Foundation Engineering
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Lecture - 27
Pile Foundation – I

So, in this class I will discuss about the Pile Foundation, but before I go to the pile foundation chapter so, I want to give you some information related to shallow foundation; so, which I probably missed in the last section. So, these are some important information that first one is that I have discussed about the inclined loads and then, I have discuss how to calculate the ultimate or the net ultimate or the safe load bearing capacity of foundation under inclined load and that time, I assume that the because inclined load has two components; one is in horizontal direction, another is the vertical direction.

Now, in that time I assume that the horizontal load is parallel to width direction ok. But if the horizontal load is parallel to length direction or the horizontal load there is two components; one is parallel to length direction, another is parallel to width direction. Then if we use the Hansen theory, then there is a you have to use the different methodology. Other theories are same whether the load is parallel to width direction or parallel to length direction.

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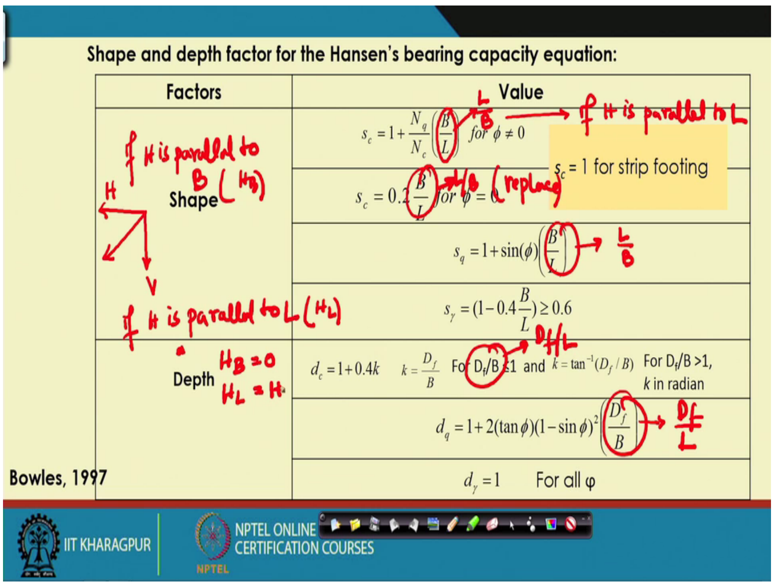

So, in case of Hansen theories that if the load is parallel to length direction so; that means, if we have the inclined load, now this inclined load has two components; one and one is vertical, another is the horizontal.

Now, if H is parallel to B, then the methodology I have discussed that you have to follow that thing. But if H is parallel to L, then we have to determine the all the factors by replacing B with L and L with B.

For example if the H is parallel to B, then we will use this factor is this ok; but if the H is parallel to L, then we have to replace this things by L by B ok. This is if H is parallel to L remember that, but this is only for Hansen's theory ok. Similarly this one will also be L by B replace it and here also it will be you have to replace it by L by B and this will also you have to replace it by D f by L and this will also be D f by L remember that. And that even if that your the; that means, if I say that is two components one is H B which is parallel to; that means, H is parallel to B that is H B and H is parallel to L that is H L, then even if the H B is equal to 0 and H L is equal to H, then also we have to do this correction ok.

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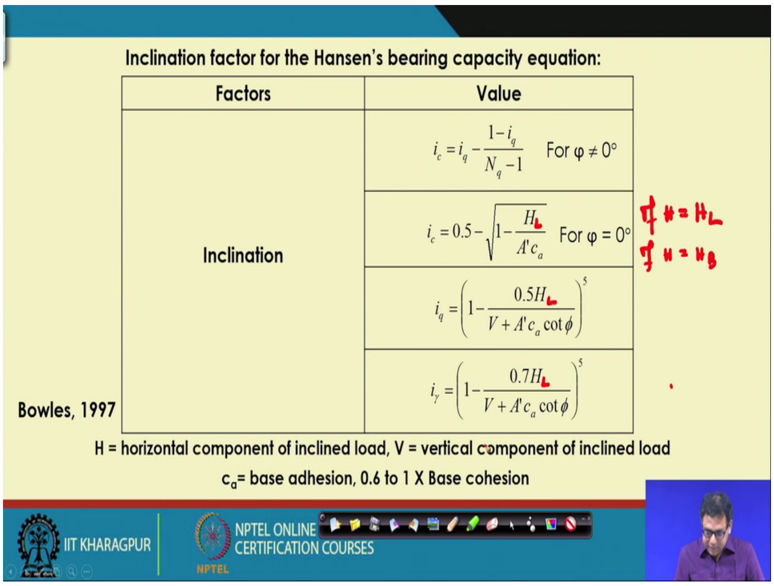

So that replaces this thing and for the inclination factor also that is will be same whether H is parallel to V so; that means, if your H is equal to H L parallel to H, then you replace it by H L. This will be H L, H L when you are doing two factors. Now if H is equal to H B, then this will be you have to replace it by H B, H B and H B ok. So, clear these things so; that means, in that case we have to do Two things; one is S c B S c B d c B gamma S gamma B. So, q B all in terms of B if it so; that means, one factors will determine by considering H B which is parallel to the width axis. And then, next one we will consider S c L S c L gamma L, q L all you put L ok. So, that mean two way we have to determine the factors clear.

