Foundation Engineering
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Lecture -34
Pile Foundation – VIII

In the last class I have solved a problem where the pile is installed in a sand clay layer soil system and I determine the tip resistance of the pile. Now today I will determine the frictional resistance of the pile. So, if I take the same problem.

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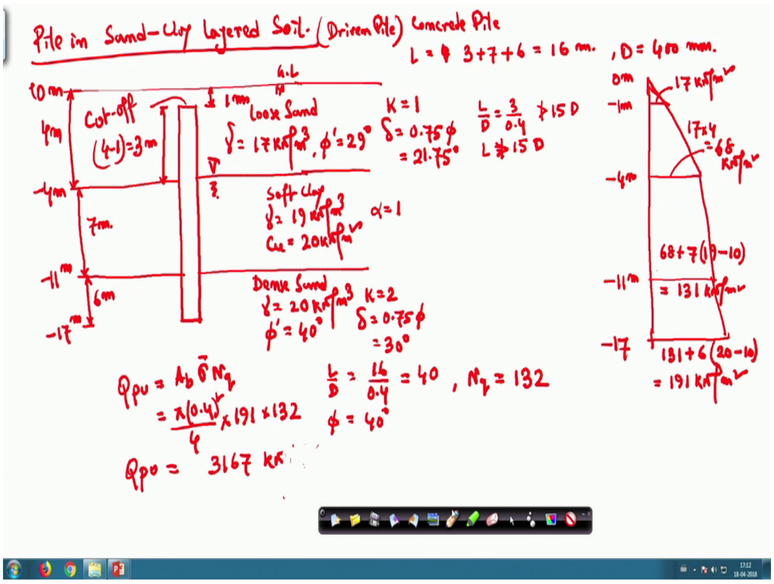

So, this was the problem ok. So, when I determine the tip resistance 3167 kilo Newton and now I will determine the frictional resistance. So, as the k value is taken is from the chart is 1 delta 0.75 phi because is a concrete pile. So, when phi value is equal to 1 here so now, I will and here I will as I mention that I will not consider the critical length concept because it is in the layer where in this case it is a doubtful whether this arching will really happen or not. So, now what I will consider that so fiction parts ok.

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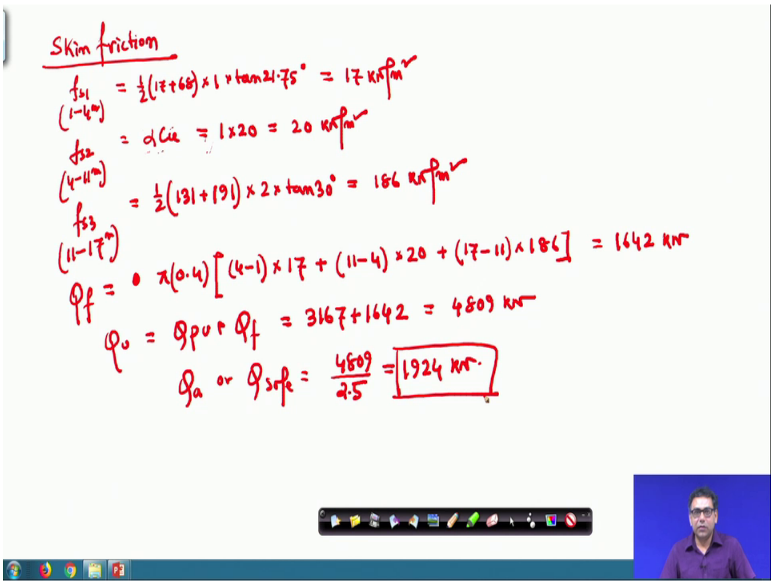

So, first skin friction that first one f s 1 form 1 meter to 4 meter, one thing here when I calculate the length I will take the 1 meter, I will I will not take this 1 I will take 3 meter because this is the 3 meter plus 7 meter plus 6 meter 16 meter total with this one I will not take. But I have considered that weight when I determine the effective overburden pressure thus remember that.

But sometimes this pile can the above the ground level also. So, do not consider that portion of the pile which is above the ground level when you calculate the friction resistance if the pile is above the ground level. So, you consider the pile which is below the ground level only during the friction calculation. So, first one is 1 to 4 meter and so the friction resistance. So, this will be the average value.

So, I am just taking this is the 17 and the 68. So, average of these 2 will be half into 17 plus 68 then k value is 1 and that delta value is tan 21.75 degree so that is 17 kilo Newton per meter square because your delta value is 21.75 degree. In the second layer I will do for the 4 meter to 11 meter the average is 68 and this is a 131. So, second layer f s 2 it is from 4 to 11 meter and this is also average is 68 plus 131 68 sorry second layer is in clay. So, will considered this is in the clay so that is that formula will not use. So, in the second layer so will not use this formula because it is in the clay.

