Chapter

1

Introduction

When a good bearing stratum is not available near the ground surface or at relatively shallow depths, the loads of superstructures have to be 'transmitted' to firm strata capable of catering such loads though may be at much depth. Such foundations made are called **deep foundations**. Thus, deep foundations are those foundations where the soil support is found at appreciable depth below the main structure. The deep foundations may be pile foundations or wells and caissons. A pile is relatively small diameter shaft which is driven into the ground or otherwise introduced into the soil by suitable means so as to support all the loads. Wells and caissons are usually installed by excavation of sub-soil. Thus in case of wells and caissons, visual inspection of the firm stratum on which they rest, may be made.

The piles are of two types, i.e.

i. Friction pile
ii. End bearing pile

i. Friction pile

The pile which supports the structure load due to friction between the pile and the neighbouring soil is known as **friction pile** (Fig. 1.1).

ii. Point bearing or end bearing pile

The pile whose lower end rests on a hard strata is called **end bearing pile** (Fig. 1.2).

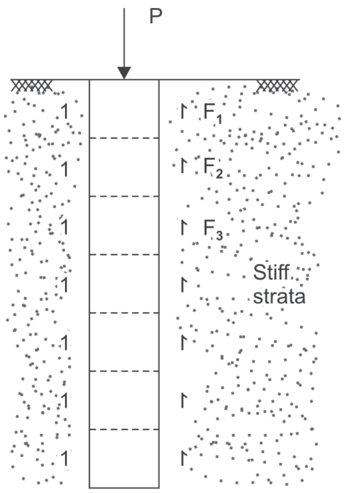

Fig. 1.1: Friction pile

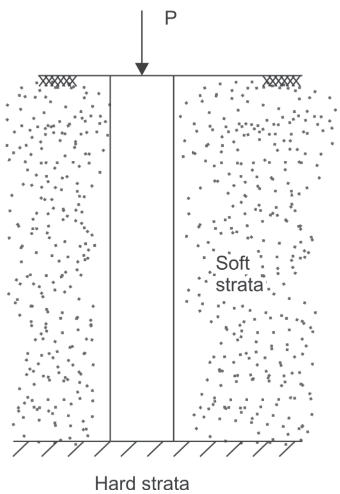

Fig. 1.2: End bearing pile

1.1 KINDS OF PILES

Depending upon the location, requirement, economy, etc. the piles may be of following kinds according to their material compositions:

a. Timber/bamboo piles
b. Concrete piles
c. Steel piles

The uses of different piles may be different. The characteristics and uses of various types of piles are summarized below:

1.1.1 Timber/Bamboo Piles

These are the piles made of tree trunks and logs. They are proved very cheap at places where timber is available in plenty. The lengths of such piles may vary from 2 to 8 m. However, more lengths can also be used with due care in bonds between two consecutive pieces. The precaution must be taken that the wood should be of good quality capable to carry loads without buckling.

The diameter of such piles may vary from 25 to 45 cm and at the tip around 12.5 to 20 cm.

The wood should be applied with a good wood preservative to withstand the alternate change in the climate or surrounding situations. Use of creosote @ 225–250 kg/m^3 of piles in fresh water and the same @ 350 kg/m^3 in saline water is recommended to be used. The piles fully submerged in water last long. The branches off shooting the main stem should be trimmed off before applying the load.

After driving to final depth, the pile head should be made square. Before concrete pouring for the pile cap, the head of the treated pile should be protected by zinc coat, lead paint or by wrapping the pile head with clothes.

The maximum design load per pile in such piles should not exceed 25 tonnes.

1.1.2 Concrete Piles

The concrete piles may be either driven or cast-*in situ* piles. The precast piles are made of uniform section with pointed tips. The square or octagonal sections are normally preferred owing to the ease in casting them. The necessary reinforcement is also provided in such piles.

The maximum load on a precast pile is around 100 tonnes. The general load capacity of smaller piles range from 25 to 70 tonnes and for large piles upto 200 tonnes.

The precast piles are suitable for the places where wooden piles are likely to be weaken by the white ants or other insects and termites. They are quick in construction and laying into the ground.

The disadvantages in using precast piles are as follows:

i. These piles are relatively heavy hence a great difficulty is sometimes involved in handling and driving them.
ii. Depending upon the availability of hard strata, a precast pile sometimes may be proved to be shorter or longer, hence a great difficulty is anticipated in case of precast piles.

