-casting speeds up the finishing process.
- It may be set up across a huge region and over extremely long distances.
- Piles can be utilised in a location where drilling is not necessary.
- The heaps are tidy and spotless.

Piling foundation: Disadvantages

- Pile-based foundations have the drawback that they are easily destroyed when driven through by rocks and boulders.
- Marine borers may damage piles in seawater.
- A pile cannot be raised above the surface.
- It is exceedingly challenging to determine the precise length needed in advance.
- When the piles are driven, vibrations are created that have an impact on nearby structures.
- Piles must be operated with powerful machinery.

NECESSITY OF PILE FOUNDATION

An insufficient bearing capacity of the soil to bear a structure will demand for pile foundation. The pile foundation will be chosen based on the:

1. Soil Condition

2. Types of Loads acting on the foundation
3. The bottom layers of the soil
4. The site conditions
5. Operational Conditions

The pile foundation consists of pile cap and piles either present in single or in groups. The loads coming from the superstructure is transferred safely to the hard strata, soil, and rocks below by means of piles. Piles are long slender members that can have a length of more than 15m. There are many functions provided by the pile foundation that result in its tremendous applications in construction. Here, we will discuss the necessity and the functions of pile found

Fig.1: Pile Foundation Construction

When and Where Pile Foundations are Used?

There are certain construction sites that can only go for a pile foundation because it exclusively satisfies certain needs. Some of these needs are mentioned below.

6. Pile foundation is needed in areas where the structures constructed are large & heavy and the soil underlying is weak.
7. In areas where settlement issues are common due to soil liquefaction or water table issues, pile foundation is a better choice.
8. In some situations, the sub-soil water table at the site will be so high that the use of other foundation will be affected badly. In such a situation, pile foundations can be easily penetrated through the water and extended until a hard stratum is reached.

9. Structures might be subjected to horizontal forces that will bring effect to the foundation. The use of pile foundation help in resisting this bending action along with supporting the vertical load coming over the foundation. Hence pile foundation is needed for the construction of earth water retaining structures and building structures highly subjected to lateral (earthquake and wind) forces.
10. The pile foundation is necessary to resist the uplift forces created due to water table rise or any other cause. Uplift forces are more common in the construction of transmission towers and offshore platforms. These structures will need pile foundations.
11. Pile foundation is necessary for areas where the structure surrounding has chances for soil erosion. This might not be resisted by the shallow foundations.
12. When the plan of the structure is not regular the load distribution also will not be uniform in nature. Employing a shallow foundation in these cases will result in the differential settlement. In order to eliminate differential settlement in such cases, the pile foundation becomes necessary.
13. Pile foundation is needed near deep drainage and canal lines.
14. The adjacent soil can be confined by means of sheet pile foundation as shown in figure-2 below.

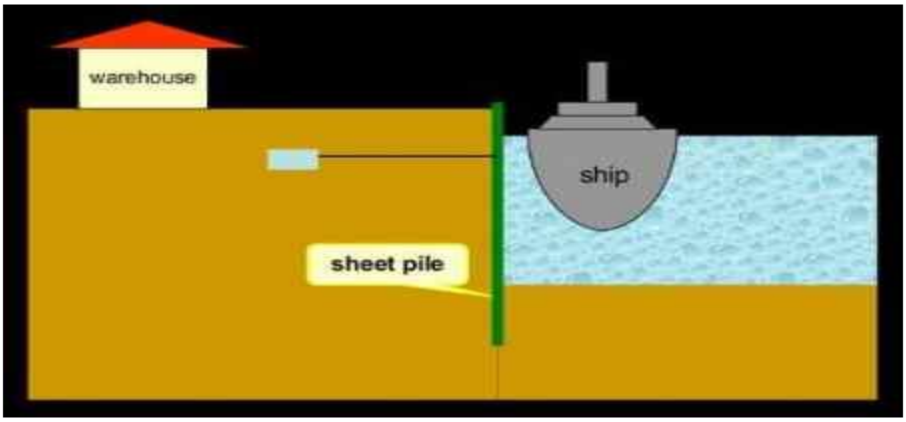


Fig.1.Sheet Pile Foundation to Confine the Soil Near the Water Body

Laterally loaded pile: Piles often experience lateral deformations due to multiple sources of horizontal loading, which include earthquakes, wind, vehicle forces, wave impact, ship impact and lateral earth pressures.

