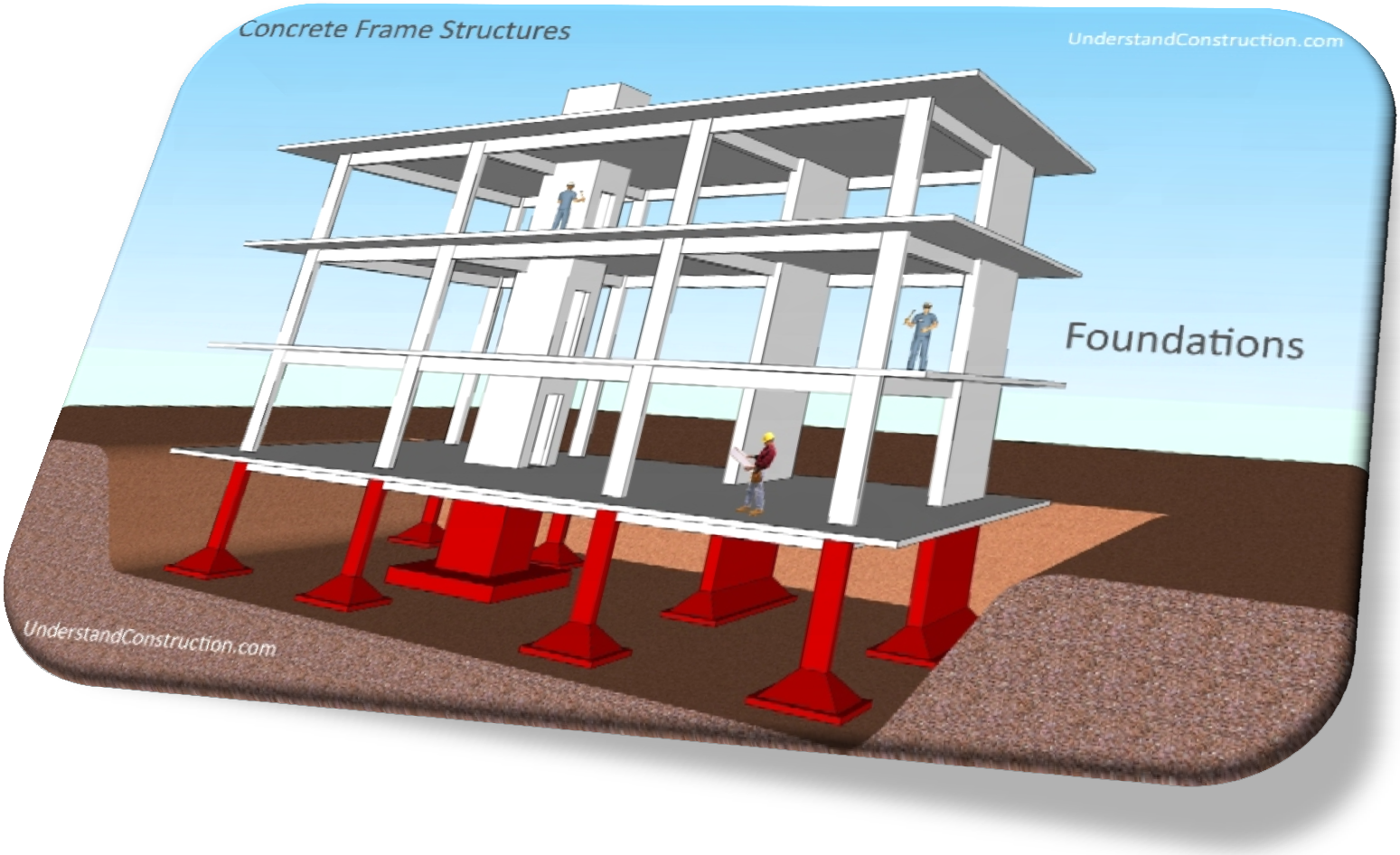
UNDERSTAND BUILDING CONSTRUCTION

FOUNDATIONS IN BUILDING ENGINEERING

CONCRET FRAME CONSTRUCTION



Name:-Haydar Muhammad SalihMuhammad Amin

Card NO. :- 6916

Mobile NO. :- 07731572892 or 07507024185

Date :- 29 / 03 / 2020

INTRDUCTIONFoundations In Building Engineering

It is the structural base witch transfers the structural load to the foundation soil or rock saiftey .or It is the soil or rock witch supports the structural. orIt is both the structural base and the foundation soil or rock beneath the ground surface.

Foundations Engineering:-Is the brunch of civil or building engineering witch deals with planning , design and construction of foundations.

Type of Foundations (with respect to depth)

In general there are two types of foundations witch respect to depth of foundations:-

A - Shallow foundations B - Deep foundations

A- Shallow Foundations:- { D f < B } (Beast of D f)

D f =Depth of foundation B = Width of footing or Diameter of footing

Must type of footings are shallow foundation such as :-

1- Continuous or strip (wall) footing under foundation wall .

2 - Single (spread) column footings (individual , soil footing) .

3 - Combined footings .

4 - Strip footing or (cantilever footing) (connected by beam) .

5 - Mat or raft foundations (base meant) .

B- Deep Foundations:- { D f > B }

Deep Foundations such as:-

a-Pile (deep) foundations b-Pire foundations (Drilled castons)

UNDERSTAND BUILDING CONSTRUCTION

WHAT ARE THE TYPES OF BULDING CONSTRUCTION :-

This section describes the different types of building construction systems commonly found in the world today. CONCRETE FRAME CONSTRUCTION :-Concrete frame construction is probably the most common kind of construction system used in the world today. As the name suggests, this has a skeleton of concrete, that is covered in a skin. The skin can be made of brick, aluminum or glass, and is attached to the outer surface of the building.STEEL FRAME STRUCTURES :-Steel is an immensely strong and flexible material. This is why steel frame structures are ideal for earthquake-prone areas. Learn about the different types of steel construction.LIGHT GAUGE STEEL STRUCTURES :-Light gauge steel construction is very widely used for residential and low-rise buildings in the US and Europe. It is very similar to

light wood construction.WOOD FRAMED CONSTRUCTION :-Wood framed construction is widely used for residential and low-rise structures in North America and Europe.Learn how it works in this article.

