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Understanding the Pile Foundation

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Abstract: A pile is basically a long cylinder of a strong material such as concrete that is pushed into the ground to act as a steady support for structures built on top of it. Pile foundations are used in the following situations. When there is a layer of weak soil at the surface. This layer cannot support the weight of the structure, so the loads of the structure have to bypass this layer and be transferred to the layer of stronger soil or rock that is below the weak layer. When a structure has very heavy, concentrated loads, such as in a high-rise structure, bridge, or water tank. Pile foundations are capable of taking higher loads than spread footings. There are two fundamental types of pile foundations (based on structural behaviour), each of which works in its own way. This paper describes the details of pile foundation, various types, including advantages and disadvantages.

Keywords: Pile foundation, Structural member, week soils

I. INTRODUCTION

1.10. **Pile Foundation and Types of Pile Foundation**

Foundations provide support to the structure, transfers the loads from the structure to the soil. But the layer at which the foundation transfers the load shall have an adequate bearing capacity and suitable settlement characteristics. There are several types of foundation depending on various considerations such as-

- Total load from the superstructure.
- Soil conditions.
- Water level.
- Noise and vibrations sensitivity.
- Available resources.
- Time-frame of the project.
- Cost.

Broadly speaking, foundations can be classified as shallow foundations and deep foundations. Shallow footings are usually used when the bearing capacity of the surface soil is adequate to carry the loads imposed by a structure. On the other hand, deep foundations are usually used when the bearing capacity of the surface soil is not sufficient to carry the loads imposed by a structure. So, the loads have to be transferred to a deeper level where the soil layer has a higher bearing capacity.

1.11 Subsurface Investigations and geology

The subsurface explorations are the first consideration from site selection through design. These investigations should be planned to gain full and accurate information beneath and immediately adjacent to the structure. The investigation program should cover the area of the foundation and, as a very minimum, extend 6m below the tip of the longest pile anticipated. The borings should be of sufficient depth below the pile tip to identify any soft, settlement-prone layers. The type of soil-boring will be determined by the type of soil profile that exists. In a clay layer or profile, sufficient undisturbed samples should be obtained to determine the shear strength and consolidation characteristics of the clay. The sensitivity of the clay soils will have to be determined, as strength loss from remoulding during installation may reduce ultimate pile capacity. Shrink-swell characteristics should be investigated in expansive soils, as they affect both capacity and movement of the foundation. Since most structures requiring a pile foundation require excavation that changes the in situ soil confining pressure and possibly affects the blow count, the standard penetration test commonly performed in granular soils will probably be of limited use unless the appropriate corrections are made.

1.12 Definition of Pile foundation

Pile foundation, a kind of deep foundation, is actually a slender column or long cylinder made of materials such as concrete or steel which are used to support the structure and transfer the load at desired depth either by end bearing or skin friction.

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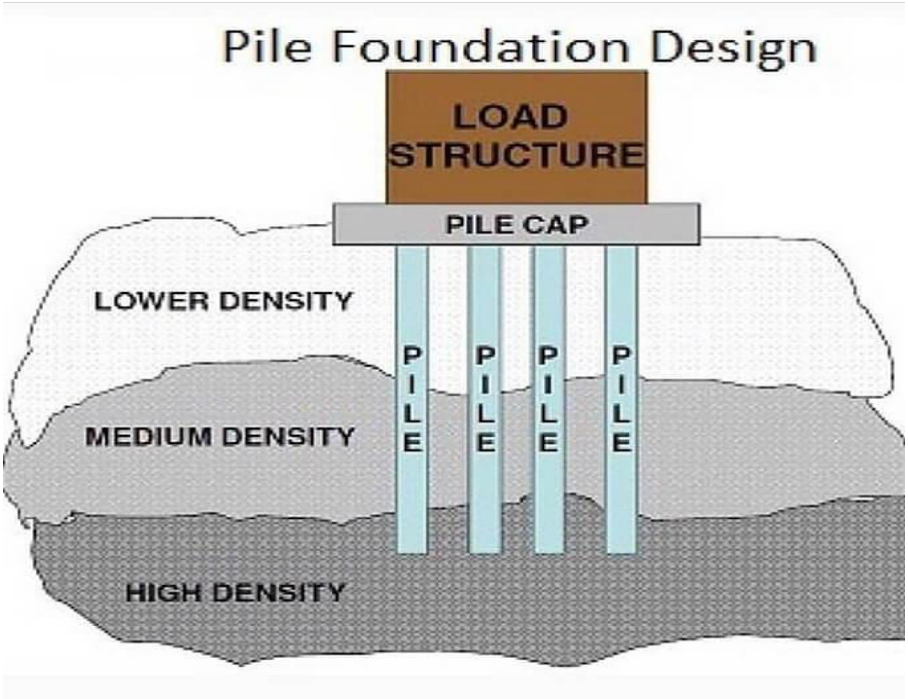

