Foundation Engineering
Dr. Priti Maheshwari
Department Of Civil Engineering
Indian Institute Of Technology, Roorkee

Module - 02
Lecture - 06
Pile Foundations - 1

Good morning, today we are going to start a new chapter on Pile Foundations, pile foundation is a typical one type of deep foundation. Now, you have already studied shallow foundations, so as far as the scope of this course is concerned, you will be studying pile foundation as deep foundations, so let us first try to see, that why deep foundations are necessary.

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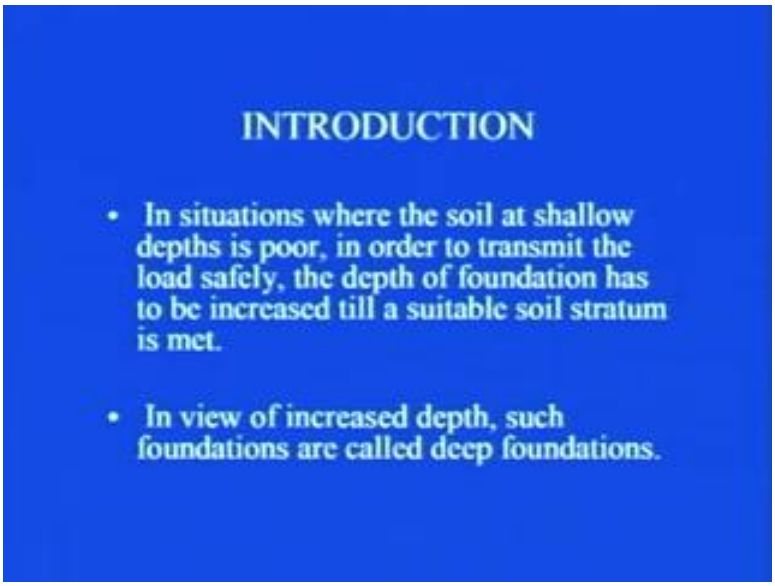

In situations, where the soil at shallow depth is poor, in order to transmit the load safely, the depth of the foundation has to be increased till a suitable soil stratum is met. See, the thing is, whatever is the load, which is coming from the super structure, it gets transferred to foundation and subsequently to the soil. So, if you are going for shallow foundation and the soil strata below that, is poor in nature, is not able to take that much of load, which is coming from the super structure.

Obviously, you have to search for some suitable data, where the foundation can transmit the load to the soil safely that is, where the load which is coming from the super structure can be transmitted safely, such that the building is safe and it is serviceable. Now, as you

go deeper and deeper from the ground surface, we expect better soil stratum, that is why, deep foundations are used to transmit the load to that particular deeper soil stratum.

In view of the increased depth, these foundations are called deep foundations, so you have already studied, various aspects of shallow foundations; and in this chapter, we will be dealing with many aspects of deep foundation and particularly of pile foundation.

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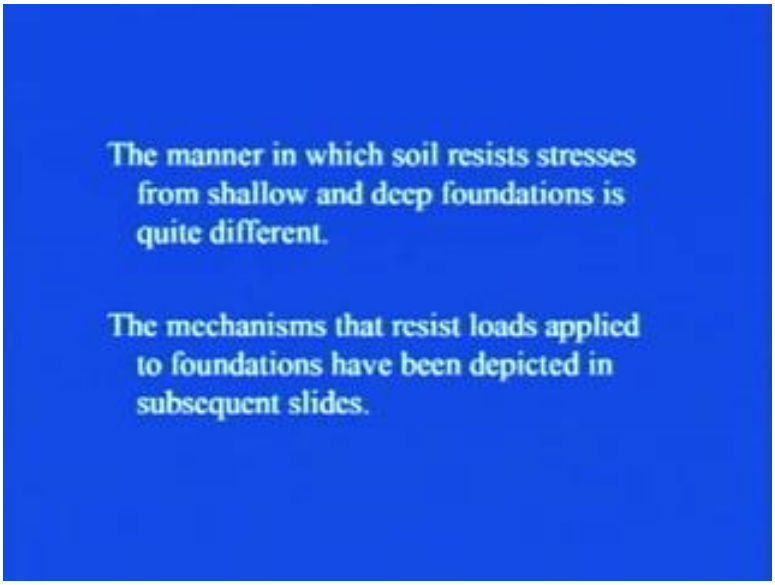

Now, the manner in which, the soil resists stresses, from shallow and deep foundations, they are quite different. In shallow footing, let us say, the load which is coming from the super a structure is compressive vertical load, the way, it will resist that particular load, that particular way is different for shallow foundation and deep foundation. So, let us try to see that, what are the various types of load which comes from super structure to the foundation.

And how, the load transfer mechanism is different in case of shallow foundation and deep foundation, so the mechanics, that resists loads applied to foundations, I am going to show you all these mechanisms in the next few slides.

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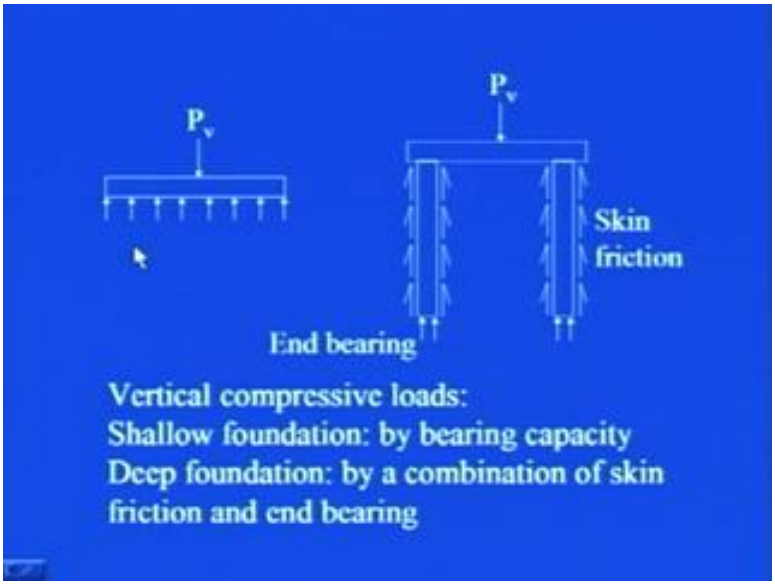

So, you see here, this is the first one, I showing you the shallow foundation, however the another one is showing you deep foundation. So, first of all, you can have a look, you already know about the shallow foundation, just have a look, how the pile foundation or deep foundation look like. You see here, let us say here is the presence of ground surface, this is the presence of ground surface, this is simply placed at a shallow depth.

But here, this kind of shafts they are provided, such that, the load is transferred at this particular level, which is much deeper as compared to, in case of shallow foundation. So, you see in case of vertical compressive load, whatever is the super structure, the load which is coming on these two structures, they it is compressive as well as vertical in nature. So, you see, how this shallow foundation will resist this particular load which is coming from the super structure.

The soil which is lying below this shallow footing, will react and it will have some ultimate bearing capacity, so that vertical compressive load is compensated by that bearing capacity. If the vertical load, which is coming from the super structure, if it is less than the bearing capacity of the soil, obviously, the foundation will be safe. However, in case of deep foundation, it is not the bearing capacity which resist the load, which is all, which balances the load, which is coming from the super structure.

So, you see, in case of deep foundation, this load is being resisted or being balanced by a combination of skin friction as well as end bearing. Here, it is kind of shaft which is been provided, all around this one is the soil, so there will be, as soon as the load comes from

the super structure, there will be more relative movement of the soil along the pile shaft, so the skin friction gets developed. However, wherever it will rest, whatever is the base area of this particular shaft, that much will be resisted by end bearing.

So, we will be using two terms very often when we talk of deep foundation or pile foundation, one is a skin friction, another is end bearing, I hope that it is clear to you, so once again you see, how this is skin friction is getting mobilised, as soon as this load comes from the super structure to the foundation. This load gets distributed, gets balanced to this skin friction, which gets mobilised along the surface area of the pile shaft and some of the end bearing will be provided by this base area of the pile.

Now, let us try to see, what type of another load which comes on the foundation from super structure.

