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**MODULE-5****PROPORTIONING PILE FOUNDATIONS****Structure**

## 5.0 Objectives

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**5.0 Objectives**

- To understand piles
- To design single pile
- To design group of piles

**5.1 Pile Foundations**

Deep foundations are employed when the soil strata immediately beneath the structure are not capable of supporting the load with tolerable settlement or adequate safety against shear failure. Merely extending the level of support to the first hard stratum is not sufficient, although this is a common decision that is reached. Instead, the deep foundation must be engineered in the same way as the shallow foundation so that the soil strata below remain safe and free of deleterious settlement. Two general forms of deep foundation are recognized.

## 1. Pile foundation

## 2. Pier, caisson or well foundation.

Piles are relatively long, slender members that are driven into the ground or cast-insitu. Piers, caissons or wells are larger, constructed by excavation and are sunk to the required depth; these usually permit visual examination of the soil or rock on which they rest. In effect they are deep spread footings or mats. They are normally used to carry very heavy loads such as those from bridge piers or multi-storeyed buildings. A sharp distinction between piles and piers is impossible because some foundations combine features of both. Piles have been used since

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prehistoric times. The Neolithic inhabitants of Switzerland, 12,000 years ago, drove wooden poles in the soft bottoms of shallow lakes and on them erected their homes, high above marauding animals and warring neighbours. Pile foundations were used by Romans; Vitruvius (59 A.D.) records the use of such foundations. Today, pile foundations are much more common than any other type of deep foundation, where the soil conditions are unfavourable.

## **5.2 Classification of piles**

Piles may be classified in a number of ways based on different criteria:

- (a) Function or action
- (b) Composition and material
- (c) Installation

### **5.2.1 Classification Based on Function or Action**

Piles may be classified as follows based on the function or action:

#### **End-bearing piles**

Used to transfer load through the pile tip to a suitable bearing stratum, passing soft soil or water.

#### **Friction piles**

Used to transfer loads to a depth in a frictional material by means of skin friction along the surface area of the pile.

#### **Tension or uplift piles**

Used to anchor structures subjected to uplift due to hydrostatic pressure or to overturning moment due to horizontal forces.

#### **Compaction piles**

Used to compact loose granular soils in order to increase the bearing capacity. Since they are not required to carry any load, the material may not be required to be strong; in fact, sand may be used to form the pile. The pile tube, driven to compact the soil, is gradually taken out and sand is filled in its place thus forming a 'sand pile'.

#### **Anchor piles**

Used to provide anchorage against horizontal pull from sheetpiling or water.

**Fender piles**

Used to protect water-front structures against impact from ships or other floating objects.

**Sheet piles**

Commonly used as bulkheads, or cut-offs to reduce seepage and uplift in hydraulic structures.

**Batter piles**

Used to resist horizontal and inclined forces, especially in water front structures.

**Laterally-loaded piles**

Used to support retaining walls, bridges, dams, and wharves and as fenders for harbor construction.

**5.2.2 Classification Based on Material and Composition**

Piles may be classified as follows based on material and composition:

**Timber piles**

These are made of timber of sound quality. Length may be up to about 5 m; splicing is adopted for greater lengths. Diameter may be from 30 to 40 cm. Timber piles perform well either in fully dry condition or submerged condition. Alternate wet and dry conditions reduce the life of a timber pile; to overcome this, creosoting is adopted. Maximum design load is about 250 kN.

**Steel piles**

These are usually H-piles (rolled H-shape), pipe piles, or sheet piles (rolled sections of regular shapes). They may carry loads up to 1000 kN or more.

**Concrete piles**

These may be 'precast' or 'cast-in-situ'. Precast piles are reinforced to withstand handling stresses. They require space for casting and storage, more time to cure and heavy equipment for handling and driving.

Cast-in-situ piles are installed by pre-excavation, thus eliminating vibration due to driving and handling. The common types are Raymond pile, Mac Arthur pile and Franki pile.

**Composite piles**

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These may be made of either concrete and timber or concrete and steel. These are considered suitable when the upper part of the pile is to project above the water table. Lower portion may be of untreated timber and the upper portion of concrete. Otherwise, the lower portion may be of steel and the upper one of concrete.

### **5.2.3 Classification Based on Method of Installation**

Piles may also be classified as follows based on the method of installation:

#### **Driven piles**

Timber, steel, or precast concrete piles may be driven into position either vertically or at an inclination. If inclined they are termed 'batter' or 'raking' piles. Pile hammers and pile-driving equipment are used for driving piles.

