Types of Foundations

Course No: 2025-31-04
Credit: 2 PDH

Najib Gerges, Ph.D., P.E.

CED engineering.com
PDH FOR THE PROFESSIONAL

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.com

Table of Contents

List of Figures

Section 1 — Definition

Overview

The definition of the term’s root words points to its archeological origins. The word “foundation” comes from the Latin word “fundatio” or “fundare”, which means “to lay a base for,” “confirm,” or “establish.” Fundare can also mean bottom or base.

“Fonder” and “fondation” arose as Old French words, and merged with the English word “found” to create “foundation” in late Middle English. The word “foundation” has declined in use since the 1760’s. The section below shows the popularity of the word foundation in print media since the 1500’s.

History

Foundations in America and Worldwide

Without a solid foundation, how does the home look like? In modern-day America, it is rare to find a home with a truly weak and dangerous foundation. But globally, there are millions of homes built without solid foundations. It can be looked to these for examples of what not to do—and why a foundational structure is the key to keeping the family safe for the long term.

Heading over to areas of South America, a wide array of what are known as stilt houses are likely to be observed. A stilt house is built upon raised piles, typically over a body of water. Stilt houses help to prevent flooding in low-lying areas. More and more houses along the Gulf Coast are being constructed or converted into stilt houses. This is not to say that the stilt house is necessarily all bad. Modern stilt houses use sturdy steel materials, in order to ensure longevity. However, the old-fashioned wood stilt house may not provide the most solid foundation over the years.

Two other common examples are the pithouse, which typically consists of a hole dug in the ground surrounded by wood and mud, and the house built upon a saddle stone foundation: a structure resting only a few solid rocks.

Home Foundations of the Past and Present

Foundations are probably taken for granted. It is assumed that most American homes have a solid foundation, due to the fact that people live in a developed nation with safe and secure residential structures, as opposed to an impoverished community where grass and straw huts make up the majority of built homes?

It is important to remember that even in contemporary America, foundations were not always as solid as they use to be. Foundations, and the methods of repairing them, have come a long way. The history of foundation repair methods is actually quite fascinating.

Roughly 15,000 years ago in the Upper Paleolithic age, the earliest remains of "pit dwellings" were discovered. Typically, pit dwellings relied on a dug-out area in the ground surrounded by a structure of wood, animal hide, or even bone. It is still debated whether these pit dwellings were used as homes or storage pits.

Either way, postholes were later added to pit dwellings to provide additional support for a roof. This is the first early example of post in-ground construction. Early postholes were dug to support wood or stone protruding from the ground. This is the earliest type of "foundation" used. The process involved digging out of the ground, or simply placing a post within the ground, to stabilize the structure.

The earliest known use of primitive concrete appeared in 6500 BCE. These solid structures were popularized by Nabataea traders in ancient Syria and Jordan. They were able to construct simple concrete foundations and floors, as well as rubble houses. Some of these structures still exist today.

The Roman Empire

Possibly the most famous example of concrete use was by the Romans. In fact, the Romans may have been one of the first civilizations to utilize concrete foundation repair. They would add horsehair to concrete to reduce the liability of cracks when the concrete hardened. The Romans also discovered that adding blood would make concrete more resistant to frost.

While this understandably sounds archaic to modern homeowners, the Romans' sophisticated understanding of foundation repair is nonetheless an indication of how this massive, powerful empire used the resources of a flourishing industrial revolution to construct buildings that remain standing to this day.

For the next 700 years, the Romans used concrete extensively. It allowed them to make more complex structures such as domes, arches, and vaults. After the fall of the Roman Empire, knowledge of concrete was lost—until around the 14th century, when it gradually began to make a resurgence.

It was not until hundreds of years later, in 1849, when reinforced concrete was invented, along with massive structures like the Hoover Dam.

The Early Bronze Age and Beyond

Around the Early Bronze Age in the 21st century BCE, the earliest large-scale buildings started to appear. These buildings appeared to have been constructed with even more advanced techniques involving stone and brick. The larger buildings and temples were built with stone foundations.

From this point onwards, foundations split into multiple techniques all over the world. In England and Northern Spain, padstones were commonplace. In Germany, German fachwerkhaus was a popular housing design. Additionally, Poteaux-sur-sol ("post on a sill") construction was a type of post in ground construction used by the early French settlers of North America between 1534 – 1763.

Rubble trench foundations, an ancient style of construction, was brought back to life and popularized by Frank Lloyd Wright in the late 1800's and early 1900's. Rubble trench foundations utilized rubble and loose stone to improve drainage and reduce the use of concrete.

To properly create a rubble trench foundation, a hole was dug below the frost line. The frost line is used to describe the depth at which groundwater in the soil freezes, and it varies slightly depending on the climate. It ranges from zero to six feet in the United States alone. Most building codes require foundations to meet the frost depth requirement, since frost heaving can cause significant damage to a building's foundation.

Evolution of the Modern Foundation

Of course, with the advancement of foundation technology, foundation repair techniques also changed. Unfortunately, before the technology had caught up with foundations, there was typically not much that could be done for older foundations in need of repair.

Minor repairs, like cracked plaster in stone foundations, could possibly be repaired, but major repairs like crumbly mortar or gaps in the joints may have required a professional mason to resolve.

It was not until the mid-20th century that technology advanced enough to allow contractors to dig deep foundation holes. This allowed for the rise of taller buildings, and eventually skyscrapers, now common to every major industrialized city in the Western world. Deep foundations allowed for larger design loads using excavation and drilling. Experts found that timber could be used for deep foundations, as well as the old standards: concrete and steel.

Foundation Repair Tools and Methods

Deep foundations are typically installed using a pile driver. Pile drivers have a unique history of their own. The earliest known pile drivers were used around 55 BC by the Romans, and the earliest known drawing of a pile driver appeared in 1475. Modern pile drivers use hydraulic motors, counter-rotating weights, and vibrations to install foundations more than one hundred feet into the ground.

The other type of modern foundation is the shallow foundation. Shallow foundations transfer soil loads to the surface rather than a range of depths like a deep foundation. Typically, shallow foundations include earthbag foundations, slab-on-grade foundations, and rubble trench foundations.

Today, foundations can be repaired with advanced machinery. Techniques that were technically impossible in generations past can now be easily resolved by basement foundation companies with expertise in foundation repair. Foundations can be repaired and even strengthened, adding durability to the building.

Some of the tools used for modern day foundation repair include screw-piles (or helical piles), earth anchors, and retaining walls. Helical piles themselves are not a new technology. Screw foundations appeared as early as the 1800's, primarily used as pile foundations for lighthouses as well as piers for harbors. The wrought-iron screw-pile was created by Alexander Mitchell in 1833, allowing for improved construction over the standard straight-pile method. However, helical piles had existed for over a decade by the time Mitchell introduced his new screw-pile design. Screw-pile lighthouses and piers stand on piles that screwed into sandy river and ocean bottoms. Over one hundred screw-pile lighthouses were placed along the United States east coast between the 1850's and 1890's.