2. When the horizontal component of the load is small in comparison with the vertical load (say, less than 20 %), it is generally assumed to be carried by vertical piles and no special provision for lateral load is made.

Reason : In case of batter piles, additional resistance is provided by the skin friction and the end bearing. Therefore, batter piles are more effective than vertical piles in resisting horizontal loads.

Culmann's Method :

1. When piles are oriented in two or three directions Culmann's method is used.
2. As the axis of the batter pile is inclined, it can resist the horizontal load equal to $Q \cos \theta$, where Q is the axial load capacity and θ is the angle which the pile makes with the horizontal.

Steps :

i. Group the piles according to their slopes [in Fig. 3.6.1(*a*), the piles are grouped in 3 directions].

ii. Draw the geometry of the pile group to some scale, and mark the directions of the inclined load Q_g and the centre line of each pile group (R_1, R_2 and R_3).

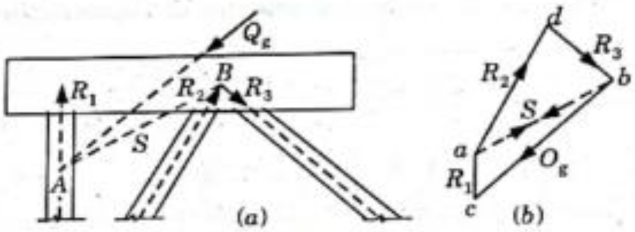


Fig. 3.6.1.

iii. Determine the location of point A which is at the intersection of R_1 and Q_g.

iv. Join A to the point B which is at the intersection of R_2 and R_3.

v. Draw the force triangle, as shown in Fig. 3.6.1(*b*).

Select the line ab parallel to AB. From b draw a line bc parallel to Q_g to some scale. Draw a vertical at c to determine ca which is equal to R_1.

From b draw a line parallel to R_3, and from a, line parallel to R_2, to complete the triangle abd.

vi. Determine forces in piles as follows :

Factors affecting load carrying capacity of pile

Following are the factors influencing pile capacities :

1. The surrounding soil.
2. Installation technique like driven or bored.
3. Method of construction (precast or cast in situ).
4. Spacing of piles in a group.
5. Symmetry of the group.
6. Location of pile cap *i.e.*, above or below soil.
7. Shape of the pile cap.
8. Location of pile in the group.
9. Drainage conditions in soil

Efficiency of group pile:

A. Pile Groups in Sand and Gravel :

1. For piles driven in loose and medium dense cohesion less soils, the group efficiency is high.
2. The piles and the soil between them move together as a unit when subjected to loads.
3. The group acts as a pier foundation having a base equal to the gross plan area contained between the piles.

i. End-Bearing Piles :

a. For driven piles bearing on dense, compact sand with spacing equal to or greater than 3*d*, the group capacity is generally taken equal to the sum of individual capacity. Thus,

$$Q_g = NQ_u$$

b. In this case, the load taken by the group is much greater ($\eta_g > 100\%$) than the sum of the individual capacities.

c. For spacing less than 3*d*, the group capacity is found for the block of piles group.

ii. Friction Piles :

a. The group efficiency of friction piles in sand is obtained from the following expression :

$$\eta_g = \frac{Q_{g(u)}}{NQ_u} \times 100 = \frac{f_s(P_g L)}{N f_s (pL)} \times 100$$

where, P_g = Perimeter of the block.
p = Perimeter of the individual pile.
L = Length of pile.
f_s = Unit friction resistance.

b. If the centre-to-centre spacing is large, the group efficiency (η_g) may be more than 100 %.

c. The piles will behave as individual piles, and the group capacity is obtained as :