Concrete cast-*in situ* piles are the piles which are casted at place on site. They are of two types, e.g. **Cased Piles** and **Uncased Piles.**

a. Cased Piles

Where a thin metal casing is driven first into the ground and subsequently the concrete is poured inside the casing they are called **cased piles**. The casing in such piles may be left in the ground permanently. They are of following types:

i. Raymond piles

In such type of piles, a corrugated thin steel sheet tapered shell is driven into the ground with the collapsible steel mandrel inside it to a desired depth. The shell diameter is around 20 cm at the tip and has the tapering of 3.35 cm/m length (Fig. 1.3). After driving into the ground, the mandrel is withdrawn and the shell is fied with concrete. The lengths vary between 6 to 15 m for such piles. Such pile is named after the patent licence of the pile with M/s Raymond Concrete Pile Co., USA.

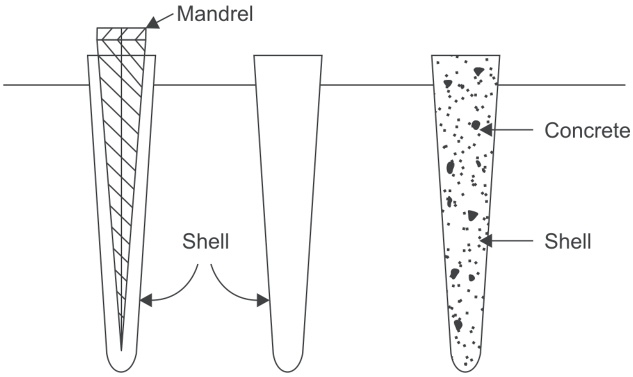

Fig. 1.3: Raymond piles

ii. Mac-arthur pile

In such piles heavy steel casing is driven into the ground (with a core inside it) to a desired depth. The core is then pulled out and a corrugated steel shell is inserted. Finally, cement concrete is poured and outer casing is withdrawn.

iii. Pipe or tube pile

In this type of piles, a tapered steel shell without any mandrel is used as casing. The dia of the pipe is 20 to 50 cm with thickness as 0.5 to 1.25 cm. The pipe is closed at the bottom. The pipe section is filled with concrete. If the pipe is driven with its bottom open, the soil inside the pipe is usually jetted out with air and water under pressure.

b. Uncased Piles

In such piles, a thin or relatively thick metal casing is driven first into the ground. The casing is then taken out gradually and concrete thus makes bond with the neighbouring soil.

The uncased cast-in-situ concrete piles are of the following types:

i. Simplex piles

In such piles, a hollow cylindrical steel casing with one pointed iron shoe attached to its bottom is driven into the ground to the desired depth. Concrete is then poured into the casing pipe for a depth of about one metre and then it is compacted. The casing pipe is then lifted up in steps. In this way the entire length of hole is filled up with compacted concrete which is a pile (Fig. 1.4).

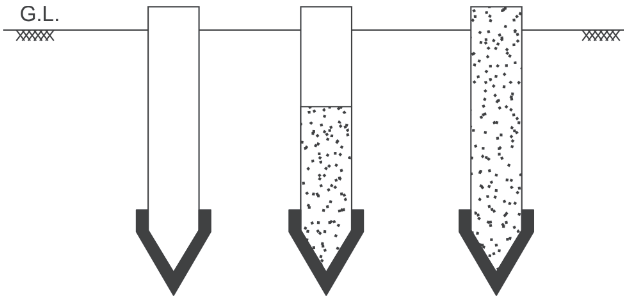

Fig. 1.4: Simplex piles

ii. Franki piles

In such piles, a steel casing of 50 cm diameter is driven into the ground for a small depth and cleaned of soil. Then the concrete (of low water-cement ratio) is placed and rammed. This concrete forms a solid plug at the end which grips the casing pipe so tightly so as to become an integral part of the casing during the driving process. The ram works inside the casing to fall from a height of 3 to 6 m on to the plug. Fig. 1.5 shows the mechanism of Franki piles.

The pipe due to impact of the falling ram penetrates into the ground. When the pile reaches its final elevation, the casing is anchored to the driving rig and the concrete plug is forced out of the pipe. Further the ramming of this expelled concrete is done to obtain a bulb of approximately 1 m diameter. The casing is then raised while successive charges of concrete are rammed in place to form as rough a surface of the finished pile as possible. Length of such piles varies up to 30 m and it is designed to cater the loads up to 100 tonnes.