LOAD BEARING MASONRY WALL CONSTRUCTION:-

Load bearing masonry walls is a form of construction that was used widely from the 1700**s to the mid**-1900**s. it consists of heavy brick or stone walls that support horizontal floor slabs.**

PRE ENGINEERED BUILDING CONSTRUCTION :-

Preengineered metal buildings are a fast, economical type of construction best suited to warehouses and industrial buildings.

INTRODUCTION TO FOUNDATIONS :-

Read our introduction to foundations and the role they play in building construction.

TYPES OF FOUNDATIONS :-

Read about the various types of building foundations, and where and when each type should be used.

PILE FOUNDATIONS :-

This article describes pile foundations, and how they are designed and constructed.

RAFT OR MAT FOUNDATIONS :-

All about raft or mat foundations, and how they are designed and constructed.

FOUNDATIONS AND FOUNDATION ENGINEERING

The foundations of the building transfer the weight of the building to the ground. While 'foundation' is a general word, normally, every building has a number of individual foundations. Most buildings have some kind of foundation structure directly below every major column, so as to transfer the column loads directly to the ground.

There are many different kinds of foundations, see our page on types of foundations for more information.

Since the weight of the building rests on the soil or rock, engineers have to study the properties of the soil very carefully to ensure that it can carry the loads imposed by the building. It is common for engineers to determine the safe bearing capacity of the soil after such study. As the name suggests, this is the amount of weight per unit area the soil can bear. For example, the safe bearing capacity(SBC) at a location could be 20 **T/m**2**, or tonnes per square metre. This figure is the maximum the soil can bear, so an engineer will take pains to see that her design does not exceed this figure in any part of the building.**

This capacity also changes at different depths of soil. In general, the deeper one digs, the greater the SBC, unless there are pockets of weak soil in the earth. To properly support a building, the soil must be very firm and strong. It is common for the soil near the surface of the earth to be loose and weak. If a building is rested on this soil, it will sink into the earth like a ship in water. Building contractors will usually dig until they reach very firm, strong, soil that cannot be dug up easily before constructing a foundation.

To study the properties of the soil before designing foundations, engineers will ask for a soil investigation to be done. A soil investigation engineer will drill a 4**" or** 6**" hollow pipe into the ground, and will remove samples of the earth while doing so. He will then send these samples to a lab to find out the detailed properties of the soil at every depth. Soil is usually composed of strata, or different layers, each with its own set of properties. Drilling technology today makes it easy and economical to drill to great depths, easily several hundred metres or more, even in hard rock.**

The soil investigation team will then prepare a soil investigation report that lists the engineering properties of the soil at regular intervals, say every 2 meters. Based on this deport, engineers designing the structure can decide at what depth of soil to provide the foundations, the type of foundations they should provide, and the size of the foundations.
Every once in a while, engineers will find fill at a site. This occurs when humans have previously dug up the earth there, and then filled it back in. This happens if a quarry was dug or a building built there previously. Since fill is loose and soft and cannot support weight, engineers will dig to a depth below that of the fill, where strong soil is found, and construct foundations there.
The study of soil, and its properties and behavior, is called soil mechanics.
Once the foundations have been built, the loose soil that has been excavated must be put back over and around the foundations. This is called backfilling. Backfilling must be done carefully, as the soil there must support the weight of the floor slab at ground level (called the first floor in the US). Backfilling is done by putting back the soil in horizontal layers about a foot thick, and then compacting the earth, or squeezing it under pressure in a wet condition. This causes the soil particles to be squished together and removes air voids, there by making the layers strong. Good backfilling also improves the performance of the foundations, as the earth holds them firmly in place, and weighs down on the foundations to anchor them in position.TYPES OF FOUNDATIONS :-Read our introduction to foundations if you have missed it.
In this article we will discuss the common types of foundations in buildings. Broadly speaking, all foundations are divided into two categories: shallow foundations and deep foundations. The words shallow and deep refer to the depth of soil in which the foundation is made. Shallow foundations can be made in depths of as little as 3ft (1m), while deep foundations can be made at depths of 60 - 200ft (20 - 65m). Shallow foundations are used for small, light buildings, while deep ones are for large, heavy buildings.SHALLOW FOUNDATION :-

Shallow foundations are also called spread footings or open footings. The 'open' refers to the fact that the foundations are made by first excavating all the earth till the bottom of the footing, and then constructing the footing. During the early stages of work, the entire footing is visible to the eye, and is therefore called an open foundation. The idea is that each footing takes the concentrated load of the column and spreads it out over a large area, so that the actual weight on the soil does not exceed the safe bearingcapacity of the soil.
There are several kinds of shallow footings: individual footings, strip footings and raft foundations.
In cold climates, shallow foundations must be protected from freezing. This is because water in the soil around the foundation can freeze and expand, thereby damaging the foundation. These foundations should be built below the frost line, which is the level in the ground above which freezing occurs. If they cannot be built below the frost line, they should be protected by insulation: normally a

little heat from the building will permeate into the soil and prevent freezing.

INDIVIDUAL FOOTINGS :-

Individual footings awaiting concreting of the footing column.