So, in the second layer it will be your that alpha c u. So, alpha value is because in this clay layer alpha value is 1 c u is 20. So, you will consider this is 1 into 20. So, this will be 20 kilo Newton per meter square, but the third layer that will form 11 meter to 17 meter so that is also in the sand. So, there I will take the average. So, here it is here 131 is 11 meter and 191 as 17 meter. So, I will take the average of this two. So, this will be half 131 plus 191 then k value is equal to 2 and delta is 30 degree. So, k value is 2 and delta is tan 30 degree.

So, this thing is coming out to be 186 kilo Newton per meter square. So, the total f is q a Q f is the pi, pi D D is 0.4 meter and the length of the first layer is 4 minus 1 that is 3 meter into this 17 then plus the length of this layer is 11 minus 4 into 20 plus the length of this layer is 17 minus 11 into 186 ok. So, this is equal to 1642 kilo Newton.

So, my Q u will be Q p u plus Q f which is equal to Q p u is 1367. So, I sorry 3167 so this is 3167 plus the fiction was 1642 ok. So, that is equal to 4809 kilo Newton. So, q allowable or q safe will be 4809 divided by 2.5. So, this is equal to 1924 kilo Newton. So, the load carrying capacity of this pile is 1924 kilo Newton.

So, with this I am just going to the next part which is the load carrying capacity of a under in pile. So, till now I have discussed about the load carrying capacity of the pile where your a diameter of the pile is uniform throughout the length of the pile circular piles I have mostly solved so the where the diameter throughout the length is uniform.

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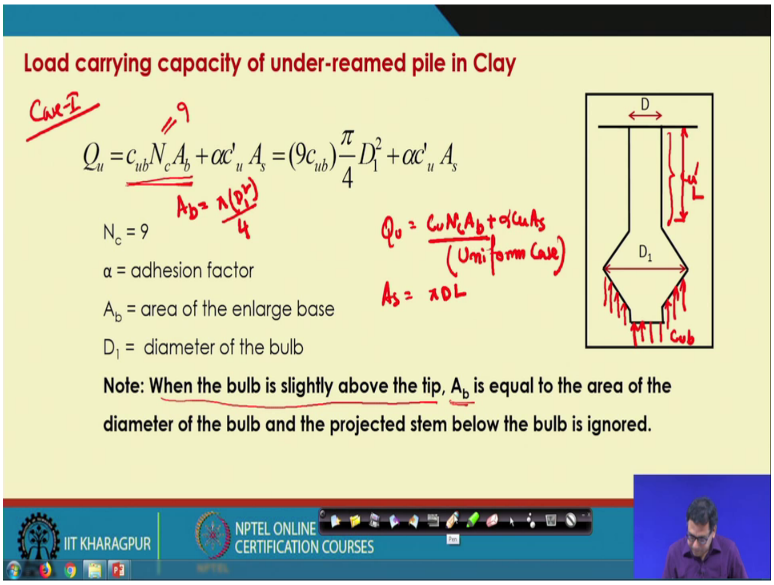

Now, in as I mentioned in some cases so we will go for the under reamed pile also and I mention that for the expansive soil clay soil will go for the under reamed pile. So, how I will calculate the bearing capacity of under reamed pile in clay? Under reamed pile means where your providing bulbs ok so these are the bulbs.

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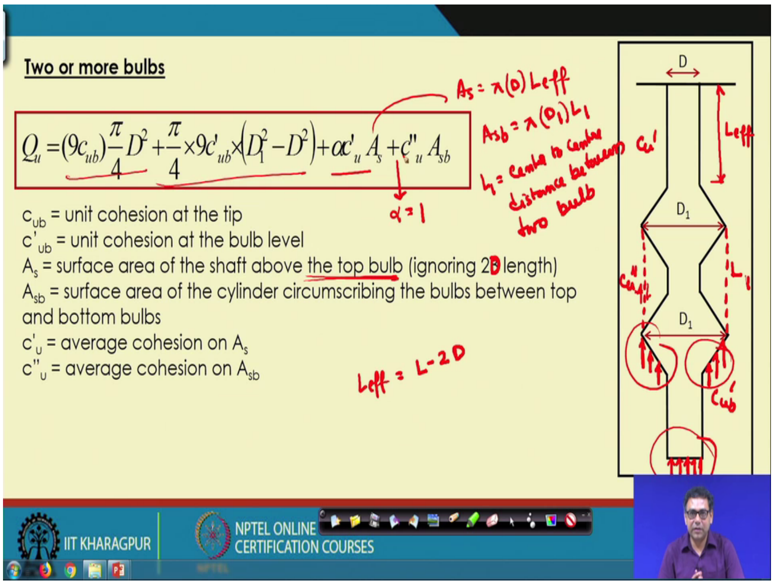

So, this can be single bulbs this can be multi bulbs also. So, how I will calculate the load carrying capacity?

