Geotechnical Engineering II / Foundation Engineering
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Lecture – 38
Pile foundation (Contd.)

Good morning. In the last lecture, I just given introduction on Pile Foundation and perhaps I have stopped at classification of pile. And, while doing classification we have discussed the classification based on material and different types of material and that time I have also discussed that about, but different type materials may not be suitable for every situation. So, how to choose, what are the problem in different condition or different material that I will start with and then I will slowly take you to the estimation of pile capacity for different condition.

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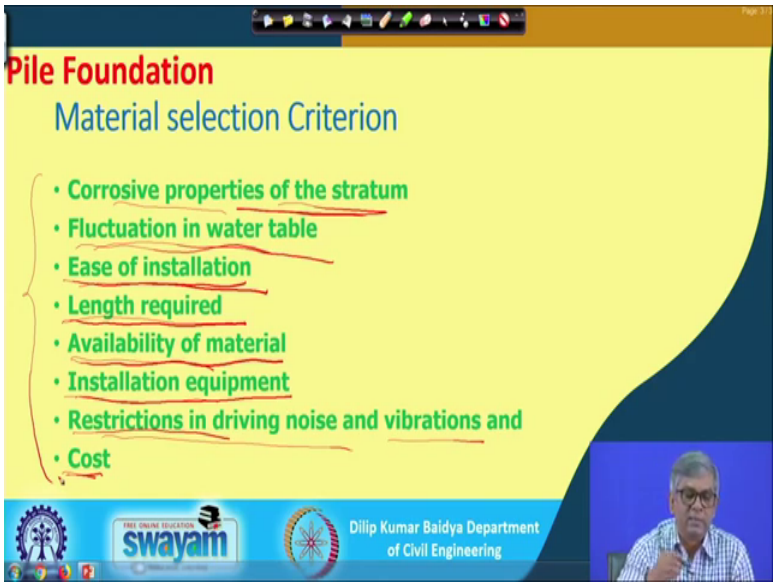

So, let me start with the first slide this is actually as I have mentioned that material based on materials pile can be classified like timber pile, steel pile then concrete pile, composite pile. And now, we will see here that what are the problems while selecting the material we have to see the corrosive properties of the material. See, if the steel sometime it will corrosive actually because of various weather condition; so, that has to be seen.

Then fluctuation in water table; suppose, if there is too much of fluctuation of water table

then suppose wood timber pile may be difficult because of waiting and drawing the sometime it will be spoiled and decompose. Ease of installation; so suppose if you want to drive a pile may be steal pile will be the better one than the concrete. So, that if you want to use driven pile then accordingly you have to consider that point.

Length required, that is another important parameter that if you require suppose pile length is suppose 60 meter and if you choose a wooden pile or timber pile may not be a good choice because wooden pile or timber pile sometime is the most of the time limited to a very certain length. And, similarly so, steel for example, steel pile again can go for unlimited length, concrete pile can have also some up to some length. So, that is also another point based on which we have to select the material.

Then availability of the material; suppose, if the timber is available plenty then it is it may be good to choose timber material, but other factor to be checked. Similarly, if like that we have to consider that point. Similarly, installation equipment: suppose, if you want to choose driven pile then equipment axis should be there if it is not there then perhaps that method should not be used.

Then, restriction in driving noise and vibration in vibration; that means, if you; that means, if there is a construction side is a close to your very residential area then sometime because of this driving noise and the vibration may prevent you to do that. So, because of that while selecting so, that is also another point to be considered.

And, last not, but least that is cost actually. Cost is the most important part again and ultimately you have to see all those things and then finally, you have to see the cost. Sometime you have to compromise because of the cost sometime. So, those things; that means, these are the parameters you have to go through and then finally, which one is the best for you that has to be selected.