The original helical piers had limited load-bearing capacity. Modern-day helical piers can hold a weight exceeding 200 metric tons. Modern helical piers also offer a variety of designs for different concrete and steel structures. They are still used today for roads, rails, lighthouses, and telecommunications. They are heavily favored for their ability to be used on pre-existing structures, as well as their fast installation. Helical piers offer a number of benefits, including easier installation, shorten project times, reduced costs and risk, and a smaller carbon footprint.

Retaining Walls: Earth Anchors & Helical Tiebacks

Retaining walls are another design in the foundation family that have existed for some time in history. Retaining walls are designed specifically to prevent sloped soil from naturally falling off. They are especially useful on hills and steep slopes, and they allow for two different elevations in areas that would typically be surrounded by hills.

The most recognizable type of retaining wall that you may be familiar with is a basement wall. A basement wall allows for a flat elevation, such as a basement, where the surrounding soil is uneven or sloped. Basement walls are built to resist pressures and pushes from the surrounding soil, but sometimes they need extra support. Earth anchors are another modern form of basement repair that have proven to be highly effective. They are also known as ground anchors or mechanical anchors. Earth anchors can be used to support retaining walls. Similarly, helical tiebacks can also be used to provide additional support for retaining walls. Unlike an earth anchor, helical tiebacks are horizontal wires or rods that are used to reinforce and stabilize retaining walls. One end of the helical tieback is anchored into the surrounding soil, while the other end is attached and secured to the wall. Helical tiebacks also work hand-in-hand with helical anchors.

As can be observed, foundations and foundation repair methods have a long and interesting history. Some knowledge was lost, some was improved upon, and who knows what will be discovered about foundation technology in the future?

Section 2 — Types of Foundations

Overview

Foundation is one of the essential parts of the structure. It is defined as that part of the structure that transfers the load from the structure constructed on it, as well as its weight over a large area of soil in such a way that the amount does not exceed the ultimate bearing capacity of the soil and the settlement of the whole structure remains within a tolerable limit. Foundation is the part of a structure on which the building stands and provides stability to the structure. The solid ground on which it rests is known as foundation bed.

The foundation should fulfill the following objectives:

- Distribute the weight of the structure over a large area of soil.
- Avoid unequal settlement.
- Prevent the lateral movement of the structure.
- Increase the structural stability.

There are different types of soil, and the bearing capacity of the soil is different for each type of soil. Depending on the soil profile, size, and load of the structure, engineers chose different kinds of foundation.

In general, all foundations are divided into two categories, shallow and deep foundations. The terms Shallow and Deep Foundation refer to the depth of the soil at which it is placed. Generally, if the width of the foundation is greater than the depth, it is labeled as "Shallow Foundation". If the width is smaller than the depth of the foundation it is called "Deep Foundation." However, deep foundations and shallow foundations can be classified as shown in Figure 1.

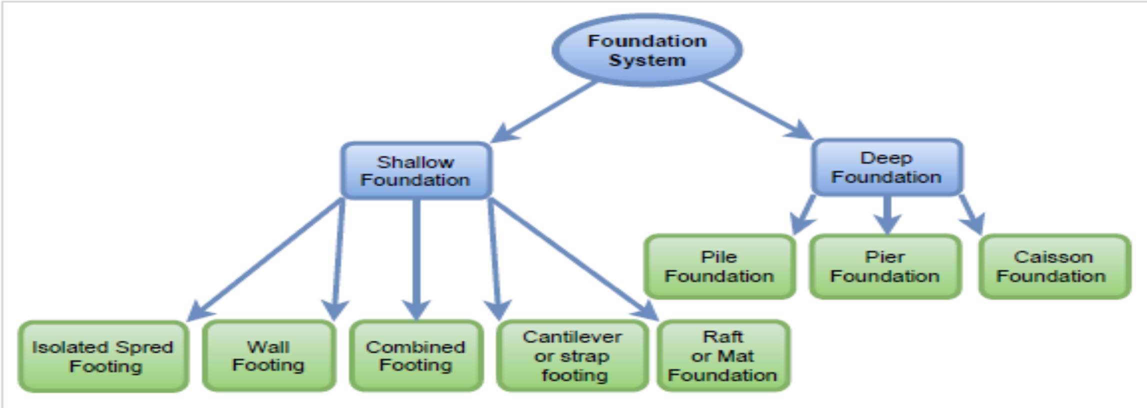


Figure 1 Classification of Deep Foundations and Shallow Foundations

The main aspects of different types of foundation, along with their images, are discussed below. As economic feasibility is one of the main factors in the type selection, it is also discussed briefly with each type.

Shallow foundation and deep foundation have several differences. The sources of the main differences between deep and shallow footings are definition, depth of foundation, cost, feasibility, mechanism of load transfer, advantages, disadvantages, types, etc. In Table 1, the main differences between shallow and deep foundation are provided.

	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.
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.

Table 1 Shallow Foundations vs. Deep Foundations

Shallow Foundations

As the shallow foundation depth is low and it is economical, it is the most popular type of foundation for lightweight structures. A shallow foundation is one in which the depth from the ground surface to the underside of the foundation is less than five times the width of the foundation. All other foundations are considered deep foundations. The types of shallow foundations are discussed below.

Isolated Spread Footings

This is the most widely recognized and most straightforward shallow foundation type, as this is the most economical type. They are typically utilized for shallow establishments to convey and spread concentrated burdens caused, for instance, by pillars or columns. They are generally used for ordinary buildings (Typically up to five stories). Refer to Figure 2.

Isolated footing comprises a foundation directly at the base of the segment. Generally, every section has its footing. They straightforwardly transfer the loads from the column to the soil. It might be rectangular, square, or roundabout.

Isolated spread footings can comprise both reinforced or non-reinforced material. For the non-reinforced footing, however, the stature of the footing has to be more prominent to give the vital spreading of the load.

Isolated spread footings should possibly be utilized when it is sure beyond a shadow of a doubt that no differing settlements will happen under the whole structure.

Spread footings are inadmissible for the orientation of large loads. It is given to lessen the twisting minutes and shearing powers in their primary areas.

Figure 2 Isolated Shallow Foundation Image

The size of the footing can be roughly calculated by dividing the total load at the column base by the allowable bearing capacity of the soil.

The followings are the types of spread footing:

- *Single Pad Footing* (Figure 3): are commonly used for shallow foundations in order to carry and spread concentrated loads, caused for example by columns or pillars. Isolated footings can consist either of reinforced or non-reinforced material.

- *Stepped Footing for a Column* (Figure 4): consists of a series of concrete prisms of progressively smaller lateral dimensions, one above the other, to distribute the load of a column to the subgrade.

- *Sloped Footing for a Column* (Figure 5): Sloped or trapezoidal footings are designed and executed with utmost attention to maintain a top slope of 45 degrees from all sides. The amount of reinforcement and concrete used in the sloped footing construction is less than that of plain isolated footing. Therefore, it decreases the utilization of concrete and reinforcement.

- *Wall Footing without Step* (Figure 6): Wall footings are pad or spread and strip footings which are used to support structural or nonstructural walls to transmit and distribute the loads to the soil in such a manner that the load-bearing capacity of the soil is not surpassed. In addition to avoiding excessive settlement and rotation and maintain sufficient safety against sliding and overturning.