If η_g is less than 100 %,

$$Q_{g(u)} = \eta_g \frac{(NQ_u)}{100}$$

d. The group efficiency can also be obtained from the Converse-Labarre equation given below,

$$\eta_g = 1 - \left[\frac{(n-1)m + (m-1)n}{mn}\right]\frac{\theta}{90}$$

where, m = Number of rows of piles.
n = Number of piles in a row.
$\theta = \tan^{-1}(d/S)$.
d = Diameter of pile.
S = Spacing of pile, centre-to-centre.
η_g = Group efficiency (expressed as a ratio).

iii. Bored Piles :

a. For bored piles in sand at conventional spacing of $3d$, the group capacity is taken as 2/3 to 3/4 times the sum of individual capacities for both the end-bearing and the friction piles. Thus,

$$Q_{g(u)} = (2/3 \text{ to } 3/4)(NQ_u)$$

b. In bored piles, there is limited densification of the sand surrounding the pile group. Consequently, the efficiency is lower.

B. Pile Groups in Clay :

1. As the pile group acts as a block, its ultimate capacity is determined by adding the base resistance and the shaft resistance of the block.
2. The capacity of the block having closely spaced piles ($S \le 3d$) is often limited by the behavior of the group acting as a block.
3. The group capacity of the block is given by,

$$Q_{g(u)} = q_p (A_g) + \alpha c (P_g L)$$

where, q_p = Unit point resistance ($N_c = 9.0$).
A_g = Base area of the block.
P_g = Perimeter of the block.
L = Depth of the block.
α = Adhesion factor (= 1.0 for soft clays).
c = Undrained cohesion.

4. The individual pile capacity is given by,

$$Q_u = q_p A_p + \alpha c (p \times L)$$

5. The group capacity considering the piles as individual piles is given by,

$$Q_{g(u)} = NQ_u \qquad ...(3.11.2)$$

6. The lower of the two values, given by eq. (3.11.1) and eq. (3.11.2), is the actual capacity.

Que 3.12. **A 30 cm diameter concrete pile is driven in a normally consolidated clay deposit 15 m thick. Estimate the safe load. Take C_u = 70 KN/m², α = 0.9 and $F.S$ = 2.5.** **AKTU 2013-14, Marks 03**

Answer

Given : Diameter of pile, d = 30 cm, Thickness of clay = 15 m
Undrained cohesion value, c_u = 70 kN/m², Adhesion factor, α = 0.9, Factor of safety = 2.5
To Find : Safe load.

1. Ultimate load capacity of pile, $Q_u = C_{ub} N_c A_b + \alpha C_u A_s \quad (\because C_{ub} = C_u)$

$$= 70 \times 9 \times \frac{\pi}{4} \times 0.30^2 + 0.9 \times 70 \times \pi \times 0.30 \times 15$$
$$= 935.17 \text{ kN}$$

2. Safe load, $Q_a = \frac{Q_u}{F_s} = \frac{935.17}{2.5} = 374$ kN

Que 3.13. **A group of 20 piles, each having a diameter of 600 mm and 12 m long are arranged in 4 rows at a spacing 1.2 m centre to centre. The capacity of each pile is 380 kN. Determine the group efficiency of pile.** **AKTU 2014-15, Marks 06**

Given : Number of pile, $N = 20$, Diameter of pile, $d = 600$ mm
Length of pile, $L = 12$ m, Spacing of pile, $S = 1.2$ m
Capacity of one pile, $Q_u = 380$ kN
To Find : Group efficiency of pile.

1. Ultimate load capacity of a pile group of 20 piles on the basis of individual action = 20 × 380 kN = 7600 kN
2. Length of pile group = 4 × 1.2 + 0.6 = 5.4 m
3. Width of pile group = 3 × 1.2 + 0.6 = 4.2 m
4. Ultimate load capacity of the pile group by block failure is given by,

$$Q_{g(u)} = C_{ub} N_c A_b + P_b L C_u \quad ...(3.13.1)$$

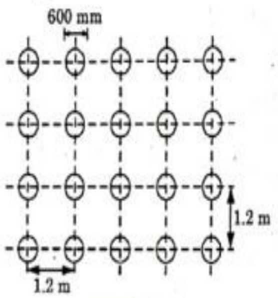


Fig. 3.13.1.