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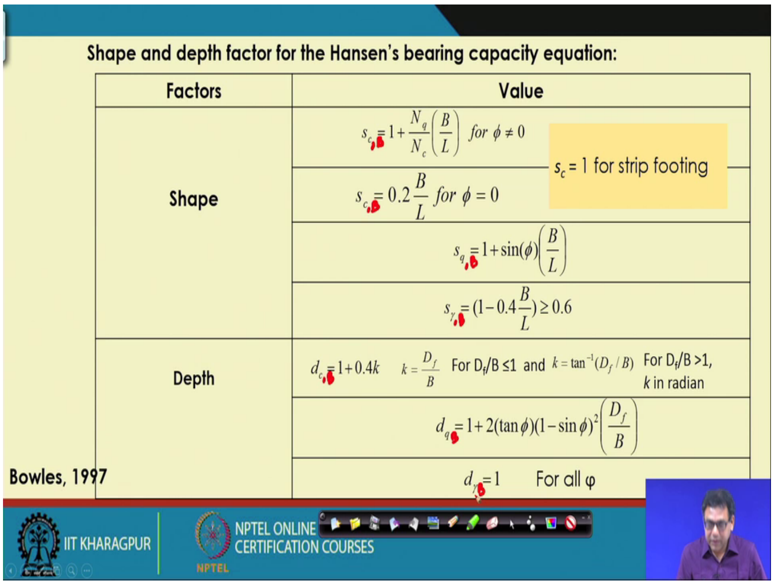

So, one way is that if the H B is parallel to the width axis, then the way that I have discuss you have to determine in that way. So, that will be the all factors suffix B and if the horizontal load is parallel to the length axis even if H B is 0, then you calculate the factors in two ways one is considering the B, another one is you replace the B with L and the L with B ok. So, that I have discussed so; that means you will get two factors.

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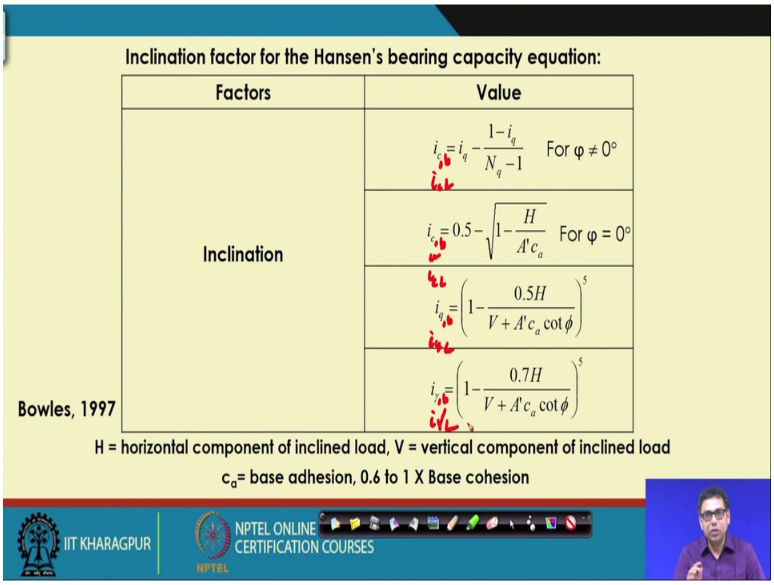

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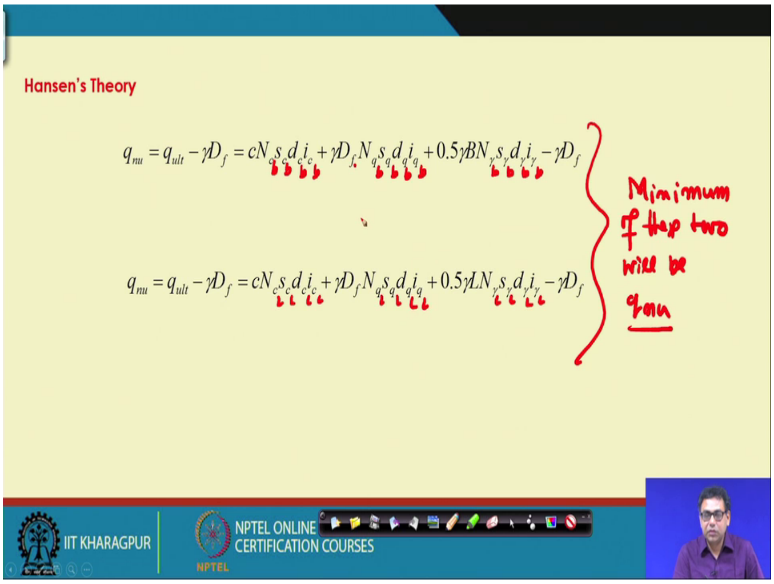

Now this will be also one will be in terms of B, another will be in terms of L and or i c L, i c L, i q L, i gamma L. So two factors will get and then you have two equation; one will be this will be b b b b all will be in terms of b and another will be in terms of L ok, but remember that in that terms you have to take L where your taking all terms in terms of L. So, among these two minimum of these two will be the q net ultimate ok. So, either these two and minimum of these two will be the q ultimate.

So, remember that, but this is only for the Hansen's theory. If you are using the Meyerhof's theory or IS code or basic then only one equation where whether where the if the load is parallel to B or the H, it does not matter you have to take only one equation. But if it is the Hansen theory, then if it is parallel to L then you have to use different methodology. If it is parallel to B, then the methods that I have discussed the last class that you have to use. So, a, but this is for information and in this course I will concentrate only the when the parallel horizontal load is parallel to width ok. So, I will not consider a L, but this is for one information.