Pile foundations are deep foundations. They are formed by long, slender, columnar elements typically made from steel or reinforced concrete, or sometimes timber. A foundation is described as 'piled' when its depth is more than three times its breadth.
Pile foundations are usually used for large structures and in situations where the soil at shallow depth is not suitable to resist excessive settlement, resist uplift, etc.

1.13 Application of Pile Foundation

Following are the situations when using a pile foundation system can be

- When the groundwater table is high.
- Heavy and un-uniform loads from superstructure are imposed.
- Other types of foundations are costlier or not feasible.
- When the soil at shallow depth is compressible.
- When there is the possibility of scouring, due to its location near the river bed or seashore, etc.
- When there is a canal or deep drainage systems near the structure.
- When soil excavation is not possible up to the desired depth due to poor soil condition.
- When it becomes impossible to keep the foundation trenches dry by pumping or by any other measure due to heavy inflow of seepage.

1.14 Pile Foundation-Types

Pile foundations can be classified based on function, materials and installation process, etc. Followings are the types of pile foundation used in construction:

A. Based on Function or Use
1. Sheet Piles
2. Load Bearing Piles
3. End bearing Piles
4. Friction Piles
5. Soil Compactor Piles

B. Based on Materials and Construction Method
1. Timber Piles
2. Concrete Piles
3. Steel Piles
4. Composite Piles

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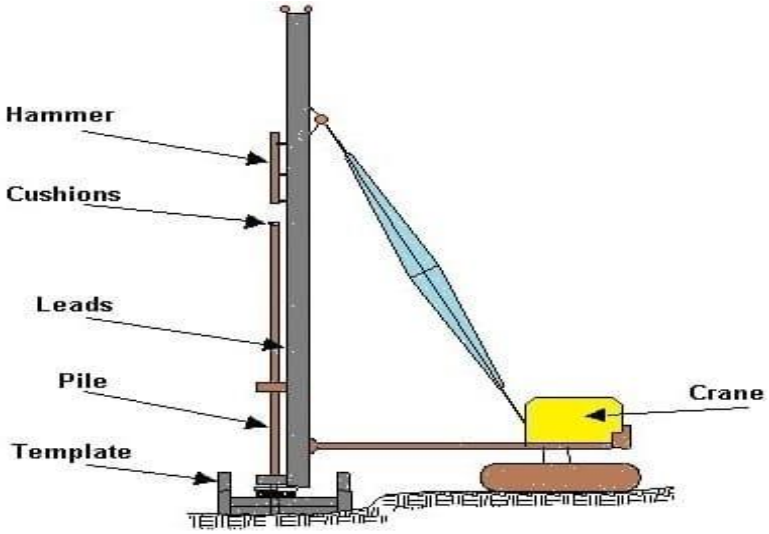
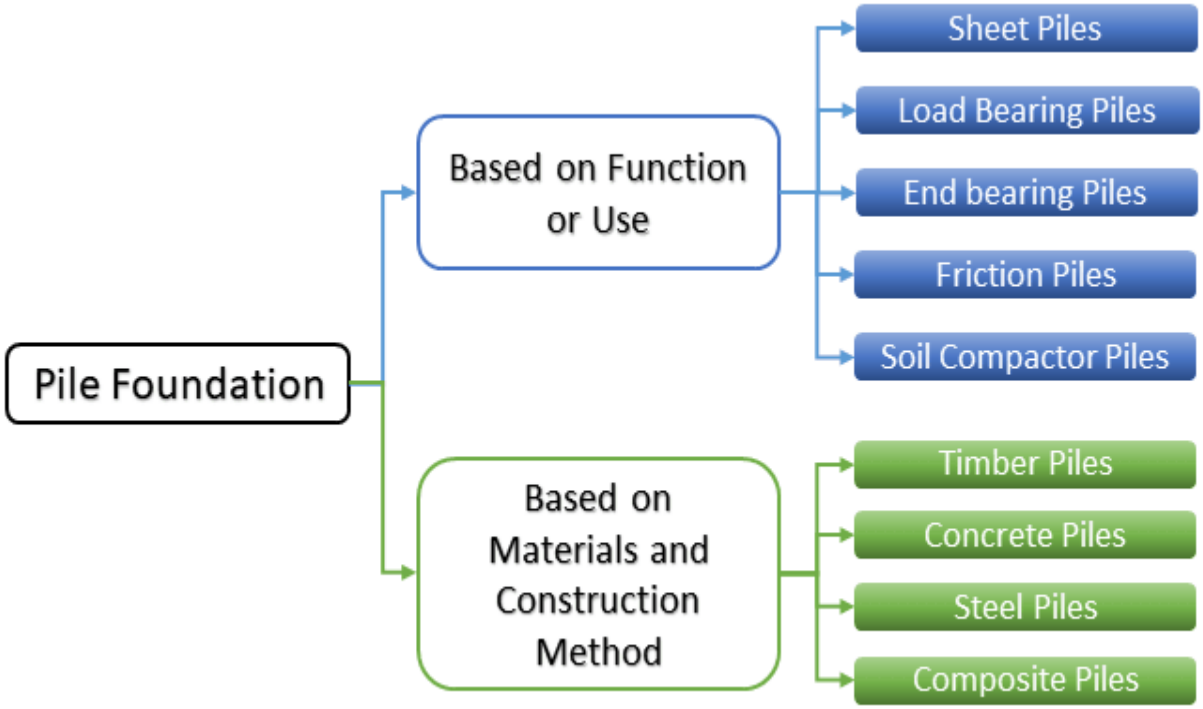


Fig.1: Pile Driving Equipment

The following diagram is representing pile foundation types discussed above.



1.15 Classification of Pile Foundation Based on Function

i.Sheet Piles

This type of pile is mostly used to provide lateral support. Usually, they resist lateral pressure from loose soil, the flow of water, etc. They are usually used for cofferdams, trench sheeting, shore protection, etc. They are not used for providing vertical support to the structure. They are usually used to serve the following purpose-

- Construction of retaining walls.
- Protection from river bank erosion.
- Retain the loose soil around foundation trenches.
- For isolation of foundation from adjacent soils.
- For confinement of soil and thus increase the bearing capacity of the soil.

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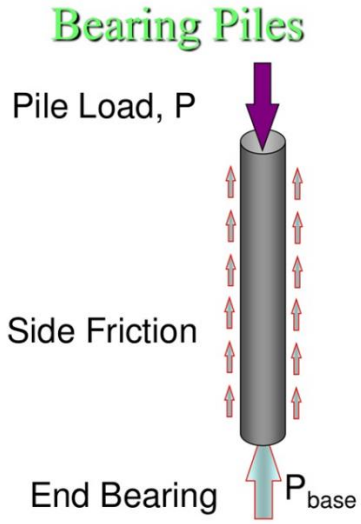
ii.Load Bearing Piles

This type of pile foundation is mainly used to transfer the vertical loads from the structure to the soil. These foundations transmit loads through the soil with poor supporting property onto a layer which is capable of bearing the load. Depending on the mechanism of load transfer from pile to the soil, load-bearing piles can be further classified as flowed.