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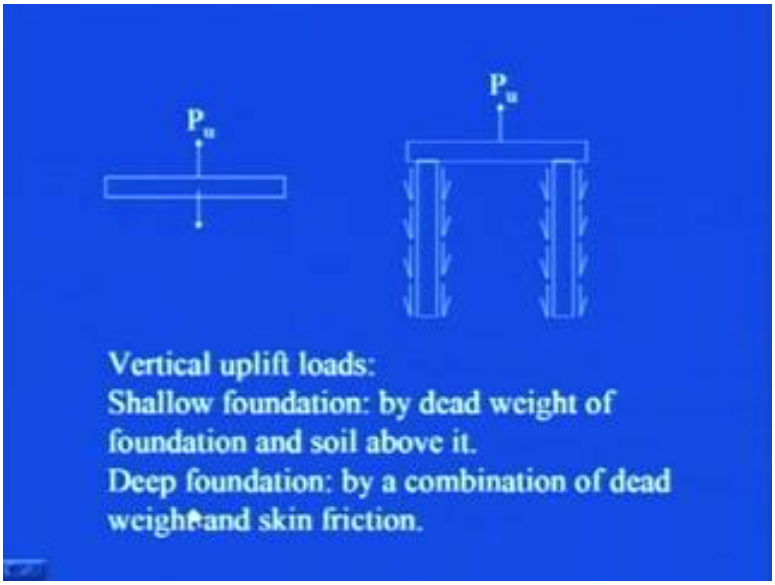

In case, the vertical uplift load is present, so in that case, in case of shallow foundation, it is balanced by the dead weight of foundation and the soil above it. You see, in case, if this is your shallow foundation, what happens, let us say here is your ground surface, so the foundation is placed below, little below the ground surface, so there will be, weight of that particular footing and there will be some soil layer on that particular footing.

So, the weight of the soil, as well as the weight of the footing will be acting and balancing the uplift load, in this particular manner. However, in case of deep foundation, it is by a combination of dead weight and a skin friction, you have already seen, that how this is skin friction gets mobilised. So, in this case also, since it is subjected to uplift

force, so the friction will be mobilised in the downward direction that is opposite direction.

So, you can see here, that it is getting mobilised in this particular direction and at the same time, it is weight, whatever is the weight of pile or the deep foundation that will also be balanced.

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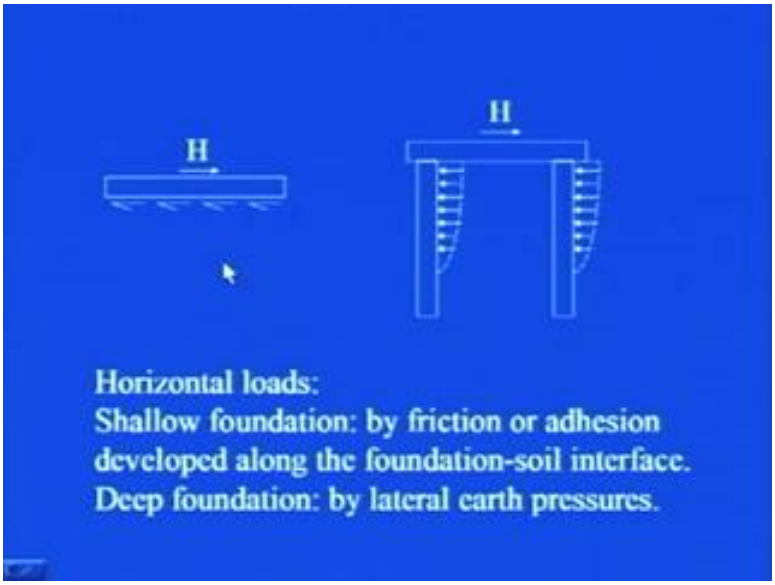

Then, let us say in case, the foundation is subjected to horizontal load, so how this shallow foundation will come in, will take care of that, that is why friction or adhesion developed along foundation soil interface. So, see here, this H is the magnitude of the horizontal force which is acting on this shallow foundation, that is coming from the super structure, so if the direction of horizontal force is this, then in the opposite direction, the adhesion or cohesion force will be there.

That is, this is due to, because here the soil is there, so wherever there is interface of soil and the footing, there this adhesion or cohesion will developed, develop and that will balance this horizontal load. However, in case of deep foundation, it is by lateral earth pressure, you have already studied, what do you mean by lateral earth pressure, so you know that, how you can estimate and what are the basic theories behind that.

So, in case of pile foundation or deep foundation, if it is subjected to horizontal load, that horizontal load is get balanced by this lateral earth pressure, in this particular manner. It will just get generated in this particular manner and this is the direction of H, so in

opposite direction, this lateral earth pressure will be generated and this will balance this horizontal force.

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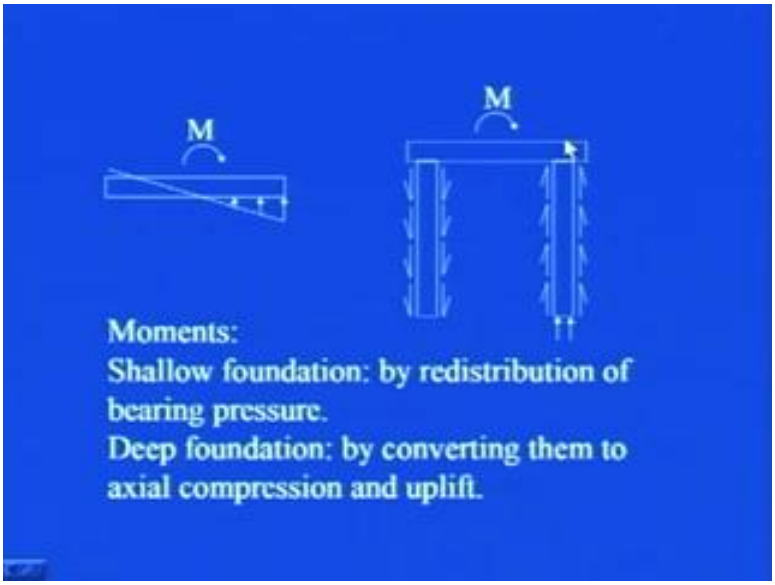

Then, what happens if the, if moment is there on the foundation, that is the foundation is subjected to moment. So, in case of shallow foundation, you see, if it is clock wise moment, here as it shown in this figure that is M, it is balanced by redistribution of bearing pressure. You see, if the movement direction is this, the foundation will have tendency to move like this and then, correspondingly the bearing capacity of the foundation will come in to picture and will balance this particular moment.

However, in case of deep foundation, it get balanced by converting them to axial compression and uplift. So, you see here, this is a moment, so this will have tendency to move in this particular direction, so this part will go downward and this part will go upward and this foundation will try to resist, this particular moment. So here, in this particular pile or in this particular shaft, what will happen, the moment will have the tendency to push this part of the foundation downward.

However, this will resist, so the resistance force is upward and in this part, what will happen, it will try to move upward. So, the friction will get developed, such that, it is getting dragged down, so it is kind of converting all this moment to axial compression and uplift.

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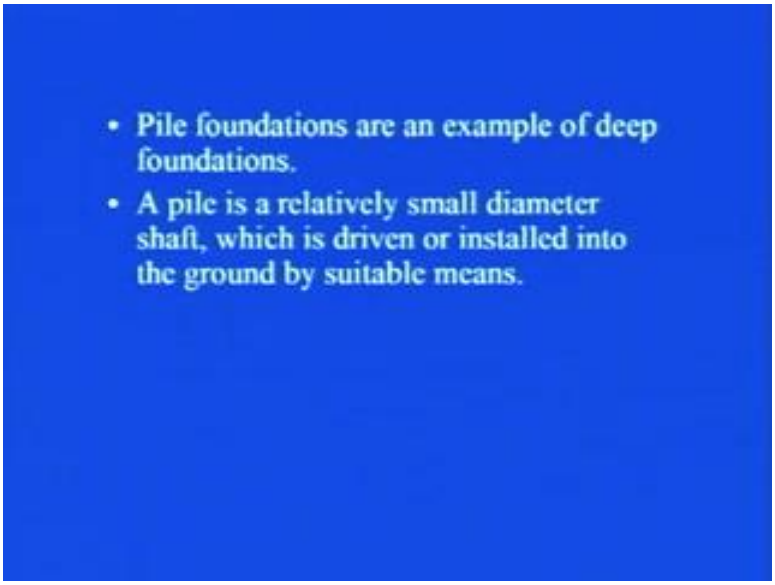

Now, some of the typical characteristic of pile foundation, they are an example of deep foundation, it is relatively small diameter shaft, which is driven or installed in to the ground by suitable means. So, you see, deep foundation, when I talk of deep foundation, it is a general term, in which you have sheet pile, you have well foundation, you have well caissons and etcetera. However, in the scope of this particular course, we will be studying this pile foundation.