Individual footings are one of the most simple and common types of foundations. These are used when the load of the building is carried by columns. Usually, each column will have its own footing. The footing is just a square or rectangular pad of concrete on which the column sits. To get a very rough idea of the size of the footing, the engineer will take the total load on the column and divide it by the safe bearing capacity (SBC) of the soil. For example, if a column has a vertical load of 10T, and the SBC of the soil is 10T/m2, then the area of the footing will be 1m2. In practice, the designer will look at many other factors before preparing a construction design for the footing.

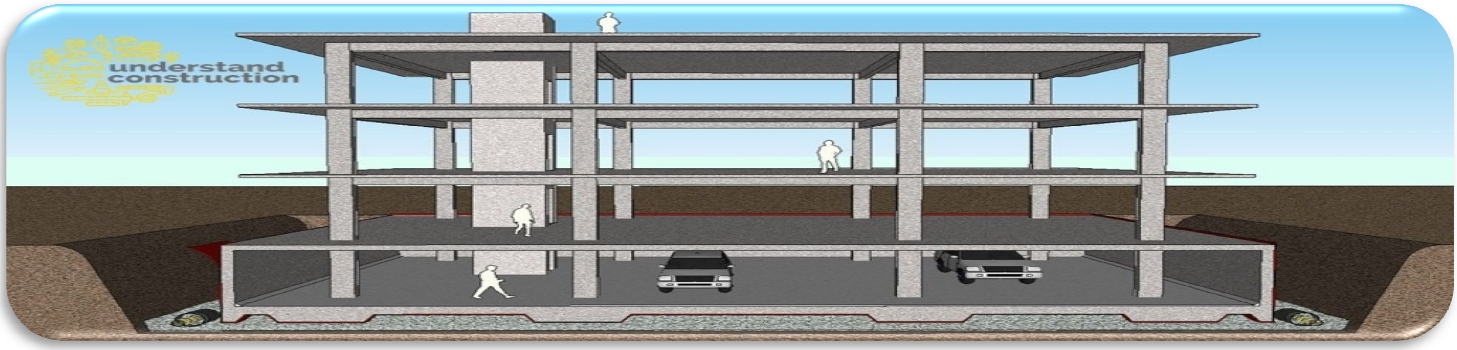
Individual footings connected by a plinth beam. Note that the footings have been cast on top of beds of plain cement concrete (PCC), which has been done to create a level, firm base for the footing.

Individual footings are usually connected by a plinth beam, a horizontal beam that is built at ground or below ground level.

STRIP FOOTINGS :-

Strip footings are commonly found in load-bearing masonry construction, and act as a long strip that supports the weight of an entire wall. These are used where the building loads are carried by entire walls rather than isolated columns, such as in older buildings made of masonry

RAFT OR MAT FOUNDATIONS



Raft Foundations, also called Mat Foundations, are most often used when basements are to be constructed. In a raft, the entire basement floor slab acts as the foundation; the weight of the building is spread evenly over the entire footprint of the building. It is called a raft because the building is like a vessel that 'floats' in a sea of soil.

Mat Foundations are used where the soil is week, and therefore building loads have to be spread over a large area, or where columns are closely spaced, which means that if individual footings were used, they would touch each other.

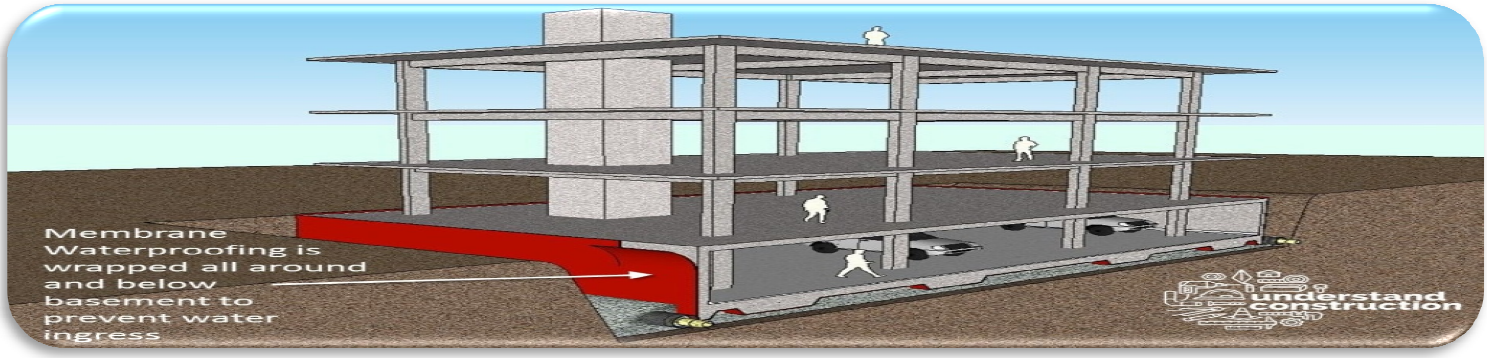
RAFT OR MAT FOUNDATIONS:-

A raft foundation, also called a mat foundation, is essentially a continuous slab resting on the soil that extends over the entire footprint of the building, thereby supporting the building and transferring its weight to the ground.A raft foundation is often used when the soil is weak, as it distributes the weight of the building over the entire area of the building, and not over smaller zones (like individual footings) or at individual points (like pile foundations). This reduces the stress on the soil.