So, now if your first case, there are 3 cases that I will discuss this is case 1 ok. So, this is the 1 where they your diameter is not uniform that is a bulb whose diameter is D 1 and the shaft diameter this is the shaft diameter which is D and this is the bulb diameter this D 1 this enlarge bulb will also increase the bearing capacity because it is your q bearing capacity will increase.

So, now if it is in the clay now the first case when the bulb is slightly above the base because in this case you can see when the bulb is slightly above the tip then A b that will be equal to the area of the bulb. So, I will then this small portion we have to neglect because in that case your tip resistance will be on this bulb ok. So, I will neglect that tip resistance for the small portion. So, I will considered the total bulb diameter as the A b area of the base and the bulb and projected steam below the bulb is neglected; that means, this small portion is neglected.

So, how will be bearing capacity for uniform case my Q u is c u N c A b plus alpha c u s this is for the uniform case, but if it is a bulb then this will be the same tip resistance the area that I will use will be the bulb area. So, that mean this is the tip resistance and this in this case A b. I will use pi D 1 square divided by 4 in this case and N c is again equal to 9 c u is the caution at this level tip level then; that means, this equation 9 c u pi this D 1 square by 4 and then the alpha into c u dash c u dash is the caution at this level and c u b is the caution as the base if it is not homogeneous soil if it is homogeneous soil then c u dash will be equal to c u b, but here the general form we are giving this expression.

So, this is the area of the s is pi D into length of the shaft ok. So, this is the length of the shaft that you will be equal to the length and keep it mind 1 thing is that that when you are talking about the length of the shaft and it is the enlarge bulb. So, it is recommended that the as the when the pile settle there is a possibility of formation of the small gap between the top of the bulb.

So that means, when the pile will settle there is a possibility that in the top of this bulb the soil there will be some separation because of these non uniform diameter your shaft diameter and this your base diameter is different. So, that is why when this when you apply the load is pile will settle. So, there is a possibility of the small separation between the pile and the this portion not this is a small separation between the pile and the shaft. So, that is why it is recommended that in such case when you take the length of the shaft you deduct the twice D of this from the shaft length ok.

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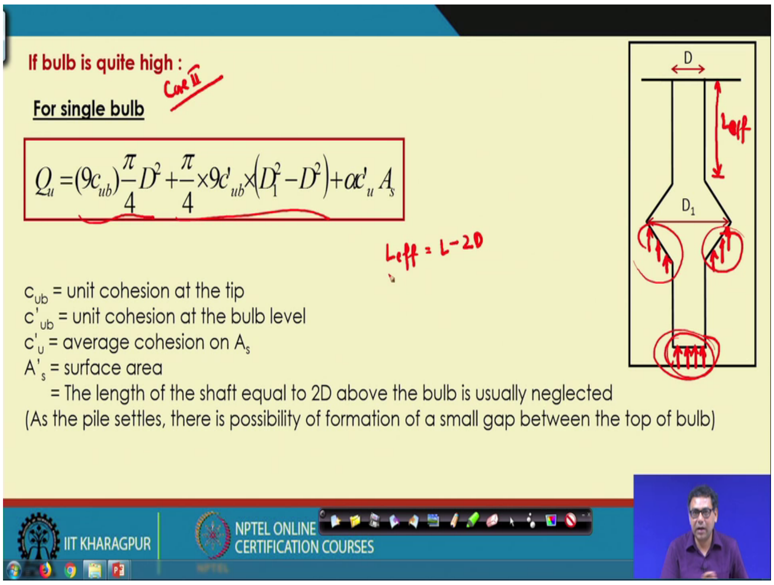

So; that means, here in first case if this is the shaft length.

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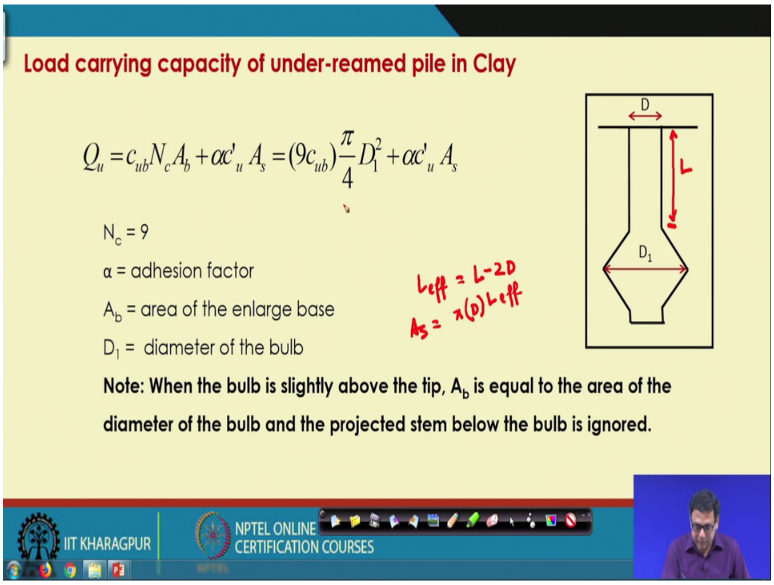

