Foundation Engineering
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Module - 02
Lecture - 07
Pile Foundations - 2

Good afternoon, last lecture we started with various aspects of Pile Foundations, first I told you, that what exactly do you mean by pile foundations and why it is required. That, when the above soil is strata, is not good or poor in nature that it is unable to take the load, which is coming from the super structure. Then, we need to extend the foundation to the larger stratum and those types of foundations, they are called deep foundations and pile foundation is one of that types.

And then, we discussed that what are the various types of pile foundation depending on the load transferring mechanism, piles can be classified as point bearing pile, skin friction, then compaction pile, tension pile, etcetera. Then, depending on the material of construction of pile, these can be classified as timber piles, then we had steel piles and then we started with concrete piles.

In concrete piles, there were two types of piles, one was Bored Cast in-situ and another was Driven Pre Cast concrete pile. So, we saw that; what are the main features of these pile in the last class. Today, let us try to see that what are the various advantages and disadvantages of these two types of concrete piles, how one can be superior to another or what exactly is the disadvantage or advantage of one particular type to the another one.

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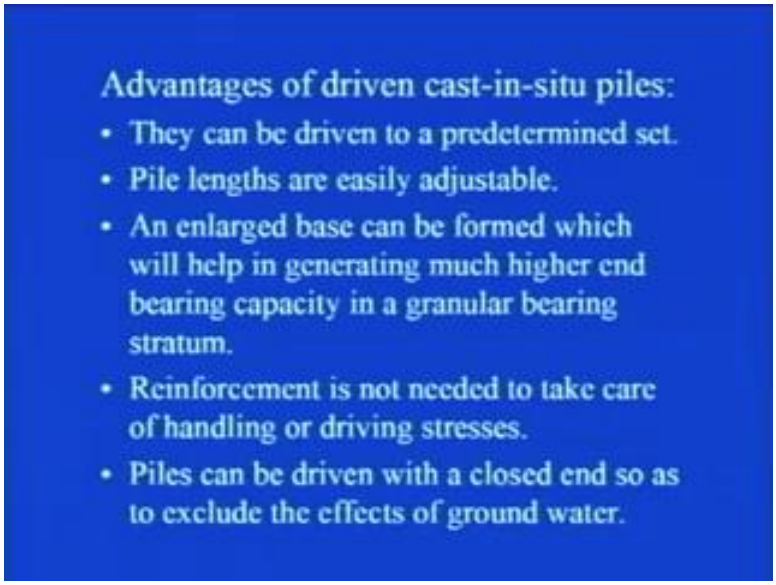

First starting with advantages of driven cast in-situ piles, once again I would like to recapitulate; that what are these words mean by driven is that you are driving it by any mechanical mean by hammering or by vibration. Cast in-situ, it is getting casted at the site itself, they can be driven to a predetermined set; pile lengths are easily adjustable, since they are being casted at site only.

So, let us say at the 11th audio you change the length of the pile, then that can be taken care of and an enlarged base can be formed which will help in generating much higher end bearing capacity in a granular bearing stratum. Let us say that, you are driving a pile in a granular bearing stratum and then towards the end of the pile, that is where it is tip will be resting. There you can provide an enlarged base, which will result into larger bearing capacity, this aspect also we discussed in the last class.

This case, reinforce is not needed to take care of handling or driving stresses piles can be driven with a closed end. So, as to exclude the effect of ground water, let us say that while driving the pile you come across somewhere ground water table. So, if the pile is driven with closed end, there you will not be having any effect of this presence of ground water table.

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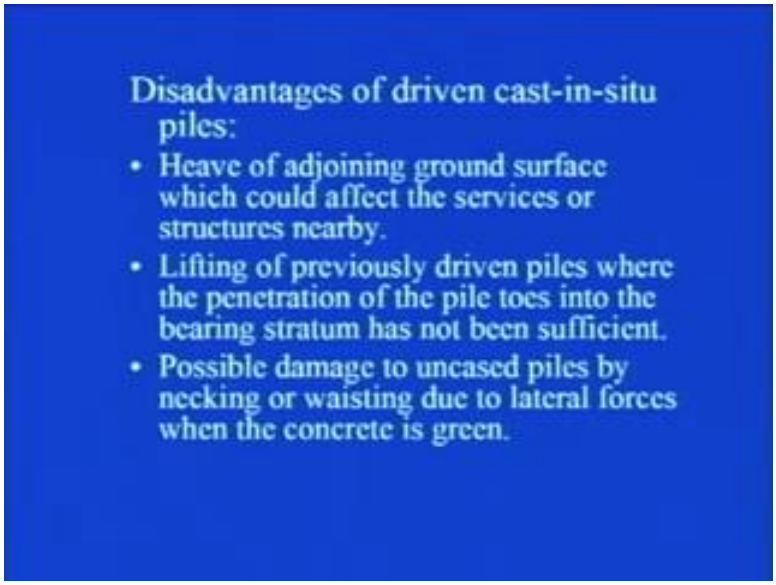

Some of the disadvantages of driven cast in-situ piles, that heave of adjoining ground surface which could not affect the services of structures or nearby. That is let us say a very sophisticated structure is there, in nearby location that does not I mean you have to protect that from any kind of vibration. So, in that case while driving the pile, there will be lot of vibration, which will take place and the heave also can occur, so that is one of the disadvantage of driven cast in-situ piles.

Lifting of previously driven piles, where the penetration of the pile toes in to the bearing stratum has not been sufficient, so that is again one of the disadvantages. Possible damage to uncased piles by necking or waisting due to lateral forces, when the concrete is green let us say that concreting is going on and the concrete is green. In that particular case and in case of uncased pile, when after concreting, you are not taking out the casing out.

So, you are taking out the casing and that type of pile is uncased pile, so possible damage can be there.

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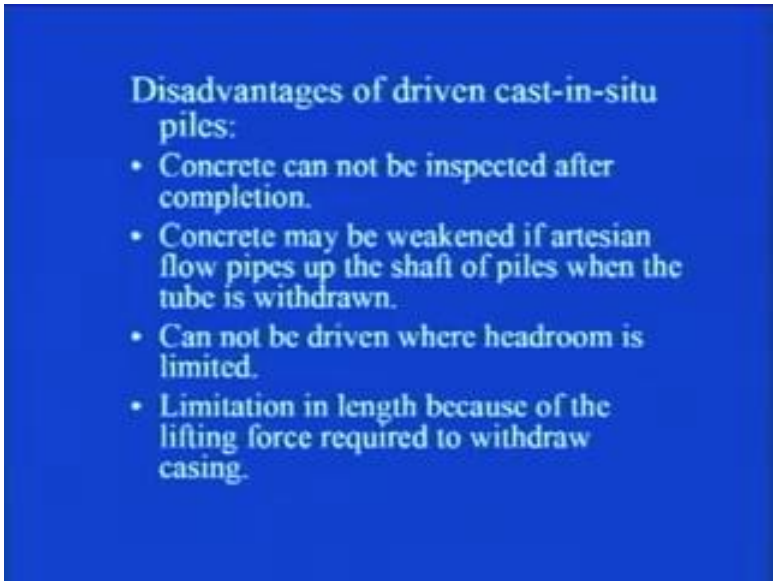

Then concrete cannot be inspected after completion, concrete may be weakened, if artesian flow pipes up, the shaft of pile, when the tube is withdrawn, again this is when the concrete is weakened; obviously, the pile bearing capacity will decrease. So, that is not desirable, so it becomes one of the disadvantages of driven cast in-situ piles. It cannot be driven where headroom is limited, then limitation in length because of lifting force required to withdraw the casing.