5. We known that, $Q_u = C_{ub} N_c A_p + \alpha C_u A_s$

$$380 = C_u \times 9 \times \frac{\pi}{4} \times 0.6^2 + 0.9 \times C_u \times \pi \times 0.6 \times 12$$

$$C_u = 16.6 \text{ kN/m}^2 \quad (\because C_u = C_{ub})$$

6. From eq. (3.13.1),

$$Q_{g(u)} = 16.6 \times 9 \times 5.4 \times 4.2 + 2(5.4 + 4.2) \times 12 \times 16.6$$
$$= 7213.032 \text{ kN/m}^2$$

7. Group efficiency of pile,

$$\eta_g = \frac{Q_{g(u)}}{NQ_u} \times 100 = \frac{7213.032}{20 \times 380} \times 100 = 94.9 \%$$

Que 3.14. **A group of 16 piles, each having a diameter of 350 mm and 10 m long, are arranged in 4 rows at a spacing 1.0 m centre to centre. The capacity of each pile is 360 kN. Determine the group capacity of the piles.** **AKTU 2015-16, Marks 10**

Given : Number of piles, $N = 16$, Diameter of pile, $d = 350$ mm
Length of pile, $L = 10$ m, Spacing of pile, $S = 1$ m,
Capacity of one pile, $Q_u = 360$ kN
To Find : Group capacity of piles.

1. Ultimate load capacity of a pile group of 16 piles on the basis of individual action

$$= 16 \times 360 \text{ kN} = 5760 \text{ kN}$$

Length of pile group = 3 × 1 + 0.35 = 3.35 m
Width of pile group = 3 × 1 + 0.35 = 3.35 m

2. Ultimate load capacity of the pile group by block failure is given by,

$$Q_{g(u)} = C_{ub} N_c A_b + P_b L C_u$$

3. We know that, capacity of one pile

$$Q_u = C_{ub} N_c A_p + \alpha C_u A_s$$

$$360 = C_u \times 9 \times \frac{\pi}{4} \times 0.35^2 + 0.9 \times C_u \times \pi \times 0.35 \times 10$$

$$C_u = 33.46 \text{ kN/m}^2 \quad (\because C_u = C_{ub})$$

4. Ultimate bearing capacity of group piles,

$$Q_{g(u)} = 33.46 \times 9 \times 3.35 \times 3.35 + 2(3.35 + 3.35) \times 10 \times 33.46$$
$$= 7863.18 \text{ kN}$$

5. Arrangement of pile group.

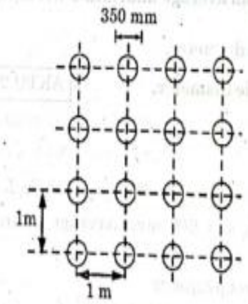


Fig. 3.14.1.

Que 3.15. **It is proposed to provide pile foundation for a heavy column the pile group consisting of 4 piles, placed at 2 m center to center, forming a square pattern. The underground soil is clay,**

Negative skin friction: is usually a downward shear drag acting on a pile or pile group due to downward sinking of surrounding soil relative to the piles. This shear drag movements are expected to occur when a segment of the pile penetrates a compressible soil stratum that can consolidate. Downward drag may be caused by

15. Placement of fill on compressible soils, lowering of the groundwater table.
16. Placement of fill on Under-consolidated natural or compacted soils.