If this is the length of the shaft then the effective length effective length will be L minus twice D, D is the diameter of the shaft. So; that means, your A s will be pi D into L effective this is 1 recommendation because there may be some separation between the shaft above the bulb and the soil above the bulb. So, and then other things are remain same now I will go to the next case that is my case 2. So, this is case 2, but here also is the single bulb and the difference of case 1 and case 2 in the case 1 bulb was just slightly above the base, but here the bulb is quite high from the base.

So, in that case we cannot neglect this portion so, in that case over. So, here this will give you the resistance, bulb will give me the resistance as well as the shaft of this portion this will also give the resistance tip resistance. So, in this case my the tip resistance will be 9 c u pi by 4 D square this is from the here and in the this is also another tip resistance that I am getting that is pi by 4 9c ub D 1 square minus D square. So, this is this one and this is the alpha c u dash into A s a s I will consider this length of this portion ok.

This is the L effective that I have to consider. So, this one is not considered. So, this length of the this above the bulb is considered when you calculate the A s again when you calculate the A s L effective will be L minus twice D this L effective will be L minus twice D and if the soil is not homogeneous then different position cohesion you have to use for this expression.

So, when you are calculate first term then cohesion of this portion is you have to be use, when you was in the second term cohesion of this portion you have to use when you are in the fiction part then cohesion of this portion you have to use it here it is layer soil then it will be the summation of this if is the number of layer the summation of the fiction resistance that I have done for the previous cases of uniform shaft diameter ok.

So, and then third case is that this is the third case where we are using the multiple bulb, we are using the 2 bulbs and I again your first I mean your bulb is quite high from the base of the a pile. So, again the resistance how I will getting the resistance? So, will getting the resistance from here when will getting the resistance from here this base so; that means, here the first one is this one the same as pi D square by 4 into 9c ub here c ub u c ub is here then this is the second resistance tip resistance is this one the same as the second case ok. So, this one c ub dash and then we have 2 frictional resistance. So, what are those 2 frictional resistance? So, 2 frictional resistance, this one is as usual the fictional resistance that you are getting for the shaft. So, this will be c u dash ok.

And again L effective is equal to this will be 2 D this is the 2 D not b if 2 D here. So, this L effectives will be L minus 2 D so; that means, we are considering the shaft resistance from the shaft above the top bulb here mention here. So, this is the shaft above the top bulb ok. So, this is we are getting and alpha value will be the a ration factor between the soil and the pile. But there is a fourth term. So, they higher also we are getting the resistance because in between the two soil in between the 2 bulb the soil of this zone this will form a cylinder when the pile deform this soil will also try to deform.

So, this will soil this the soil between the 2 bulbs will also try to deform ok. So, that is why they this portion of soil or soil cylinder will give you the resistance or the frictional resistance. So, that frictional resistance will be so this will be the c u double dash and area of these portion or these cylinder, but here the alpha value is equal to 1 because here the friction resistance that you are getting here it is between the soil and soil because this person is also soil and this portion is also soil. So, the soil cylinder there alpha value will be 1, but here the addition factor alpha value will only 1 because this is the pile materials soil that is why they are be alpha and here the alpha is not considered because your alpha value is 1 as this is the resistance of the soil cylinder I am getting and this is the soil versus soil.

So, that is why it will be the alpha and this your A s this A s will be pi into D into L effective and this A s b will be pi into D 1 into the L 1 L 1 is the centre to centre distance between 2 bulbs where L 1 is the centre to distance between 2 bulb ok. So, this way we can calculate. So, here there will be 2 tip resistance and 2 frictional resistance. So, this a 3 cases I have discuss that first case single bulb, the bulb is base of the pile or just above the base of the pile and second case the bulb single bulb is quite high from the base and third case 2 bulbs case and the bottom bulb is quite high from the base ok.

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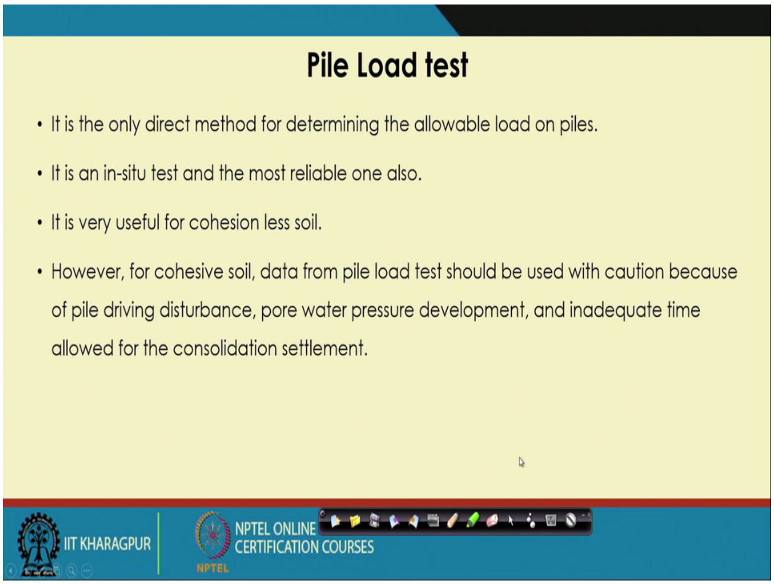