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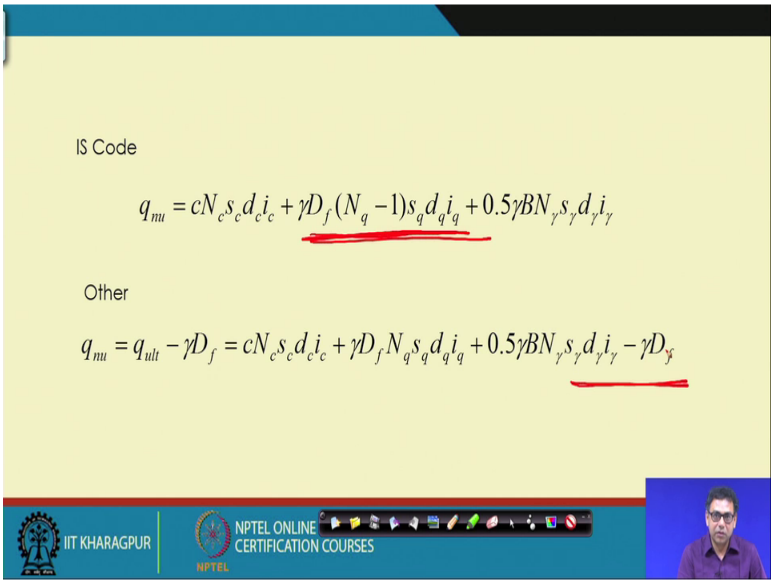

And then the next one is that if this is also one thing that I have mentioned in previous classes also that if the IS Code you use for the net ultimate you use these expression N q minus 1, but for the others you use these expression minus gamma D f that is also one important information.

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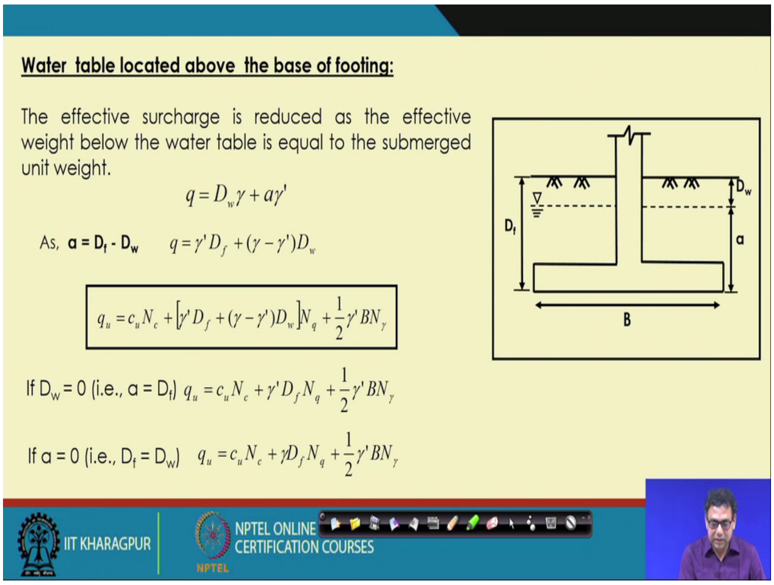

Then next one is that if you are incorporating the water table effect, then the procedure I have discuss that the effect of water table in the second term and the third term. If the water table is above the base of the foundation, then the your surcharge term or the second term will also be affected and the third term you have to consider the gamma sum. And if it is below the base of the footing, then second term will not be affected gamma third term will be affected. So, that method I have discussed. So, this is this you can apply for all the others method except the IS method remember that. If it IS method, then this methodology you cannot use because that is the recommendation. This is you can use for the other methods ok. These things I have discussed already.

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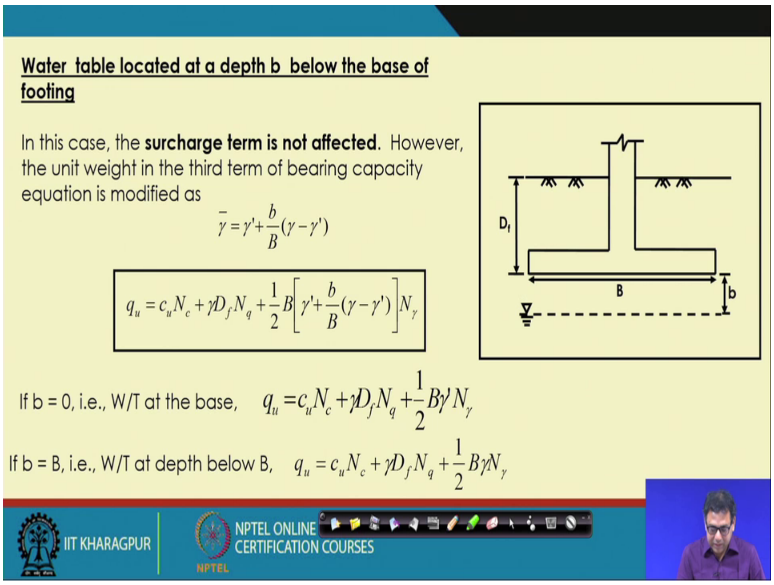

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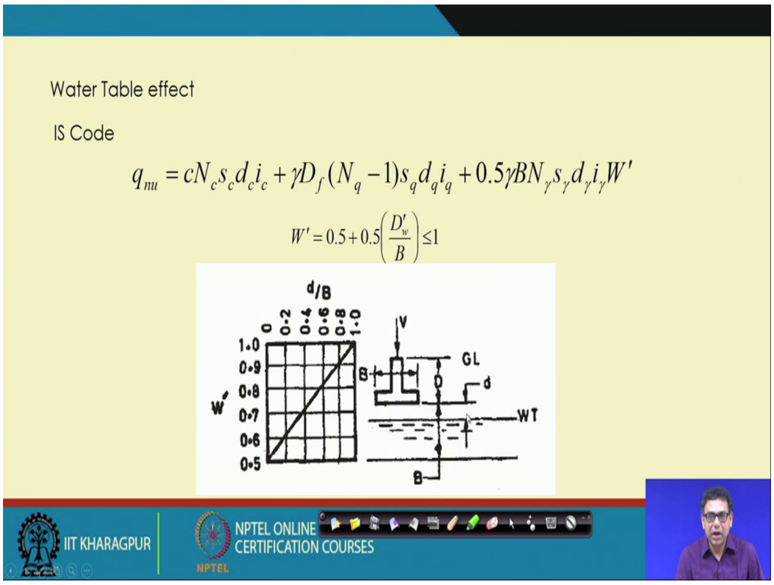

And, but if it is the IS method, then in the IS method it is recommended that if the water table is at the base of the footing then and above then it is always 0.5. So, the second term you no need to apply any corrections because it is mentioned that if it is above base of the footing, then it is always 0.5 and this is the W dash ok.