So, let us say in case of uncased pile, you have to take out the casing, so in case of higher length of the pile, the lifting up of the casing becomes more and more difficult, in case of driven cast in-situ pile.

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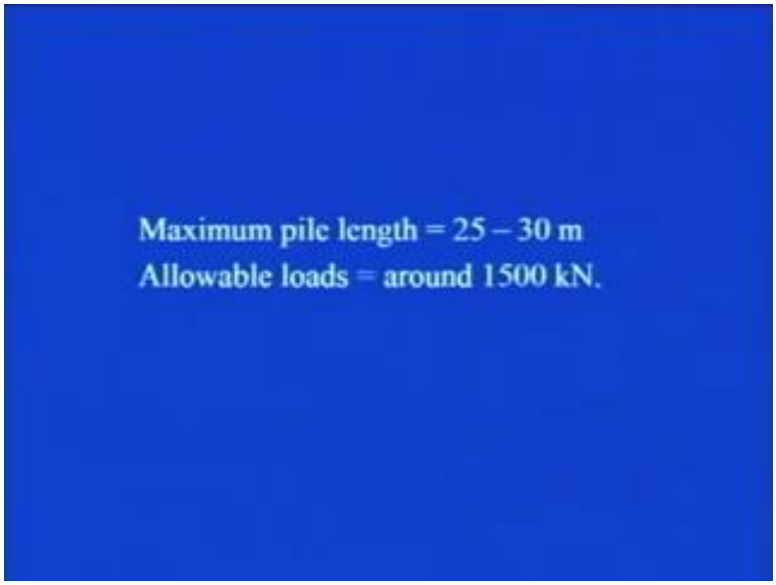

The maximum pile length, which you can go for, in case of driven cast in-situ pile is of the order of 25 to 30 meter and allowable load which any driven cast in-situ pile can take depending on the soil condition can be of the order of 1500 kilo Newton.

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Now, some of the advantages of bored cast in-situ piles, what do we mean by bored word here, that you have to first create a void by boring or some excavation measure. And then, you have to fill that with concrete which will form as bored cast in-situ pile, cast in-situ, it is getting casted at the site only. Very little displacement or no risk of ground heave, as you know that this falls under the category of non displacement piles.

So, in this case and there is no mechanical hammering, which is taking place while driving this kind of pile. So, very little displacement is there and there is no risk of ground heave at all, length can be readily varied, soil can be inspected and checked with soil investigation data. See, when you will be creating the void or excavation, so whatever is the soil, that you are taking it out, you know at which particular depth, you are taking that soil out by examining that particular soil.

And by comparing with the soil exploration data, it is gives you to check, whether your soil exploration data is proper or not it just confirms that information Piles can be installed in very great lengths and very large diameter, this is one of the main advantage of bored cast in-situ piles.

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End enlargements of up to two to three shaft diameters are possible in clay or soft rocks; see in the earlier case, it was for driven cast in-situ piles, it was the enlarged base was able to form in granular deposit. However, in case of bored cast in-situ pile, this end enlargement can be possible in clays or soft rocks. It can be installed without much noise and vibration and with limited headroom.

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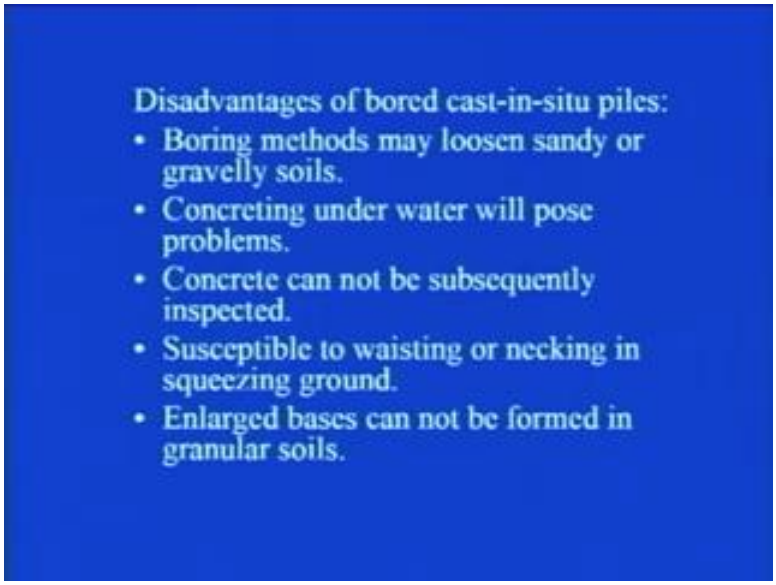

Now, some of the disadvantages of bored cast in-situ piles, that boring methods may loosen sandy or gravelly soil, see if the soil is of claye in nature then this bored cast in situ piles are quite advantageous. But, in case of sandy or gravelly soil in the process of boring or excavation or creating the void, there can be loosening of the soil strata, which is not at all desirable as far as construction is concerned.

Concreting under water will pose problem, because it is Cast in-situ, you are creating a void and then, you are filling that with concrete. So, in case if the water is present somewhere, along the length of the pile, that can pose the problem, then concrete cannot be subsequently inspected. Once, you have created the whole of let us say 30 meter depth, then you have to go on pouring the concrete and then go on compacting it.

But, we really cannot inspect that to what extent, it has got compacted, whether we have achieved that desired degree of compaction of concrete or not, so that becomes one of the disadvantage of this kind of piles. Now, these are susceptible to waisting or necking in squeezing ground, enlarged base bases cannot be formed in case of granular soil. In case of clay soils yes you can do that, but in case of granular soils it is not possible.

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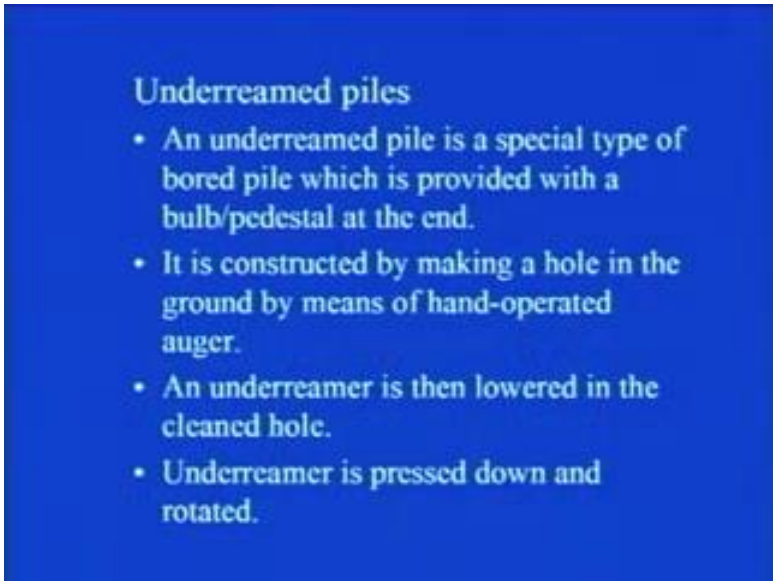

Then every time we are talking of enlarged base or say providing little more cross section as compared to the pile shaft. So, these kind of piles they are usually called as under reamed piles, let us see that what exactly are the few features of these kind of pile, an under reamed pile is a special type of bored pile, which is provided with a bulb or pedestal at the end.

So, enlarged base, it forms a kind of bulb; that we call as under reamed piles, it is constructed by making a hole in the ground by means of hand operated auger. So, what are the steps how it is being carried out, how it is being constructed that we will be discussing one by one in the subsequent slides, an under reamer is then lowered in the cleaned hole.