So, that is the next topic that I will discuss that goes I have mentioned there is a 4 ways we can determine the pile load capacities, one is the static formulae that I have discuss for the granular soil as well as the clay soil next one is the pile load test third one is the from the your driving formulae for the driven piles that I will discuss and the fourth 1 is the form the SPT and the CPT or a cone penetration values ok. So, that is how the second method is the pile load test so I have discuss the plate load test for the shallow foundation it is also similar test for the pile.

So, it is only the direct method to determine the allowable load on the pile because the advantage of this method. So, directly we can get the allowable load on the piles from these method ok other methods we are using a determining the soil properties those we are using in the expression and you are getting the pile load capacity. But here directly from the test we will get the pile load capacity.

So, it is a in situ test and most reliable one compared to the other methods it is very useful for cohesion less soil because all the field test or in situ test I have mentioned is useful the cohesion less soil or granular soil because the cohesion soil there is a time dependent or the long term behavior, but this test are short term. So, it is very difficult to get that long term behavior of the soil cohesive soil in this in-situ test.

So, that is why it is also very reliable for the cohesion less soil, but for the cohesive soil data from the pile load test should be used with some caution because in the pile driving disturbance in the pore water pressure development and a inadequate time to allowed for the caution consolidation settlement, consolidation settlement is a time dependence settlement, but this tests are short term test. So, we are not allowing this pile for the consolidation settlement another issue I have mentioned that if you are driving a pile in the soil and if it is a clay then you are not allowing this water to dissipate.

So, for water pressure will generate and that will reduce the effective overburden pressure and your strength of the soil will reduce. So, your pile load carting capacity will reduce because it is a short term test you are not allowing this water to move ok. So, these things we have to take care when you are using the pile load test data in clay, but in the sand it is very useful.

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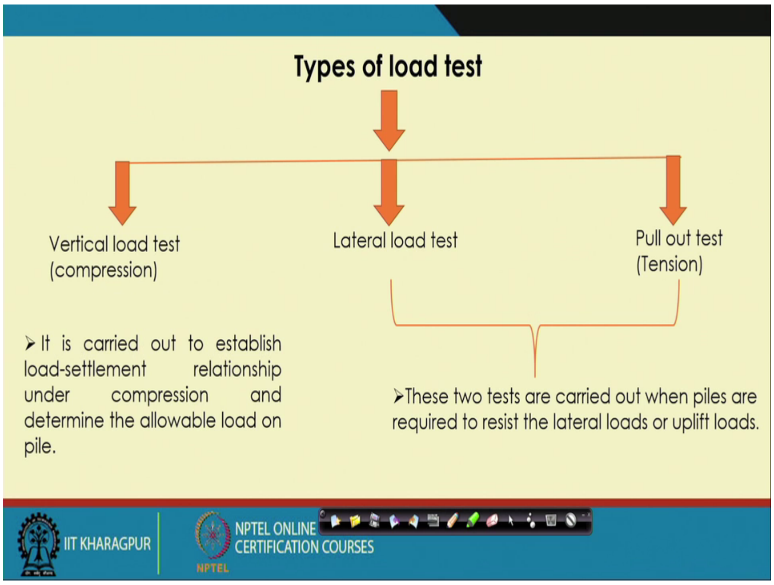

So, there are 3 types of pile load test can be conducted the vertical pile load test, lateral pile load test and pull out pile load test or the tension, but as I mention all the discussion about pile and talking about only compressive load I am not talking anything about lateral load on the lateral or the tension load in this course. So, the pile load test I will discuss only for the compression so; that means, the this is current pass the compression it is carried out to establish the load settlement relationship under compression and determine the allowable load on pile.

So, will get a lot settlement curve I have basically we apply the load will measure the settlements will give the load settlement curve form that load settlement curve will get the allowable load carrying capacity of the pile and the lateral load and the tension load these are conductive when it is required because when the pile is subjected to lateral load or the tension load in those cases we conduct the lateral load or the pull out test on the pile. So, that is why first I will discuss the first case.