So, from now onwards, I will be using pile foundation term only instead of deep foundation, it is relatively smaller diameter shaft, which is either driven or bored in the ground by different suitable means. All these details, we will be studying in the subsequent classes and may be few aspects in this class also. Usually, these are driven in groups to provide foundations for structure, see, whatever load is coming from the super structure, it may happen, that a single pile is not able to take that particular load, that is why, it is always provided in groups.

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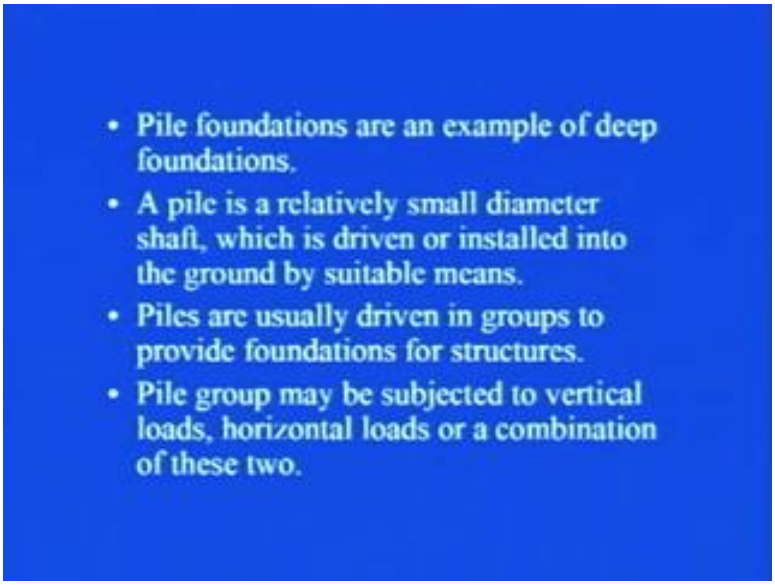

Pile group, may be subjected to vertical loads, horizontal load or a combination of these two, depending on what is the type of super A structure, where it is getting constructed , what is the type of the soil, what are the characteristic surrounding things, depending on that, the pile foundation will be subjected to either vertical load or horizontal load or both can be present.

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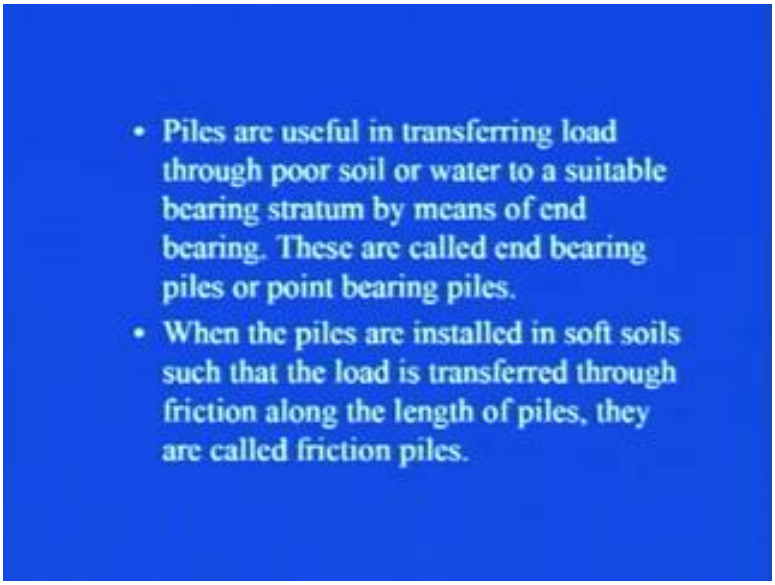

Then, these piles are useful in transferring load poor, through poor soil or water to a suitable bearing stratum by means of end bearing, these are called end bearing piles or point bearing piles. So, you see, let us say, that on top from the ground surface, there is

very poor soil strata which is present or let us say, if you have to go for the design of foundation, for this thing, river abutment, then what will happen, there water is present. So, in that particular case, when you have poor soil strata, just below the ground surface or there is presence of water table, in that case, what happens is, the load is transferred through these piles to hard bearing strata. That is, it is transferred to a larger depth, let us say, that at any particular site, there is fifteen meter of soil covered and beyond that you get rock strata. So, what happens is, the bearing capacity or the whatever load a soil, a rock strata can bear is much more than a soil strata.

So, what happens is, if fifteen meter soil cover is there, I would like to install the pile foundation of, let us say sixteen to seventeen meter, such that the fifteen meter depth of the pile is there in the soil strata and remaining one or two meter is socketed in rock. So, in that case what happens is, since the above soil layer is poor, whole of the load is getting transferred to that good rock strata, so in that case, the main function or the main resistance of the load from the super structure, it is beard by this end bearing.

That is why, such type of piles are called end bearing piles or point bearing piles, then, it is the second case, when the piles are installed in soft soils such that the load is transferred through friction along the length of piles, they are called friction piles. In the few previous slides, we have seen a skin friction and end bearing. So, as soon as the load comes, it gets transferred to the soil, so in case, the component through the skin friction or through the friction, which is mobilised along the pile shaft, in that case that is called the friction piles.

However, in case of end bearing pile, the load is basically shared by that end bearing only.

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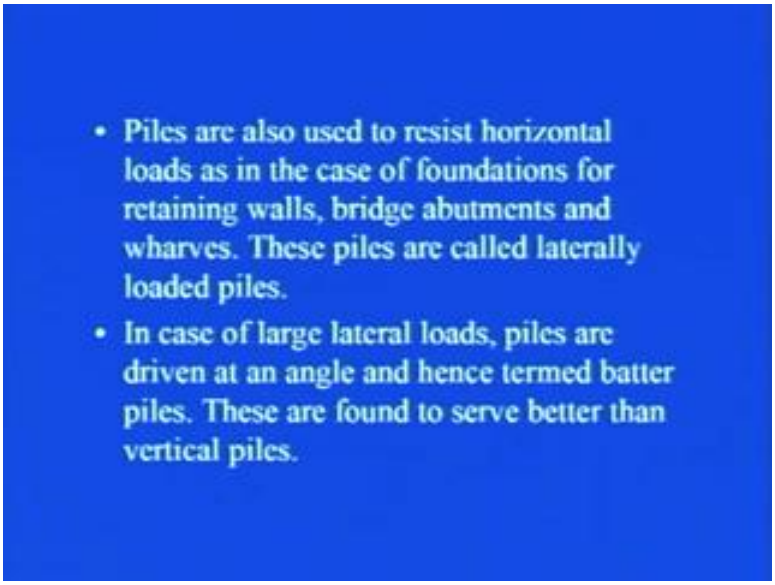

Now, piles are also used to resist horizontal loads, as in case of foundations for retaining walls, bridge abutments and wharves. These piles are called laterally loaded piles, so you see, depending on, how the pile is resisting or transferring the load from the super structure to the soil, we are getting different types of piles. First we saw, end bearing pile and then we saw friction pile and here it is, the third type which is laterally loaded pile, so laterally loaded piles basically resist horizontal load.

Wherever the horizontal loads are present, usually it is function becomes, that it has to transfer the horizontal load, so it is called laterally loaded piles. In case of large lateral loads, piles are driven at an angle and hence, they are termed as better pile, these are found to serve better than vertical piles. That means that, when the pile is getting driven, it is not being driven vertically, but to some inclination from the ground surface.