So, first a hole is created a bore hole is created, then you can insert an auger into that and by hand operation, you can increase the diameter at the end. And then, an under reamer is lowered in the bore hole which has been cleaned, the under reamer is pressed down and rotated.

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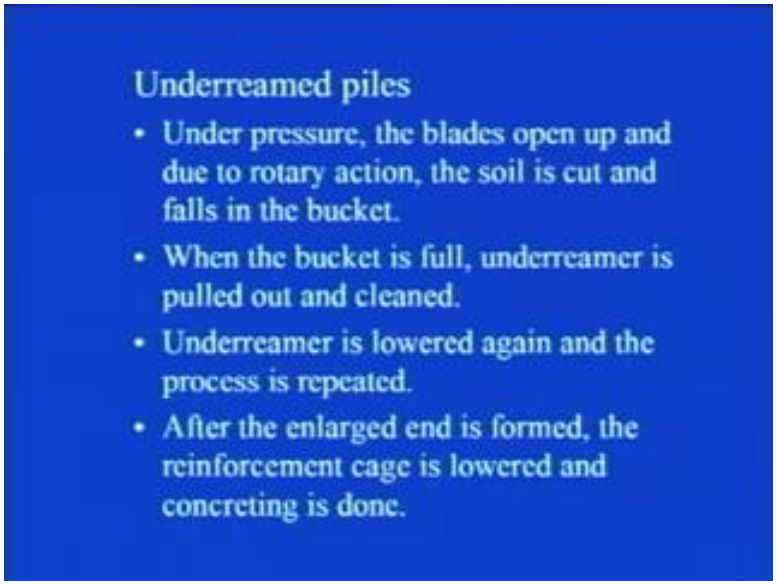

Then, under pressure the blades open up, the blades of under reamer, they opens up and due to rotary action the soil is cut and falls in the bucket. So, once the bore hole is created, you insert the under reamer and then with pressure you try to rotate it. So, as soon as it, there is a pressure on the under reamer, it is blades get opened and with the rotary action. In the clay part or in the soil part, they are below at the end of the pile, what happens is the soil is getting cut and then it falls into the bucket associated with it.

When the bucket is full, under reamer is pulled out and cleaned. So, the soil is being cut it gets accumulated there in the bucket associated with under reamer, it is then pulled out and then it is cleaned and then this process is being repeated again. So, the under reamer is lowered again and the process is repeated. After the enlarged end is formed, the reinforcement cage is lowered and the concreting is done in this case.

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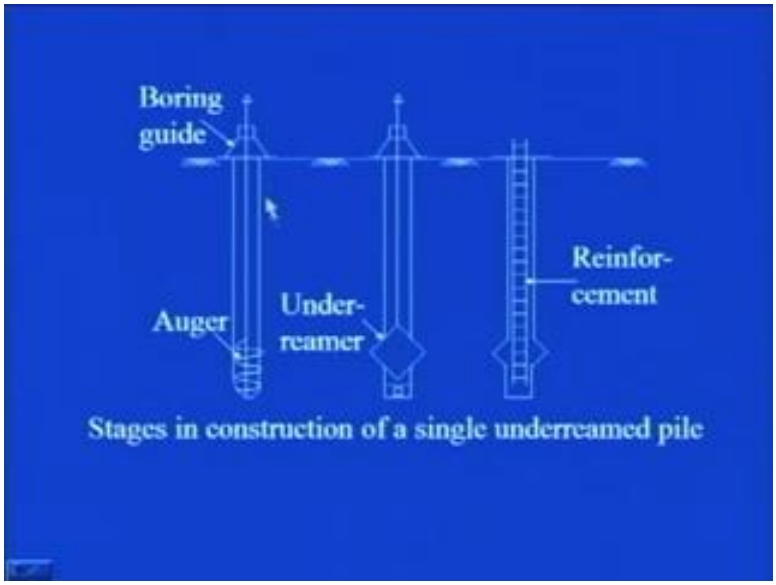

So, you see here with the help of figure, if I explain you, so first this hole is prepared that is called bore hole, that is boring guide with the help of this, you insert it the auger, see it is of this kind of shape. Now, what happens is with the auger, you just put the rotary action and then you take out the soil. So, this is the process of preparing this bore hole, once this bore hole is prepared, you insert the under reamer.

It is of this shape and then you apply the pressure from this point, what happens is, it is blades get open up and if you rotate it from this point, that is top. The soil at this particular level will get cut and it will get deposited in a bucket, which is hum which is with this particular assembly. Then, you simply take this out, empty the bucket put lower down the under reamer again with the pressure.

Again, the blades will get open and the soil will again cut and then you can take out the soil, I mean you can repeat this process again and then you can simply lower down the reinforcement cage in this particular manner and then the concreting can be done. So, these are the various stages in the construction of single under reamed pile.

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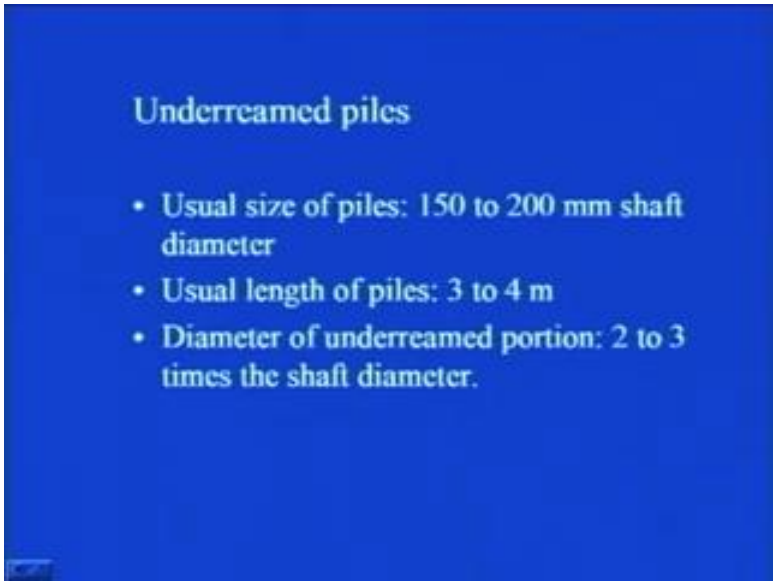

Now, these under reamed piles, usual size of piles is of the order of 150 to 200 millimetre shaft diameter, usual length of piles, they are 3 to 4 meters length diameter of under reamed portion 2 to 3 times the shaft diameter. So, if a pile is having a diameter of let us say 500 mm, then you can go for the size of the bulb for 2 to 3 times the 500 mm, but usually in case of under reamed pile the diameter of the pile shaft is of the order of 150 to 200. So, let us say if it is 150, then the diameter of under reamed portion can be 300 mm to 450 mm.