  Wall footing runs along the direction of the wall. The size of the footing and the thickness of the foundation wall are specified on the basis of the type of soil at the site. The width of the wall footing is generally 2-3 times the width of the wall.

  The wall footing can be constructed from stone, brick, plain concrete, or reinforced concrete. Economical wall footing can be constructed provided that the imposed load needed to be transmitted are of small magnitude and the underlying soil layer is of dense sand and gravels. Therefore, wall footing is best suited for small buildings.

- *Stepped Footing for Walls* (Figure 7): consists of a series of concrete prisms of progressively smaller lateral dimensions, one above the other, to distribute the load of a wall to the subgrade.

- *Grillage Foundation* (Figure 8): consists of one, two, or more tiers of beams (typically steel) superimposed on a layer of concrete to disperse load over an extensive area. It is used at the base of columns. These tiers are encased in concrete and are at right angles to each other.

To decide when to use shallow foundations, it is necessary to know when it is economical. It is economical when:

- The load of the structure is relatively low.
- Columns are not closely placed.
- The bearing capacity of the soil is high at a shallow depth.

Figure 3 Single Pad Footing

Figure 4 Stepped Footing for a Column

Figure 5 Sloped Footing for a Column

Figure 6 Wall Footing without a Step

Figure 7 Stepped Footing for Walls

Figure 8 Grillage Foundation

Wall Footings or Strip Footings

Wall footing (Strip footing) is also known as continuous footing. This type is used to distribute the loads of structural or nonstructural load-bearing walls to the ground in such a way that the load-bearing limit of the soil is not outperformed. It runs along the direction of the wall. The width of the wall foundation is usually 2-3 times the width of the wall. Refer to Figure 9.

Figure 9 Wall Footing or Strip Footing Image

The wall footing is a continuous slab strip along the length of the wall. Stone, brick, reinforced concrete, etc. are used for the construction of wall foundations.

- On account of block walls, the footing comprises a few courses of bricks, the least course being generally double the expansiveness of the wall above.
- On account of stone masonry walls, the counterbalances could be 15 cm, with the statues of the course as 30 cm. Along these lines, the size of footings is marginally more than that of the block divider footings.
- If the heap on the wall is substantial or the soil is of low bearing limit, this reinforced concrete foundation type can be given.

Wall footing is economical when:

- Loads to be transmitted are of small magnitude.
- It is placed on dense sand and gravel.

Combined Footings

The combined footing is very similar to the isolated footing. When the columns of the structure are carefully placed, or the bearing capacity of the soil is low and their footing overlap each other, combined footing is provided. It is fundamentally a blend of different footings, which uses the properties of various balances in a single footing dependent on the necessity of the structure (Refer to Figure 10).

The foundations which are made common to more than one column are called *combined footings*. There are different types of combined footing, including slab type, slab and beam type, rectangular, raft, and strap beam type. They may be square, tee-shaped, or trapezoidal. The main objective is the uniform distribution of loads under the entire area of footing, for this is necessary to coincide with the center of gravity of the footing area with the center of gravity of the total loads.

Figure 10 Combined Footing Image

Combined foundations are economic when:

- The columns are placed close to each other.
- When the column is close to the property line and the isolated footing would cross the property line or become eccentric.
- Dimensions of one side of the footing are restricted to some lower value.

Cantilever or Strap Footings

Strap footings are similar to combined footings. Reasons for considering or choosing strap footing are identical to the combined one.

In *strap footing*, the foundation under the columns is built individually and connected by a strap beam. Generally, when the edge of the footing cannot be extended beyond the property line, the exterior footing is connected by a strap beam with interior footing (Refer to Figure 11).

Figure 11 Cantilever or Strap Footing Image

Raft or Mat Foundations

Raft or mat foundations are used where other shallow or pile foundations are not suitable. It is also recommended in situations where the bearing capacity of the soil is inadequate, the load of the structure is to be distributed over a large area or structure is subjected continuously to shocks or jerks (Refer to Figure 12).

Raft foundation consists of a reinforced concrete slab or T-beam slab placed over the entire area of the structure. In this type, the whole basement floor slab acts as the foundation. The total load of the structure is spread evenly over the entire area of the structure. This is called raft because, in this case, the building seems like a vessel that floats on a sea of soil.

Figure 12 Raft or Mat Foundation Image

Raft foundations are economic when:

- The soil is weak (low bearing capacity) and the load has to be spread over a large area.
- Individual or any other foundation area that approximately covers 50% of the total ground area beneath the structure.
- The structure includes a basement.
- Columns are closely placed such that the individual footings would overlap.
- Stress on soil needs to be reduced.
- Other kinds of foundations are not feasible.
- Differential settlement is to be prevented.
- When soil strata are unpredictable and contain pockets of compressible soil.

Types of Raft or Mat Foundations

Several types of raft foundation may be used depending on the condition of soil and the load imposed on the foundation.

Followings are the different types of raft foundation used in construction:

- *Flat Plate Mat* (Figure 13): This is the simplest form of raft foundation. This type of mat is used when the columns and walls are uniformly spaced at small intervals and the subjected loads are relatively small. Reinforcement is placed in both directions and more reinforcement is required at the column locations and load-bearing walls. The thickness of this types of raft foundation is generally restricted within 300mm for economic reason. A thicker slab would not be economical.

- *Plate Thickened under the Column* (Figure 14): When the columns and load bearing walls are subjected to heavier loads, the slab is thickened under the columns and walls and extra reinforcement is provided to resist against diagonal shear and negative reinforcement.

- *Two-Way Beam and Slab Raft* (Figure 15): In this type of raft, beams are cast monolithically with the raft slab connecting the columns and walls. This type of raft is suitable when the columns are placed at a larger distance and the loads on the columns are variable.

- *Plate Raft with Pedestals* (Figure 16): In this type of mat, a pedestal is provided at the base of the columns. Purpose of this type of foundation is same as flat plate thickened under columns.

- *Piled Raft* (Figure 17): This type of raft foundation is supported on piles. A piled raft is used when the soil at a shallow depth is highly compressible and the water table is high. Piles under raft help in reducing settlement and provides resistance against buoyancy.

- *Rigid Frame Mat or Cellular Raft Foundation* (Figure 18): In this type of raft, the foundation walls act as a deep beam. Rigid frame mat is referred when columns carry extremely heavy loads and the connecting beams exceeds 90cm depth. Here two concrete slabs are placed, one on top of another and connected with foundation walls in both directions and thus forms a cellular raft foundation. This type of raft is very rigid and is economical when the required slab thickness is very high.