The concept of stress is very basic to civil engineering. Stress is simply weight divided by area. For example, if a building measuring 5 **x** 5 **weighs** 50 **tons, and has a raft foundation, then the stress on the soil is weight / area =** 50/25 **=** 2 **tons per square meter.**

If the same building were supported by say 4 **individual footings, each of** 1 **x** 1**m, then the total area of the foundation would be** 4 **m**2**, and the stress on the soil would be** 50/16**, which is about** 12.5 **tons per square meter. So increasing the total area of the foundation can dramatically lower the stress on the soil, which is nothing but weight per square meter.**

A raft foundation is also very good for basements. Foundations are created by excavating soil in order to find strong, compact, undisturbed natural soil that is at least a few feet below ground level. This soil is much stronger than the loose soil at the surface. If we construct a raft foundation at say 10 **feet below ground, and build concrete walls around the periphery, this makes an excellent basement. Therefore, an engineer designing a building with a basement will tend to choose a raft foundation over other types of foundations.**

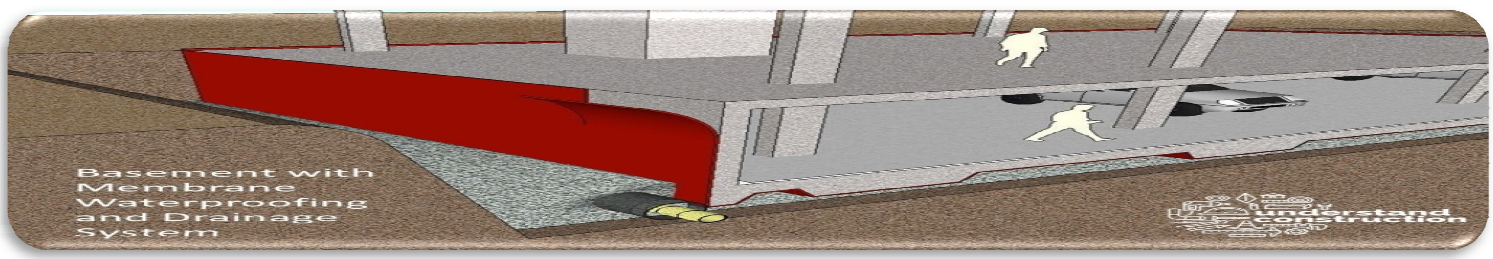


HOW TO CONSTRUCT A RAFT OR MAT FOUNDATION:-

A raft foundation is constructed by first excavating the ground to a uniform, flat level. Then, a waterproof plastic sheet is laid over the earth, and a thin 3" layer of plain cement concrete (PCC) is poured just to create a perfectly flat and level base for the foundation. After this, a waterproofing layer is installed, and then reinforcement steel for the raft slab is tied in place. After all the steel has been put in place, concrete is poured to the desired thickness, which is usually in the range of 200mm (8") to 300mm (12") thick for small buildings: this can be much thicker if heavy loads are to be carried.

WATERPROOFING OF BASEMENTS:-

Basements often extend several stories below ground. The soil or rock around the basement can easily be saturated with water. This water will seep into the building if the building is not waterproofed properly, as concrete is not impermeable to water (it allows water to pass through). So engineers pay a great deal of attention to the waterproofing design of basements, as once this is done, there is no way to repair it, so it must be done perfectly during construction. The best way to do this is to wrap the outside of the basement in a waterproof layer called a waterproofing membrane. This should cover the bottom and all sides of the basement, and should be placed between the soil and the concrete, so that the concrete always remains dry. The waterproofing membrane must also be physically strong, as the raft will be constructed on top of it, and the weight of the building will press down on it. This layer also serves to chemically isolate the building, as soil may contain chemicals that adversely affect concrete in the long run. In some cases, engineers will work out a way to remove water from the soil below the basement whenever it builds up. While this sounds difficult, the solution is rather simple: during construction, perforated pipes are laid in the soil a few inches below the concrete raft. These are wrapped with geotextile, which is a kind of cloth that allows water to pass through, but not particles of soil. Stone chips are then packed around the pipes to allow water, but not soil to pass through. The raft is then constructed. The pipes then are turned to follow the walls of the basement and appear above ground. Later on, if engineers suspect that lots of water is in the soil around the basement, they can remove it by attaching pumps to the pipes and sucking out the water.



THE CONCEPT OF UPLIFT:-

When working with basements, one needs to understand the concept of uplift. Uplift happens when the soil outside a basement gets saturated with water, say during a period of very heavy rain. Then, the basement begins to act like a ship that floats in a sea of water. The water will exert a strong upwards force on the basment.

In case this upwards force is balanced by a strong downwards force, such as the weight of many floors above the basement, there is no problem. If, however, there is no balancing force, as may be the case if the basement has just been constructed, and there is nothing above, then the upwards force may be strong enough to lift the basement out of the earth, ruining it completely and causing great damage.

UNDERPINNING

UNDERPINNING :-What is underpinning? When is it done?The act of strengthening a foundation is called underpinning. It can also be called foundation repair. While it is difficult to conceive of how foundations (that are underground in an occupied building) can be repaired or strengthened, there are techniques that can achieve this. In a sense, these methods can be likened to surgery performed on a patient.

Underpinning is done for a number of reasons. Read all about underpinning here.

UNDERPINNING IN FOUNDATIONS:-

Underpinning is the act of strengthening an existing foundation system in an existing building. It is usually done in one of the following situations:-

- **the building is showing signs of sinking into the ground or cracking, indicating that the foundation system is not able to bear the weight of the building**
- **the building is either being enlarged or converted for use in a new type of activity, resulting in heavier loading than it was designed for**
- **a large new building with deep foundations or basements is being constructed close to an existing building, causing problems for the existing building**

In the third case, the danger to the building can come simply from deep excavation in an adjacent plot. As each foundation has a cone of soil below it that supports it, if a very close new excavation cuts into it, the foundation can lose some or all of its bearing capacity.

TYPES OF UNDERPINNING:-

Underpinning can be done in one of two ways: one, improve the foundation system by enlarging the existing foundations or adding new foundations, and two, to improve the properties of the soil below the foundations without touching the building at all.