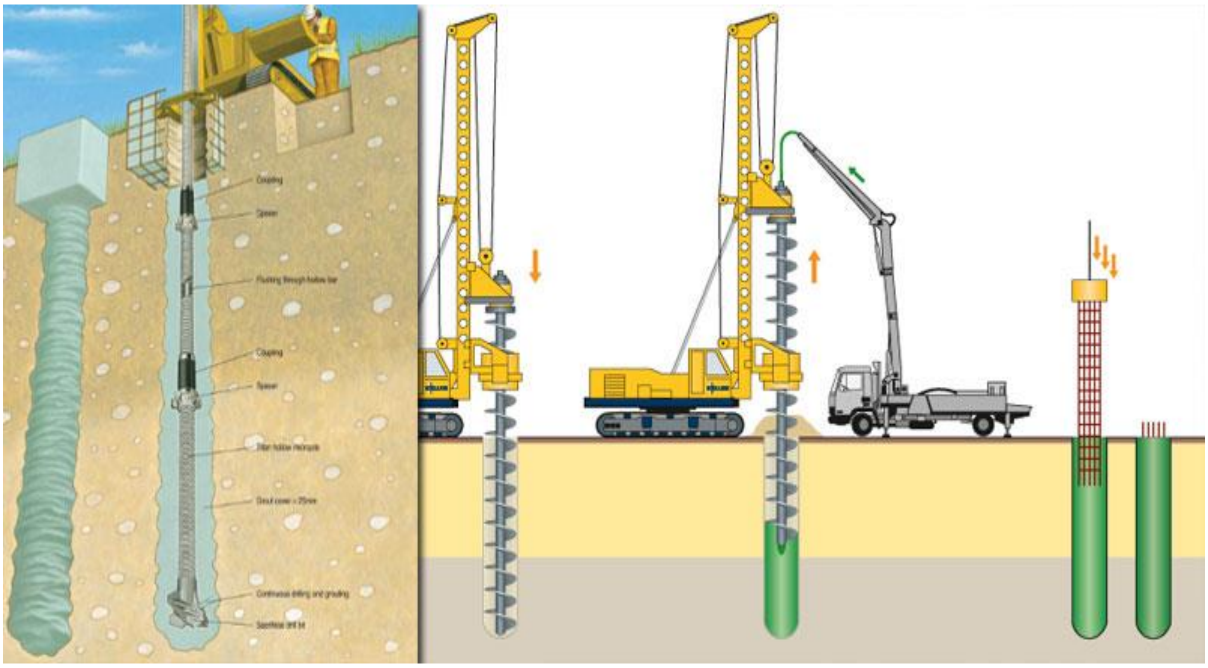
These situations in the site can cause the compressible soils surrounding the piles to consolidate. When the tip of pile is bearing in a relatively stiff stratum, the upper compressible soil will move down relative to the pile this will induce a drag load on the pile/pile group. This induced drag load can be quite large and it should be added to the design load for assessing the stresses in the pile.

Effect of negative skin friction on:

- pile Newly placed fill material on compressible soil before the completion of consolidation.
- If fill material is loose cohesionless soil
- When fill material is deposited over layer of soft soil or peat.
- Lowering groundwater which increases the effective stress causing consolidation of soil with resultant settlement and friction force being developed on the pile.
- Negative skin friction contributes to the uneven settlement of piles or pile group.
- For piles in compressible soils where pile capacity is contributed by both point resistance and shaft adhesion, the problem of negative skin friction should be considered a settlement problem.
- In bearing piles where the settlement of the pile is negligible, negative skin friction becomes a pile capacity problem.

PILE INSTALLATION METHOD

January 29, 2017 No Comments



The instalment procedure and strategy for instalment are similarly critical variables as of the plan procedure of pile foundations. Pile establishment strategies are establishment by pile mallet and exhausting by mechanical wood screw.

Keeping in mind the end goal to stay away from harms to the piles, amid designing, installation methods and establishment gears ought to be precisely chosen.

On the off chance that installation is to be done utilizing pile hammer, then the accompanying variables ought to be taken into thought:

The size and the mass of the pile
The driving resistance which must be overcome to accomplish the outline infiltration
The accessible space and head room on the site
The accessibility of cranes and
The commotion limitations which might be in drive in the region.

Pile driving techniques (Displacement piles)

Methods or techniques of pile driving are listed below:

Dropping weight
Explosion
Vibration

Jacking (restricted to micro-pilling)
Jetting

Drop hammers

A hammer with the tentative weight of the pile is higher-ed to a appropriate height in a guide and suspended so that it strikes the pile head. This is an easy procedure form of hammer utilized in conjunction with test piling and light fames, whilst it may not be cost-effective to bring a steam boiler r on to the site to drive very limited quantity of piles.