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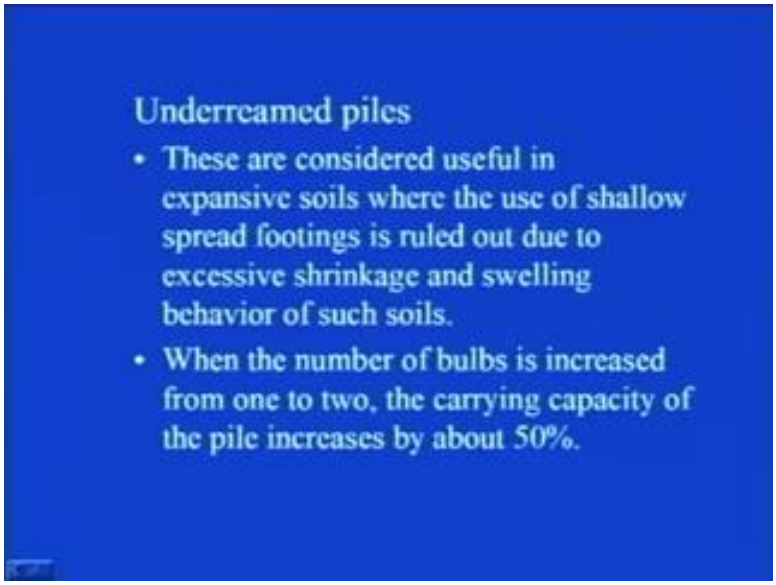

These are considered useful in case of expansive soils, where the use of shallow spread footings is ruled out due to excessive shrinkage and swelling behaviours of such soils. That expansive soil with the presence of water or the increase in temperature, they frequently either shrink or get swells. So, in that case the shallow footing does not serve the purpose. So, therefore, the deep foundations, they are usually recommended for such type of soils and in those type of soils, this under reamed piles they are proved proven to be very useful.

When, the number of bulbs is increased from 1 to 2, the carrying capacity of pile increases by about 50 percent. This is just a rough idea it is not a hard and fast rule that, it will get increased by 50 percent, it will all depend upon what is the type of the soil, which is surrounding the pile. And then, what is the bulb diameter or what exactly is the spacing, so all these things, you have to design, in case of under reamed piles.

Let us see some of the experiences that I had at one particular site, where this pile driving and construction of pile was going on. As, I told you that in case of driven precast piles, what happen is, your piles they are casted at some particular work shop. And then, they are being transported to the site and with the help of driving rigs, they are being installed in the ground. So, while driving the pile lot of hammering and vibrations, they occur

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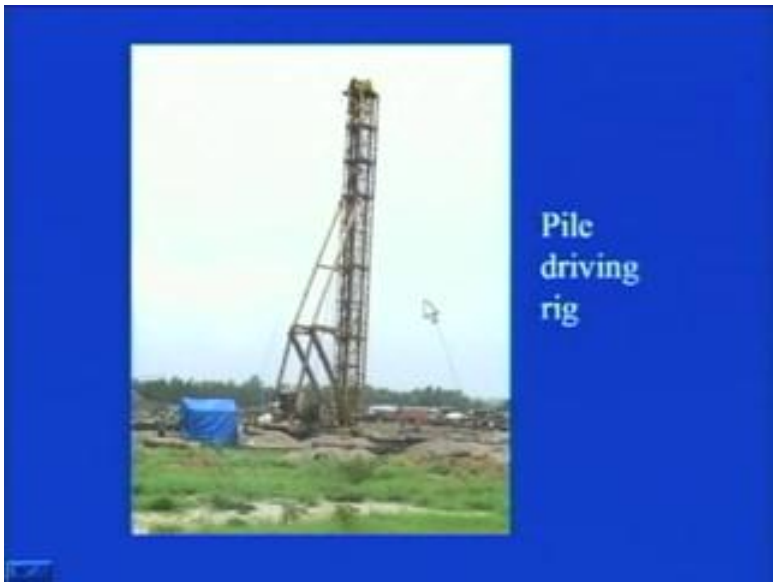

So, you can see here it such a huge driving rig, you see when it just hammers one particular blow to the pile, how much noise that it will be creating and if there is some

sensitive structure nearby, then it can cause problem to that. But, in case of barren lands, you can see here, that nearby, there are no structures only some trees and some barren land, it is there.

So, that is why at this particular site, they could go for this driven piles and then when we were dealing with the person, who was taking care of these construction of piles, usually in case of this driven piles, they go for 550 mm diameter in India. So, this becomes a limitation of driving, I mean in case of driven piles, however in case of bored cast in-situ piles, you can have the diameter of the pile as large as up to the extent of 1 or 1.5 meters.

So, you see this is the assembly; it is a kind of driving rig and here there is one hammer, it is just centre at that particular point, where you have to drive the pile and just with hammering the pile is getting driven. You see with the help of cables, you can see here, here and then some of the cables are here, they are held vertical in position.

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Then, in that was the case of driven piles, in case of bored piles, first you have to prepare the bore hole and then let us say the soil you have to go for say 25 to 30 meter pile. So, for that much depth of the pile, when you prepare the bore hole you have to make sure that the wall of the bore hole they should not collapse. So, for that you have to provide either some temporary or permanent measure to stabilise the walls of bore hole.

So, what happens either you insert a casing and then to the concreting and remain left the casing as it is in the position or another method can be that with casing, you pour the

concrete, when the concreting is over you take out the casing. Out of these two, usually there is the third one, which is being used in the construction procedure is that, you know the bentonite soil. Pond of bentonite slurry is being created and with the help of one pipe, this bentonite slurry is being filled into the bore hole which is prepared for the concreting.

So, what happens is this bentonite slurry, it gets in contact with the wall of the bore hole and then, it for the time being it strengthens the wall of the bore hole. So, you can see here that, it is filled with this bentonite slurry, you can see this is the circumference of that bore hole, this part this much part is seen here in this particular figure. Then, what is done is with the help of a pipe, this bentonite slurry is getting filled into this and there is another pipe, which takes out this particular slurry.

That is once, this slurry is being has come in contact with the soil, which is lying at the wall of this bore hole, once it get stiffened, the wall of the bore hole get stabilised. So, what happens is, then you can take out the remaining slurry, which is lying there in this and then with the help of water you have to clean the hole. Because, if this bentonite slurry remains in the bore hole, concrete will be in contact with this bentonite not with the soil, which is really lying over there that is not a desirable situation.

So, you see here a worker, he has put some weight, some weight is there with this cable he is trying to measure that at what particular depth, the soil has been taken out. See you have to go, let us say for 30 meter, so there should be some measure to ascertain, whether you have reached to that particular 30 meter length or not. So, this is a kind of you know check that they provide at the site.

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Then lowering of reinforcement cage in bore hole, see if you are going for 30 meter long pile, then the length of the reinforcement cage will be of that order and becomes like these are all steel bars and there you can see here this circular ones, rounded ones, they are ties, which tie these vertical main reinforcement of the pile. So, while lowering it down you see at a stretch you really cannot prepare a reinforcement cage of 30 meter and in one go you really cannot lower it down.

So, what happens is that, first they prepare a reinforcement cage of, let us say 10 meter, they lower down it to some depth, then they hold it back, they weld the another reinforcement cage of 10 meter. Once, it is getting welded, then they lower down this remaining part and so on, so in one go it is not been lowered. So, you can see that with the help of this rig, they just go on lowering this particular reinforcement cage.

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Then, as I told you that in one go you cannot lower this reinforcement, so you see to get this reinforcement cage, in position what is the kind of arrangement, that usually at site they go for, it is like a bamboo this thing, slab kind of a thing. They just place it in this bore hole and then you can see that they have made, it rested with the help of this lateral reinforcement, what are vertical reinforcement bar, we are main reinforcement.

However, this one is lateral reinforcement and these are lateral ties, which are either wired or welded to the main reinforcement. So, this is how they place or keep this reinforcement in position, that is some of the portion is inside the bore hole and some is outside the bore hole, why it is done, that will be clear in this one.

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You see here, this is the bamboo that you are seeing with the help of which the reinforcement has been kept in position and you can see here that this particular labour is welding here. So, you see, this was up till this one, there was one reinforcement cage; some most of the portion has been lowered into the bore hole. However, with the help of this rig, another reinforcement cage has been lowered to the extent that, this particular worker is welding it.