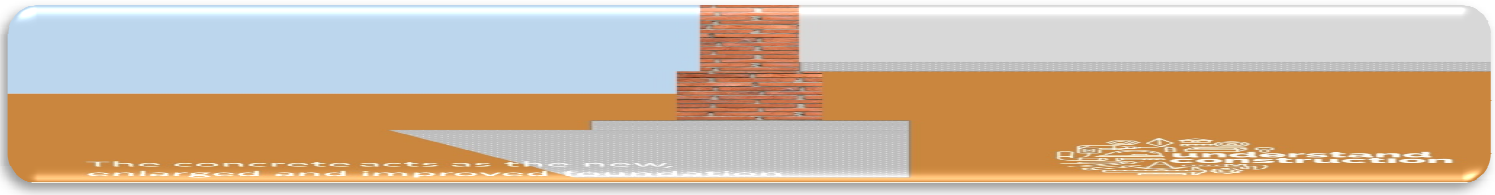
A key aspect to consider is how much disturbance to the building the underpinning method will cause. As you will see below, some methods will cause extreme disruption to the ground floor and external areas of the building.

All such interventions must be done only by qualified structural engineers after much study and calculation, as the operation can cause serious structural damage or total collapse if not done correctly.

PART A - IMPROVING THE FOUNDATION SYSTEM

Foundations may be improved in a great number of ways, and a creative engineer can sometimes find a new way to transfer the weight of a building to the soil.

UNDERPINNING METHOD 1:- PIT METHOD



This is done in the following way:-

١. **A temporary foundation system is first constructed around the existing one.**
٢. **Then a pit is dug <u>around and below</u> the existing foundations, thereby relieving them of load-carrying duties.**
٣. **Then, a new foundation is built below the existing one by filling the pit with concrete.**
٤. **Once the concrete has set, the temporary foundations are dismantled, allowing the load to settle onto the improved foundation system.**

The most important thing to understand is that this is done insmall sections at a time, not for the entire building. Each section could be from 8' to 12' long (2 - 4m approx) depending on the size of the building. The new sections are interspersed among the old, thereby making the whole process much safer.

Lets talk about each step in greater detail:-

<u>Step 1:-</u> a temporary foundation is constructed to bear the weight of the building, so that the existing foundation is relieved of its weight and can be worked on. This is usually done so as to cause minimal disruption inside the building. However, this usually means significant disruptions to the ground floor of the building, as the floor will have to be dug up to install the temporary foundations.

The building is then supported on needle beams. A needle beam is a new beam that is constructed at right angles to the existing foundation, and is pushed into the existing foundation wall (a hole is cut for it first) like a needle through cloth. A number of such needle beams are constructed at regular intervals so as to bear the weight of the building above. For temporary needle beams, it is convenient to use steel I-beams that can be re-used at every new site. Once the beam has been pushed in, the gap between it and the foundation wall is sealed with strong cement mortar so that the wall can transfer weight to it.

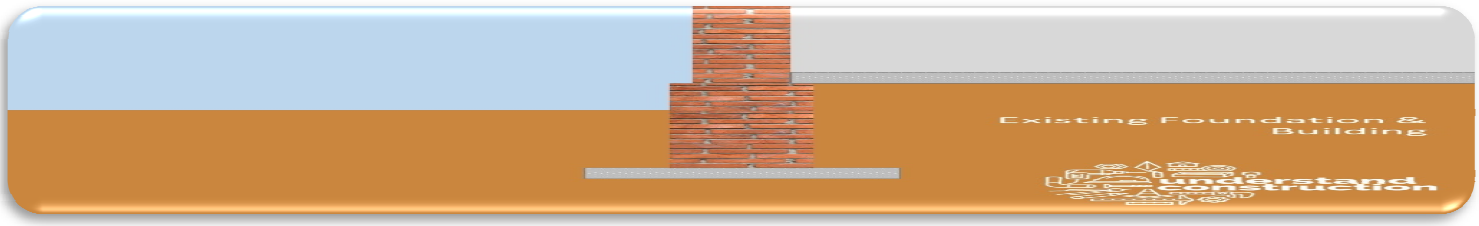
<u>Step 2:-</u> once the temporary foundation is in place and has been checked, a pit can then be dug by hand below and around the existing building. The existing foundation will then hang in mid-air. This is an operation that must be done very carefully, as it can be quite dangerous. It is important to note that the pit method can <u>only be done if the soil at the site is a cohesive soil</u>. A cohesive soil is one that holds its shape, and does not collapse when excavated or cut, which could kill the construction workers inside it.

<u>Step 3:-</u> the foundation is then underpinned by filling the pit with concrete. It is very important that there be no gap between the new foundation and the old, as if there is, the building will settle into this gap, causing cracks and damage above. Therefore filling in the last few inches below the existing foundation is critical.

<u>Step 4:-</u> Once the concrete has set, the temporary foundation can be removed, the earth filled in, and the internal floors repaired and re-tiled. The concrete is the new, enlarged foundation, that rests on soil at a greater depth, giving it a higher safe bearing capacity.

This whole operation is done in small sections at a time. For example, if the entire peripheral wall of the building is say 100 feet long, then this may be done in 10-foot sections at one time.

UNDERPINNING METHOD 2:- NEEDLE BEAM METHOD



This is done in the following steps:-

١. **First construct two micropiles at a specified distance from the building. This is done with a micropiling rig.**
٢. **Then cut a hole just large enough to take the needle beam.**
٣. **Construct the RCC needle beam over the piles and inside the foundation wall.**
٤. **Once the beam has set, fill in the earth over the beam. The new foundation system can now take additional load.**

This method has the great advantage of not disturbing the inside of the building.