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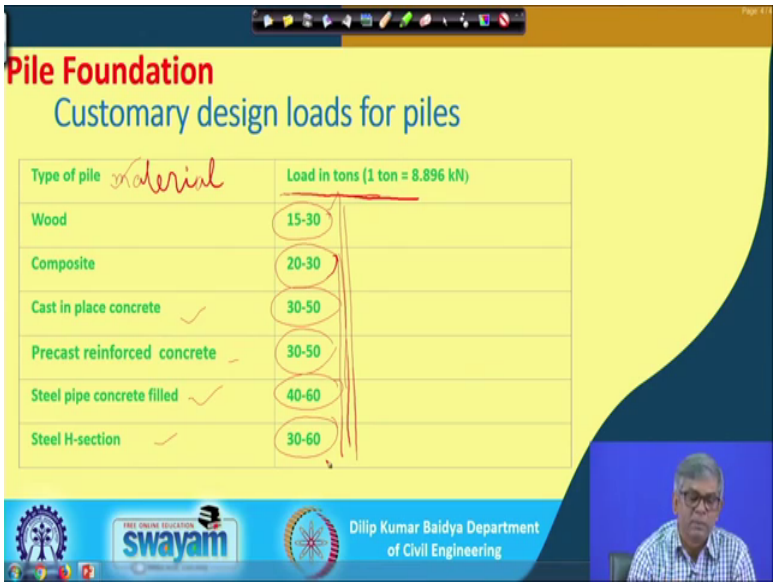

Next one is that is what as I have mentioned that there are some limitation in length you can see the type of pile material, type of pile material you can say here material and then low and this is not sorry length it is a actually given actually capacity. So, different pile can have different capacity actually can if it is a heavy by capacity then accordingly you have to choose a particular pile which is suitable for that.

So, that is the so one actually guideline here that wooden pile if it is up to 15 to 30 ton then may be suitable, if it is not the you should not choose. Similarly, composite pile 20 to 30; then cast in place concrete 30 to 50; precast reinforced concrete 30 to 50, then steel pile steel pipe concrete filled actually 40 to 60 and steel H-section 30 to 60.

So, like that there are range. So, again based on capacity and then other environmental condition etcetera and then cost accordingly you have to choose you have to bring the capacity also one of the parameter for based on which actually can select the material type. So, if it is a shorter length comparatively then generally is wood pile sometime can be used.

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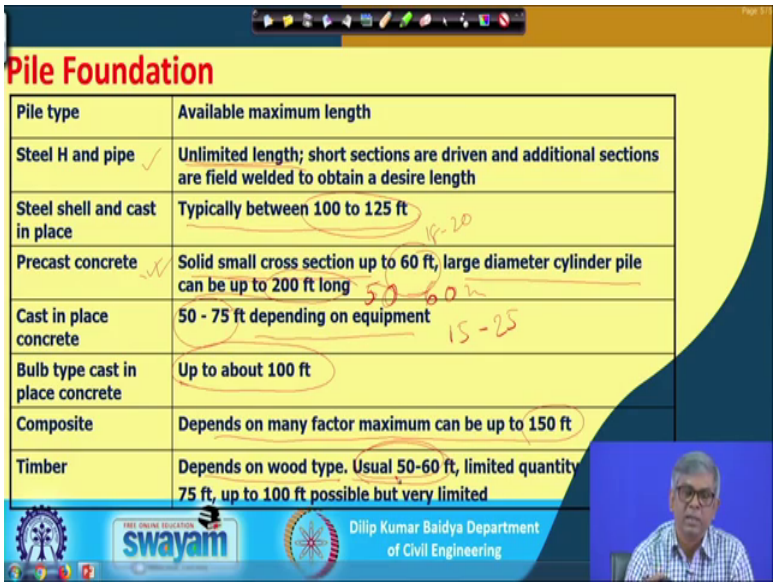

And, then the next part as I was telling that the limitation of the length actually steel H and pile; you can see unlimited length, any length you can do. Generally unlimited length at a time you cannot do. What we have to do actually it is what section to be driven first and then it has to be welded in the field and then you can continue to do that until unless you reach to the desired depth.

Steel shell and cast in place, the typically between 100 to 125 feet; 100 feet means actually it will be just 30 meter. And, similarly precast concrete solid small cross section up to 60 feet; that means, around 20 meter 18 to 20 meter and large diameters cylinder pile can be up to 200 feet long; 200 means around 50 to 60 meter also we can go this precast concrete pile. These are the typical range of length we can achieve by this type of pile.

Similarly, casting place concrete generally 50 to 75 feet depending on the equipment that is casting plus and 50 means around 15 meter to around 25 – 30 meter actually this will be there. Bulb type cast in place concrete up to about 100 feet; that means, 30 meter; and composite depends on many factors maximum can be 150 feet. And, timber depends on wood type usually 50 to the 10 – 15 meter actually very common; if it is more than that special consideration you have to see.

So, that means, your you have to see your length requirement and based on that you can choose also of course, it has to be supported by other condition like environmental and

other thing, equipment access all those things.