#### **Cast-in-situ piles**

Only concrete piles can be cast-in-situ. Holes are drilled and these are filled with concrete. These may be straight-bored piles or may be 'under-reamed' with one or more bulbs at intervals. Reinforcements may be used according to the requirements.

#### **Driven and cast-in-situ piles**

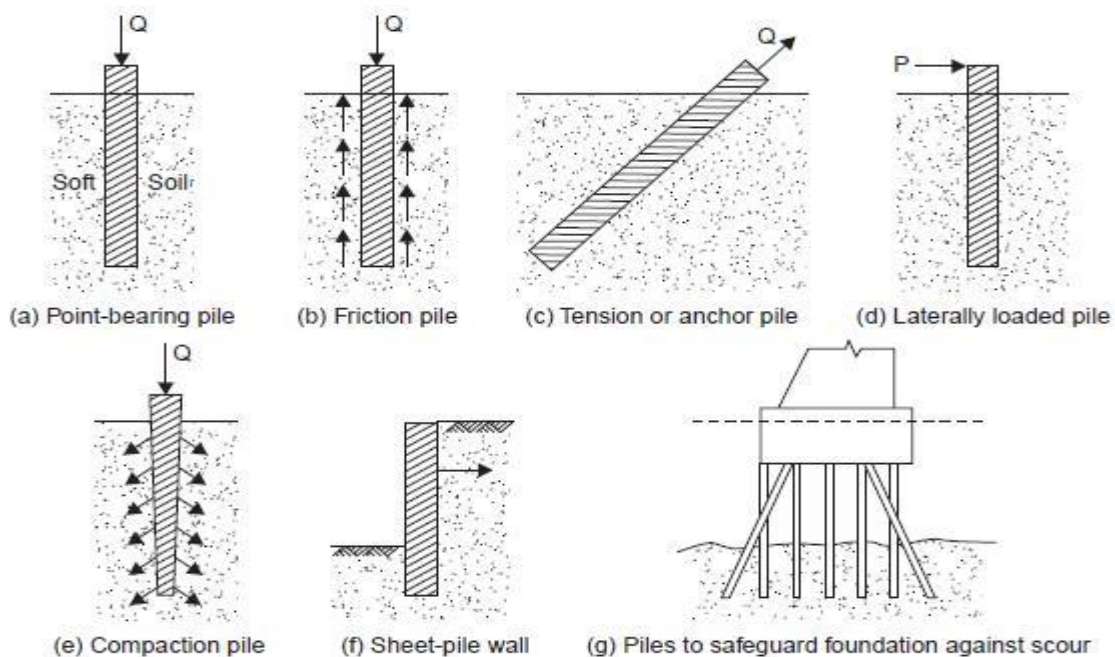
This is a combination of both types. Casing or shell may be used. The Franki pile falls in this category.

### **5.3 Use of piles**

The important ways in which piles are used are as follows:

- (i) To carry vertical compressive loads,
- (ii) To resist uplift or tensile forces, and
- (iii) To resist horizontal or inclined loads.
- (iv) To resist the applied moments in quays

Bearing piles are used to support vertical loads from the foundations of buildings and bridges. The load is carried either by transferring to the incompressible soil or rock below through soft strata, or by spreading the load through soft strata that are incapable of supporting concentrated loads from shallow footings. The former type is called point or end-bearing piles, while the latter are known as friction-piles. Tension piles are used to resist upward forces in structures subjected to uplift, such as buildings with basements below the ground water level, aprons of dams or buried tanks. They are also used to resist overturning of walls and dams and for anchors of towers, guy wires and bulkheads. Laterally loaded piles support horizontal or inclined forces such as the foundations of retaining walls, bridges, dams, and wharves and as fenders in harbour construction. In case the lateral loads are of large magnitude they may be more effectively resisted by batter piles, driven at an inclination. Closely spaced piles or thin sheet piles are used as cofferdams, seepage cut-offs and retaining walls. Piles may be used to compact loose granular soils and also to safeguard foundations against scour. These are illustrated in Fig.