So, once it is getting welded at all the location, what happens is, then you can proceed this lowering down of this particular reinforcement cage. I hope that now, you can appreciate, why it is necessary to held the reinforcement in position using this particular measure. So, that the work which has to be done, above the bore hole can be conducted in this particular manner.

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Then, you can see here, that particular reinforcement cage is lying, see these are longitudinal reinforcement, these are the, this is the particular rig, which is your lateral reinforcement and these are your ties. To bind this vertical parts, in position, then you can see there is a slab sort of cylindrical kind of a thing with a hole in between, you can see here in this one.

See here, this is a hole and this kind of thing is there you see this facilitates, when you lower down this reinforcement cage in the bore hole, it should not get in contact with the wall of the bore hole. So, it gives you it works as a spacer plus being of this shape, it is not fixed, so it can rotate, so it facilitates the lowering of the reinforcement cage in the bore hole.

See all these things, you will not be getting in any of the books, it is just that the experience, that we get from various sites. Because, I did not even IS code any standard book, they do not give any specification, that you should provide such kind of this while going for this lateral ties and all. But, then to ease in construction to ease in work man ship, all these measures are taken care of while construction is going on.

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You can have a look here, this is a completed pile, it was of one meter diameter, when we were there at the site. So, we recommend that the one meter diameter pile should be there. So, this is how it looks, with reinforcement and all, ever all the concreting has been done and then from top also, all the concreting has been done and it is quite clean. And, if you see, but if you see the subsequent slide, then you will really get the feel that how exactly these pile foundations look like above the ground.

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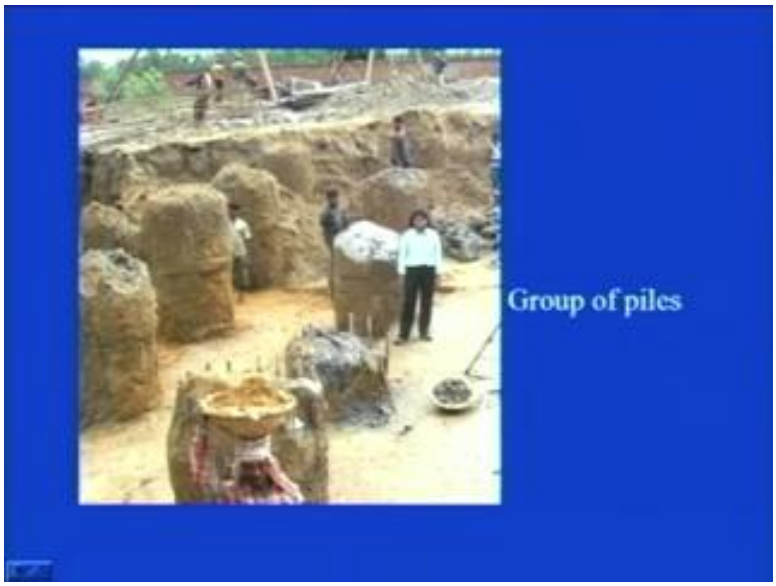

So, you see here these are the groups of piles, as I mentioned you that, you never go for one particular pile, it is always that group of piles they are provided. So, you see this

much excavation has been taken place and then the two views are there, these are all completed piles. And, if you check of some of them concrete from the top of this particular the pile, what will happen that reinforcement will get exposed of which is here.

In this particular case, these vertical bars are seen, they are in the process in this particular pile and then in this particular pile it has not been chipped off. So, you can see that that the concreting is done in soil cover is also there little bit of soil layer is there.

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Now, how do you chip off the piles, see once the concreting is done and we really go for m 30 grade of concrete. So, and if the compaction has been done properly it becomes really difficult to chip off the concrete from that particular pile. So, with the help of this drilling machine, they just chip off that particular concrete, you must be wondering, that first we completed the pile at 30 meter and now we are chipping off this particular material from the top.

Why exactly, it is being done, so the answer to this particular question will be obvious in the subsequent slides, it is not that only pile will be there, you have to provide a connection in all the piles. Such that, the load from the super structure will come to this and will get distributed uniformly to all the piles and then to subsequent soil strata. So, this reinforcement of the pile will go in the in that particular structure, which will be coming just on top of the pile.

Let us say it is a kind of a raft that will come or that will join all the piles, so we will be seeing typical view of that particular thing. Also then, you will be appreciating, this

particular thing that, why exactly it is necessary to expose off, some of the reinforcement part from top of the pile.

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So, you can have a look, that many workers are doing their work, some are drilling here you see, that drilling part is going on some are just washing off that particular area. On that day, it was rainy day, so you can see some of the water is getting accumulated at different places. So, if you see at if you have a look on this particular thing, particular pile, what happens is that typical lateral tie is also exposed in this case and then these vertical bars, they have got bended like this in the different direction.

So, likewise if you have an area, in that one you particularly design that how you have to provide these piles, what should be the spacing, what should be the arrangement, whether they should be arranged in triangular fashion or rectangular fashion or some other pattern. That you have to first decide upon and then only go for the construction, but this is how the situation looks like at any construction site and this is how it looks above the ground.

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Then, this is another view, you see here that all the piles they have chipped off the concrete from the top and they have cleaned it and this is how I mean all the piles, you have the large area, lot of many number of piles are there. Some are being cleaned and some are there in the process of that chipping off and then cleaning of the concrete.

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As, I was telling you, that this is what is this vertical bars, they which are visible here in this particular picture, they are the main reinforcement of the pile. And, this is the grid, which you are seeing this one, you can see that this is the particular grid; that is for the raft.

When you will be studying the shallow foundation, then you must have studied this kind of foundation that isolated footing and then combined footing and one particular type of shallow foundation is raft foundation. So, when the raft foundation is provided with this pile foundation, the combination is called pile raft foundation.

So, to have monolithic in construction, that monolithic word means, that the pile and the raft, they will behave as one single unit, it is not that that the when the load will be coming, the raft will behave separately and the piles will be behaving separately know. They will behave as one unit to so to be in monolithic in construction, to have monolithic construction, this thing is being done.

That the reinforcement of the pile is continued, till the raft is placed; that means that the main reinforcement of the pile gets into the raft also, to have monolithic construction.

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Then, now you see first we saw that, what the various types of pile are and then we had some of the pictures; that I took from one particular construction site, where the pile for pile construction was going on, that how it is being constructed. Now, once it has constructed, we have to see that, what exactly is the magnitude of the load, that a particular pile can take or what exactly is the load, which are group of piles can take. So, it is construction procedure is over, now the estimation of it is capacity will be there.

So, what exactly do we mean by that, how we can calculate that load carrying capacity of the pile in compression, that we will be studying in the subsequent slides. That in general, this is general thing, general requirements for satisfactory behaviour of pile

foundations are adequate safety against shear failure and permissible settlement. The load capacity of pile can be estimated by several methods, which may be grouped into several categories.

So, in case of shallow foundation, when you were checking that ultimate bearing capacity, as well as the settlement criteria, likewise in case of pile foundation also you have to see to it, that pile is not failing against shear. As well as, it is not undergoing excessive settlement; that means, one is from this safety point of view, another one is from serviceability point of view, stability and serviceability.

So, the settlement should be within permissible limit as and along with that the pile should be safe against shear failure. There are various methods from where, this pile load carrying capacity in compression can be estimated and usually they are grouped in four categories.