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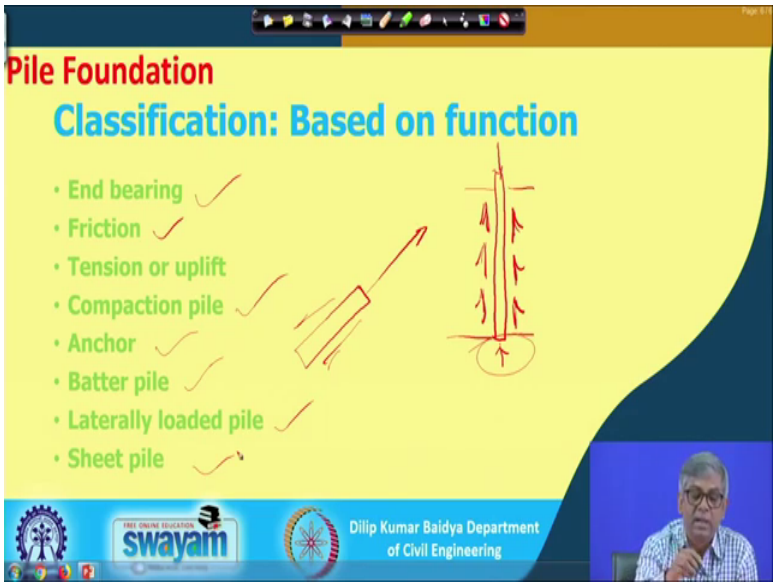

And, now that is classification based on material and then how material can influence you to select the type of pile that we have discussed. Now, actually that is another classification based on the function how pile what type of function it will perform based on that pile can be classified and you can see here that it can be mentioned as end bearing. End bearing means what? Pile actually is going like this and I i will show that in a in a one sheet, so; that means, load is applied through here and finally, load is transferred here that is end bearing.

Then, there is a friction; that means, if there is no stiff layer then throughout the depth actually. There will be friction developed between the soil and the pile and that actually can support the load; so, that is the friction pile. Tension and uplift pile; that means, there may be some pile will be there. So, load is this direction then friction will be in this direction. So, that is tension pile, compaction pile, then anchor batter pile laterally loaded pile sheet pile. So, all those thing I will just show in the next slide together.

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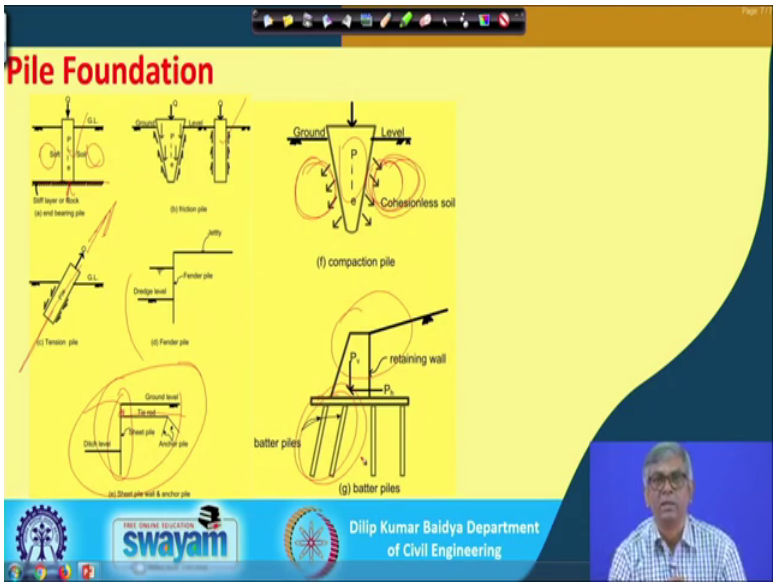

You can see here I have shown all those thing now you can see here this is actually end bearing pile; that means, this the pile and this is standing finally, on a very stiff layer or rock. And, this soil may be loose or soft and as a as a result that friction resistance from the side will be comparatively smaller you can it when you say it one can say it is negligible, then this load will be totally taken by this base.

And this is actually friction pile. You can see friction pile when this type of section we take and if you apply load then from the side there are frictional resistance will be there or if it is straight also like this there will be load applied and then there is no hard base here. Then, if you push the pile like the by load then our frictional load will be opposite direction. So, by that actually entire load will be supported; so that is friction pile.