Lets now discuss each step in full detail:-

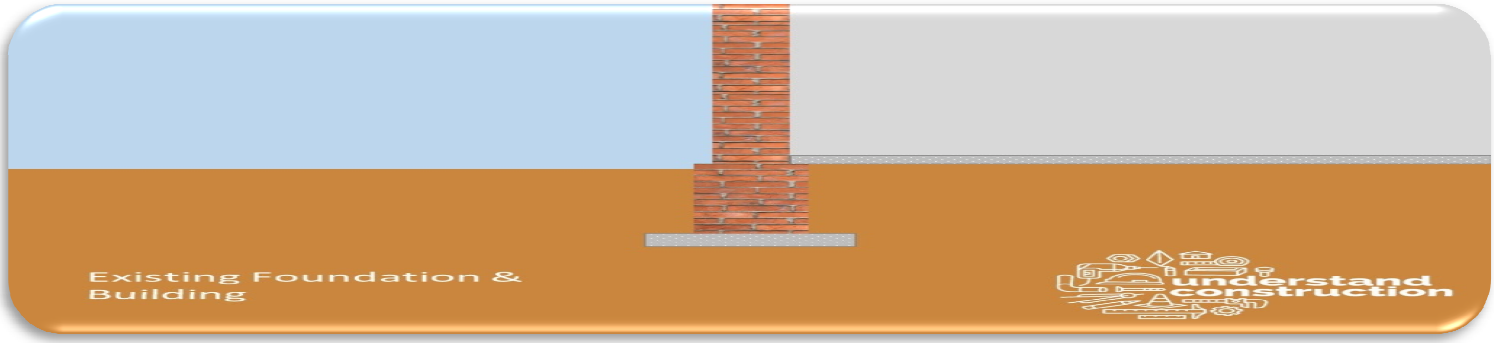
Step 1:- Use a small piling rig to make the micropiles close to the building. First check that the building is not so weak so the vibrations from the micropiling rig cause damage to it. When loaded, one pile will act in compression, and the other in tension.

Step 2:- Excavate the area where the needle beam is to be constructed. Then cut a hole just large enough to take the cantilever needle beam in the foundation wall.

Step 3:- Cast the RCC cantilever needle beam in situ, making sure to have a good connection between the micropiles and beam.

Step 4:- Backfill earth into the open areas, and you are done.

UNDERPINNING METHOD 3:- MICROPILING METHOD



This is done in the following steps:-

١. **Construct micropile just below existing foundation at an angle, as shown in the sketch.**
٢. **Excavate earth till the top of the micropile.**
٣. **Then manually remove all earth between the pile and the existing foundation, creating a cone shaped void that rests on the micropile.**
٤. **Fill in this void with concrete. Once it sets, the existing foundation can transfer forces to the micropile, thereby dramatically increasing its capacity.**
٥. **Repeat this at regular intervals.**

We can now talk about each step in detail:-

Step 1:- Use a micro-piling rig to construct micro-piles at an angle, just below the existing

foundation. Before doing this, one should excavate earth adjacent to the existing strip foundation to find out exactly how deep it is.

Step 2:- Excavate the portion of earth till the top of the micropile, ensuring there is enough space for a worker to use her tools.

Step 3:- Now remove the earth between the micropile and the bottom of the existing foundation.

Step 4:- Fill in this gap with concrete. Then repeat the whole process at regular intervals till the entire periphery is done.

PART B - IMPROVING THE SOIL BELOW THE FOUNDATION

In this section, we will talk about how to improve the properties of the soil below and around the existing foundations. This is another way in which we can improve the performance of the foundation system.

This method has the great advantage that the building is not disturbed. In some cases, it can be done while the building is occupied. As you will see,

DEEP FOUNDATIONS :-

PILE FOUNDATIONS :-

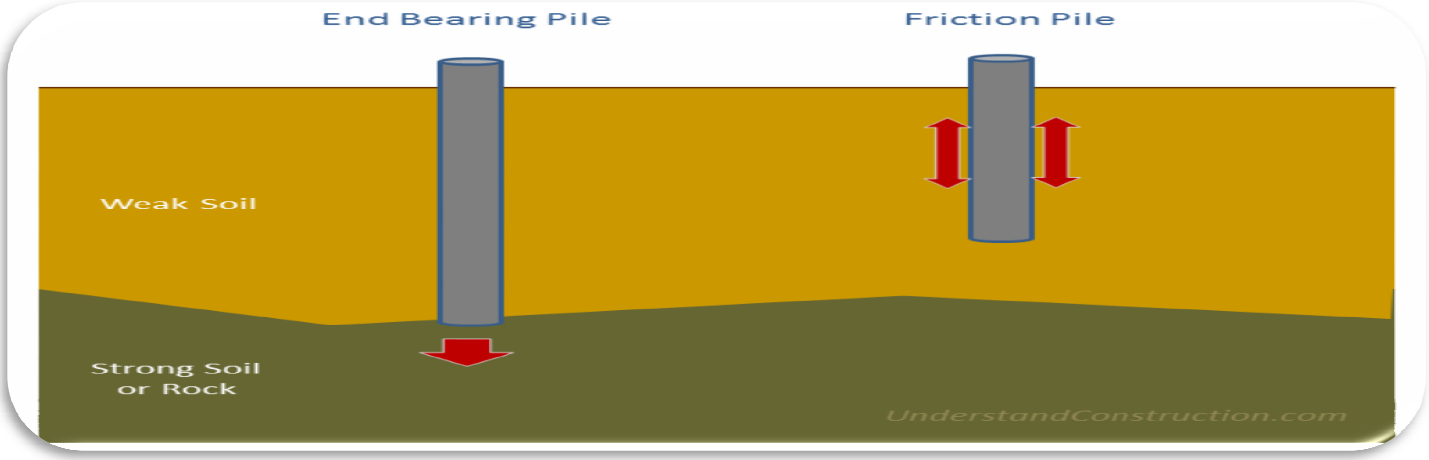
A pile is basically a long cylinder of a strong material such as concrete that is pushed into the ground so that structures can be supported on top of it.