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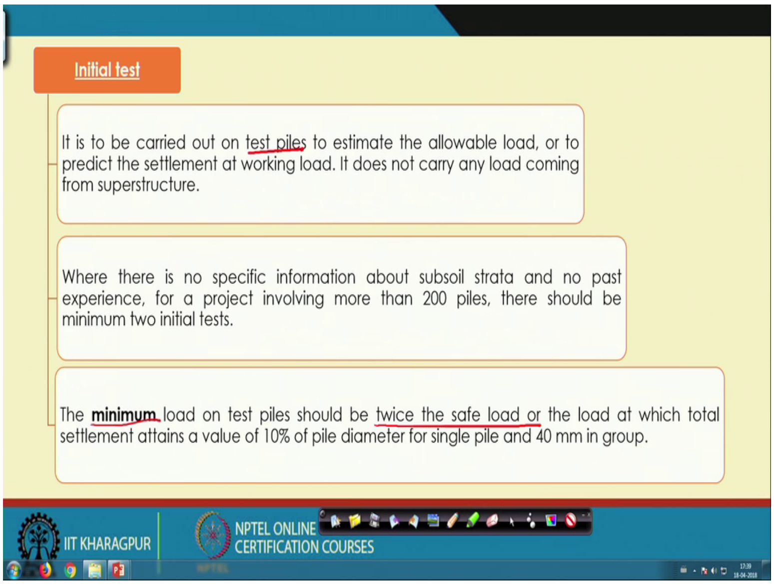

So, there are 2 types of test generally conducted one is called initial test another is called the routine test. So, what is initial test? So, this is carried out on test pile.

So, there is another term is the test pile. So, this is on the test pile another is the working pile. So, what is the difference between test pile and working pile the test piles are used only for the testing purpose. So, these piles will not be used in future to carry the load which is coming from the superstructure, these are used for only for the testing purpose and working piles working piles of the piles those piles can be used for this testing purpose and these piles will carry load in the future which is coming from the superstructure ok. So, this is the basic difference between test piles and the working piles. So, your initial test are conducted on test piles and the routine test are conducted on working piles ok.

So, initial test are carried out on test pile to estimate the allowable load or to predict the settlement at working load ok. So, it does not carrying the load coming from superstructure that I have mentioned. So, the what will be the number so if no information is available about the soils subsoil strata or no past experience. So, generally if for a project involving 200 piles there should be minimum 2 initial test. So, if you are you are required piles 200 then you have to do you have to construct 2 test pile in the site and your to test on those 2 pile that is minimum recommend you can do more ok.

So, another one what would be the load we can apply on the test pile as we can we will not use this test pile in the future for load carrying capacity purpose. So, we can apply we can go up to the failure even required for this test pile, but the load that mean the minimum amount of load this test pile should be applied is twice the safe load of the pile ok. So, how will calculate the safe load? So, we have to get the data from the site and by using the expression for the static pile formula you can get what will be the safe load. So, we have to apply twice the safe load that is minimum, remember that minimum you can apply more ok.

When you can go up to the failure if required because this piles will never be used in future, but the minimum requirement is first you calculate the safe load based on the static formula and then you use the twice of that safe load as your during the testing purpose that is the minimum requirement or at which the load the total load at which at load at which the total settlement attains a value of 10 percent of pile diameter for single pile or 40 millimeter in group pile which your will achieve earlier. So, either or twice minimum is twice the safe load or if the pile settlement attains 10 percent of diameter of the pile for single pile or 40 millimeter for group if I doing the test on group pile which ever will reach earlier ok.

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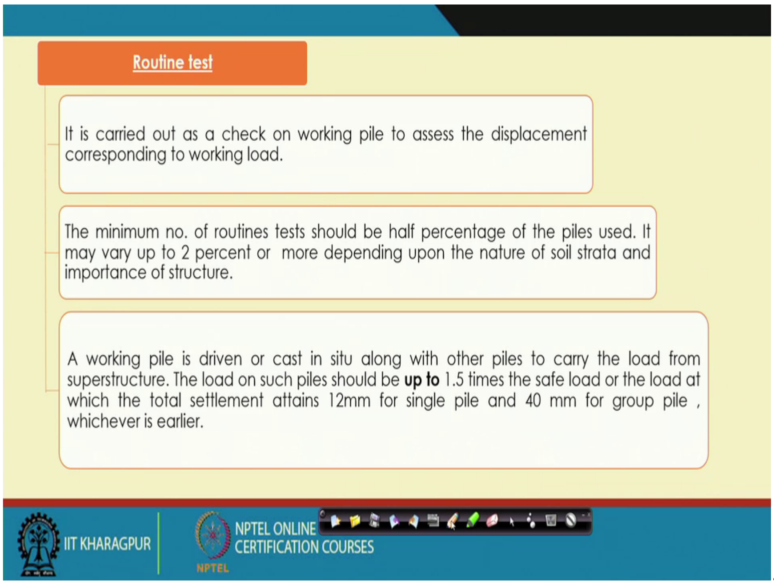

So, next one is that routine test so this as I mention routine test done on the working pile to assess the displacement corresponding to working load. So, the what is the minimum number of routine test that should be half percentage of pile used, half percent suppose you are in the side there is 200 pile. So, number of routine working piles for test half percent of 200; that means, 1 ok. So, it may vary it may increase up to 2 percent also or depending upon the nature of soil and the important of the structure if your a structure importance is very high or the soil variability is more than you can go up to 2 percent of the of the total pile that you use in the field and here as this pile will be used in the future so you cannot go up to the failure.