And, this is actually compaction pile; that means, if the loose soil if this type of members actually if you push inside the soil, then surrounding the soil when this soil will be displaced and this volume actually ultimately equal equal volume will be compression will be; that means, this soil. So, when the site soil get compressed; that means, of that amount then that will automatically soil get compacted. So, this is sometime a number of piles can be driven and then based on that the site soil will be getting compressed or densified; so that is called compaction pile.

And, this is actually can see some time you can use this way; that means, if you if the load is this is for holding something suppose load is applied in this direction; that means,

within the pile some certain sufficient length should be there within the pile. So, that because of this friction the external load will be resisted. So, that is called tension pile, this is fender pile, then this is sheet pile wall. Actually sheet pile wall; that means, if you have a these are actually is this wall actually very thin cross section and would be locking arrangement will be the one after one.

It will be connected and driven and then there will be wall like wall like structure will be form and they are comfortably flexible and when it is it can stand itself then sometime you can make free cantilever sheet pile wall and if it is length is very high and because of thin cross section you may deflect too much. So, in that to hold it then sometime you can do it tie, ok; so, that is actually anchored sheet pile wall.

And, sometime this is actually batter pile you can see, suppose this type of retaining wall or something and below that there direction of force will be different. So, to prevent tilting of this sometime pile will be constructed like that and this type of pile when it battered it will not only take axial force it will take also some amount of other horizontal force. So, that actually a batter pile also some.

So, that means, based on function; that means, it is taking this is taking only axial load, this is also taking axial load, this is only compacting the soil, this is taking axial load, but tension this is actually also taking pressure lateral pressure this is actually taking both lateral and vertical; so, like that different classification based on how the pile is performing for resisting the load.

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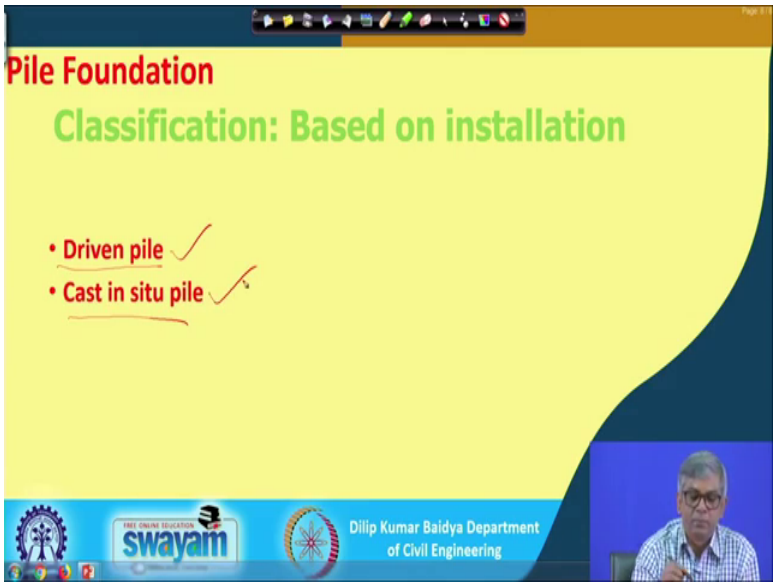

Then classification based on installation that is actually you can see here that it is given driven pile or cast in situ pile. So, that is again; that means, driven pile means it will be either that is the timber pile or steel pile generally as it is we can drive it inside the soil or if it is a concrete sometime you have to precast in the factory and that can be again driven. So, that is why one is cast in situ pile and another is driven pile. So, driven pile can be many type and cast in situ pile means generally concrete pile. So, we have to make a drill hole and then we have to concrete it to get the pile.

So, that is in general there are two classification actually driven pile and cast in situ pile.

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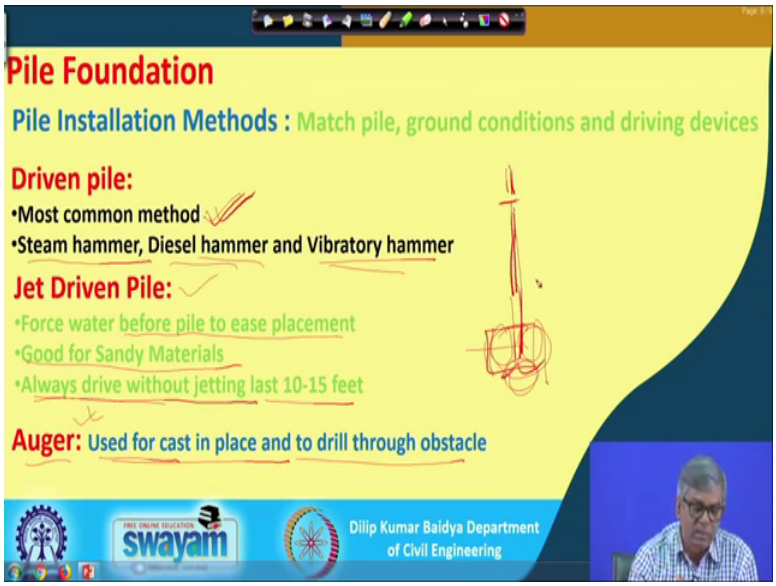