**Fig.** Uses of piles

## 5.4 Pile load capacity

The ultimate bearing capacity of a pile is the maximum load which it can carry without failure or excessive settlement of the ground. The allowable load on a pile is the load which can be imposed upon it with an adequate margin of safety; it may be the ultimate load divided by a suitable factor of safety, or the load at which the settlement reaches the allowable value. The bearing capacity of a pile depends primarily on the type of soil through which and/ or on which it rests, and on the method of installation. It also depends upon the cross-section and length of the pile. The pile shaft is a structural column that is fixed at the point and usually restrained at the top. The elastic stability of piles, or their resistance against buckling, has been investigated both theoretically and by load tests (Bjerrum, 1957). Both theory and experience demonstrate that buckling rarely occurs because of the effective lateral support of the soil; it may occur only in extremely slender piles in very soft clays or in piles that extend through open air or water. Therefore, the ordinary pile in sand or clay may be designed as though it were a short column. The pile transfers the load into the soil in two ways. Firstly, through the tip-in compression, termed 'end-bearing' or 'point-bearing'; and, secondly, by shear along the surface, termed 'skin friction'. If the strata through which the pile is driven are weak, the tip resting on a hard stratum transfers most part of the load by end-bearing; the pile is then said to be an end bearing pile. Piles in homogeneous soils transfer the greater part of their load by skin friction, and are then called friction piles; however, nearly all piles develop both end-bearing and skin friction.

The following is the classification of the methods of determining pile capacity:

(i) Static analysis (ii) Dynamic analysis

(iii) Load tests on pile (iv) Penetration tests

### Problems

1. A timber pile was driven by a drop hammer weighing 30 kN with a free fall of 1.2 m. The average penetration of the last few blows was 5 mm. What is the capacity of the pile according to Engineering News Formula?

Allowable load on the pile

$$Q_{ap} = \frac{500 W_h \cdot H}{3(s + 25)} \text{ for drop hammer,}$$

$H$  being in metres and  $s$  being in mm.  $W_h = 30 \text{ kN}$   $H = 1.2 \text{ m}$   $s = 3 \text{ mm}$

$$Q_{ap} = \frac{500 \times 3 \times 1.2}{3 \times (5 + 25)} t = 200 \text{ kN.}$$

2. A pile is driven with a single acting steam hammer of weight 15 kN with a free fall of 900 mm. The final set, the average of the last three blows, is 27.5 mm. Find the safe load using the Engineering News Formula.

Allowable load on the pile

$$Q_{ap} = \frac{500 W_h \cdot H}{3(s + 2.5)} \text{ for steam hammer,}$$

$H$  being in metres and  $s$  in mm.

$$W_h = 15 \text{ kN} \quad H = 900 \text{ mm} = 0.9 \text{ m}$$

$$Q_{ap} = \frac{500 \times 15 \times 0.9}{3(27.5 + 2.5)} \text{ kN} = 75 \text{ kN.}$$

3. A reinforced cement concrete pile weighing 30 kN (including helmet and dolly) is driven by a drop hammer weighing 30 kN with an effective fall of 0.9 m. The average penetration per blow is 15 mm. The total temporary elastic compression of the pile, pile cap and soil may be taken as 15 mm. Coefficient of restitution 0.36. What is the allowable load on the pile with a factor of safety of 2? Use Hiley's formula.

$$W_p = 30 \text{ kN} \quad W_h = 30 \text{ kN} \quad R = \frac{W_p}{W_h} = 1$$

$$\text{Effective fall} = \eta H = 0.9 \text{ m} = 900 \text{ mm}$$

$$s = 15 \text{ mm} \quad C = 1/2 \text{ (total elastic compression of pile, pile cap and soil)}$$

$$C_r = 0.36 = 1/2 \times 15 = 9 \text{ mm}$$

$$\begin{aligned}
 Q_{ap} &= \frac{Q_{up}}{2} = \frac{1}{2} \left[ \frac{W_h \cdot H \cdot \eta}{(s + C)} \left( \frac{1 + C_r^2 \cdot R}{1 + R} \right) \right] \\
 &= \frac{1}{2} \left[ \frac{30 \times 900 \times 1}{(15 + 9)} \times \frac{1 + (0.36)^2 \times 1}{(1 + 1)} \right] \\
 &= \frac{1}{2} \cdot \frac{30}{24} \cdot 900 \times \frac{11296}{2} \\
 &= 317.7 \text{ kN}
 \end{aligned}$$

Approximate safe load may be taken as  
**315 kN.**

### 5.5 Assignment Questions

- What is a pile? Explain pile group capacity
- Derive expression for capacity of a single pile
- Derive expression for capacity of a pile group

### 5.6 Outcomes

Students should be able to

- Decide upon soil exploration techniques to be adopted for different site condition
- Conduct soil exploration and to do the report of the same
- Collect soil sample by using proper sampling technique base on requirement
- Understand dewatering techniques and efficiency of lowering of water table

### 5.7 Further reading

- <https://theconstructor.org/geotechnical/foundations/pile/>