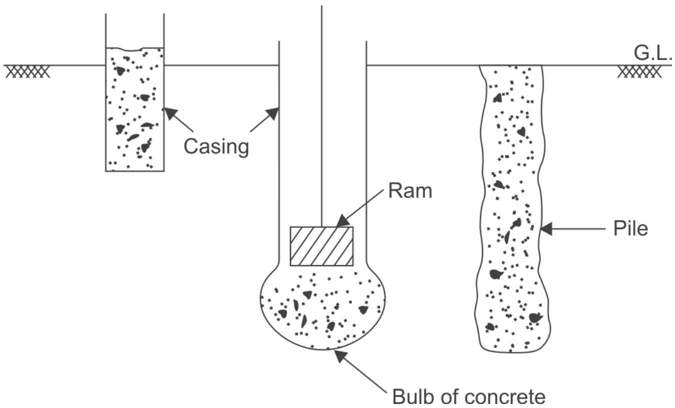

Fig. 1.5: Franki piles

iii. Vibro piles

A hollow steel tube with a cast iron shoe at its bottom is driven into the ground to the desired depth. Then the reinforcement is placed in position. The tube is then filled with concrete and extracting links are fitted to it. The extraction of the tube and formation of the concrete pile are affected by upward and downward movement of the hammer.

The shoe is left into the ground only. The section of the pile is enlarged at the base and at other location by suitably ramming the freshly laid concrete.

iv. Bored piles

They consist of holes made with auger filled with concrete. Such piles can be used in relatively firm ground. Under-reamed piles are the special type of bored piles. In such piles, a hole is bored by means of an auger. After digging the hole a under-reamer is lowered into the hole. It is then pressed down and rotated. By this, the blades get widen due to pressing and they cut the soil from the sides by rotations. A bucket is attached under the under-reamer. When this bucket is full, the under-reamer is pulled out and the soil is removed. Again the under-reamer is lowered and the soil is removed and thus a bulb is made at the required depth. Then the reinforcement is lowered into the hole and then concrete is poured in.

Such piles are very useful and economical in expansive soils like black-cotton soils. Such soil is mostly achieved in Madhya Pradesh in India. The usual size of these piles is 15 to 25 cm in diameter and 3 to 4 m long. The diameter of the bulb is 2 to 3 times the diameter of the piles.

v. Pressure piles

The pile which is made by pouring cement concrete inside a casing pipe in layers of 30 cm and each layer compacted by compressed air is called a **pressure pile.** While constructing this pile, the casing pipe is gradually lifted and the pile is thus completely casted. Such piles can resist shocks and vibrations to a greater extent.

vi. Under-reamed pile

Under-reamed piles are cast-in situ concrete piles which have bulb (called **under-ream**) on its periphery (Fig. 1.6) . These piles are often used as load bearing and anchor piles and are suitable in all type of soils. For clayey soils or expansive soils, such piles are a boon. A single under-reamed pile is suitable for anchor pile, while double under-reamed piles are used to increase the load carrying capacity of the pile. The design of such piles is given in subsequent chapters of this book. The approx capacity of under-reamed pile may be computed by following equation also:

$$Q_u = \Sigma \propto C_{u_1} f_s + \frac{\pi d_0^2}{4} C_{u_2} N_c \qquad \ldots (1.1)$$

where,

C_{u_1} = Undrained shear strength of clay along pile shaft
$\propto$ = Reduction factor
d_0 = Diameter of under-ream
C_{u_2} = Undrained shear strength of clay at pile tip
N_c = Bearing capacity factor.

The specialty of such piles is that for double under-reamed pile, the soil between the bulbs acts as part of the pile and the frictional resistance for the length (L_0) may be calculated for the diameter, d_0. While for rest of the pile length above the under-ream, the skin friction develops over the diameter (d).

Under-reamed piles are normally not recommended for dry cohesionless soils (or collapsible soils), owing to the doubts about formation of bulb in soils, because of no cohesion in such soils.