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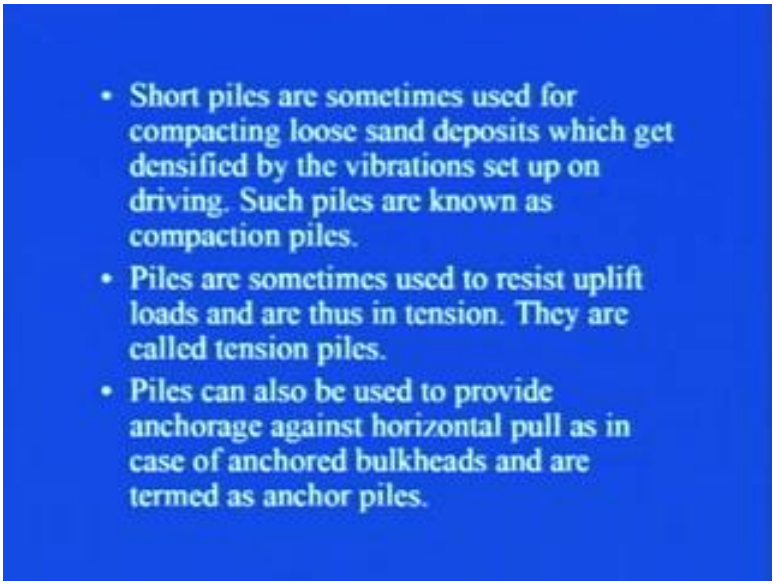

Short piles are sometimes used for compacting loose sand deposit, which get densified by the vibration setup on driving. Such piles are known as compaction piles, so let us say, at any particular site, wherever you want to go for some construction, there, loose sand strata is there. So, in on loose sand strata, you really cannot construct the super structure, what you need to do is, you have to first make that either compact or it is quality better, so for that purpose also, the piles are used.

Now, what happens is, you will be learning this, in a subsequent slides, that how these piles are installed in the field. So, what happens in this case that, when these compaction piles are used, the loose sand strata, you see when the pile is getting driven, so due to the vibration, which is given to drive the pile in to the sandy strata, loose sandy strata, what happens is, due to the vibration, the sand strata gets compacted. So, that compaction enhances in the bearing capacity of the foundation and the soil.

Piles are sometimes used to resist uplift loads and thus are in tension, they are called tension piles, you have seen that, from the super structure uplift load can come into picture. So, in that case, the function of the pile mainly becomes to resist these kind of uplift load and when it has to resist the uplift load, obviously, the friction will be mobilised in the downward direction and the pile will be in tension. So, these piles are called tension piles.

Then, piles can also be used to provide anchorage against horizontal pull, as in case of anchored bulk heads and are termed as anchor piles. So, let us say that, there is

horizontal load and up pull is there, then what happens is, the pile the foundation has to resist that particular pull, so it acts as an anchor. So, this pile is called as anchor pile.

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Piles may be required to increase the stability of tall structures, where the foundations are subjected to large eccentric loads, inclined loads and moments. Can it may happen only eccentric loads are present, only inclined loads are present or only moments are present, but usually, for tall structures or heavily loaded structures, all these types are, all these types of loads are present. They are also used to avoid damage, due to the possible scouring of the soil immediately below the foundation.

Let us say, that you have to go for some foundation, for may be river abutment or bridge pear or whatever, wherever this water is present, so when the water is flowing, then it has the tendency to scour the soil, in that case also, piles are very useful. Now, type of the piles, depending on its function, its method of installation in the field, its material of construction, they have been divided in to various categories. Because, we have seen, just now that, how this piles, they are being classified.

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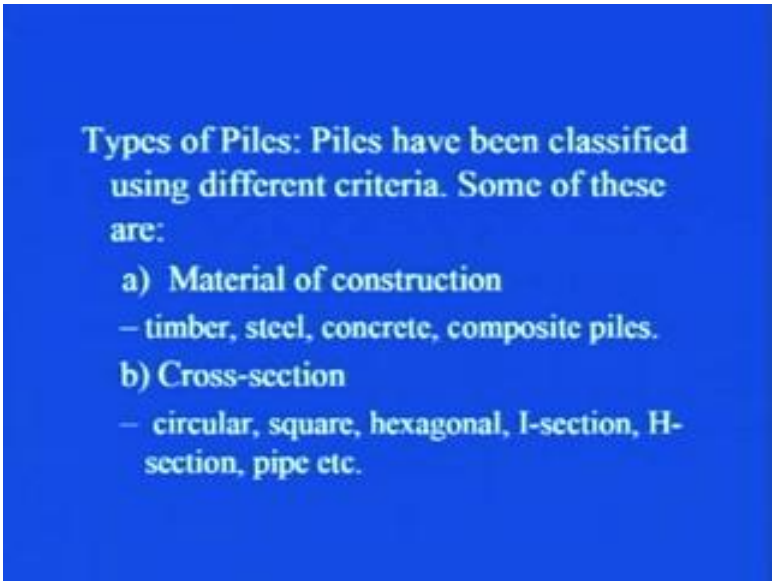

As far as, load transferring mechanism is concerned, you have seen that, if the load is getting transferred through end bearing, it is called as end bearing pile. If it is through friction, it is frictional pile, then laterally loaded piles, anchor pile, tension pile, compaction pile etcetera. So here, based on material of construction, you have timber piles, steel piles, concrete piles and composite piles, however, in case of cross section, the cross section of the pile can be circular, it can be square, it can be hexagonal, I section, H section or pipe section.

So, depending on the cross section you can call, if the cross section of the pile is circular, it will be known as circular pile, square, square pile, maybe I section, so I section pile. Now, based on shape, it can be cylindrical, tapered or under reamed, this under reamed, we will be discussing little in detail, may be in subsequent slides or in subsequent lectures.

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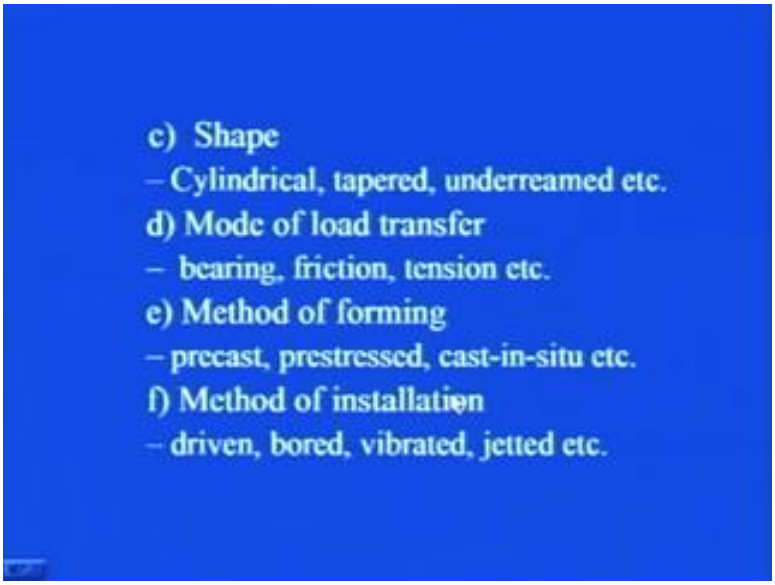

Then, mode of load transfer, this we have already seen, that bearing, friction, tension etcetera. Then, how it is formed, that is whether it is already precast at some other location and then transferred to the site, where it has to be installed or it may happen, that it is getting casted at the site, that is called as cast-in-situ. You see here, cast-in-situ, this means that, the pile is being casted at the site only, it has not been pre casted and transferred to the site, it is getting casted over there, on the spot only.

Then method of installation, that is pile can be driven, it can be bored, it can be vibrated or jetted. So, depending on this method of installation, there are various types of piles.

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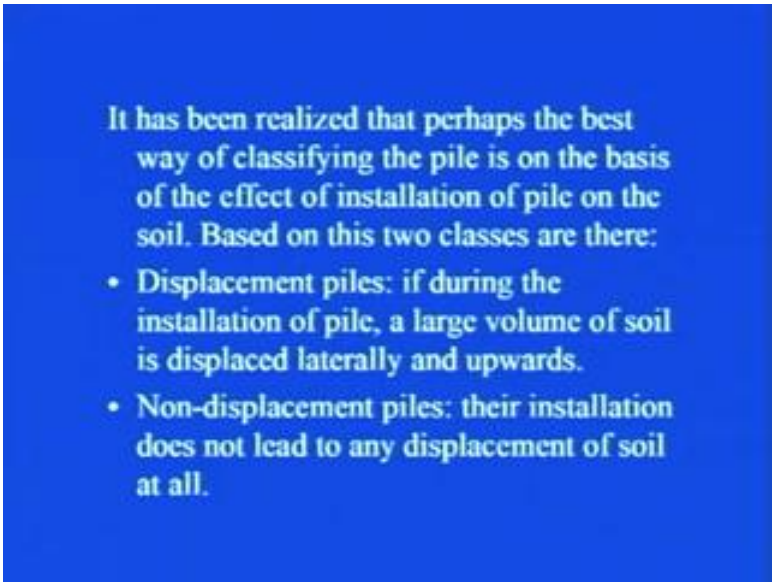

Now, it has been realised, that perhaps, the best way of classifying the pile, is on the basis of the effect of installation of pile on the soil. So, based on this, two classes are there, one is displacement pile, if, during the installation of pile, a large volume of soil is displaced laterally and upwards, so when, let us say that during the construction or during the installation of pile, if the method adopted is such that, a large volume of soil is displaced laterally or upward, then those piles are called displacement piles.