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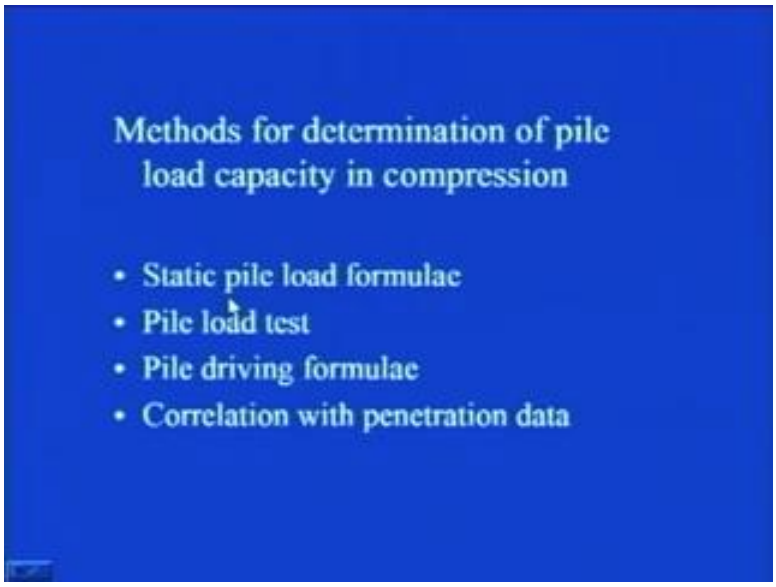

And they are that you can find out the load capacity of pile in compression by static load formulae. There are various formulae for different types of soils, then by conducting pile load test in the field, let us say that you constructed a pile and there itself you tested and find it out, that what exactly is the load that it is taking. Then, pile driving formula depending on what type of hammer that you are using, what type of motor that you are using, depending on it is efficiency and all other things.

You can estimate this load carrying capacity of the pile in compression, using this pile driving formulae and then there are some correlations, which have been developed over

many years using the penetration data. I hope that, you have studied that standard penetration test, while you studied soil exploration chapter and from there, once you get the data; that can be correlated to the load carrying capacity of the pile in compression.

So, these are the mainly four categories from where you can estimate the load carrying capacity of the pile.

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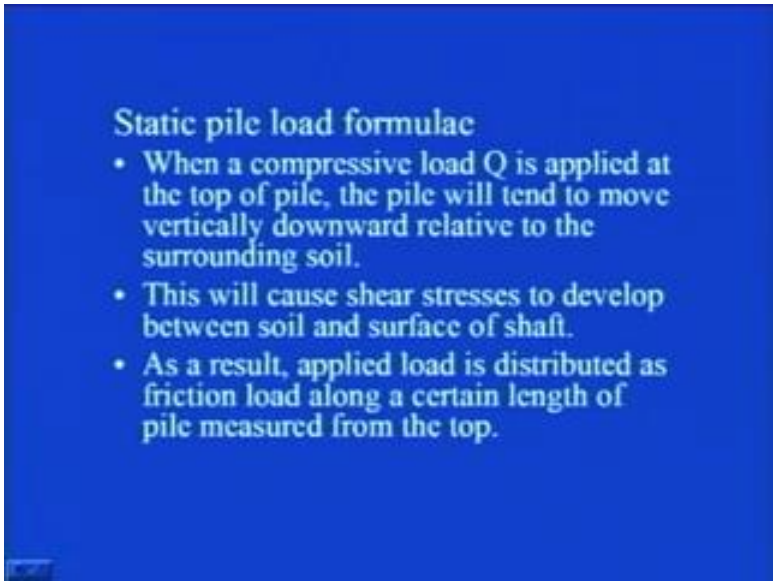

So, let us start with static pile load formulae, that how we can find out the capacity of the pile using these formulae, when a compressive load Q is applied at the top of the pile, the pile will tend to move vertically downward related to the surrounding soil. Obviously, when you apply the load to any kind of a structure, it will try to displace, so in the case of pile, also let us say that you are applying a load Q from the top, which is compressive in nature, the pile will is have the tendency to move with respect to the surrounding soil.

And then, this will result in shear stress to develop between the soil and surface of the shaft, there will be relative movement in pile shaft and the soil strata, which is surrounding that pile shaft, which will develop the shear stress. So, as a result the applied load is distributed as friction load, along a certain length of pile measured from the top.

So, as soon as the shear stress is developed, whatever is that is applied load, this Q which is compressive in nature. It will get distributed as the frictional load along the shaft length.

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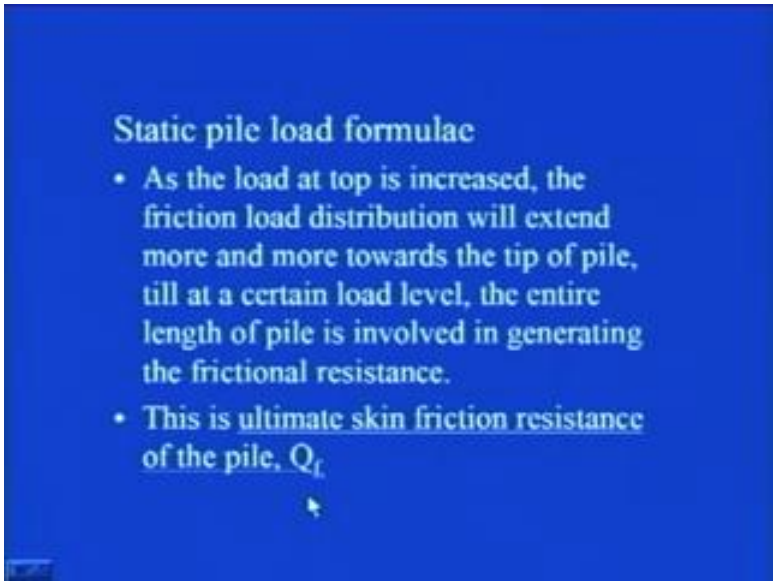

But, earlier it will be to some particular length, now what will happen, that when the load at the top will go on increasing, the length of generation of this particular friction load will go on increasing along the pile shaft. So, you see here, as at the top is increased, the friction load distribution will extend more and more towards the tip of the pile. Till at a certain load level, the entire length of the pile is involved in generating the frictional resistance.

You remember when we when we were discussing about that end bearing pile and skin friction resistance of the pile there also we saw this exactly the same kind of mechanism. What happens is that from the top, when the load is being applied, it will be getting applied slowly, you can just imagine a process of construction which will be taking place.

Let us say first the dead load of any you cannot just create, let us say if you are going for 7 storey or 8 storey building, you really cannot construct 8 storey building at one go, you will be going in stages. Let us say first you completed first storey, then second, then third and then subsequently, the load will be increasing. So, the load is not applied suddenly, it is a gradual one.

So, as you go on increasing the load on the pile from the top, the length along which the friction load is developed, will go on increasing and this length will go on moving towards the tip of the pile. One situation will come; whole length of pile or the pile shaft will be creating or causing that whole friction load. In that case, that particular resistance

is called ultimate skin friction resistance of pile and we represent that by Q subscript f, that is Q f.

You can see here, this is this is ultimate skin friction resistance of the pile, where the friction load is getting mobilised, all along the length of the pile shaft, it is only, when the load at the top of the pile exceeds Q f.