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 building, so the loads of the building have to bypass this layer and be transferred to the layer of stronger soil or rock that is below the weak layer.**
- **When a building has very heavy, concentrated loads, such as in a high rise structure.**

Pile foundations are capable of taking higher loads than spread footings.

There are two types of pile foundations, each of which works in its own way.



End Bearing Piles :-

In end bearing piles, the bottom end of the pile rests on a layer of especially strong soil or rock. The load of the building is transferred through the pile onto the strong layer. In a sense, this pile acts like a column. The key principle is that the bottom end rests on the surface which is the intersection of a weak and strong layer. The load therefore bypasses the weak layer and is safely transferred to the strong layer.

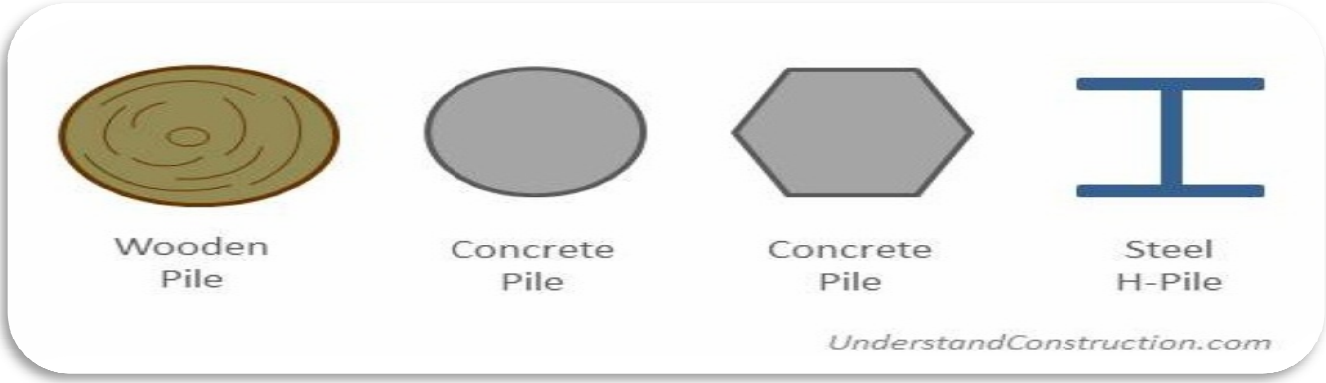
Friction Piles:-

Friction piles work on a different principle. The pile transfers the load of the building to the

soil across the full height of the pile, by friction. In other words, the entire surface of the pile, which is cylindrical in shape, works to transfer the forces to the soil.
To visualise how this works, imagine you are pushing a solid metal rod of say 4mm diameter into a tub of frozen ice cream. Once you have pushed it in, it is strong enough to support some load. The greater the embedment depth in the ice cream, the more load it can support. This is very similar to how a friction pile works. In a friction pile, the amount of load a pile can support is directly proportionate to its length.
In practice, however, each pile resists load by a combination of end bearing and friction.

WHAT ARE PILES MADE OF?

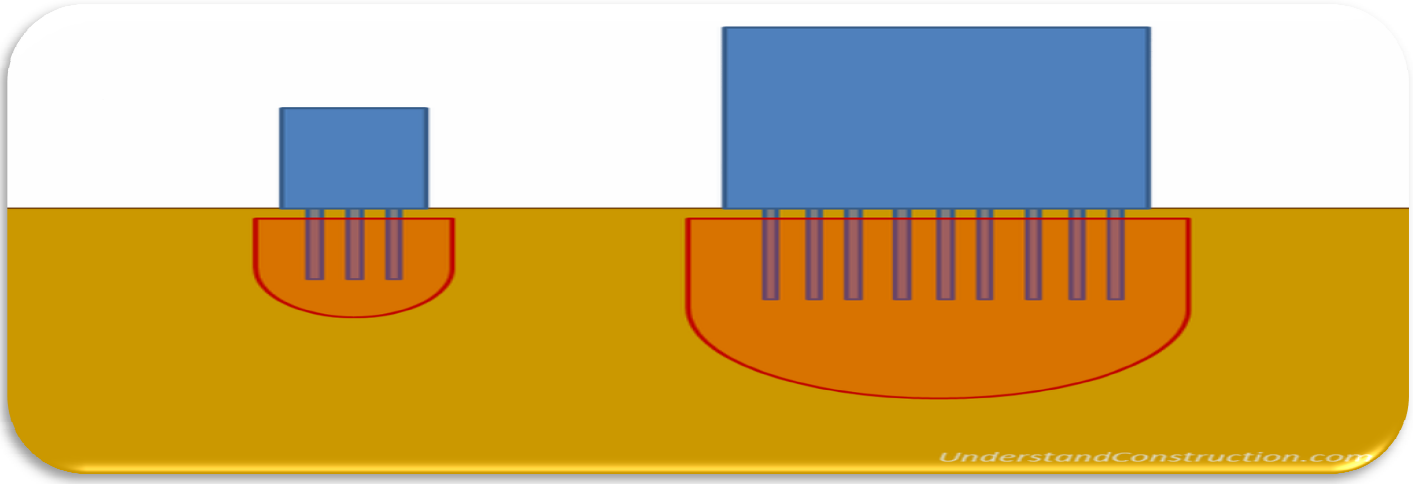
Piles can be made of wood, concrete, or steel.
In traditional construction, wooden piles were used to support buildings in areas with weak soil. Wood piles are still used to make jetties. For this one needs trees with exceptionally straight trunks. The pile length is limited to the length of a single tree, about 20m, since one cannot join together two tree trunks. The entire city of Venice in Italy is famous for being built on wooden piles over the sea water.



Cross sections of various pile foundations

Concrete piles are precast, that is, made at ground level, and then driven into the ground by hammering - more on that later. Steel H-piles can also be driven into the ground. These can take very heavy loads, and save time during construction, as the pile casting process is eliminated. No protective coating is given to the steel, as during driving, this would be scraped away by the soil. In areas with corrosive soil, concrete piles should be used.