In case of non displacement piles, in their installation procedure, there is no displacement of the soil at all. That means that, there is no displacement or the soil is remaining as it is, it was there in the original position.

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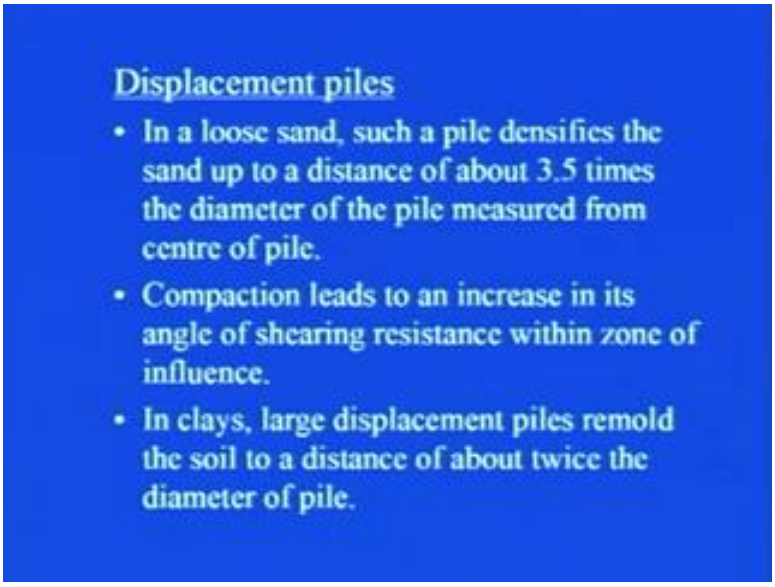

Now, let us try to see some of the aspects related to displacement piles, so in loose sand, such a pile densifies the sand up to a distance of about 3.5 times the diameter of pile measured from the centre of the pile. You see, what happens is, when you, as I explained you that, in case of loose sand strata which is present over there, if you drive a pile, sometimes it may serve the purpose of compacting that particular loose sand strata, that is called compaction pile.

So, usually, when in, when a pile is getting driven into the sand strata, let us say one pile is getting driven, what happens is, if the dia of the pile, is say one meter, then around that 3.5 times the diameter of the pile. So, if one meter is the diameter, so around 3.5 meter distance, around the pile will get densified, whatever sand is there in that particular area,

it will get densified. So, this compaction leads to an increase, in its angle of shearing resistance within the zone of influence.

So, what is zone of influence, here in this case is 3.5 times the diameter of the pile, obviously, when the loose sand is getting compacted, it will increase in the shearing strength parameter, it is strength will increase and so, it is, this shear parameters will also increase. Now, what happens in clay, in clays large displacement piles remold the soil to a distance of about twice the diameter of the pile. So, that was, in the case of loose sand, that is cohesion less material.

In that one, the extent of influence zone was 3.5 times the diameter of the pile, however, in case of clay, this is two times the diameter of the pile.

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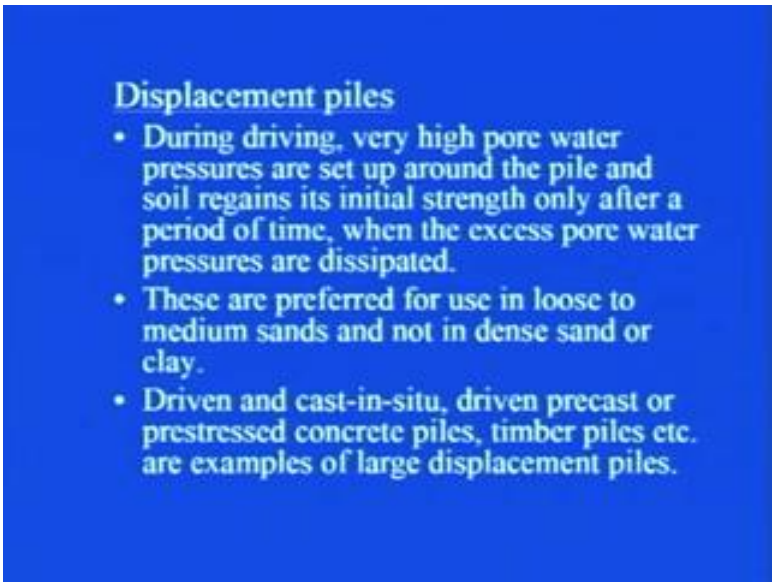

Now, during driving, very high pore water pressure are set up around the pile and soil regain, it is initial strength, only after a period of time, when the excess pore water pressure are dissipated. You see in clays, what happens is, if the water table is present, the mostly the phenomena is the consolidation, what is consolidation is that, the dissipation of the pore water pressure with time.

So this, when, if during driving, very high bore water pressure are setup around the pile, so the soil will regain, it is strength after some time, when that extra pore water pressure gets dissipated, after that only. These are preferred for use in loose to medium sands and not in dense sand or clay. That means, the displacement piles, they are preferably used in

loose to medium sands, because in case of dense sand, what will happen, it will become very difficult to drive these piles, right.

Because they have the tendency to compact the soil about 3.5 times, the diameter of the pile. However, in case of clay, what will happen, it remoulds the clay about two times the diameter of the pile and so, in, with that the high pore water pressure gets generated, soil loses it is strength, that is why, it is not preferable in case of dense sand or clay. The various type of, what are the various types of large displacement piles, they are driven in cast-in-situ, driven precast or pre stressed concrete piles, timber piles etcetera.

These are various examples, now, if I see the driven, what do we mean by a driven term, that I am using here. The driven is, that you are driving, see there are two methods that simply the pile is constructed already, you are driving it, with some mechanical hammering or some vibration technique, so that term is known as driven. Then, cast-in-situ, as I explained you, it is getting casted on the, in the field itself, then driven precast, it has been casted already, transferred to the site and then getting driven by some mechanical hammering process.

Pre stressed concrete pile, in that one, the pile gets stressed during its construction, that is, when it is getting precasted or when it is getting casted, then there is some stress, which is being inbuilt, which is forced to inbuilt in the pile, that is what is pre stressed concrete pile and then timber pile, you know, if it is made of timber that is timber pile.

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Now, displacement piles again, there are some piles like the rolled steel section piles, screw piles, open ended hollow section piles etc. which are classified as small displacement piles as on account of their a small cross section, they produce small displacement of piles, so you see, in case of rolled steel section, screw piles etcetera, what happens is, since their cross section is small, they cause or they produce very small displacement of the soil, which is around these piles.

That is why, they are called this small displacement piles, these small displacement piles are preferred, when ground displacements and disturbances are to be minimised. Now, when this condition can occur, let us say that, wherever is your construction site, some nearby structure is very sophisticated one and you really cannot allow that soil to be disturbed. So, in that case and at the same time, you cannot go for shallow foundation, so at the, those type of locations, you need to go for these small displacement small displacement piles.

So, now let us try to see, some of the features of non displacement piles, how they are formed.

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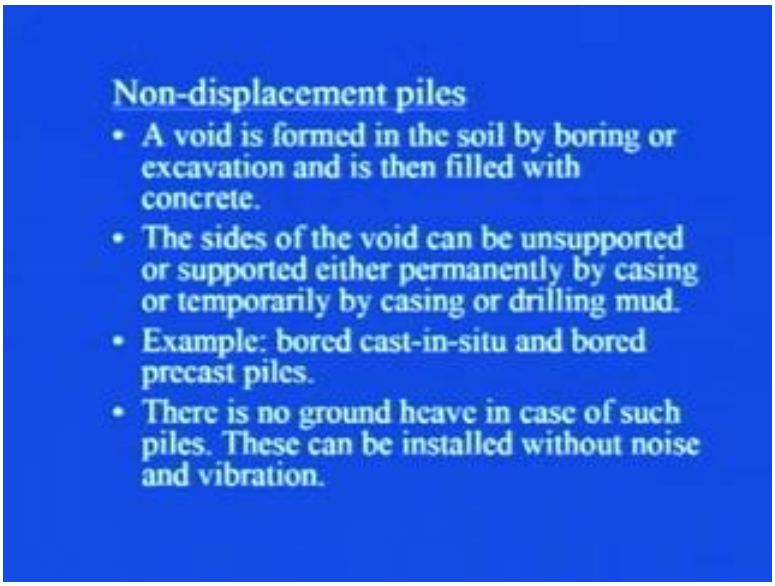

A void is formed, in the soil by boring or excavation and is then filled with concrete, you saw, that in displacement piles, what was happening that while driving or while installing the pile, the disturbance was caused in the surrounding soil and so, that particular type of pile was not suitable for all type of soils. However, in case of non displacement piles

what happens is, a boring is done or some excavation kind of thing is done and then, concrete is poured in to that particular void, which is created by boring or excavation.