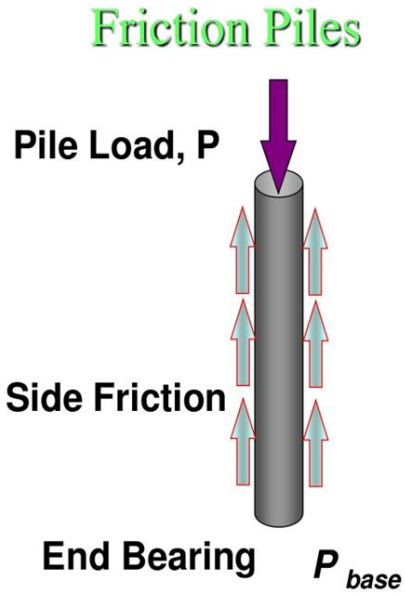
iii.End Bearing Piles

In this type of pile, the loads pass through the lower tip of the pile. The bottom end of the pile rests on a strong layer of soil or rock. Usually, the pile rests at a transition layer of a weak and strong slayer. As a result, the pile acts as a column and safely transfers the load to the strong layer. The total capacity of end bearing pile can be calculated by multiplying the area of the tip of the pile and the bearing capacity of at that particular depth of soil at which the pile rests. Considering a reasonable factor of safety, the diameter of the pile is calculated.



iv.Friction Pile

Friction pile transfers the load from the structure to the soil by the frictional force between the surface of the pile and the soil surrounding the pile such as stiff clay, sandy soil, etc. Friction can be developed for the entire length of the pile or a definite length of the pile, depending on the strata of the soil. In friction pile, generally, the entire surface of the pile works to transfer the loads from the structure to the soil. The surface area of the pile multiplied by the safe friction force developed per unit area determines the capacity of the pile.



While designing skin friction pile, the skin friction to be developed at a pile surface should be sincerely evaluated and a reasonable factor of safety should be considered. Besides this one can increase the pile diameter, depth, number of piles and make pile surface rough to increase the capacity of friction pile.

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v.Soil Compactor Piles

Sometimes piles are driven at placed closed intervals to increase the bearing capacity of soil by compacting.

1.15 Classification of Piles Based on Materials and Construction Method

Primarily piles can be classified into two parts. Displacement piles and Non-displacement or Replacement piles. Piles which causes the soil to be displaced vertically and radially as they are driven to the ground is known as Displacement piles. In case of Replacement piles, the ground is bored and the soil is removed and then the resulting hole is either filled with concrete or a pre-cast concrete pile is inserted. On the basis of materials of pile construction and their installation process load-bearing piles can be classified as follows:

a) Timber Piles

i.Untreated

ii.Treated with Preservative

b) Concrete Piles

iii.Pre-cast Piles

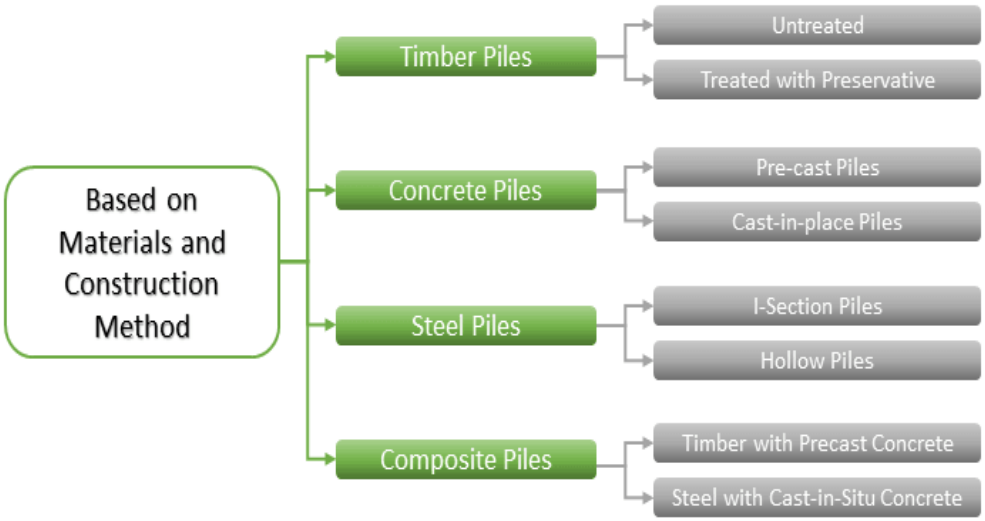
iv.Cast-in-place Piles

c) Steel Piles

v.I-Section Piles

vi.Hollow Piles

d) Composite Piles



a) Timber Piles

Timber piles are placed under the water level. They last for approximately about 30 years. They can be rectangular or circular in shape. Their diameter or size can vary from 12 to 16 inches. The length of the pile is usually 20 times of the top width.