Mat Foundations

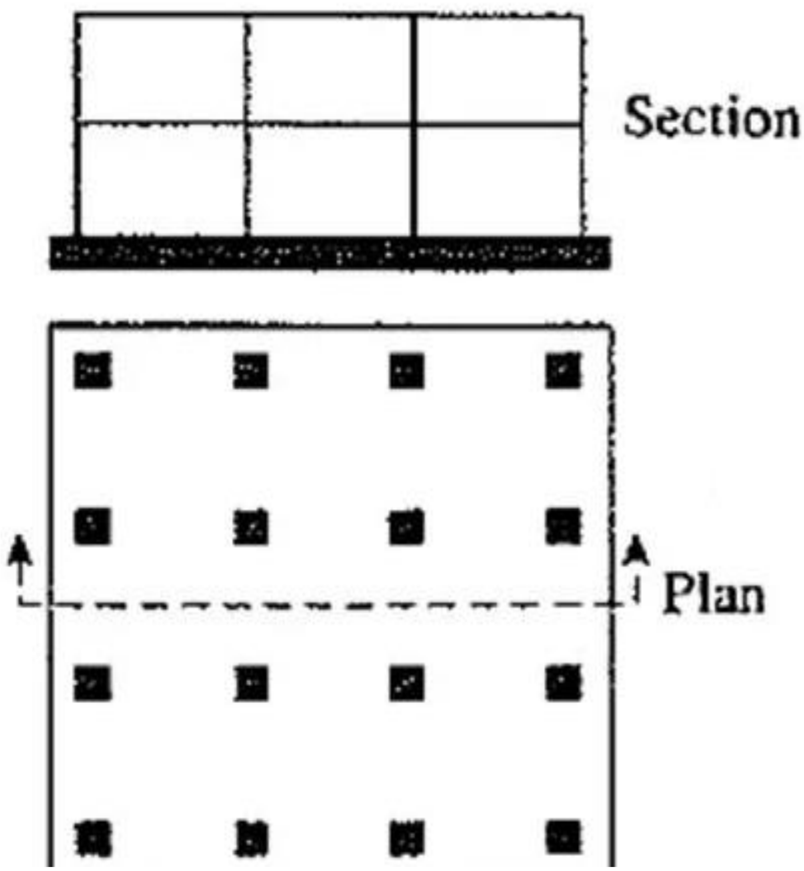

Section
Plan

Figure 13 Flat Plain Mat Foundation Image

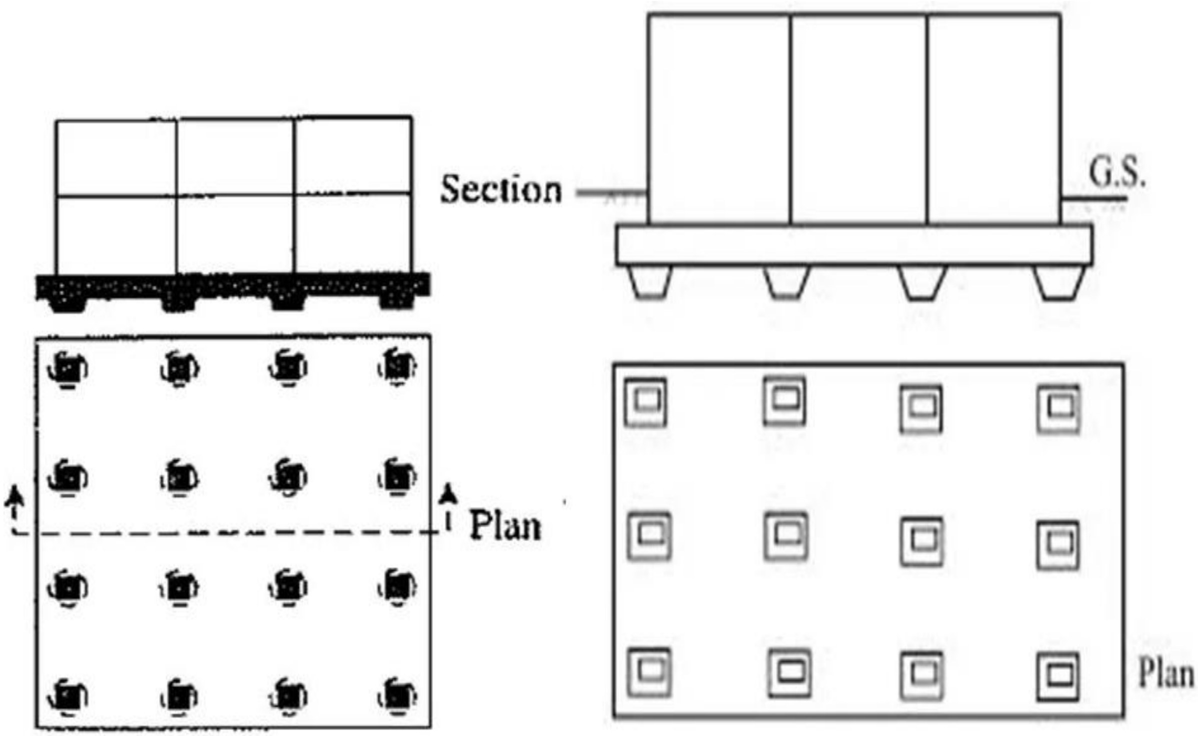


Figure 14 Plate Thickened under the Column Image

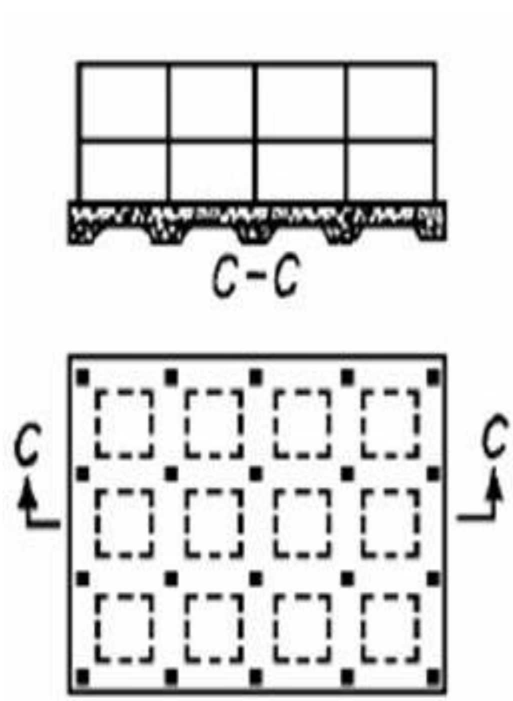


Figure 15 Two-Way Beam and Slab Raft Image

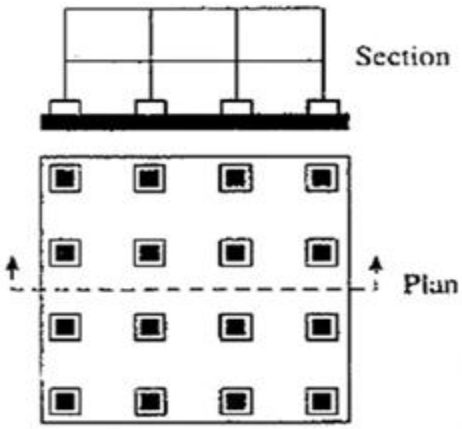
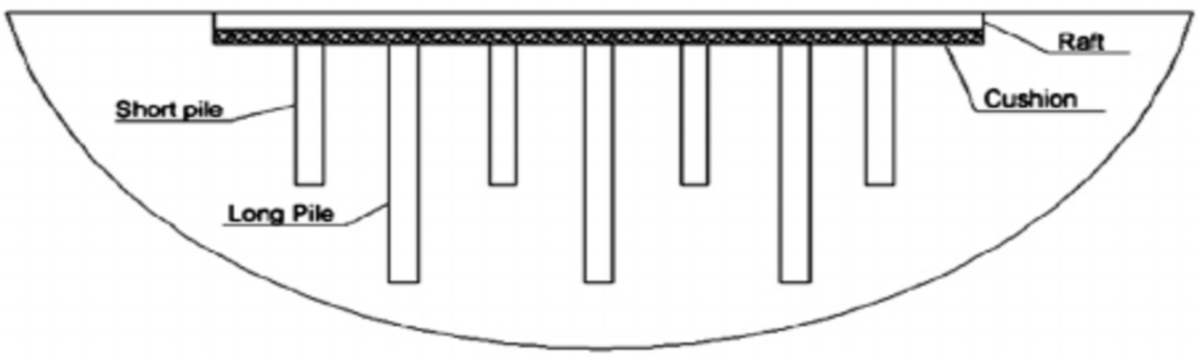