Two main kinds of drop hammer

Single-acting steam which is also basically known as compressed-air includes a massive mass in the shape of a cylinder. Steam or compressed air released into to the cylinder raises it above the settled piston rod. At the apex of the stroke, or at a smaller depth which could be monitored by the operator, the steam is cut off and thus the cylinder is suspended freely on the top of the pile helmet.
Double-acting pile hammers could be led by steam or compacted air. A pilling frame is not necessary with this kind of hammer which could be joined to the apex of the pile by leg-guides, the pile being held up by a timber framework. When utilized with a pile frame, back guides are fastened to the hammer to connect with leaders, and just short leg-guides are utilized to stop the hammer from moving moderately to the apex of the pile. Double-acting hammers are basically utilized for sheet pile driving.
Pile driving by vibrating

Vibratory hammers: are basically electrically powered. In some cases they are also hydraulically powered and incorporates contra-rotating eccentric masses inside a housing connecting to the pile head. The amplitude of the vibration is enough to dismantle the skin friction on the corners of the pile. Vibratory techniques are most applied to sand surface or gravelly soil.

Jetting

To contribute in the infiltration of piles in to sand or sandy gravel, water jetting method can be applied. On the other hand, the technique has very restricted effect in firm to rigid clays or any soil incorporating much coarse gravel, boulders or cobbles.

Boring Methods (Non-displacement piles)

Continuous Flight Auger (CFA)

The techniques is specifically effective on soft ground and leads to establish an assortment of bored piles of different diameters that are capable to infiltrate a multiple level of soil conditions. However, for triumphant operation of rotary auger the soil has to be practically free of tree roots, cobbles, and boulders.

Underreaming

A specific property of auger bored piles which is usually utilized to lead to exploit the bearing capability of appropriate strata by giving an amplified base.

Types of Shallow Foundations

1. Individual Footing or Isolated Footing

Individual footing or an isolated footing is the most common type of foundation used for building construction. This foundation is constructed for a single column and also called a pad foundation.

The shape of individual footing is square or rectangle and is used when loads from the structure is carried by the columns. Size is calculated based on the load on the column and the safe bearing capacity of soil.

Rectangular isolated footing is selected when the foundation experiences moments due to the eccentricity of loads or due to horizontal forces.

For example, Consider a column with a vertical load of 200 kN and a safe bearing capacity of 100 kN/m^2 then the area of the footing required will be 200/100 = 2m^2. So, for a square footing, the length and width of the footing will be 1.414 m x 1.414 m.

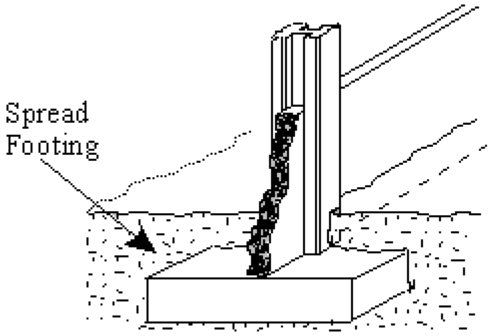
2. Combined Footing

Combined footing is constructed when two or more columns are close enough and their isolated footings overlap each other. It is a combination of isolated footings, but their structural design differs.

The shape of this footing is a rectangle and is used when loads from the structure is carried by the columns.

3. Spread footings or Strip footings and Wall footings

Spread footings are those whose base is wider than a typical load-bearing wall foundation. The wider base of this footing type spreads the weight from the building structure over more area and provides better stability.



Spread footings

Spread footings and wall footings are used for individual columns, walls and bridge piers where the bearing soil layer is within 3m (10 feet) from the ground surface. Soil bearing capacity must be sufficient to support the weight of the structure over the base area of the structure.

These should not be used on soils where there is any possibility of a ground flow of water above bearing layer of soil which may result in scour or liquefaction.

4. Raft or Mat Foundations

Raft or mat foundations are the types of foundation which are spread across the entire area of the building to support heavy structural loads from columns and walls.

Raft or Mat Foundation

The use of mat foundation is for columns and walls foundations where the loads from the structure on columns and walls are very high. This is used to prevent differential settlement of individual footings, thus designed as a single mat (or combined footing) of all the load-bearing elements of the structure.