So, W dash you can use by these equation that I have already given or you can use these chart that I have used for the settlement correction or calculation based on the SPT as per the IS code where D is the depth of water table below the base of the footing. So, this method you can use for the IS code. For the other methods, you can other theories you can use the methodology that I have discussed previously ok.

So, and the next one is that Skempton theory is valid for only if phi is equal to 0 that mean if it is only cohesive soil, this is one information. Another information for the local shear failure I have given that if it is cohesionless soil or phi soil, then I have given the recommendation and if it is cohesive soil also then if it is very soft too soft very soft, then you can consider the local shear failure. But if it is c phi soil, then based on the load settlement curve you have to decide whether it is a it will be local shear failure or general shear failure I have discussed that. So, in the problems if it is c phi soil, it will be mentioned which type of failure is occurs. So, based on that you have to take whether it will be a local shear failure or general shear failure in the example problems it will be mentioned.

Then the main question is I have discussed the several theories and which one I will use ok. So, in the last class I have shown that depending upon the strain parameter and the dimension of the footing. So, different theories will give different values ok. So, different values in the sense in some way the in some case one theory will give the higher value compared to others, but in the other case cases another theory may will give the higher value compared to the other.

So, that is why as I mention the Terzaghi theory is simple that is why we use that theory, but it is I would prefer that you use for different theories and then you judge which one you will use or you can take the lower value that is coming from those theory. So; that means, you use different theories and take the lower value that can be one option.

And then I have discussed the foundational layer soil but there I have taken the weighted average, but foundational layer soil theories are available, but that is not discussed in this course because that is not part of this course, but here weighted average method you can take which is reasonable. And, but if you want to get the in a specific values, then you have to use those theories, but that is not discussed in this class.

Then next one is the foundation on slope is also that is theory, but which is also not discussed in here because here we have concentrated on shape factor depth factor and inclination factor because those theories are as the part of advanced foundation engineering foundation engineering.

And another one is that that we are talking about the stress base of the foundation. So, we always take the assume the uniform stress below the foundation, but actually in the field on depending upon the type of soil or type of foundation your stress and the settlement below the foundation is not always same.

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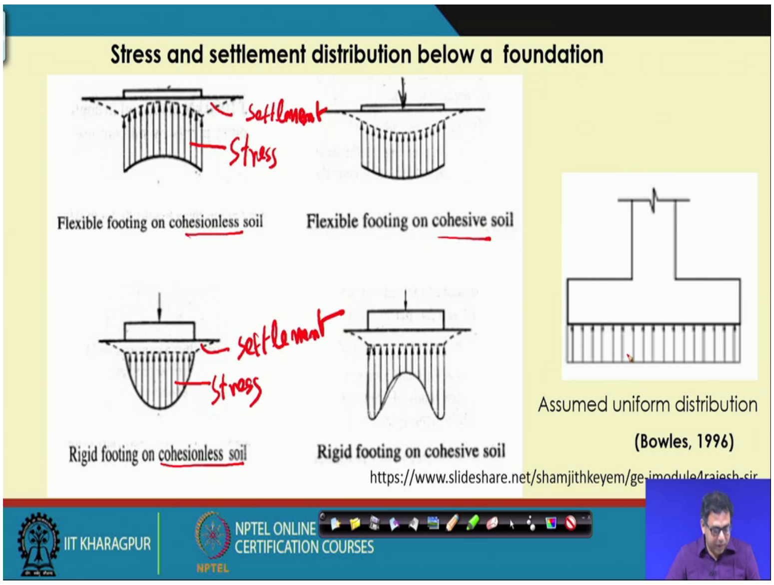

So, I can give you that information that if you have the flexible footing, this is on the cohesionless soil and flexible footing on the cohesive soil you can see because this is the stress distribution. This one is the stress, but this is the settlement ok. This is the settlement and you can see that for the cohesive soil if the foundation is flexible, then your stress distribution is always uniform whether it is a cohesive soil or cohesionless soil or cohesive soil. You can see the foundation stress distribution is always uniform, but settlement is different because in case of cohesionless soil settlement at the centre is less compared to the edge because the elastic modulus of the soil at the centre is more compared to the edge in case of cohesionless soil.

So, we have the less settlement, but the opposite trained is observed with the cohesive soil where settlement is maximum at the centre and minimum at the edge or it is less at the edge compared to the centre, but in the cohesionless soil settlement at the centre is less and the edge is maximum. But if it is rigid foundation, then settlement is uniform whether it is cohesiveless cohesionless soil or cohesive soil, but the stresses are different ok so this is the settlement.

So, in case in case of rigid foundation or raft foundation on cohesionless soil your stress at centre is maximum and at the edge is lowest, but in case of cohesive soil the stress at the centre is less, but at the near to the edge is more. So, these but when we do the analysis we assume uniform stress for all kind of foundation resting on any kind of soil ok. But this is the it is true for uniform stress distribution if the soil is the foundation is flexible foundation, but the, but the rigid foundation it is different, but in that case also we assume the uniform stress distribution. So, these are some information I think that you will remember you will you should remember when you solve any shallow foundation problem.

With this thing I will go to, now I am going to the next chapter which is the pile foundation ok. So, pile foundation is basically deep foundation. So, I have discuss the shallow foundation and I have given the definition of shallow foundation, moderately deep foundation and the deep foundation.