Figure 16 Plate Raft with Pedestals Image



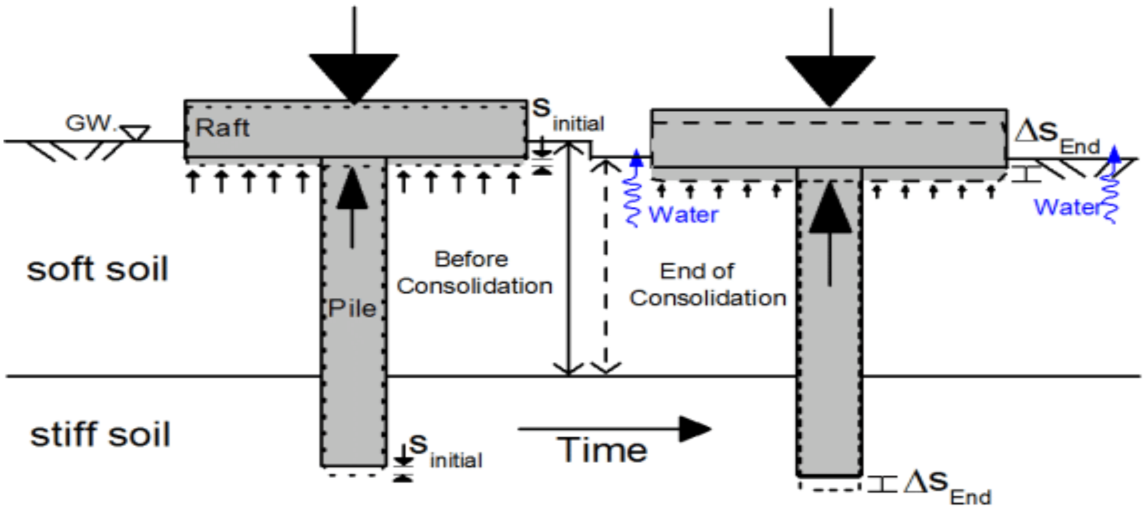


Figure 17 Pile Raft Foundation Image

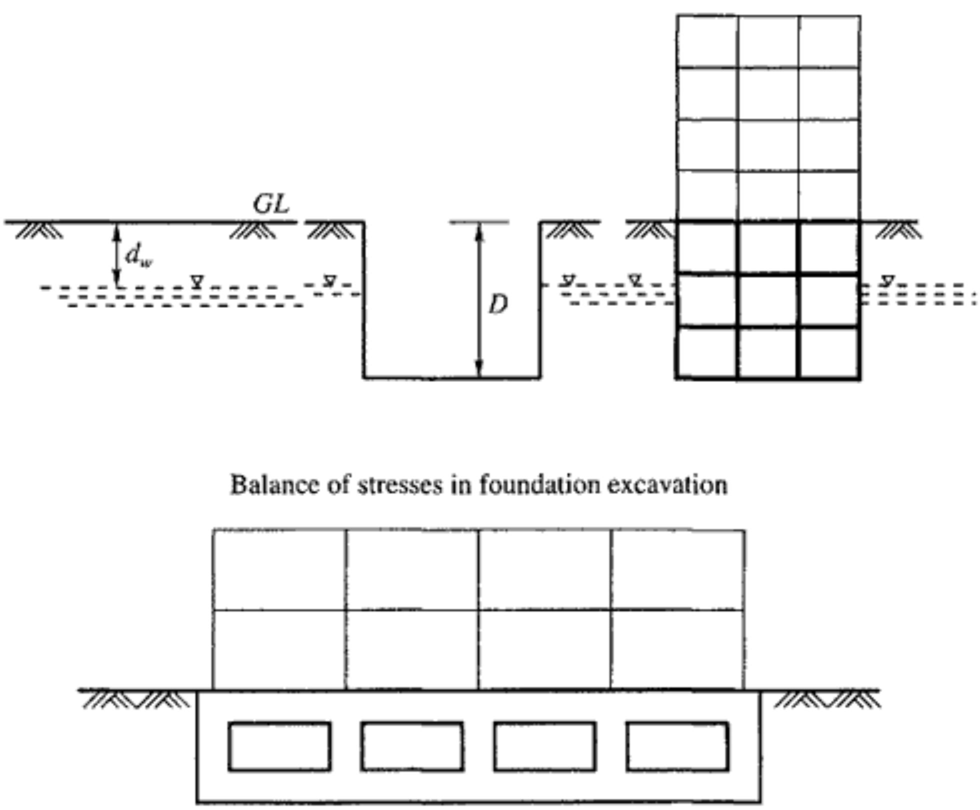


Figure 18 Rigid Frame Mat or Cellular Raft Foundation Image

Deep Foundations

A deep foundation is a type of foundation which is placed at a greater depth below the ground surface and transfers structure loads to the earth at depth. The depth to width ratio of such a foundation is usually greater than 4 to 5. The followings are the types of deep foundation.

Pile Foundations

Piles are common types of deep foundation. They are used to reduce cost, and when as per soil condition considerations, it is desirable to transmit loads to soil strata which are beyond the reach of shallow foundations.

The followings are the types of pile foundations based on function or use:

- *Sheet Piles* (Figure 19): Sheet piles are sections of sheet materials with interlocking edges that are driven into the ground to provide earth retention and excavation support. Sheet piles are most commonly made of steel, but can also be formed of timber or reinforced concrete. Sheet piles are commonly used for retaining walls, land reclamation, underground structures such as car parks and basements, in marine locations for riverbank protection, seawalls, cofferdams, and so on.

Figure 19 Sheet Pile Image

- *Load Bearing Piles* (Figure 20): 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. A load bearing pile is the type of pile foundation that transfers the vertical loads of the structure to the underlying soil by either an end-bearing mechanism or by frictional mechanism.