They are usually designed for 15 to 20 tons. Additional strength can be obtained by bolting fish plates to the side of the piles.

Advantages of Timber Piles-

- Timber piles of regular size are available.
- Economical.
- Easy to install.
- Low possibility of damage.
- Timber piles can be cut off at any desired length after they are installed.
- If necessary, timber piles can be easily pulled out.

Disadvantages of Timber Piles-

- Piles of longer lengths are not always available.
- It is difficult to obtain straight piles if the length is short.
- It is difficult to drive the pile if the soil strata are very hard.
- Spicing of timber pile is difficult.
- Timber or wooden piles are not suitable to be used as end-bearing piles.
- For durability of timber piles, special measures have to be taken. For example- wooden piles are often treated with preservative.

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b) Concrete Piles

Pre-cast Concrete Pile

The precast concrete pile is cast in pile bed in the horizontal form if they are rectangular in shape. Usually, circular piles are cast in vertical forms. Precast piles are usually reinforced with steel to prevent breakage during its mobilization from casting bed to the location of the foundation. After the piles are cast, curing has to be performed as per specification. Generally curing period for pre-cast piles is 21 to 28 days.

Advantages of Pre-cast Piles

- Provides high resistance to chemical and biological cracks.
- They are usually of high strength.
- To facilitate driving, a pipe may be installed along the center of the pile.
- If the piles are cast and ready to be driven before the installation phase is due, it can increase the pace of work.
- The confinement of the reinforcement can be ensured.
- Quality of the pile can be controlled.
- f any fault is identified; it can be replaced before driving.
- Pre-cast piles can be driven under the water.
- The piles can be loaded immediately after it is driven up to the required length.

Disadvantages of Pre-cast Piles

- Once the length of the pile is decided, it is difficult to increase or decrease the length of the pile afterward.
- They are difficult to mobilize.
- Needs heavy and expensive equipment to drive.
- As they are not available for readymade purchase, it can cause a delay in the project.
- There is a possibility of breakage or damage during handling and driving od piles.

Cast-in-Palace Concrete Piles

This type of pile is constructed by boring of soil up to the desired depth and then, depositing freshly mixed concrete in that place and letting it cure there. This type of pile is constructed either by driving a metallic shell to the ground and filling it with concrete and leave the shell with the concrete or the shell is pulled out while concrete is poured.

Advantages of Cast-in-Place Concrete Piles

- The shells are light weighted, so they are easy to handle.
- Length of piles can be varied easily.
- The shells may be assembled at sight.
- No excess enforcement is required only to prevent damage from handling.
- No possibility of breaking during installation.
- Additional piles can be provided easily if required.

Disadvantages of Cast-in-Place Concrete Piles

- Installation requires careful supervision and quality control.
- Needs sufficient place on site for storage of the materials used for construction.
- It is difficult to construct cast in situ piles where the underground water flow is heavy.
- Bottom of the pile may not be symmetrical.
- If the pile is un-reinforced and uncased, the pile can fail in tension if there acts and uplifting force.

c) Steel Piles

Steel piles may be of I-section or hollow pipe. They are filled with concrete. The size may vary from 10 inches to 24 inches in diameter and thickness is usually ¾ inches. Because of the small sectional area, the piles are easy to drive. They are mostly used as end-bearing piles.

Advantages of Steel Piles

- They are easy to install.
- They can reach a greater depth comparing to any other type of pile.
- Can penetrate through the hard layer of soil due to the less cross-sectional area.
- It is easy to splice steel piles
- Can carry heavy loads.