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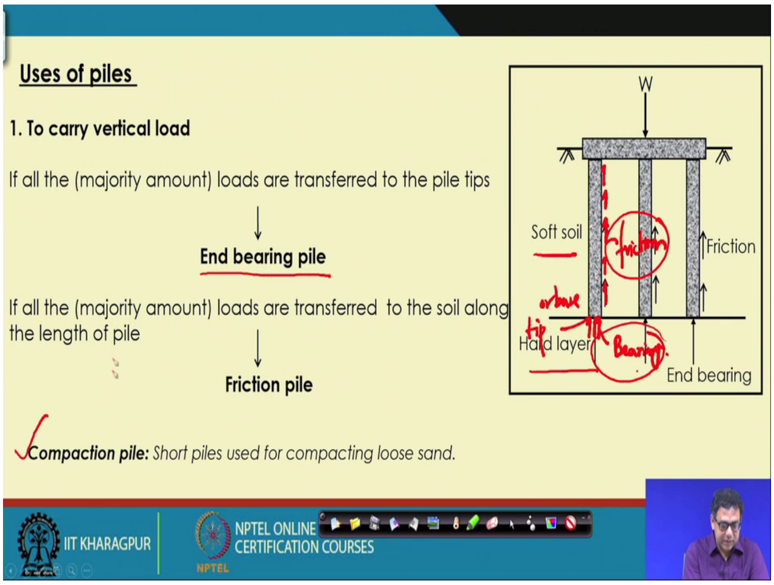

So, in the deep foundation can be different types it can be pile or piers or the well foundation. But here in this course I will discuss only about the pile foundation. Even though even in the pile foundation these are subjected to number of different types of loadings like the compressive load, tension then the tension or uplift or the lateral load, but in this course I will concentrate or I will discuss only the pile under compressive load ok. So, those analysis under different other combinations of load are not part of this course.

Ok so now, as I mentioned that pile; so, first of all what is pile? And the pile suppose if your I mean you have a very soft or poor layer where in the in the top zone where your shallow foundation is not sufficient in that case, we can go for the pile foundation where your pile will transfer the load through the soft layer to a hard stratum because this is the pile and if the soil is soft, then it will transfer the load through this soft soil to a hard layer ok.

So, depending upon the type of loads the pile can be classified in compressive loaded pile that is the vertical load; that means, and depending upon the loads load shearing ok. When we are applying the load on a pile, so this pile is suppose vertically loaded. This is the we are talking about single pile actually pile is applied in a group. So, we will later on discuss about the group pile also.

So now, if I apply the load on the pile then this pile will so; that means, this will deformed into the through the soil ok. So, that deformation depends on the what is the type of soil. But; that means, when you apply the load; that means, the resistance the pile will get from the tip this is called tip or base ok. So, this is the bearing and another one it will get the resistance by the friction between the pile surface and the soil ok. So, this is the friction and this is the bearing and this is the bearing ok.

Now that depending upon the type of soil if the majority of the load is transferred to this hard stratum or the majority of the resistance it is coming from this bearing compared to the friction, then the pile is called the end bearing pile ok. So, this is the called the pile tip or the base tip or base ok.

Now, if the all or the majority amount of loads are transferred to the soil along the length of the pile; that means, along the friction majority of the load is transferred to this friction or the majority of the resistance is getting through this friction, then it is called friction pile. So, that means, the resistance when you apply the load pile will get the resistance or bearing capacity that pile is getting is getting from two ways; one is the bearing that is from the base, another is the friction ok.

Now, if the majority of the resistance is getting from the bearing then it is called the end bearing pile. If majority of the resistance is getting from the friction, then it is called friction pile and sometimes short piles are also used to compact the loose sand because if you install a drive a pile loose sand it will compact. So, that type of pile also called the compaction pile. So, this is one information, but this is the measure to end bearing and friction pile. So, I will discuss which type of soil will have the end bearing and which type of soil will get the friction majority of the resistance from the friction. So, I will discuss later on when I will discuss about the classifications of pile.

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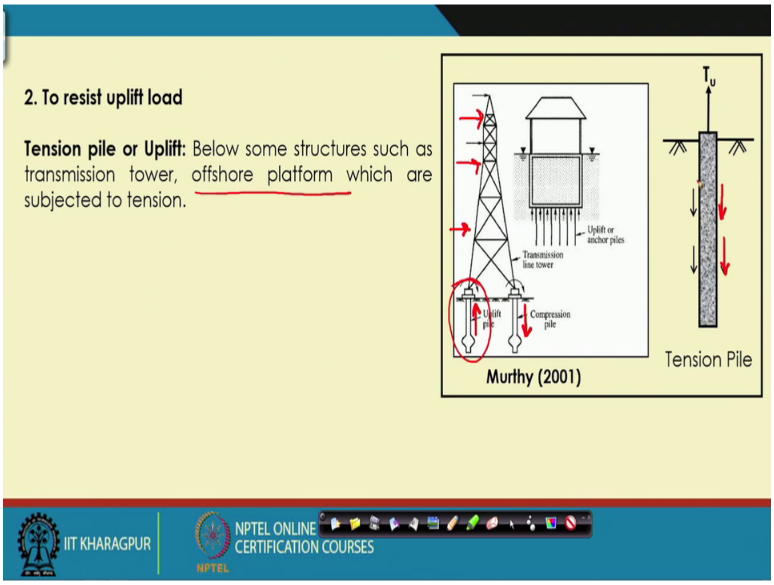

Then pile can be subjected to tension or uplift ok so the compressive load, pile is under compressive which is very common. So, any structure if you are constructed on a pile, so the majority of the load is the compressive load so, which is very common. But if pile is constructed under a say tall tower or chimney ok; this is a see electric tower, so and these are the piles in the base of two this is the base of the towers and so, this is the one pile and this is another pile or it may be the group of piles. Now if any wind load is coming in this direction, then what will happen? This will try to move in this side. So, here it will be the uplift and here it will be the compressive so this is one example.