And, see driven pile again you can see. So, driven pile most common method many types actually quickly that pile can be driven. And, steam hammer different types of hammer are used steam hammer, diesel hammer, vibratory hammer; that means, pile will be first placed on the ground and then by putting hammer it get a load there will be head and on that head there will be load will be applied through that instant load it will be pushed inside the soil. So, that different type of hammer will be the steam hammer, diesel hammer, vibratory hammer by which the pile will be pushed inside the soil.

And so, again driven pile can be of different types different mechanism can be used to drive the pile. So, jet driven pile and auger driven pile also. So, jet driven pile how actually first of all water jet will be allowed first before pile placing the pile. So, force water before pile to ease placement. So, suppose this is the pile so, there will be some mechanism. So, water will be forced here so, the soil will be loosen and then and then if you can pushed a pile easily and this will be generally by forcing water very easily sand particles since there is no cohesion particles can be separated easily.

So, sandy soil that jet driven pile will be easier and always drive within and then finally, if you entire length if you do by this loosening and then put the pile then pile may not get sufficient frictional strength and because of that what it is convention is always drive without jetting last 10 – 15 feet; that means, towards ends some portion has to be driven by hammer because there will be no jet by loosening by the jet. In that way actually this

will be having a very fixed fixity will be there by that otherwise entire pile will be a like a floating.

So, site soil will be loose and when you put the pile that pile will looks like floating. Whereas that last 10 – 15 feet actually if you put it by hammering then that that will be a form base; that means, fixity will be proper and by that actually we can get good friction as well as base resistance.

And, auger actually used for cast in place auger method actually generally used cast in place and to drill through the obstacle. So, that means, though jet method we are using some time if that is a problem then see the some strong layers are appeared thin may be. So, sometime by augering you can cut through and go it go deeper. Otherwise the augering is used most of the time and most frequently and most common actually for cast in pile.

So, cast in site pile means actually what you have to do; if the pile length is suppose 30 meter then by some means you have to make a hole of 30 meter length and equal to and diameter equal most slightly more than the diameter of the pile. And, then after that you have to put desired enforcement and then you have to put concrete and then solidifying based on that and after that the pile will when become solid that become pile. So, that is actually auger most use actually common use is actually for cast in situ pile.

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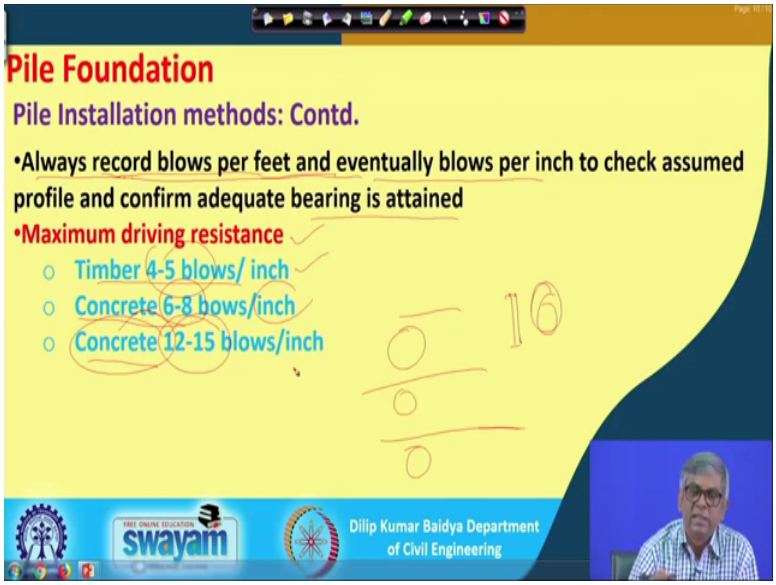

And, so, then if it is a driven pile actually see you have to always record blows per feet eventually blows per inch to check the assumed for profile and confirm adequate bearing is attained. That means, while driving pile suppose while we have selected a particular pile based on soil condition there and then and you have chosen driven pile because driven pile means it will have definite resistance, accordingly we have suppose ready with the equipment.