HOW PILES ARE USED:- As pile foundations carry a lot of load, they must be designed very carefully. A good engineer will study the soil the piles are placed in to ensure that the soil is not overloaded beyond its bearing capacity.
Every pile has a zone of influence on the soil around it. Care must be taken to space the piles far enough apart so that loads are distributed evenly over the entire bulb of soil that carries them, and not concentrated into a few areas.



The load pattern of the piles on the soil surrounding them. This is also called a zone of influence.

Engineers will usually group a few piles together, and top them with a pile cap. A pile cap is a very thick cap of concrete that extends over a small group of piles, and serves as a base on which a column can be constructed. The load of this column is then distributed to all the piles in the group.

HOW PILES ARE CONSTRUCTED:-

Piles can be either cast-in-place or precast driven piles.

Cast-in-place piles are made in the following steps:-

- **hammer a thin-walled steel tube into the ground**
- **remove all earth left inside the tube**
- **lower a steel reinforcement cage into the tube**
- **cast the pile by pouring wet concrete into the tube**

The thin walled steel tube is called the casing, and only serves to form a secure mould for casting concrete that is free from earth and debris. It has no structural role to play after the casting is complete.

Some soils are highly cohesive, meaning that if one drills a hole into the soil that is say 1 foot wide by 50 feet deep, then the soil holds the shape of the hole and does not collapse into the hole and block it. If such soil is present at the site, then one does not need to leave a casing in place: one can use the casing to drill the hole for the pile, and then remove it, and then cast the pile in place. This saves costs as the same casing tube can be used to drill holes for all the piles.

Precast Driven Piles are first cast at ground level and then hammered or driven into the ground using a pile driver. This is a machine that holds the pile perfectly vertical, and then hammers it into the ground blow by blow. Each blow is is struck by lifting a heavy weight and dropping it on the top of the pile - the pile is temporarily covered with a steel cap to prevent it from disintegrating. The pile driver thus performs two functions - first, it acts as a crane, and lifts the pile from a horizontal position on the ground and rotates it into the correct vertical position, and second, it hammers the pile down into the ground.

Piles should be hammered into the ground till refusal, at which point they cannot be driven any further into the soil.

SPECIAL PILES:-

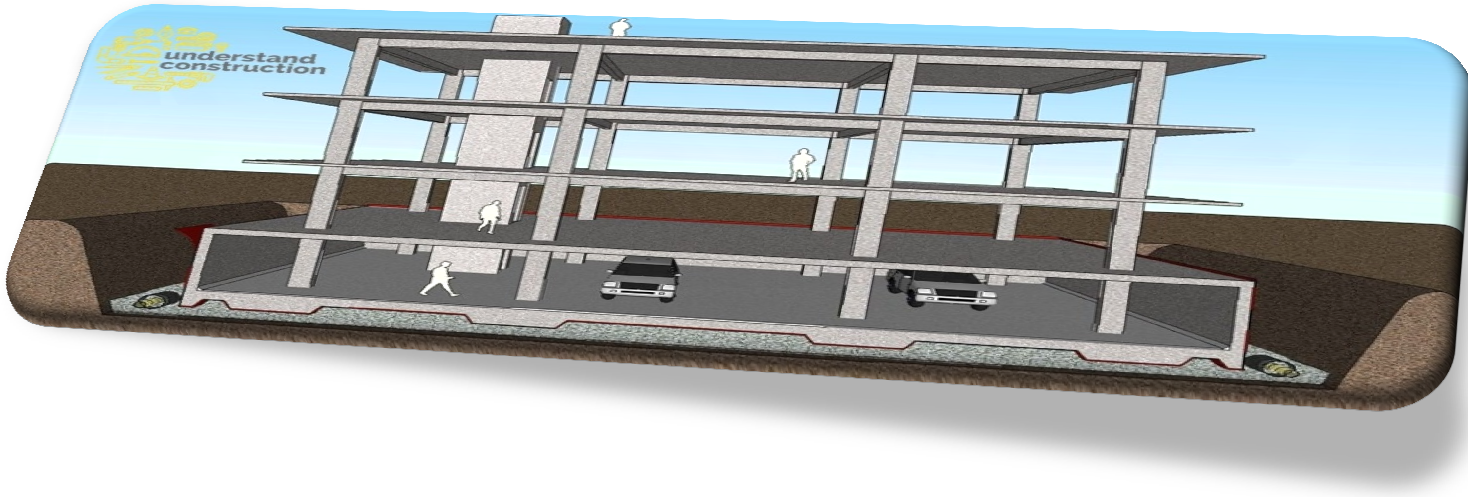
Pile driving is very noisy and causes massive vibrations through the soil. For this reason, it is sometimes difficult to use them in sensitive locations. For example, if an operational hospital or science lab is to be extended, driving piles would cause unwanted disturbance. Their use is also restricted in residential areas in many countries. The vibrations could also cause structural damage to older buildings that are close by. In such situations it is possible to use micropiling or helical piling, neither of which rely on hammering.

Micropiles or minipiles are small piles that are constructed in the following way:

Step 1:- a hole a little larger than the pile diameter and the full length of the pile is dug into the ground using an apparatus like a soil boring machine.

Step 2:- a precast concrete pile is lowered or pushed into the hole.

Step 3:- a concrete grout is poured into the gap between the pile and the earth. Helical piles are steel tubes that have helical (spiral) blades attached to them. These can be drilled into the ground, meaning that the pile acts as a giant drill bit, and is rotated and pushed into the ground from above, much like a screw drills into wood. Once the steel pile is driven into the ground, a pile cap is poured on top of the pile to prepare it for the construction above.



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* ***Foundation Engineering By Das .B.***
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