So, then similarly the offshore platform also subjected to tension load because this is the if this is there is a offshore structure, there also we will get the tension load. If the tall tower or chimney because of the wind load we will get the tension in one side of the pile and you will get the compression in one side of the pile. So, in those cases we have to check the bearing capacity of the pile foundation under both tension as well as compressive loads ok.

So, here as the it is applied in the uplift direction. So, the friction will act in the downward direction, but if the load is in compressive direction so; that means, if the load is applies in the compressive direction, so there will be a deformation of the pile in the downward direction. So, friction will up in the act in the upward direction. But here the pile is moving in the upward direction so friction is acting on the downward direction. So, that is called the tension pile.

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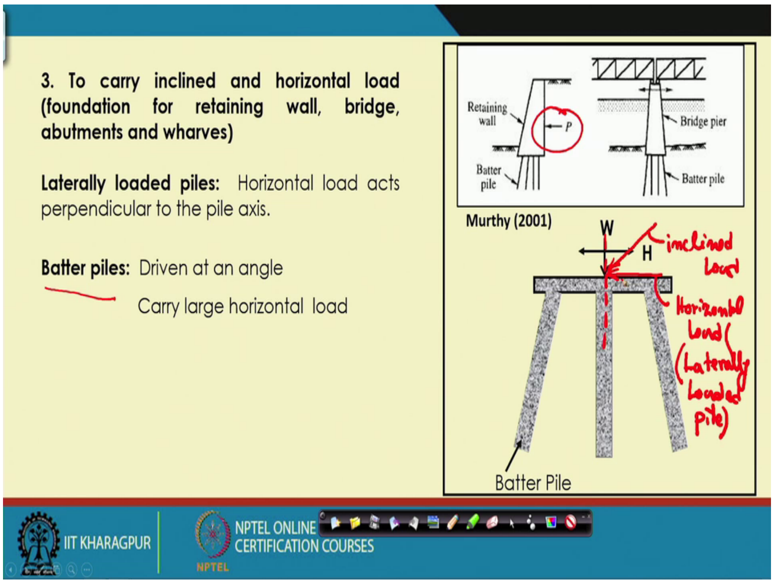

Say then the in the next type of pile based on the loading is called the pile can be subjected to inclined or horizontal load. So, that type of if the pile is constructed below a retaining wall or bridge abutment or in the offshore where the waves are coming waves or the sea waves are coming which is in the form of lateral load. So, in those cases pile is subjected to horizontal or it can be subject to inclined load also.

So, you can see if it is below the retaining wall where the retaining wall is resting the earth pressure, earth pressure is acting in the horizontal direction. So, this is earth pressure which is acting in the horizontal direction. So, pile is also be subjected horizontal or the inclined similarly for the bridge abutment ok. So and depending upon that type of loading pile can be batter pile also. What is batter pile? If the pile is within angle ok so other two cases I have discuss the pile is or as an perfectly vertical, but here which is an angle. So, batter piles is a driven at an angle and it can carry the large amount of the horizontal load.

So, if the load is horizontal then we will provide batter pile. So, that will carry the large amount of the horizontal load and what is the lateral loaded pile? The horizontal load perpendicular, so this is horizontal load which is perpendicular which is at perpendicular the pile axis. So, this is the pile axis and this is the perpendicular to the pile axis. So, this is horizontal if it is say with an angle. So, this is called the inclined load and this is call the lateral load or horizontal load ok.

So, if it is perfectly perpendicular to the pile axis then it is called the if the horizontal load is perfectly pile perpendicular to the pile axis, then this type of pile is called the lateral loaded pile. So, horizontal load if it is perfectly perpendicular to the pile axis, then this is called the laterally loaded piles ok another way is this pile is also can be inclined. So, these are the different types of piles.

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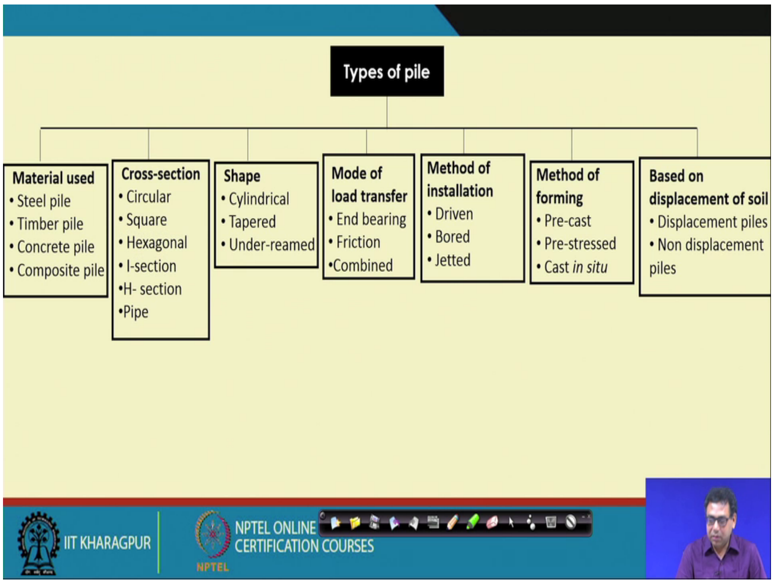

So, these are the types of pile so I was talking about. So, based on the material used pile can be steel pile, timber pile, concrete pile or composite pile; that means, timber steel and concrete both I will discuss later on one by one all these classification. So, based on the cross section pile can be circular, square, hexagonal, I-section, H-section or the pipe section or it can be the hollow pile and based on the shape it can be cylindrical, tapered or under reamed. And mode of load transfer as I mention, it can be the end bearing if the majority load is transferred through the bearing and it can be friction, if the majority load is transferred through the friction or it can be combination of both; some part is coming from the end bearing or some part is coming from the friction ok.