So, here it is up to 1 point times the safe load in previously minimum you have to go for 2 times of the safe load for the routine for the test pile, but the working pile you cannot go beyond the 1.5 times of the safe load at or the load at which settlement attains 12 millimeter for single piles and 40 millimeters for group pile whichever is earlier. So, whichever is earlier so if this condition is satisfied you have to go up to that.

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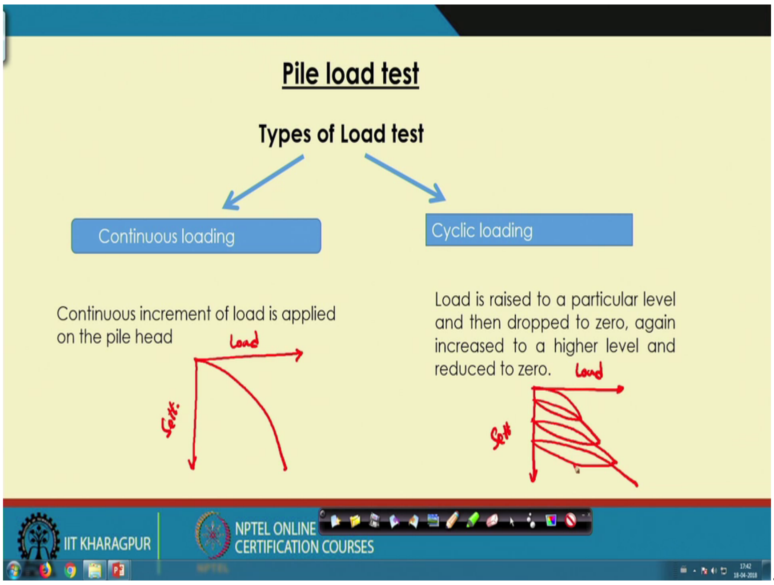

So, the process there are 2 types of pile load test even in compressive pile one is the continuous loading another is the cyclic loading. So, I will discuss what is continuous loading, continuous means you will continuously increase the load and first you are putting 1 load then getting the deformation then you increase the load getting you will note down the deformation and it will it will be continuous one ok so always loading.

But in the cyclic one so you first load it then again unload it fully then again load it then again unloaded so it is a cyclic pattern. So, that mean the continuous one your load settlement plot would be if it is load and this is settlement then you plot maybe something like this is always loading continuous one. But for the cyclic your load settlement plot will be so this is the loading then unloading then again loading then unloading so again loading unloading again loading like this ok. So, this is the cyclic your loading unloading.

So, what is the purpose of these 2 test. So, this continuous test I will get the allowable load carrying capacity of the pile. So, from this test I will not get what is the contribution of the tip resistance what is the contribution of the friction resistance separately, but from the cyclic pile load test I will get separately what is the contribution of the tip resistance and what is the contribution of the friction resistance ok. So, this tip contribution and the fiction contribution both I will get from this cyclic load test.

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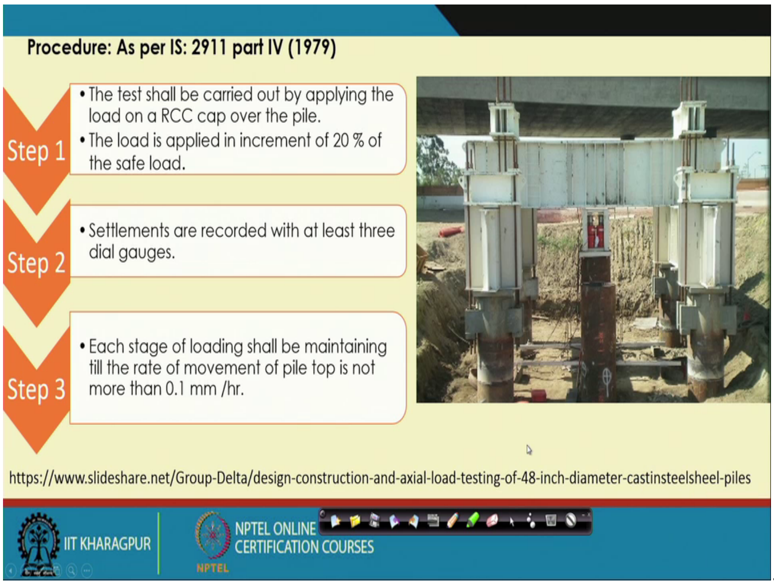

So, first the procedure of the pile load test that test can be carried out by applying the load on RCC cap over the piles.