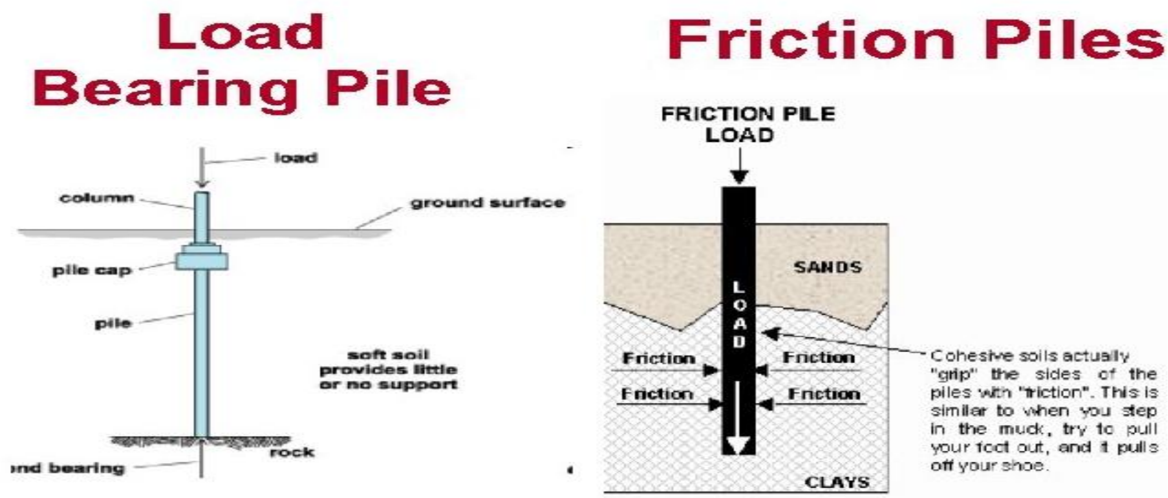


Figure 20 Load Bearing Pile Image

The types of load bearing piles are:

- *End Bearing Piles:* The end-bearing piles are driven into the ground such that the bottom end tip of the pile rests at the intermediate layer between weak and strong soil layers. End-bearing piles act as a column and transfer the load coming from the superstructure to the underlying soil.

- *Friction Piles:* The friction pile is the type of load-bearing pile that transfers the load to the soil by the friction mechanism between the surface of the pile and the surrounding soil layer. Friction force can be developed along the entire length of the pile or a certain length of the pile depending upon the strata of the soil. Unlike end-bearing piles, in friction piles, the entire pile surface functions to transfer the loads from the superstructure to the soil.

- *Soil Compactor Piles* (Figure 21): One of a group of piles, driven in a pattern, to compact a surface layer of loose granular soil to increase its bearing capacity.

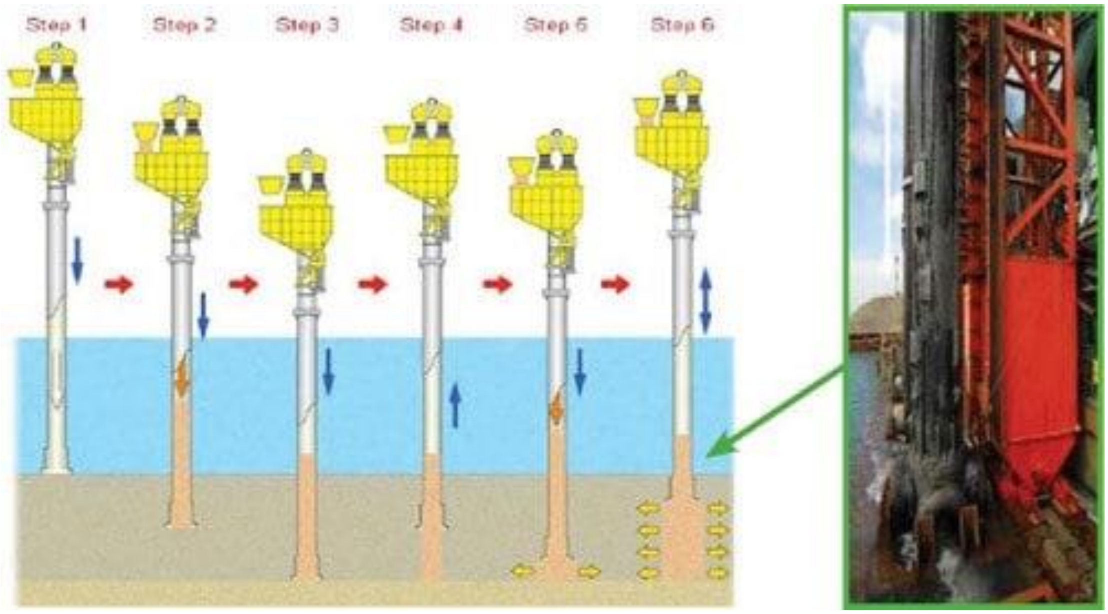


Figure 21 Soil Compactor Pile Image

The followings are the types of pile foundations based on materials and construction method:

- *Timber Piles* (Figure 22): Timber pile is a trunk of a tree, trimmed of branches. A timber pile is usually designed for a maximum load of 15 to 25 tons/pile. Additional strength can be obtained by bolting fish plates to its side. These piles last for about 30 years. The breadth of these piles ranges from 12 to 16 inches.

Figure 22 Timber Pile Image

- *Concrete Piles* (Figure 23): A concrete pile is a foundation driven deep into the ground to support the structure, unlike shallow or wide foundations such as isolated footings or combined footings. They are usually much thinner in diameter or width than in length.

Figure 23 Concrete Pile Image

- *Steel Piles* (Figure 24): Basically, steel piles are a big screw, made of galvanized steel with a helical flange that not only helps to insert the pile, but also helps secure it into the ground. By using a mini-excavator with special attachments, a drill can enter the ground while measuring the load bearing capacity of the soil.

Figure 24 Steel Pile Image

- *Composite Piles* (Figure 25): 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.

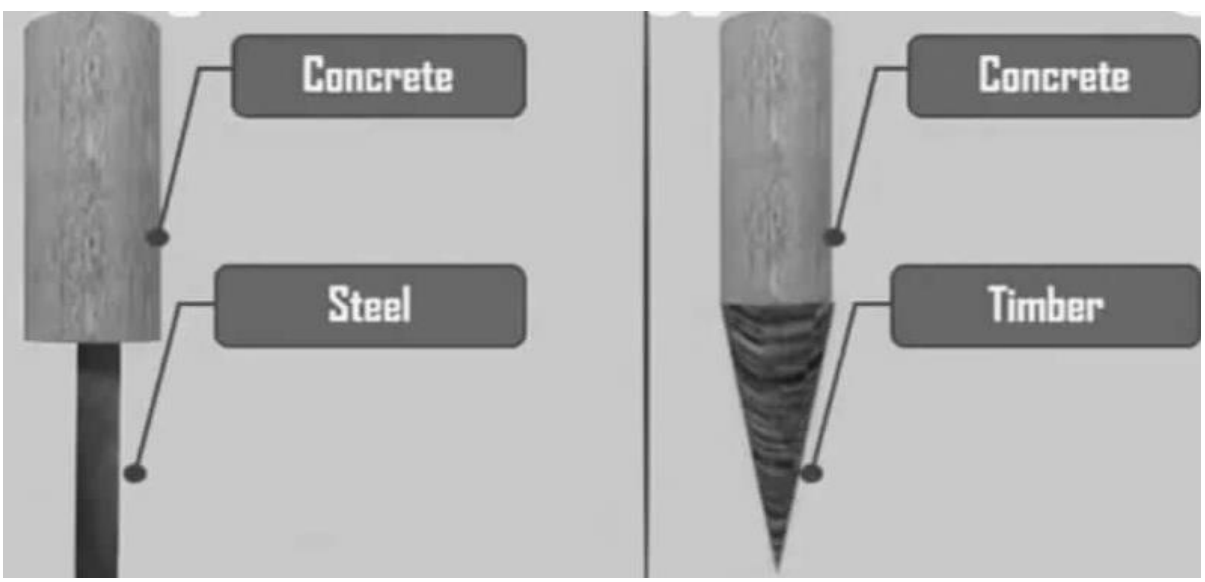


Figure 25 Composite Pile Image

Pile is a slender member with a small cross-sectional area compared to its length. It is used to transmit foundation loads to a deeper soil or rock strata when the bearing capacity of soil near the surface is relatively low. Pile transmits load either by skin friction or bearing. Piles are also used to resist structures against uplift and provide structures stability against lateral and overturning forces.