And it is filled with concrete to form the pile, the sides of the void can be unsupported or supported, either permanently by casing or temporarily by casing or drilling mud. Now, the thing is, let us say, that you have to go obviously, wherever you are going for pile foundation, the soil strata is going to poor, be poor. Now, if the length of the pile, say it is of the order of twenty five to thirty meters. Sometimes, it becomes difficult to make that particular bore or that particular bore hole exactly vertical.

It may happen, that the voids of that vertical bore hole may get collapse, so in case, we need to support them. So, how we can support them, either permanently or temporarily, so permanently, casing can be used to support that particular bore hole or temporarily by casing or drilling mud. Examples of non displacement piles are bored cast-in-situ piles and bored precast piles. Now, here I am introducing this new term as bored, earlier it was driven.

So, the method of installation was with the help of some mechanical measure, that is by hammering or due to vibration, but in case of bored is what, first the void is getting created which is usually called as bore hole and then, in that one, the concrete is being filled. So, in that case, it is getting casted on the site itself, so that becomes bored cast-in-situ pile. However, if the void is being formed, due to boring or excavation and in that one, the pile is getting lowered, that is the pile is, has already been casted not at the site, but in some work shop or somewhere else.

And then, it has got transported to the site and simply, you lower down that particular pile which has already been casted in the pore hole, that type of pile is called as bored precast piles. There is no ground heave in case of such piles, these can be installed without noise and vibration. So, you see, in case of installation of pile using the hammer, what can be the case, one when you go on hammering the pile, it may happen, that the ground may get upward, so that is what is called the ground heave.

However, in this case, since the void is first formed due to boring or excavation, there is no question of ground heave and at the same time, another advantage is, that there is no noise and vibration in the nearby surrounding soil or nearby structure, while installing these non displacement piles.

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Length of these piles can easily be varied at site, so you see, what happens is while construction or while installation of these piles, first the bore hole is prepared or a void is prepared. So, depending on whatever is the length of the pile, let us say at the site, there is some change, some sudden change, usually it does not happen, but let us say in some case, the sudden change is there in the length of the pile. So, that you can take here, in case of non displacement piles.

However, in case of driven piles, you cannot take that into account, it is further possible to install very long piles with very large diameters. Construction of enlarged end up to about three times pile diameter, is possible in clay, so you see here, since you are preparing a void by boring. So, depending on whatever is the diameter or the length of the pile, required for the design of pile foundation, you can decide upon the dimension and the extent of the pore hole also.

Let us say, that you require a pile of one meter diameter and twenty five meter length, so accordingly at site, you can prepare a void or bore hole of let us say little more than one meter, diameter and the height, the depth of twenty five meter. Apart from that, what is the further advantage of this non displacement pile, you see, the construction of enlarged ends up to about three times the pile diameter, so if the pile is of diameter one meter, you can make the end of the pile.

That is at the tip of the pile, you can make that to extent of three meter, is in case of clays, the result, in this results in the substantial increase in point bearing owing to larger

bearing area. So, if at base, the area of the pile is more obviously, the end bearing will be more and which will result in to higher point bearing capacity. The construction process enables inspection of the excavated soil and it is comparison with the soil exploration data.

See, before going for any construction, at any particular site, you go for soil exploration, that you have already studied in the beginning of this particular course foundation engineering. So, whatever data that you get from the soil exploration, that can be checked, here in this process, because when you are, when the process of installation is going on, what happens is, you prepare a pore hole, in that particular process, you can take out some of the soil samples at different depth level.

And then, you can check the proper, you can get them tested and then, you can check the property of these samples to the soil exploration data that you already have. So, in case that any particular thing gets left out, let us say, any presence of some cavity or may be loose soil pocket at the larger depth, in that case, that can be taken in to account during the installation of these non displacement piles.

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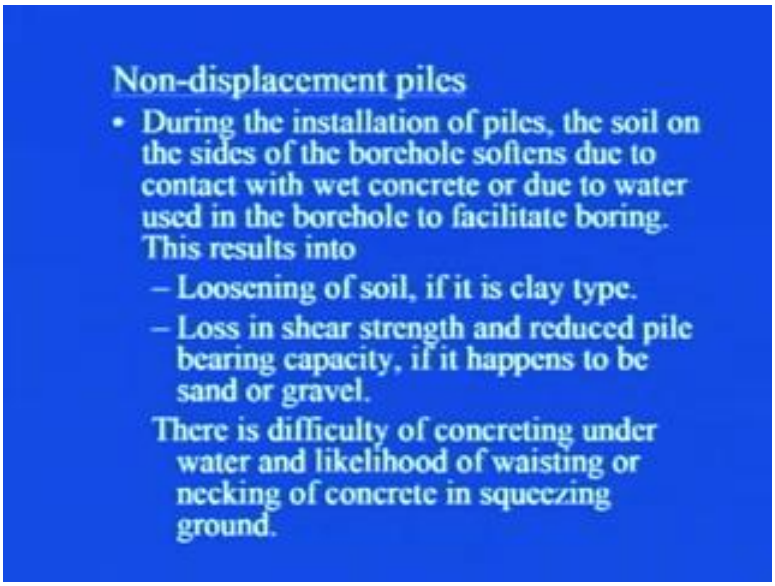

Then, during the installation of piles, the soil on the side of the borehole softens due to contact with wet concrete or due to water, used in the borehole to facilitate boring. See, what happens is, when you go for boring, you have to avoid sand voiding or many a times to facilitate the boring, because it may happen that the soil strata as you go deeper

and deeper, it is very compact in nature. So, what is done in the field is that, they just pour some water from top of the bore hole, which actually loosens the soil.

That is the wall of the bore hole, the soil adjacent to that, it gets loosened or may be, in case the water is not used, so when you place the concrete, when you pour the concrete, concrete is wet in that condition. So, the soil, which is in contact with that wet concrete, it also gets loosened, in that case, this particular two cases, they result into some of the things which we must take in to account.

First observation is, the loosening of soil, if it is of clay type, if you are digging a bore hole or you are planning to install the pile, in clay type of material, what happens is, in the presence of, say use of water during boring or the contact of wet concrete with the bore hole wall, the loosening of this clay soil can be there, which results in to loss in shear strength and reduced pile bearing capacity, if it happens to be sand or gravel. So, in case of clay, loosening of soil takes place, obviously that loosening results in to lesser capacity of the soil.

However, in case of sand, what happens is that, it results in to the loss of shear strength and subsequently the pile capacity gets reduced. There is difficulty of concrete in, under water and likelihood of wasting or necking of concrete in squeezing ground. Now, what do you mean by squeezing ground, say, if there is a variation of natural water table and the soil is sensitive to that, that is known as your squeezing ground and in case of that kind of soil is present over there.

So, due to the presence of water table or making of concrete, what happens is, it becomes very difficult to go for concreting. So, this is a little disadvantage of these non displacement piles.

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Then, bulbs cannot be made in granular soil, if it is clay, then bulbs at the end can be made and which they, you have seen that they result in to larger point bearing resistance. However, in case of sand, that thing is not possible or in case of granular soil, it is not possible, it is essential, that concrete is placed as soon as possible after the boring is done to minimise the softening of the soil. See, when the boring is done, some water is poured to facilitate it.

Now, if you leave that for some time, the water will get in to the soil for further loosening of the soil. So, what happens is that time, should be minimised by any means in between the concreting and the completion of the bore hole to minimise the softening of the soil.