But, when you are in field and if you feel that that the pile is pushing or driven without any referred; that means, soil is not good and you have to see that what type of soil is confirm from the soil report and if you find different then you have to again re examine and then you have to modify the your whatever you have recommended. So, that is the thing; that means, you have to while doing this you have to do not only that you have to drive the pile and you have to be happy.

What you have to do while driving you have to also certain checks are there you have to perform; that means, for each blow how much it is pushing inside that to be counted you can see always record blows per feet; that means, for every feet of pile driven inside how many blows are required? And that to be seen and based on that if there is a number of layers are there, somewhere it will be less number somewhere it will be more number from there you will get some idea about the different layers. And, you have to confirm that that layering whatever we have report it is reported from the soil in machine that should match by enlarge. If it is not then you have to re examine the entire thing.

And, there is a guideline actually maximum driving resistance when it is a timber pile 4 to 5 blows per inch and if it is more than that actually if it is record more; that means, soil is better of course, and if it is require less number of and this blows; that means, soil is very loose and that you have to check what you have to do.

Then if it is a concrete actually 6 to 8 blows require for 1 inch driving and if it is a concrete sometime 12 to 15 blows per inch also maximum this is both are concrete, but there may be some variation. So, that means, concrete different types of concrete you have the maximum blows 12 to 15 per inch and if it is more than that then you it is better, but it if it is too much energy is required of course, it is not good; while too many blows if you make then actually your pile may get disturbed.

At the same time if the two less number of blows required; that means, soil is not good

and if it is already examined as no good then it is ok, but if you find that whatever recommended the soil report if it is other than that then you have to re-examine.

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Then, next thing is whatever general about pile, classification based on material, then classification based on installation method, classification based on function and then all those things and then you know what function the particular pile to be perform for your project and accordingly considering the site condition, considering the availability of material, considering the equipment access all those things and cost you have to select the pile.

Now, when you select a particular type of pile then you have to next job is to find out the length requirement or what will be the each pile should carry how much is the capacity of each pile and what should be the length diameter that has to be designed. So, that is the pile capacity estimation is the most important work perhaps for geotechnical engineers and then pile capacity when you will calculate. Then first of all you have to calculate single pile capacity and pile in single condition highly used most of the time and actually the pile will be used in a group.

So, we cannot start with actually capacity with group. First of all we have to understand how to estimate the capacity for single pile and then from there how to get the group capacity we have to learn. So, I will first take the actually pile capacity for single pile and then I will take pile capacity for group one by one.

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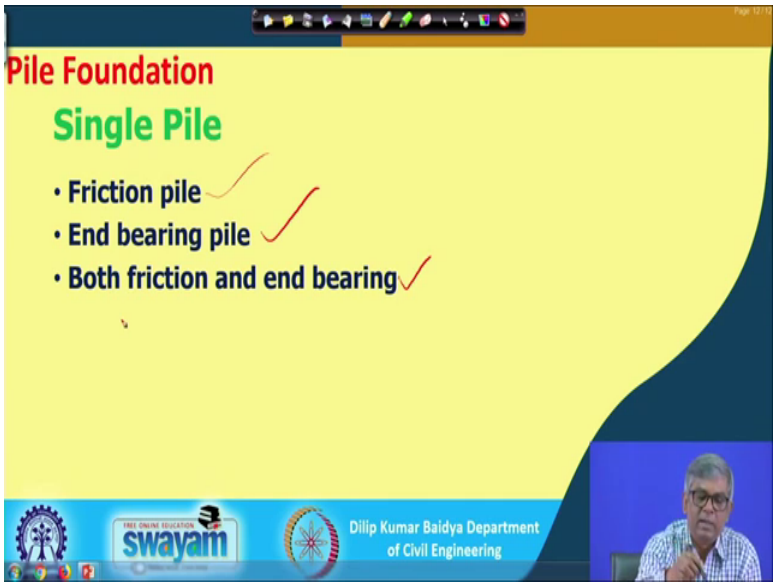

And, you can see when you do single pile again we can see the pile can be friction pile, pile can be end bearing pile, pile can be of friction and end bearing both. That means, what friction pile means actually when this pile is driven and then enters are through the surface of the pile there will be frictional resistance between the soil and the pile surface. And, that frictional resistance what the entire length whatever amount that should be equal to the load applied to the pile. So, that if the fictional pile; then we have to estimate the frictional resistance.