So, we have a pile then there will be a pile cap over the top of the pile on that pile cap will apply the load the load will be applied by this reaction frame you can see this frames these are entered into the soil. So, we are putting the reaction to hydraulic jack to this frame, this frame is giving the reaction and that is applied as a load on the pile and settlement at least 3 say dial gauge are these are the dial gauge. So, this 3 dial gauge are placed in on the pile so we have to take the reading of 3 dial gauge the average of this site 3 dial gauge will be reading will be treated as a settlement and we apply the load. Then how we applied the load the load will be applied in the like the your plate load test that one fifth of the safe load or 20 percent of the safe load. So, first you have to calculate the safe load though you increment of the load will be one fifth of that.

So, first increment we applied 20 percent of that or one fifth of that next one will be the two fifth of that then the three fifth of that or the 60 percent then 80 percent, 100 percent and then have we have to go for minimum twice for the test pile so and it will go on like this and then when you apply the first stage of loading. So, when I will apply the next stage. So, when the your settlement of the pile is 0.1 millimeter per hour or less than that it is not more than that then you will apply the second increment.

So, first increment you wait unless the settlement change is less than or equal to 0.1 millimeter per hour then we apply the we note down that settlement then you apply the next increment ok.

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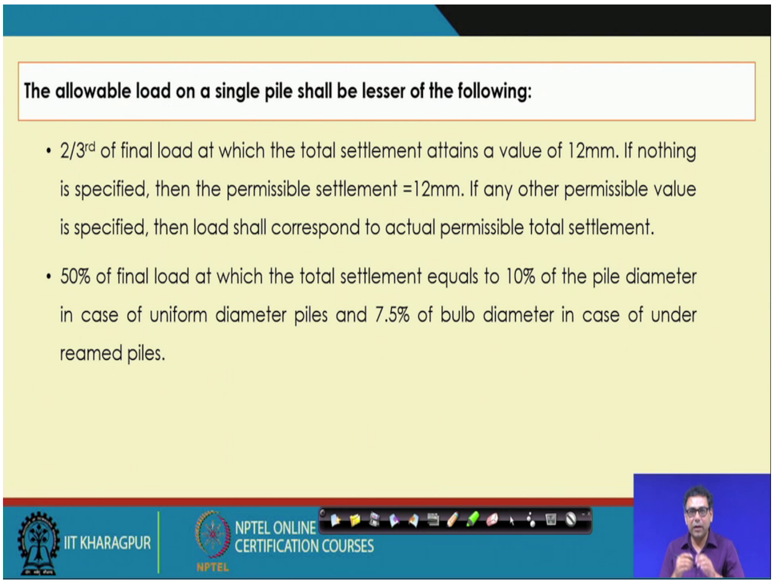

So, then once you get the so, ultimately what you have we are applying the load and you are getting the settlement where measuring the settlement. So, ultimately you will get a load settlement plot ok. So, that load settlement plot I will use to calculate the allowable load carrying capacity of single pile as well as the group pile.

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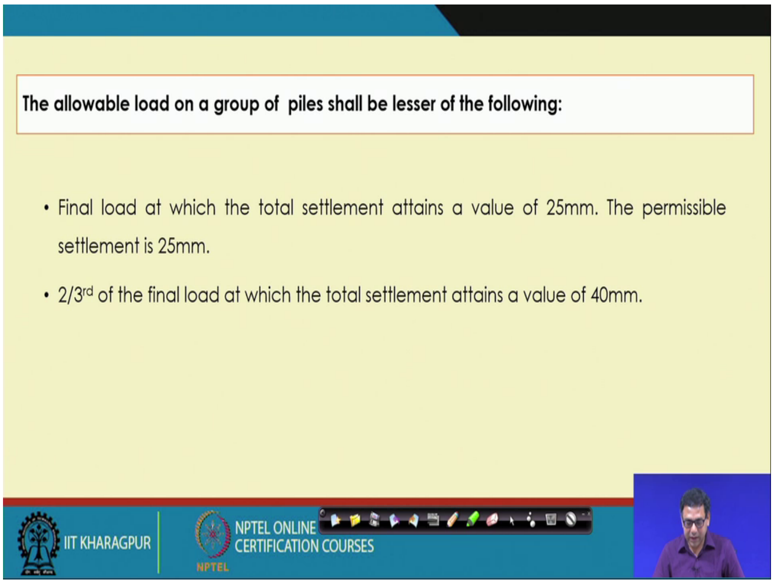

So, in the next class I will discuss how from the load settlement curve I will determine the allowable load carrying capacity of a pile based on the IS code recommendation.

Thank you.