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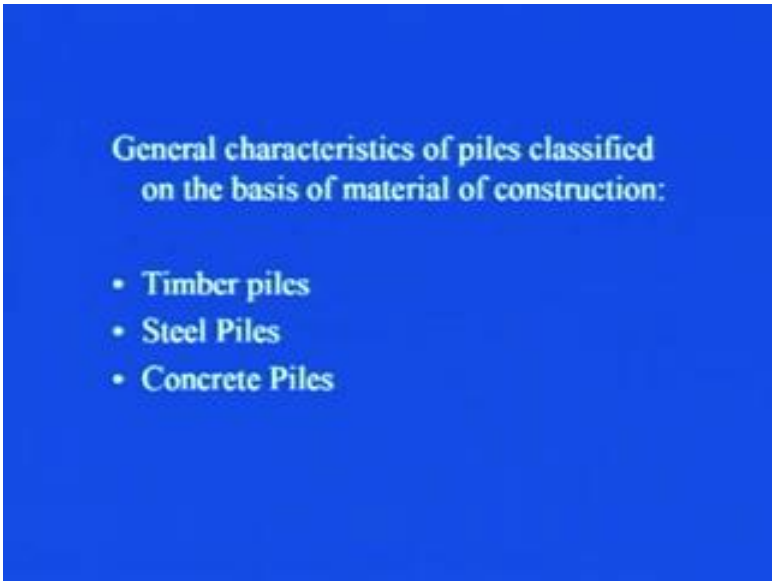

Now, these were some of the aspects related to displacement piles and non displacement piles. General characteristics based on piles, classified on the basis of material of construction, that we will be discussing now. Mainly, I will be taking up three types, that is timber piles, second is steel piles and the third one is concrete piles, as the name suggest and you are seeing that, the first line states that, on the basis of material of construction.

That means, timber pile, in timber pile, timbers have been used for construction these piles, steel piles, steel has been used and in concrete, concrete is used. So, in case of timber piles.

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A timber pile is primarily a trunk of a tree, with its branches chopped off, an iron shoe may be provided at the tip and iron cap at the top to prevent damage during driving. So, it is, just as its name suggests, it is made up of timber and to avoid any damage to this pile, at the top and at the bottom iron cap is to be provided. They are very cheap and easy to handle, length up to thirty meter has been used for these, I mean various places, till the maximum depth of thirty meter, these timber piles can be used.

In situations of fluctuating water table, these should be suitably treated to enhance their lives, because you know, when a timber is in contact with water, it has a tendency to disintegrate. So, to avoid that, it should be properly treated, an untreated pile, above water table is likely to be eaten away by insects, pores, termites etcetera and hence chemical treatment is desirable. Now, the allowable loads on these piles, they vary from 100 to 250 kN per pile, see, why I am giving you this guideline.

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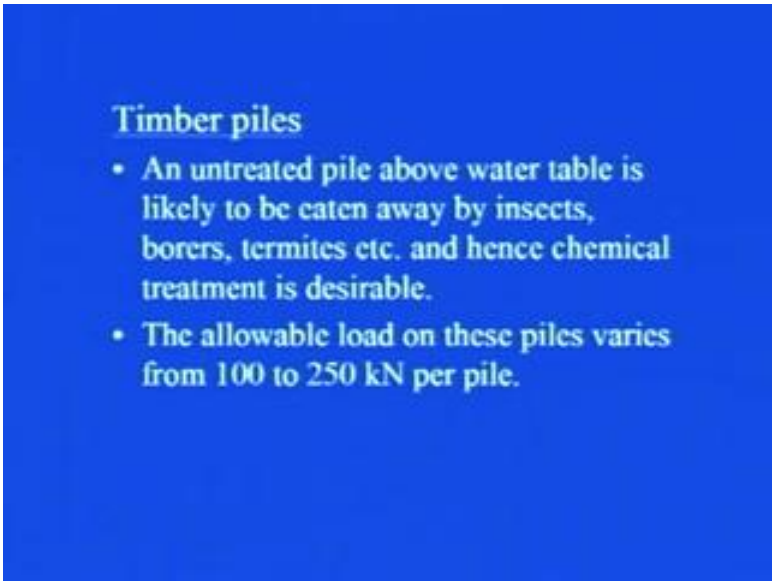

That usually, when you will be going for construction, it will be your decision that, which type of pile, what should be the length, what should be the diameter, what should be the size of the pile that you should use. So, if you know the property of typical piles of different types, you can make your choice easily, depending on, whatever is the conditions at the site, you can pick, that if the load is lesser, if there is no water table present, if it is suitable for timber piles, we can go ahead for timber piles.

Otherwise, steel piles or concrete piles.

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Let us see, what are the main features, salient features for steel piles, these are small displacement piles. As you have seen, that wherever we have to minimise the vibration or the disturbance, there we use small displacement piles and usually they are steel piles. Heave and ground displacements are minimal in this case, it may be a rolled section, a pipe or any fabricated shape, you know, that different I section, x section, they are available, they can be used as steel piles.

These require heavy equipment for driving, because their weight is very high and they are obviously, they are precast, they, we, you just cannot cause them at the site only. So, you simply have to drive that, so that is why, you require heavy equipment for them. The pipe piles are made of seamless or welded pipes and are usually filled with concrete, so that becomes a combination of steel and concrete both.

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These pipes, may be driven close ended with a driving point or open ended, you see, what happens is, let us say that you have provide, you have driving it, what happens is, the, in case of pipe, both the ends can be open ended. So, you simply drive that particular pile and pour the concrete in to it, the end which is at the larger depth, it can be close ended or it can be open also. Steel piles can be used to carry very heavy loads, splicing of these is also easy.

Now, these are likely to be affected by corrosive action and hence, needed painting or encasement in concrete to resist corrosion. So, you see, in case of timber piles, the water

was the main problem, the presence of water was the problem. However in case of steel piles, it is the corrosion.

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Commonly adopted length is up to 40 meters and allowable load can go up to 1800kN per pile. So, you see in case of timber pile, it was around 200, 250 kilonewton and here, it is 1800 kN.

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Now, concrete piles, these are considered more or less permanent, based on mode of forming and mode of installation, they are usually divided into two categories, first is driven precast concrete piles, second is cast-in-situ concrete piles. Basically, if you will

see, that for all the practical purposes, usually these concrete piles are provided, they are more or less permanent in nature and two categories, driven precast, so you see, the mode of installing the pile is by driving.

However, the mode of its forming or its construction is precast, that is, it is being casted at the work shop and it has been transferred to the site. Then, cast-in-situ, it is being casted on the spot only.

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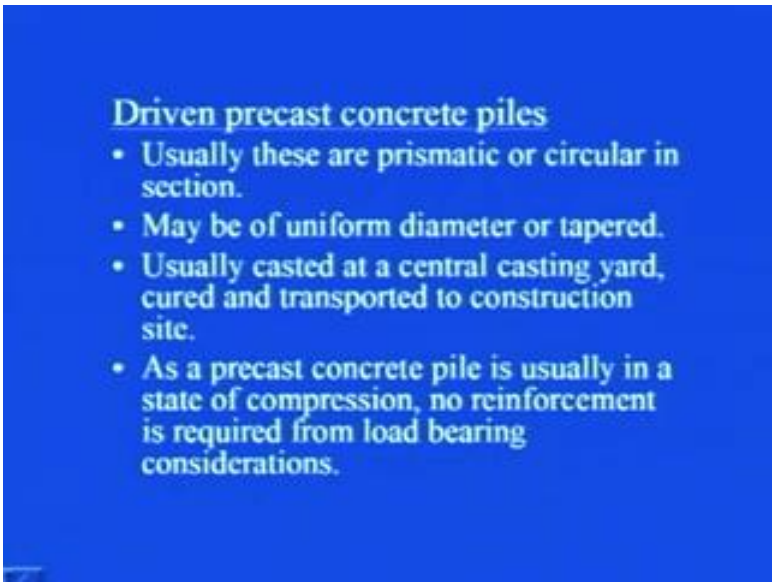

Let us first have look, on some of the salient points on driven precast concrete piles, driven, it is getting driven by some mechanical means due to vibration, hammering, precast. It has been constructed or casted at work shop, it has been transported to the site, so wherever, there is precast pile, its size, shape is going to be fixed, you cannot alter them. Usually, these are prismatic or circular in section, that is the cross section, is either prismatic or circular.

It can be of uniform diameter throughout its depth or it can be tapered, depending on the requirement. They are usually casted at the central casting yard, cured and then transported to construction site, you see, wherever you need to use concrete to attain its full strength, you have to properly cure that, so first, casting is done, then curing and then the transportation to the construction site. Now, as the precast concrete pile is usually in a state of compression, no reinforcement is required from load bearing consideration.