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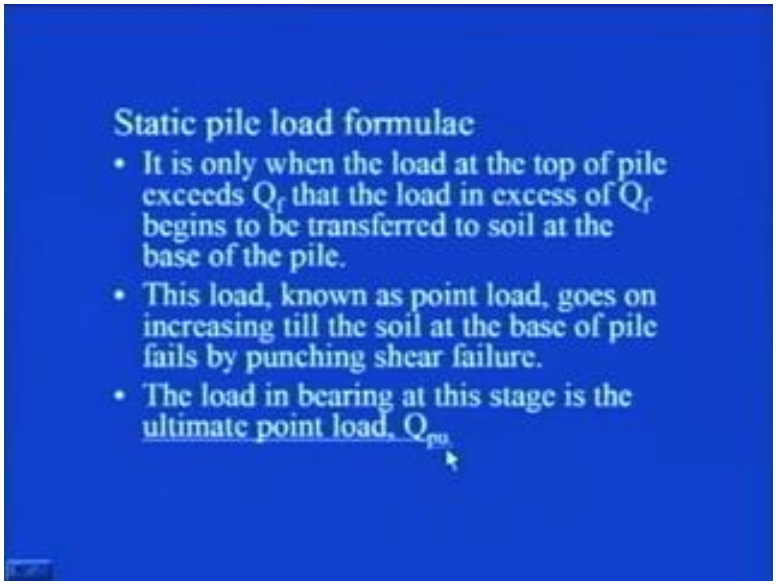

That the load in excess of Q f, begins to be transferred to soil at the base of the pile, so you see the load is gradually increasing and from there a situation will come, when this friction load will get mobilised, along the total length of the pile shaft. And that particular stage, we are calling as ultimate skin friction resistance Q f, so at that particular situation or condition, your Q which is applied from the top will become equal to Q f.

Let us say that this Q f you attain after the completion of construction of the second storey, but you have to go till eight storey building. So, what will happen that, when you will start the construction of beyond this second storey or the construction of third storey, this Q value will go on increasing. The moment it increases the value of Q f, that is the ultimate skin friction resistance, this will get transferred to the base of the pile.

This load is known as point load and this will go on increasing till the soil at the base of pile, fails by punching shear failure. It is not that to the infinite extent you can go on increasing the load and pile can take that particular load, it has it is capacity. So, the

frictional capacity you can estimate using that Q f, whatever is your Q f; that will be the frictional resistance or the capacity of the pile.

In case the Q exceeds the value of Q f in that particular case, this remaining load that is Q minus Q f load will gets transferred to the base of the pile. And you can go on increasing the value of the load Q, till the soil at the base of the pile fails by punching shear failure. So, whatever is the resistance of the soil at the base of the pile, that much only extra load, you can put as point load.

The load in bearing at this stage is called as ultimate point load, which is represented by Q p u, p is for point, u is ultimate and that is ultimate point load. So, you got familiar with two terms; that is ultimate skin friction resistance and now this ultimate point load.

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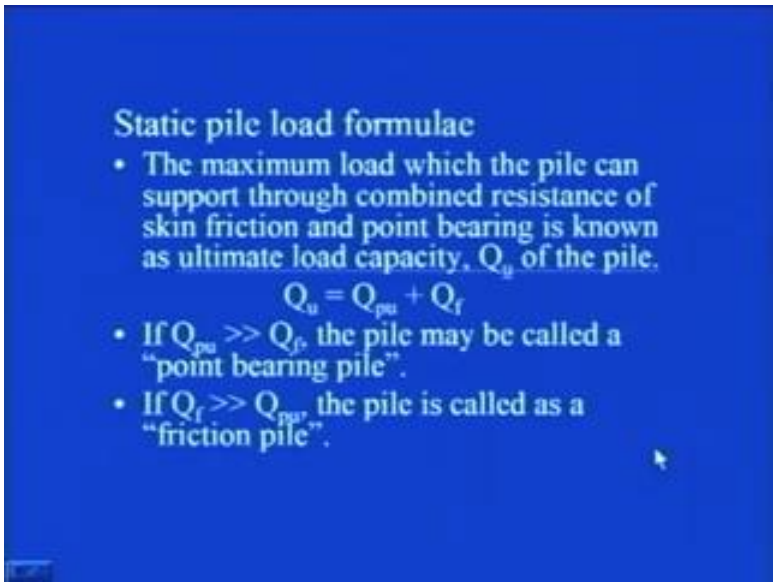

Then, the maximum load which the pile can support through combined resistance of skin friction and point bearing is known as ultimate load capacity, which we represent usually by Q u of the pile. So, whatever is the distribution or how it is getting transferred, whatever the load which is coming on the pile; that is compressive load from super structure.

First, it will get transferred to the pile shaft in the form of frictional resistance and once that particular stage is over, where Q becomes equal to Q f and if Q goes on increasing beyond that, then that particular increase will get transferred to the point bearing. And sum of these two, that is ultimate skin friction resistance and ultimate point load, gives you the maximum load which a pile can support through combined resistance of skin

friction. And point bearing, which is called as ultimate load capacity or Q u, it is notated by Q u.

So, you see here, this Q u will become equal to Q p u plus Q f, first one is ultimate point load, second is ultimate skin friction. If this Q p u is quite high than as compared to this Q f, the pile may be called point bearing pile; that means, the soil surrounding the pile shaft is such that. That it is not able to mobilise, that much of the friction resistance as compared to the ultimate point load.

So, mainly the pile resists the load through point bearing that is this Q p u is quite higher as compared to Q f; in that case the pile is called as point bearing pile. Now, there can be another situation that if, this Q f is quite high as compared to Q p u, then this pile is called frictional pile.

That the resistance, through friction becomes, so much that the load which is coming from the super structure is not getting transferred to the tip of the pile or the base of the pile. In that case, the function of the pile or the load transfer mechanism usually is by this friction only, so in that case the pile is called the frictional pile.

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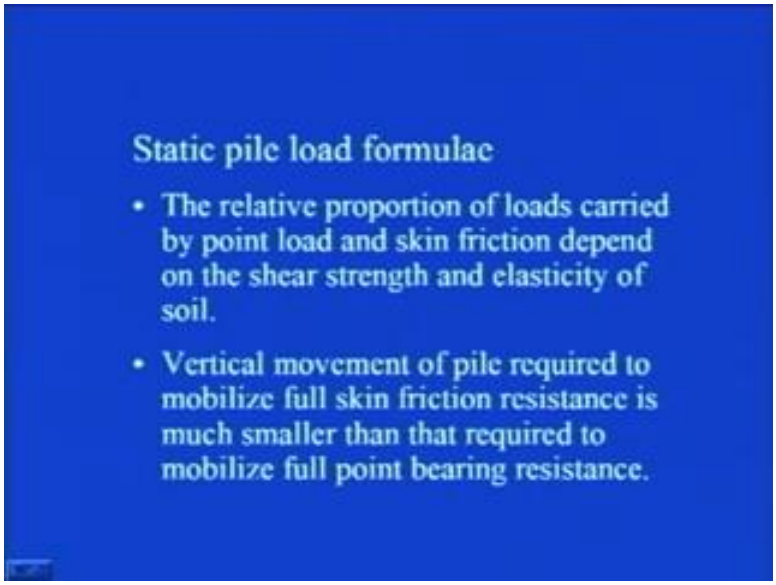

The relative proportion of loads carried by point load and skin friction they depend on the shear strength and elasticity of the soil, so you see depending on the type of the soil, which is lying surrounding the pile shaft. Let us say, if able to mobilise good friction resistance along the pile shaft; obviously, the frictional resistance will be more and then the pile will be acting as friction pile.

And in case, the soil is not able to provide, that much frictional resistance or in case the soil is lying below the pile is resting on the good soil strata or may be rock. Then, in that case the soil surrounding the pile shaft will not be able to mobilise, that much of the frictional resistance as compared to the end bearing resistance and so it will be acting as point bearing pile.

And then, the vertical movement of pile required to mobilize full skin friction resistance is much smaller than that required to mobilize full point bearing resistance. This is a very important the aspect which is that vertical movement of pile required to mobilize full friction resistance is much smaller than that required to mobilize full point bearing resistance.