Disadvantage of Steel Piles

- Prone to corrosion.
- Has a possibility of deviating while driving?
- Comparatively expensive.

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d) Composite Piles

Composite Piles are those piles of two different materials are driven one over the other, so as to enable them to act together to perform the function of a single pile. In such a combination, advantage is taken of the good qualities of both the materials. These prove economical as they permit the utilization of the great corrosion resistance property of one material with the cheapness or strength of the other. The different stages in the construction of a composite piles having a timber pile at its lower part and precast concrete pile above are shown below. This type of composite pile is used with the object of achieving economy in the cost of piling work. Another type of composite piles commonly used consists of a steel pipe or H-pile at the bottom and cast-in-situ concrete pile at the top. This type of composite pile is recommended in cases where the designed length of the pile works out to be greater than that available for the cast-in-situ type of pile.

2.10 Factors Affecting Selection of Pile Foundation Type

There are several types of pile foundation available to use for a particular project. Few factors influence the selection of a particular type of pile foundation. These factors are noted below-

1. Type and loads from the superstructure.
2. Properties of soil.
3. The depth of the soil layer capable of supporting the piles.
4. Variations in length of pile required.
5. Availability of materials.
6. Durability required.
7. Available equipment for pile driving.
8. Budget.
9. The depth of water level and intensity of underground water flow.
10. Types of surrounding structures.

2.11 Causes of Pile Foundation Failure

Pile foundation is one of the most popular choices for heavy loaded structures and in cases where poor soil conditions are found at a shallow depth. But pile foundations may fail due to different reasons. One must take proper precautions before designing pile foundations so that the possibility of such failure reduces. Causes of failure of pile foundation are given below-

1. Load implied on the pile is greater than designed load.
2. Defecting workmanship.
3. Dislocation of reinforcement of pile.
4. End bearing pile resting on soft strata.
5. Faulty soil investigation.
6. Selecting the wrong type of pile.
7. Under-reinforcement of the pile.
8. A decay of piles. (like attack of insects, corrosion etc.)
9. Deformation of piles due to lateral loads.
10. Incorrect assessment of pile capacity.
11. Not considering lateral forces for designing of piles.

2.12 Difference Between Shallow and Deep Foundation

Foundation is one of the most important parts of the structure. It transfers the total loads from the structure to the soil and provides stability to the structure. Foundation can be primarily classified into two parts, such as Shallow Foundation and Deep Foundation. They are basically classified depending on the depth at which the foundation is provided.

2.13 Shallow Foundation Vs Deep Foundation

Shallow foundation and deep foundation have several differences. Sources of main differences between deep and shallow footings are definition, the depth of foundation, cost, feasibility, mechanism of load transfer, advantages, disadvantages, types, etc. In the following table the main differences between shallow and deep foundation are given:

Sl.No.	Sources	Shallow Foundation	Deep Foundation
1	Definition	Foundation which is placed near the surface of the earth or transfers the loads at shallow depth is called the shallow foundation.	Foundation which is placed at a greater depth or transfers the loads to deep strata is called the deep foundation.

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Sl.No.	Sources	Shallow Foundation	Deep Foundation
2	The depth of the foundation	The depth of shallow foundation is generally about 3 meters or the depth of foundation is less than the footing with.	Greater than the shallow foundation.
3	Cost	A shallow foundation is cheaper.	Deep foundations are generally more expensive than shallow foundations.
4	Feasibility	Shallow foundations are easier to construct.	The construction process of a deep foundation is more complex.
5	Mechanism of load transfer	Shallow foundations transfer loads mostly by end bearing.	Deep foundations rely both on end bearing and skin friction, with few exceptions like end-bearing pile.
6	Advantages	Construction materials are available, less labor is needed, construction procedure is simple at an affordable cost, etc.	Foundation can be provided at a greater depth, Provides lateral support and resists uplift, effective when foundation at shallow depth is not possible, can carry a huge load, etc.
7	Disadvantages	Possibility of a settlement, usually applicable for lightweight structure, weak against lateral loads, etc.	More expensive, needs skilled labors, complex construction procedures, can be time-consuming and some types of deep foundations are not very flexible, etc.
8	Types	Isolated foundation, strip foundation, mat foundation, combined foundation, etc.	Pier foundation, pile foundation, caissons etc.