Pile foundations are economic when:

- Soil with great bearing capacity is at a greater depth.
- When there are chances of construction of irrigation canals in the nearby area.
- When it is very expensive to provide raft or grillage.
- When the foundation is subjected to a heavily concentrated load.
- In marshy places.
- When the topsoil layer is compressible in nature.
- In the case of bridges, when the scouring is more in the river bed.

Pier Foundations

Pier is an underground structure that transmits a more massive load, which cannot be carried by shallow foundations. It is usually shallower than piles. The pier foundation is generally utilized in multi-story structures. Since the base region is determined by the plan strategy for the regular establishment, the single pier load test is wiped out. Along these lines, it is increasingly well known under tight conditions. Refer to Figure 26.

Pier foundation is a cylindrical structural member that transfers heavy load from the superstructure to the soil by end bearing. Unlike piles, it can only transfer load by bearing and by not skin friction.

Pier foundation is economic when:

- Sound rock strata lie under a decomposed rock layer at the top.
- The topsoil is stiff clay which resists driving the bearing pile.
- When a heavy load is to be transferred to the soil.

Pier foundation has many advantages:

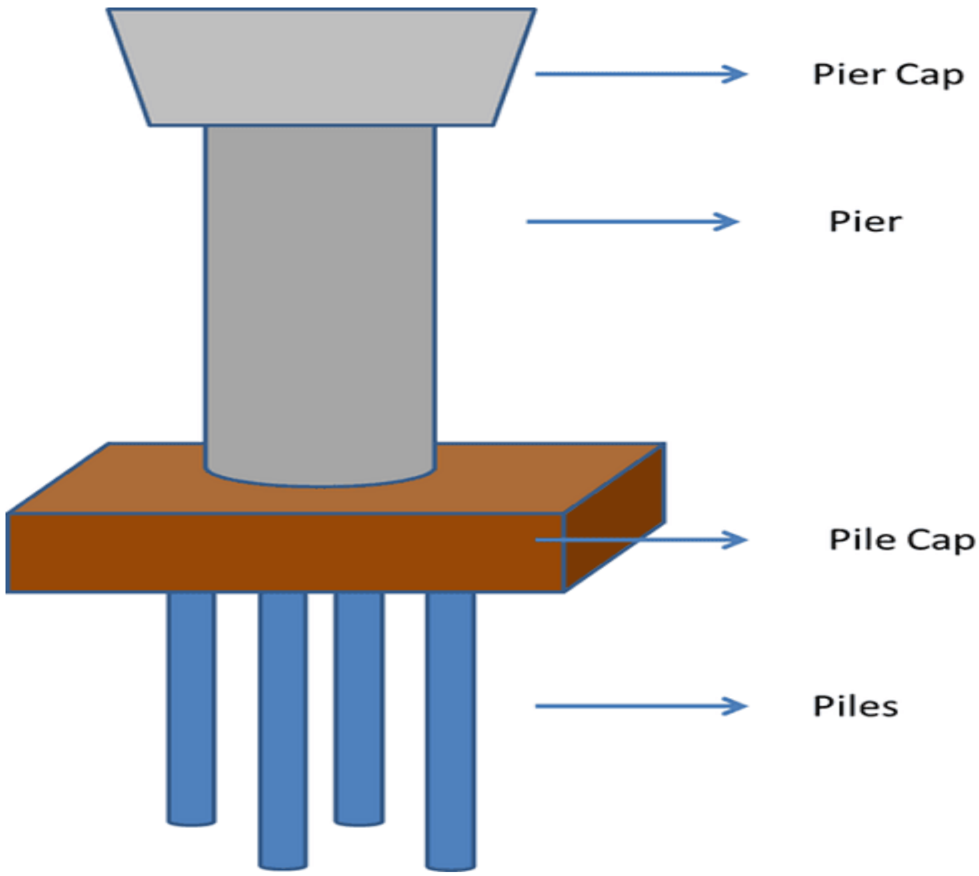


Figure 26 Pier Foundation Image

- It has a broad scope of assortment with regards to structure. There are different materials to build a stylish view, and stays within spending limit.
- It sets aside cash and time as it does not require broad removal of a ton of cement.
- Bearing limits can increment by under-reaming the base.

Along with the advantages, it has a few disadvantages as well:

- If one post or dock is harmed, it can prompt critical harm to the general establishment.
- It can be vitality wasteful if not protected appropriately.
- Floors must be intensely, vigorously protected, and shielded from critters.

Caisson Foundations

Caisson foundation is a watertight retaining structure used as a bridge pier, construction of the dam, etc. It is generally used in structures that require foundation beneath a river or similar water bodies. The reason for choosing the caisson is that it can be floated to the desired location and then sunk into place. Refer to Figure 27.

Caisson foundation is a ready-made hollow cylinder depressed into the soil up to the desired level and then filled with concrete, which ultimately converts to a foundation. It is mostly used as bridge piers. Caissons are sensitive to construction procedures and lack construction expertise.

Figure 27 Caisson Foundation Image

There are several types of caisson foundations:

Box Caissons (Figure 28): A box caisson is a structure designed to allow construction activities to be carried out on water or in wet environments. These watertight caissons may be constructed from timber, steel or reinforced concrete. The structure is first assembled on land, and is then sunk into to the appropriate location using sand, concrete or gravel for additional weight.

Floating Caissons (Figure 29): The floating caissons are prefabricated concrete box-like elements with cylinder cavities or cells that are built with the help of a special equipment named "Floating Docks." The floating caissons dimensions are customized to each project requirements within certain limits.

Pneumatic Caissons (Figure 30): A pneumatic caisson is a watertight box or cylinder-like structure that is closed at the top and open at the bottom, resting on the bed of the waterbody.