So, method of installation; so, pile can be driven, bored or jetted ok. Method of forming: pile can be pre cast, pile can be pre stressed and pile can be cast in situ also ok. Based on displacement of soil pile can be displacement piles or pile can be non displacement piles. So, pile displacement means when you are installing pile whether the soil surrounding soil is displayed or not ok. So, based on that pile can be two types either displacement piles or non displacement piles ok. So, this is the all about classifications of the piles so different types of piles.

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Now, first one based on the material used ok. So, based on the material used pile can be timber pile, it can be steel pile, this is the steel pipe or hollow pile, this can be H-section or steel H pile, this is the concrete pile, this is the pre cast pile or this is the or this is precast concrete, this is also both are concrete. So, timber, steel this can be hollow or H pile or the concrete and this is the composite concrete and steel. So, this is the photographs of a concrete piles and this is the steel pile and this is the timber pile ok. So, these are different types of piles.

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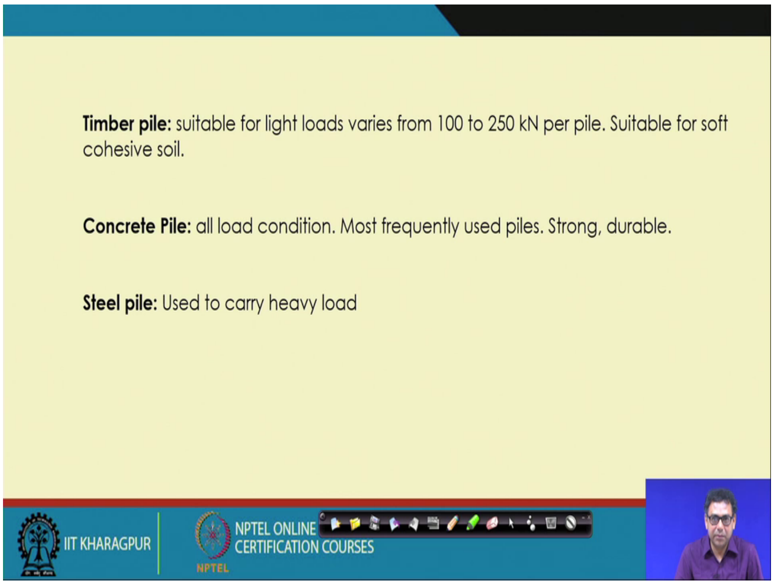

Now, when we will use the timber pile? So, it is suitable for light loads when the loading is very less or comparatively less varies from 100 to 250 kilo Newton per pile and suitable for soft cohesive soil because then it is very easy to drive into the soil was if the soil is very hard, then the pile may be this timber piles maybe damaged because of this because your soil is very stiff you are applying the driving force. So, it will there is a possibility this piles can be damaged.

So, if it a cohesive soil or less loaded pile, then we can use the timber pile. And the concrete pile can be used for all kind of loading condition and it is most frequently used pile it is durable and strong and one thing in the timber piles to protect it for you have to paint this pile outside ok so that is also required and this is the strong and durable. Analyze steel pile which we can use for heavy when the load is heavy, but one problem in the steel pipe that the corrosion may takes place ok. So, the corrosion take place so that is why we have to take we have to take care for this steel pile and the concrete pile is most frequently used because it is strong and the durable.

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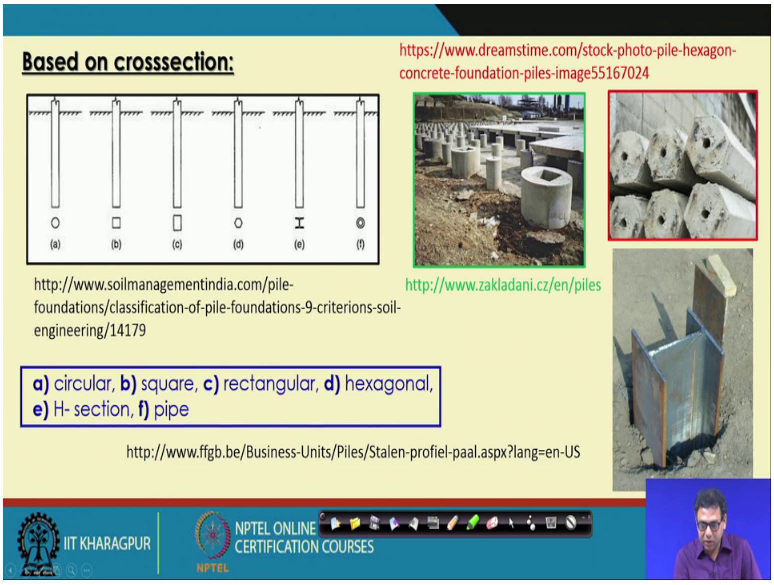

And then the next one based on the cross section ok. So, based on the cross section pile can be circular, square, rectangular, hexagonal, H-section and the pipe. So, this is the hexagonal type of pile, this is the H pile and this is the hollow pile and this is the circular pile also ok. So, these are the different types of pile based on the cross section.