3.10 Friction Pile, Capacity Calculation & Details

The ultimate bearing capacity of a pile foundation is the maximum load it can carry without any shear failure or excessive settlement. The allowable load on a pile is the load which can be imposed on it with an adequate margin of safety; it can be the ultimate load divided by a suitable factor of safety**.**

Pile foundation, a kind of deep foundation, is actually a slender column or long cylinder made of materials such as concrete or steel which are used to support the structure and transfer the load at desired depth either by end bearing or skin friction.

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Friction pile is a kind of pile foundation. This type of pile utilizes the frictional resistance force between the pile surface and adjacent soil to transfer the superstructure load. Depending on the subsoil strata condition, resistance force due to friction can develop in a definite pile length of on the full length. For a stable foundation condition, the friction force must be adequate to support the superstructure.

3.11 Calculation of Friction Pile Capacity

To calculate the capacity of a friction pile one has to multiply the pile surface area to the safe friction force developed per unit area. The load carrying capacity of a pile can be determined by the following methods:

1) Dynamic formulae 2) Static formulae 3) Pile load tests, and 4) Penetration test Methods of determining 'Load carrying capacity'

The skin friction to be developed at a pile surface should be evaluated sincerely and a reasonable factor of safety should be considered.

3.12 Increase Friction Pile Capacity

To increase the friction pile capacity pile diameter, depth, pile number, and pile surface roughness, etc. can be increased appropriately.

4.10 Major Difference Between Pile and Pier Foundation

Pile and Pier foundations are two different types of deep foundation used in construction. To choose between these two types of deep foundations a foundation engineer must know the differences between them. The main differences between the pier and pile foundation are given below.

S.No.	Pile Foundation	Pier Foundation
1	In pile foundation, the loads are transferred by means of vertical timber, concrete or steel.	Pier foundation consists of cylindrical columns to support and transfer large superimposed loads to firm strata.
2	Piles are driven through the overburden soils into the load-bearing strata.	Piers are drilled with the drill machine.
3	Pile foundations transfer the load through friction (in case of friction piles) or through both friction and bearing (in case of combined end bearing and friction piles).	Pier foundations transfer load through bearing only.
4	Pile foundations are of great depth.	Pier foundations are of shallow depth.
5	Pile Foundation exists where there are no firm strata at reachable depth and the loading is uneven	Pier foundation is used where top strata consist of decomposed rock, stiff clays.
6	The types of pile foundation are end-bearing piles, friction piles, compaction piles, anchor piles, tension or uplift piles, sheet and batter piles, etc.	The types of pier foundations are masonry or concrete piers and drilled caissons.
7	Pile foundation is required to resist greater loads like a load of bridge or flyover.	Pier foundations are required for small loading.

6.10 Conclusion:

There are some advantages and disadvantages of pile foundation:-

6.11 Advantages of Pile Foundation

- ❖ According to the specification we pre-order the pile
- ❖ The pile can be pre-made its length breadth its size according to site use
- ❖ Precast is the process through which reducing the completion time
- ❖ Can be installed in a very large area.
- ❖ Can be installed in very long lengths.
- ❖ We can use piles in a place where drilling and holes are not done.
- ❖ Work of pile is very neat and clean.

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6.12 Disadvantages of Pile Foundation

- A pile can be damaged quickly by driving through stones and boulders.
- Piles are can be attacked by marine borers in salt water
- A pile cannot be above ground level.
- It is very difficult to know the actual required length in advance.
- Vibrations generate when piles are driving which affects the neighbouring structures.
- Heavy equipment is required by driving the piles.
- Pile is not containable for low drainage.

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BIOGRAPHY

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Chief Geo Technical Expert-Bhopal Metro Project,Working since 06-02-2020
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Overall responsible for the project Construction management of design n build FIDIC contract, and GTI & Underground Strucures,operations for completion.
:: SADBHAV GROUP Feb.2014-May.2015 General Manager-Tunnel
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