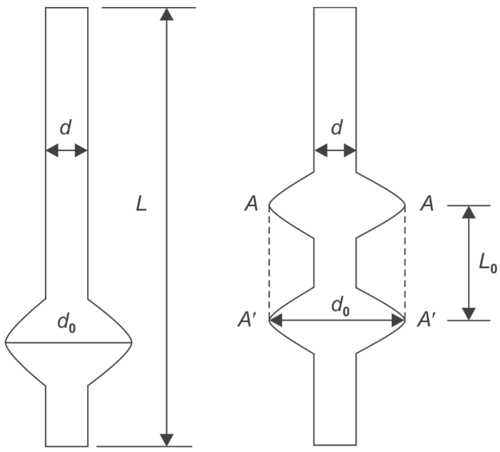

Fig. 1.6: Under-reamed pile

c. Steel Piles

Steel piles are usually rolled H-shapes or pipe piles. H-piles are proportioned to withstand large impact stresses during hard driving (Fig. 1.7). Pipe piles are either welded or seamless steel pipes which are driven either open ended or closed ended. Pipe piles are often filled with concrete after driving, although in some cases it may not be necessary. The load range on steel piles is 40–125 tonnes.

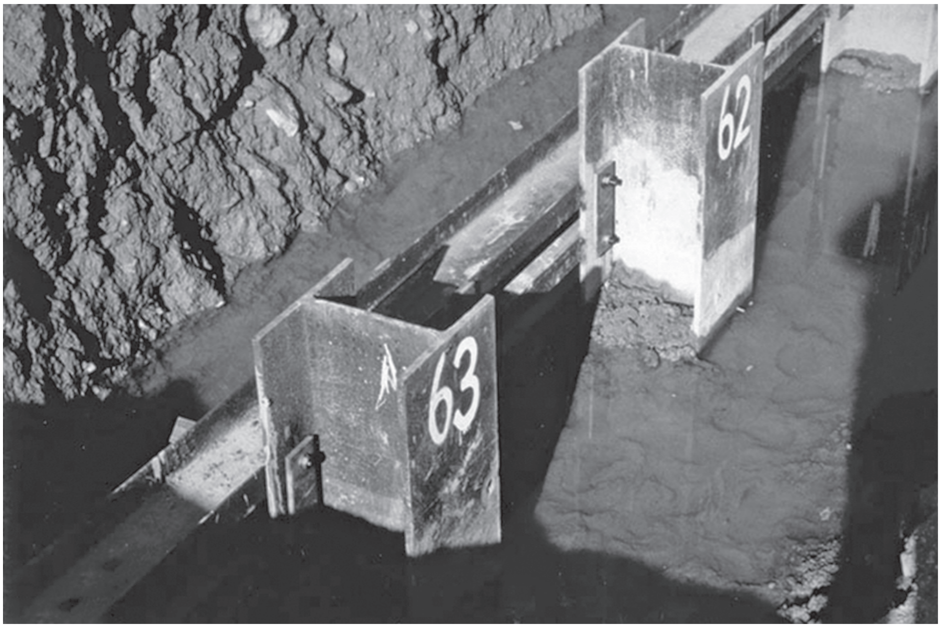

Fig. 1.7: H-Piles (Steel Piles)

1.2 BATTER PILES (INCLINED PILES)

For inclined loads or high lateral loads, piles can be provided at some angle (called **batter**). A maximum batter of 30° is possible for piles under dry ground conditions and around 10–15° for submerged grounds. Batter under-reamed piles (Piles with underground bulb) are used under transmission line tower foundations and as anchors under direct and lateral loads. The batter pile is illustrated in Fig. 1.8.

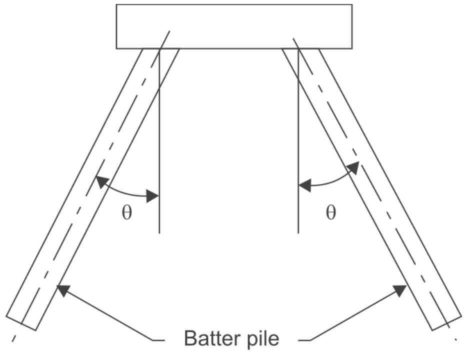

Fig. 1.8: Batter piles

1.3 TEST PILE

It is a pile which is selected for load testing over it. The test pile may become a working pile if it is subjected to routine load test with upto 1.5 times the safe load.

1.4 WORKING PILE

It is the pile which forms the part of the foundation of a structural system.

1.5 TRIAL PILE

The piles which are not working piles are installed initially to assess the load carrying capacity of a pile. They may be one or more in numbers. These piles are tested either to their ultimate load capacity or upto twice the estimated safe load. Such piles are called *Trial piles*.