So, you simply cast there, with the help of concrete, get it cured, transported and then simply drive it at the site.

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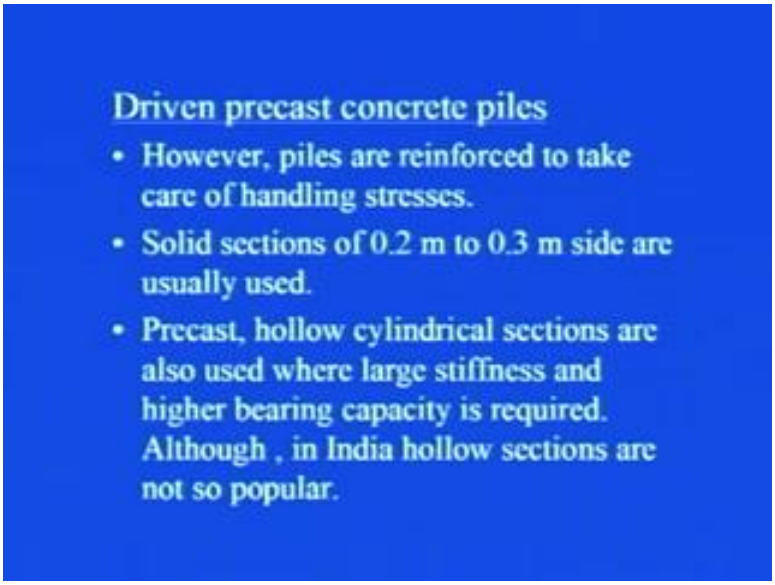

However, piles are reinforced to take care of handling stresses, although, from the load bearing point of view, you do not require any kind of reinforcement, however, for stresses, you need to provide some reinforcement, solid sections of 0.2 m to 0.3 m sides are also use. Now, precast, hollow cylindrical sections are also used where large stiffness and high bearing capacity is required. Although, in our country India, this hollow sections are not so popular, however in abroad many countries, this has been used in the construction.

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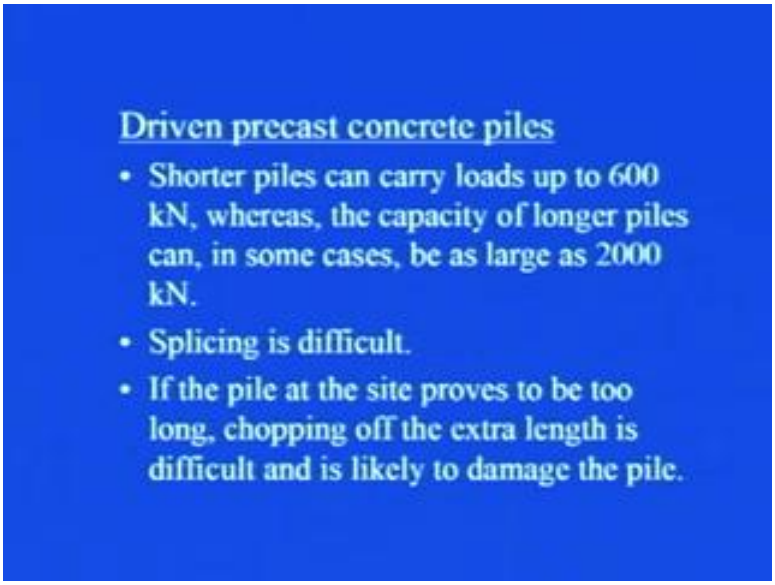

Then, what is the load area, load range, that is shorter piles can carry loads up to 600kN, whereas, the capacity of longer piles can, in some case, be as large as 2000kN. So, you saw that, last, in the last one, when we were talking of the steel piles, it was 1800kN per pile. However, in this case, if you go for larger pile, longer piles, then this capacity is of the order of 2000kN, in this one splicing is difficult, if the pile at the site proves to be too long, chopping of the extra length is difficult and is likely to damage the pile.

As, I explained you earlier, when I started this particular topic, that any alteration in it is size and shape, is little difficult in case of precast concrete pile. So, in this case also, this is a kind of disadvantage of this particular type of pile, that in case, that at site you find that the particular size is not suitable, it is difficult to alter the size and shape.

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Then, it is handling and driving require, heavy equipment, then heave and disturbance of surrounding soil may also cause difficulty. See, it is precast and if you can imagine, that pile diameter of one meter and of length twenty five meter, if it is precast and get, have got transported, it how difficult it will be to carry that upward and then to drive it in to the soil. So, that requires very heavy equipment and in that particular process, lot of ground heave and disturbance of the surrounding soil takes place, which may cause problem to the neighbouring structure or surrounding soil.

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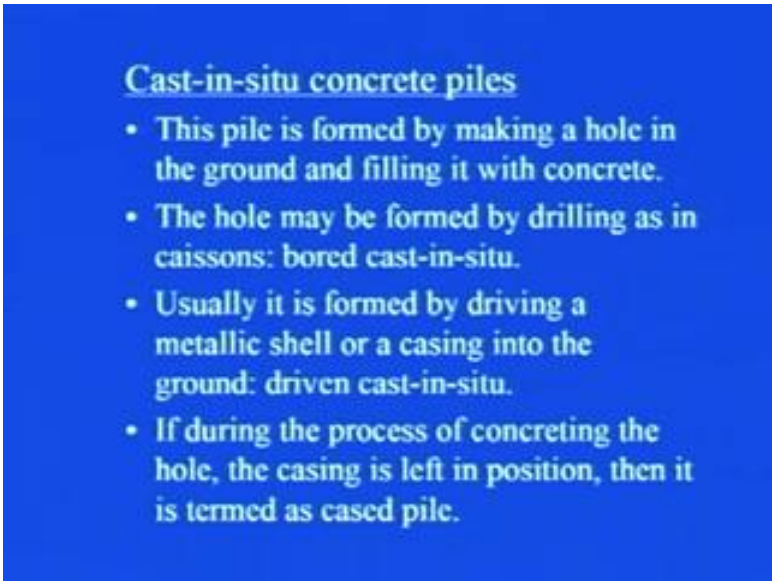

Now, cast-in-situ concrete piles, cast-in-situ means, it is being casted at the site itself, these piles, if they are formed by making a hole in the ground and filling it with concrete, This hole is usually called as bore hole, this hole may be formed by drilling, as in caissons, that is bored cast-in-situ. Usually, it is formed by driving a metallic shell or a casing in to the ground, that is driven cast-in-situ. So, you must understand the difference between this bored and driven term here, at this particular, at these two points.

See, in this case, bored cast-in-situ pile, the hole may be formed by drilling as in case of caissons, you simply go on drilling and then you take out the material and the hole is formed and in this one, usually it is formed by driving a metallic shell or the casing in to the ground, so if you drive the casing, you take it out and that way, the void or this bore hole will be formed. If, during the process of concreting the hole, the casing is left in position, then it is termed as cased pile.

Let us say, that here, as I told you that in case of driven cast-in-situ pile, the hole, bore hole is formed by casing, driving the casing in to the ground. If you leave the casing, as it is in position, then that particular type of pile is called cased pile.

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If, in case, this casing is withdrawn gradually, in that case, it is called as uncased pile, so either the casing can be left, as it is in position or it can be withdrawn, accordingly it is named as cased pile or pile or uncased pile. Uncased piles can be of different diameter and may be provided, with an enlarged end or a pedestal, so in case, if you have to drive that casing out, in that case, you have this flexibility. So, today, what we saw that, I introduced you that what exactly are the deep foundations.

How they are different from shallow foundations, as far as load transferring mechanism is concerned. Then, we saw that, based on this load transferring mechanism, how they can be classified, like end bearing, friction piles, compaction piles etcetera. Then, we saw that, how based on the mode of construction they are formed, that is, when a pile is getting constructed or getting installed, then it is causing lot of displacement around the surrounding soil, then it is called as displacement piles, otherwise, it is non displacement piles.

And then, we saw that, based on the material of construction, how the piles are classified, that is timber piles, we saw some of the aspects, main salient features of timber piles, then steel piles and then concrete piles. In concrete piles, we saw bored piles and driven piles, so in the next class, we will be discussing their relative advantages and disadvantages and I will be sharing, some of my experience at particular site, where the construction was going on.

Thank you.