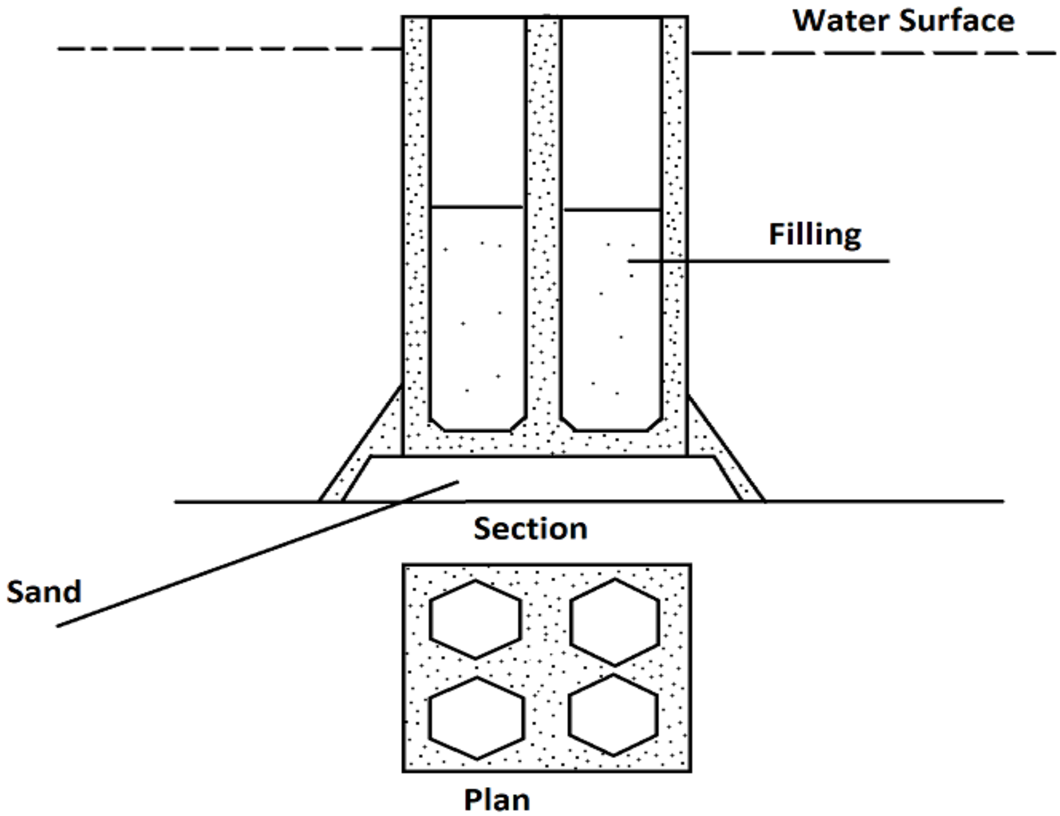


Figure 28 Box Caisson Image

Figure 29 Floating Caisson Image

They are used for underwater construction of foundations for bridge piers, abutments in rivers, and foundations for large multi-story buildings. They are designed to keep water out of the construction zone and act as a seal that keeps the inside of the caisson dry for workers to carry out work safely.

The inside of the caisson is kept dry by using compressed air to force water out of the structure. This process creates an airtight working chamber where construction activities, such as excavations, can be carried out safely. Pneumatic caissons are ideal for challenging situations where it is not possible to carry out wet ground excavations in the open. However, this method is complex, time-consuming, and relatively expensive when compared to other types of caissons.

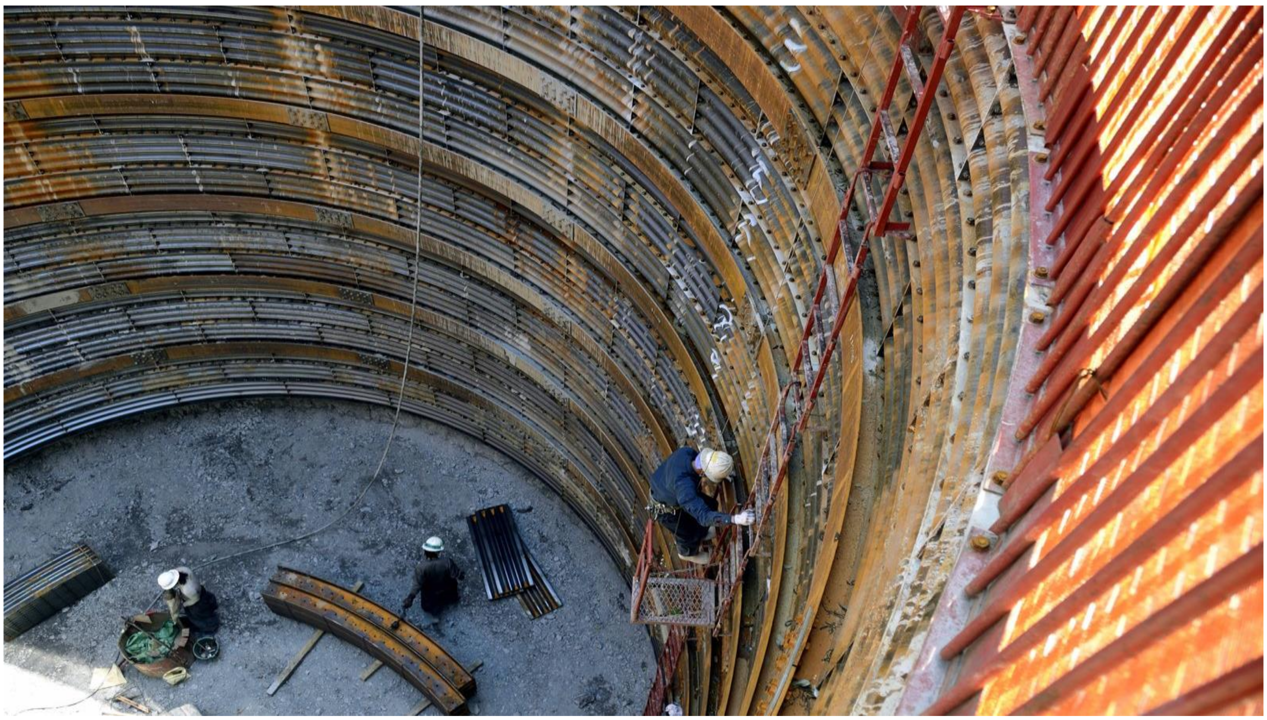


Figure 30 Pneumatic Caisson Image

Open Caissons (Figure 31): An open caisson, open at both the bottom and the top, is fitted with a cutting bottom edge, which facilitates sinking through soft material while excavation is carried out inside through a honeycomb of large pipes, or dredging wells. As excavating proceeds and the caisson sinks, additional sections are added to the shaft above. This process is continued until the caisson has sunk to the required depth. A floor, usually of concrete, is laid to provide a bottom seal. The dredging wells can then be filled with concrete to complete the structure.

Excavated Caissons (Figure 32): Excavated caissons are just as the name suggests, caissons that are placed within an excavated site. These are usually cylindrical in shape and then back filled with concrete.

Figure 31 Open Caisson Image

Figure 32 Excavated Caisson Image

Caisson foundations are economic when:

- The pile cap requirement is to be minimized.
- Noise and vibration needed to be reduced.
- Highly lateral and axial loading capacity is required.
- It has to be placed beneath water bodies.

Section 3 — References

The Foundation Engineering Handbook, 2nd Edition, Edited by Manjriker Gunaratne Copyright Year 2014.