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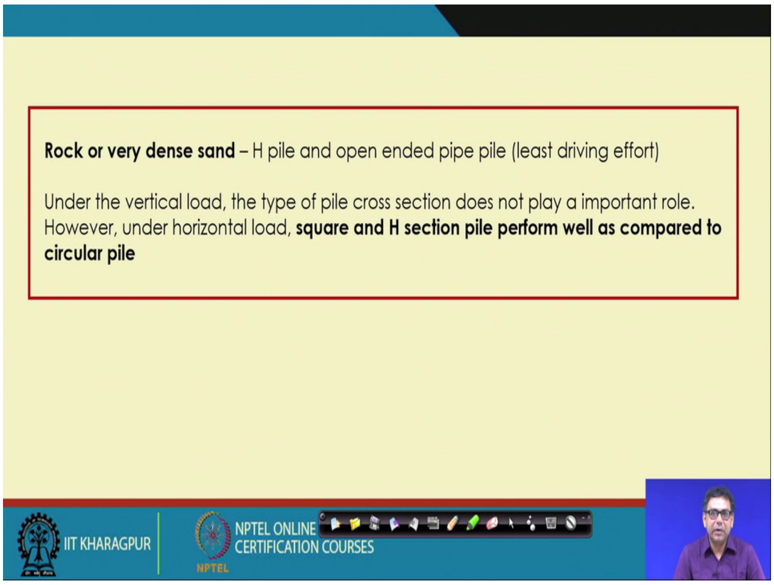

And so, for the rock and heavy dense sand H pile and open ended pipe pile is suitable and the all this example I am giving this is the suitable this is not the only application this is the suitable, but you can use the other kind of pile kinds of piles also, but this is one of the example where it is more suitable.

So, this is the open ended pile or because here you have apply the least driving effort and under the vertical load, the type of cross section does not play a important role; but under horizontal load square and H pile section perform well as compare to the circular pile. If it is a horizontal load your applying, then it prefer to you square or H section pile because that performs better for these sections perform better as compared to the circular pile. But if it is a vertical loaded pile, then cross section will not give you a significant change or effect.

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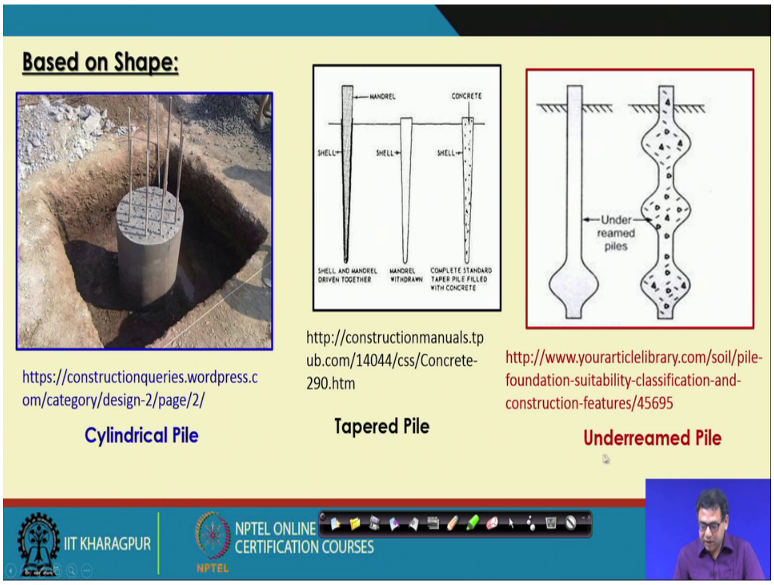

So, next on the based on the shape of the pile; so, it can be cylindrical pile, it can be tapered pile or it can be under reamed pile or cylinder pile means is a uniform diameter throughout the length of the pile ok. In tapered pile, its diameter is changing you can see the diameter is changing so from the top to bottom; so that is the tapered pile. And an under reamed pile, here we are provided this bulb ok. So, that can be single bulb or that can be multiple bulb also. So, this is the multiple bulb this is the single bulb so this is the under reamed pile also.

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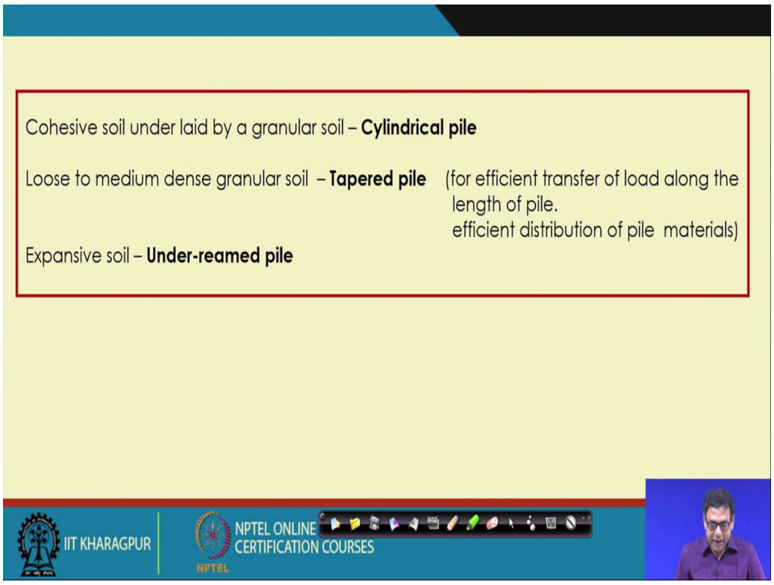

So, and then which type of soil we will use, if the soil is cohesive soil under laid by a granular soil cylindrical pile is preferable; loose to medium dense granular pile, tapered pile and for the expansive soil which will expand ok so that is the under reamed pile is suitable. So, and this is tapered pile which is efficient to transfer the load along the length of the pile and efficient distribution of pile material because we are taking the tapered section. So, we can save the material also we can distribute the material and the load efficiently we can transfer through this type of pile, if it is and this is most preferable is loose to medium dense granular soil ok; so, loose to medium actually granular soil.

And so, in this I am discussing I have discussed this three types of pile are based on the each material, based on it shape and based on its cross section ok. So, in the next class I will discuss the other types of piles and then I will discuss about the pile load carrying capacity.

Thank you.