So, you can see first as soon as the load is coming on the pile first the friction is getting mobilized along the length; obviously, when the load is coming, the pile is getting displaced from that the shear stresses are getting developed and so they are resulting into frictional resistance. So, by the time your Q will become equal to Q f; that is at ultimate skin friction resistance, the deflection of the pile is not that much.

So, to mobilize the full point bearing resistance of the pile, you need large vertical movement of the pile.

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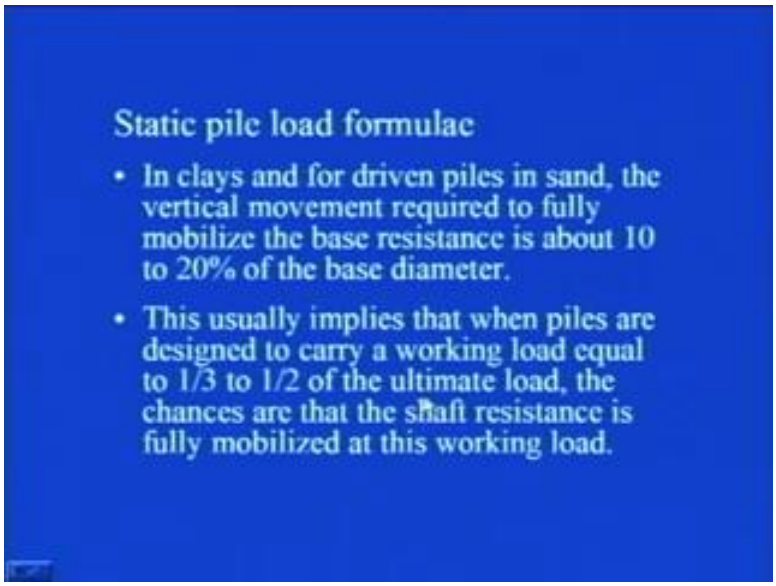

In clays and for driven piles in sand, the vertical movement required to fully mobilize the base resistance is about 10 to 20 percent of the base diameter. So, we really have to keep a check that, what exactly should be the vertical movement, such that the total skin

friction is being mobilised. Along the length of the pile shaft and then beyond that the point bearing is getting mobilized.

So, in case of clays and for driven piles in sand, this to mobilise the base resistance fully, the vertical movement is of the order of 10 to 20 percent of the base diameter. So, let us say, if you are the diameter of at the base is one meter then around 01 meter to 0.2 meter is the vertical movement; that will be required to fully mobilize the base resistance.

This usually implies that, when piles are designed to carry a working load equal to one-third or half of the ultimate load the chances are that, the shaft resistance is fully mobilised at this working load. So, usually what happens is that piles are designed to carry a working load equal to one-third or half of the ultimate load. See ultimate load is being calculated using this static pile load formula or any other measure.

Then, it is half or one-third and then the design structural design of the pile is carried out using this particular half or one-third of this ultimate load. So, as you can see that, the base to fully mobilize the base resistance, you required 10 to 20 percent vertical movement of the base diameter. So, at this particular position, there are chances that the shaft resistance is fully mobilized at that that particular working load it may happen that the fully mobilisation of point load may not take place.

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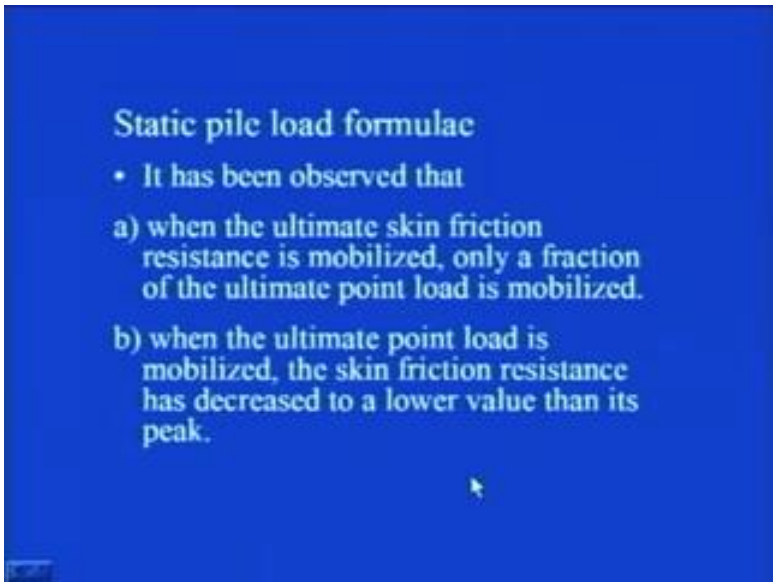

It has been observed that, one case is that, when the ultimate skin friction resistance is mobilized, only a fraction of ultimate point load is mobilized, so first is that the skin friction is getting mobilized. So, whenever a load is coming from the super structure to a

pile, first it is getting mobilized, along the pile shaft to a particular length, as you go on increasing this value of Q.

The length over which this will get mobilized or the length along which the frictional load will get mobilized will go on increasing and a stage will come, where you will achieve ultimate skin friction resistance. So, when the ultimate skin friction resistance is mobilized, what does this means, that at this particular point the applied load becomes equal to the ultimate skin friction resistance.

In this particular case, only a fraction of the ultimate point load is mobilised, that is very obvious and when you will increase the load which is coming from the super structure, beyond this particular stage, then this ultimate point load will go on increasing. And then, the second one is, when the ultimate point load is mobilized, the skin friction resistance has decreased to a lower value, than it is peak.

See, what is happening in this procedure is that, as you are increasing the value of Q, which is coming from the super structure. A condition is occurring, that a particular condition is occurring, that this load Q is becoming equal to ultimate skin friction resistance, there will be a point, when this point bearing resistance will be just equal to 0. When you will go on increasing the load, what will happen, the resistance which has been developed at the tip of the pile will go on transferring to the point bearing resistance.

And in that process at any particular point of time, what will happen is that, the ultimate skin friction resistance value will be always less than it is peak value. So, what is there is the second point, which we need to keep in mind that when the ultimate point load is mobilized, the skin friction resistance will be reduced to the lower value from it is peak value.

So, today we saw that, what are the various advantages and disadvantages of concrete piles; that is two types of concrete piles, that we discussed one was driven cast in-situ and another was bored cast in-situ piles. Then, I shared some of my experiences with you, as far as the construction of the pile is concerned.

We saw that, how driving rig drives the pile, how high is that particular rig, then what how this reinforcement cage is being lowered, what are the various techniques, that is

being adopted at as far as the construction of the pile is concerned. How the piles can be constructed monolithically to the super structure or other parts of the foundation.

And then, after the construction, it was the point of concern; that how we can find out or estimate the load capacity of the pile, under the compressive loads. So, we saw that there are four categories, that we can find out or four ways; that we can find out this load capacity of the pile in compression.

They were static load formulae, then pile load test and then dynamic load formulae and the fourth one was correlation with penetration data. Then, we started the detail of static pile load formulae and in that one, we saw that; what exactly is the load transfer mechanism from the super structure to the pile.

We saw that when a compressive load from the super structure comes to a pile, first the skin friction is mobilized, a condition is reached. When this friction becomes equal to the applied load and when this load is further applied, then it gets transferred as point bearing resistance. And then, depending on which whichever is the more, whether the ultimate skin friction resistance is more or the ultimate point bearing is more, the pile is named as skin friction pile or end bearing pile.

We will see the mathematical details of static pile load formulae, how we can utilise them as far as estimating the pile load capacity in compression is concerned. And then, we will proceed that, how we can estimate the pile load capacity using in-situ tests and all other things in the subsequent classes.

Thank you.