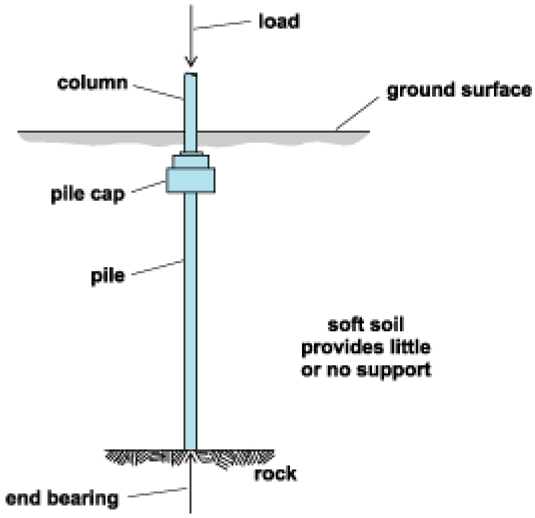
It is suitable for expansive soils whose bearing capacity is less for the suitability of spread footings and wall footings. Raft foundation is economical when one-half area of the structure is covered with individual footings and wall footings are provided.

These foundations should not be used where the groundwater table is above the bearing surface of the soil. The use of foundation in such conditions may lead to scour and liquefaction.

Types of Deep Foundation

5. Pile Foundations

Pile foundation is a type of deep foundation which is used to transfer heavy loads from the structure to a hard rock strata much deep below the ground level.



Pile Foundation

Pile foundations are used to transfer heavy loads of structures through columns to hard soil strata which is much below ground level where shallow foundations such as spread footings and mat footings cannot be used. This is also used to prevent uplift of the structure due to lateral loads such as earthquake and wind forces.

Pile foundations are used for soils where soil conditions near the ground surface is not suitable for heavy loads. The depth of hard rock strata may be 5m to 50m (15 feet to 150 feet) deep from the ground surface.

Pile foundation resists the loads from the structure by skin friction and by end bearing. The use of pile foundations also prevents differential settlement of foundations.

6. Drilled Shafts or Caisson Foundation

Drilled shafts, also called as caissons, is a type of deep foundation and has an action like pile foundations discussed above but are high-capacity cast-in-situ foundations. It resists loads from structure through shaft resistance, toe resistance and/or combination of both. The construction of drilled shafts or caissons are done using an auger.

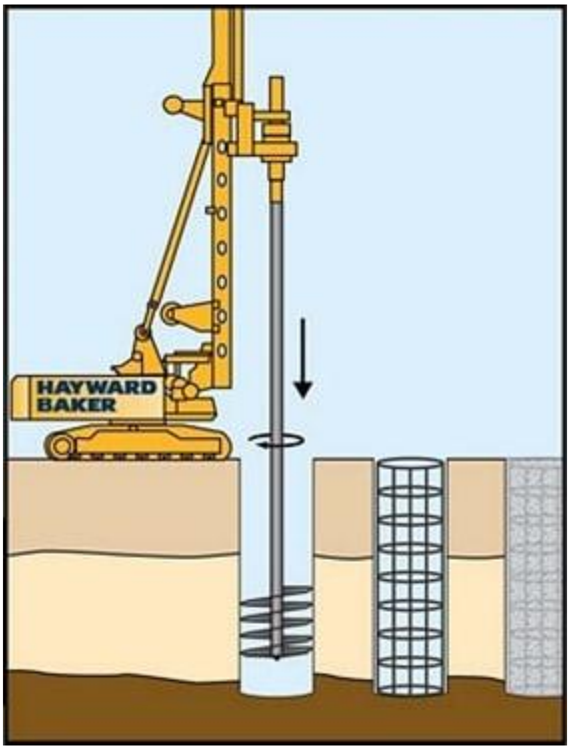


Fig: Drilled Shafts or Caisson Foundation (Source: Hayward Baker)

Drilled shafts can transfer column loads larger than pile foundations. It is used where the depth of hard strata below ground level is located within 10m to 100m (25 feet to 300 feet).

Drilled shafts or caisson foundation is not suitable when deep deposits of soft clays and loose, water-bearing granular soils exist. It is also not suitable for soils where caving formations are difficult to stabilize, soils made up of boulders, artesian aquifer exists.