Whereas, the end bearing pile; that means, you have driven the pile up to a rock or very stiff layer and from the actually main capacity of the pile will be from the base of the pile. So, at the base resistance of the pile has to be estimated; that means, end bearing actually bearing of the bearing capacity of the end has to be estimated and from there you have to find out the actual capacity.

And, if it is the both friction and end bearing; that means, soil is moderately stiff, it has got a moderately stiff layer base at the pile; at the end of the pile and also it has moderately cohesion or adhesion of the soil then some frictional resistance will be there that to be estimated plus base resistance that to be estimated these two together should be equal to the load applied; so that is what, so of course, with some factor of safety.

So, pile can be again single pile, again can be of friction pile, it can be of end bearing pile or it can be both friction and end bearing. So, when it is a friction pile you have to

estimate the frictional resistance, when the end bearing pile you have to estimate the end bearing at the base and when the fiction and end bearing both then we have to estimate the frictional resistance and base resistance that to be together for that to be added to calculate the capacity of the pile.

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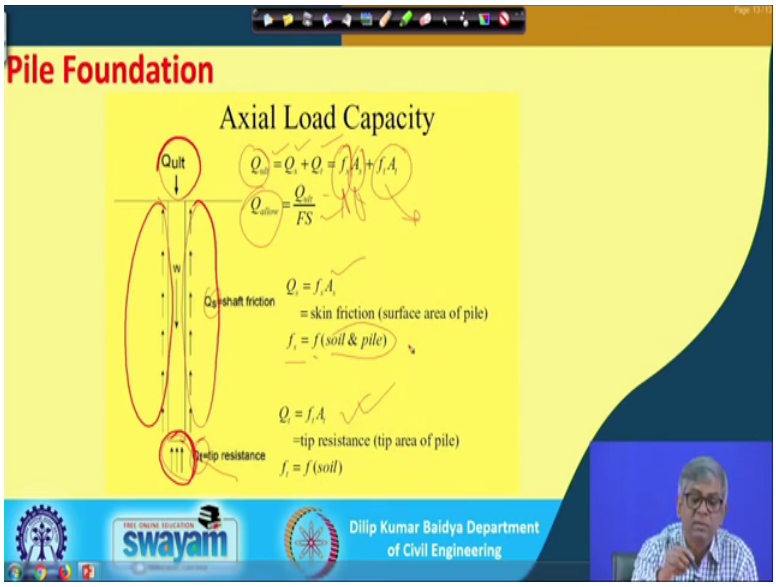

And, you can see that now whatever I have already shown and this is actually axial load capacity at the friction pile. So, load is applied from here and you can see this is a generalised one first of all I have shown and you can see at the base there is a base resistance at the surface there are frictional resistance. So, friction unit skin friction multiplied by the area surface area that will be equal to your frictional load or frictional total frictional resistance and here actually allowable pressure at the base multiplied by base area will be the actual load here.

So, this load will be Q t and this load will be equal to Q s. So, Q t, so, Q ultimate will be Q s plus Q t and which is Q s actually can be written as f s multiplied by A s that f s is the unit construction and A s is the total vertical surface area and Q t can be written as a f t plus f t into A t; f t is what, actually the tip resistance. So, at the tip what is the pressure? What is the allowable pressure we can allow and multiplied by cross sectional area of the pile. So, that together will be equal to Q t and that two together will be Q ultimate. So, Q allowable will be Q ultimate by factor of safety.

And, you can see Q s equal to f s a s which is skin fiction and so, and f s actually

function of soil and pile. So, different types of pile will have different types of friction and of course, in combination of pile and soil both. So, actually see if the smooth pile with clay, smooth pile with sand rough pile with clay and rough pile with sand, so, these are the different combination for which different values of frictional coefficient will be there. So, this is already I have mentioned; so I will just go to next slide ok, thank you.

So, I think rest of the things I will do the next session that is actually how to estimate the single pile capacity based on frictional resistance and base resistance and how what is the factor of safety to be used all those thing to be discussed in the subsequent lecture, ok.

Thank you.