Foundation Engineering
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Lecture - 38
Pile Foundation – XII

So, last class I have discussed above the load carrying capacity of pile based on SCPT data. So, how we will how we can calculate the load carrying capacity of pile using the SCPT data. Today I will discuss how we can calculate the load carrying capacity of pile based on the SPT data.

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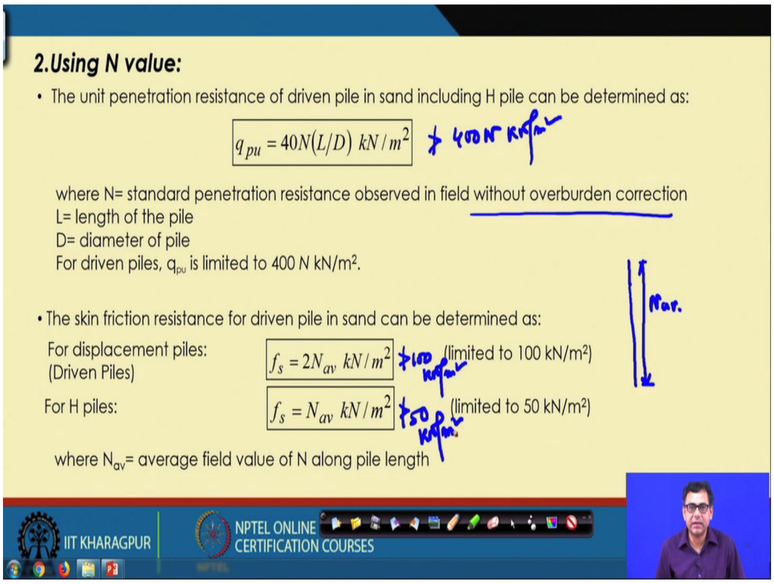

So, this is the second method or using the N value. So, again penetration correlation penetration data correlation that is the using the N value. N value is the SPT value. So, this is the q pu I can determine by using this expression.

Where L is the length of the pile, this is the diameter of the pile and remember that this value cannot be greater than 400 N. It is in kilo Newton per meter square.

N is the SPT value without overburden correction remember that. So, this is the way we can determine and another one that for the friction resistance we can use this is the N average were 2 for the devein pile or the displacement pile.

And for the H section pile f s is the N average an average field value is the along the pile. So; that means, when I calculate the friction one then this total length average N value is the average ok.

So, that is called the N average along the length of the pile for fiction calculation. Again this value cannot be greater than 100 kilo Newton per meter square also this cannot be greater than 50 kilo Newton per meter square ok.

And the tip resistance generally the where the pile is rested that portions N value is consider. So, this is the expression for the N value part and similarly, IS code also given similar type of expression for load carrying capacity of the pile.

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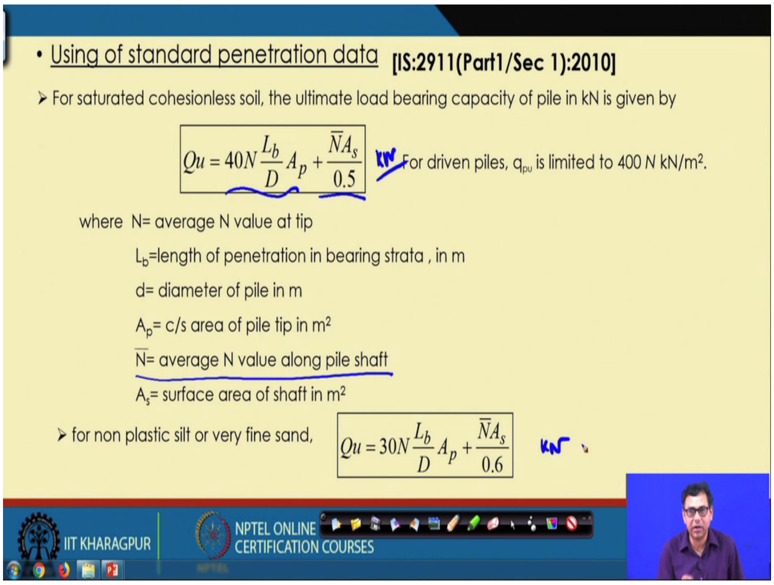

This is the tip resistance, this is the friction resistance. The similar value in average here is the N bar is the N average. So, this is the along the pile shaft.

And this A is the A P is the cross section area of the pile tip in meter square. N is the average value in pile tip and this is this area is the meter square. So, ultimately you will get kilo Newton and this is the area you are multiplying. So, ultimately the unit will be kilo Newton.

This is for the coefficient less soil and this is for the plastic sealed or verifying sand. This is also kilo Newton. So, this way you can determine the average value.

The way I discussed about the SCPT data case so, you can use that method. So, in this way we can determine the load carrying capacity of the pile.

So, on this way I have discussed about the 4 methods that the static equations, your pile node test. Then based on dynamic equation and then based on the penetration correlations or the penetration value the SCPT and the SPT values and all the equations or the correlations are given for driven pile.

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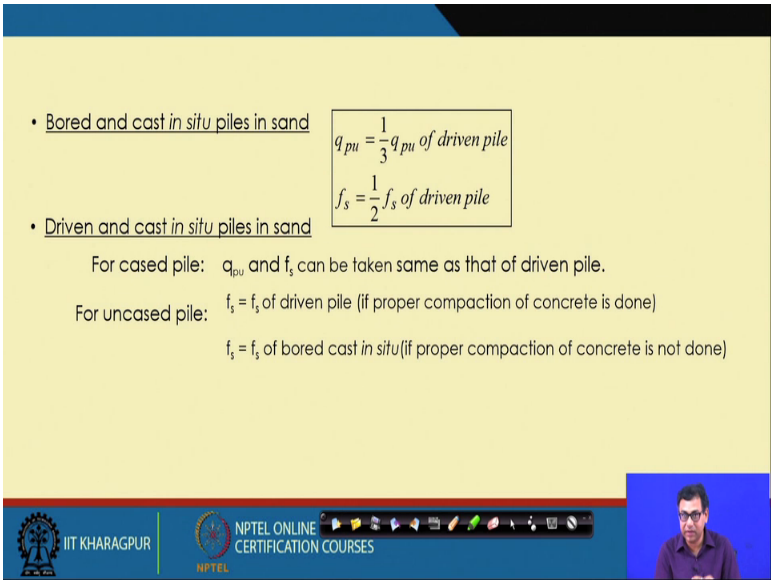

Now, if their pile is board or the cast and cast in situ then the tip resistance is one third of the pile resistance given by the both driven pile. And frictional resistance is half of the frictional resistance that you will got for driven pile.

So, what you do? You calculate the q pu and f s based on the equations given for driven piles. Then for tip resistance you divide it by 3 for the board and cast in situ pile. And for the friction resistance you divided by 2 for the board and cast in situ pile.

And for the driven and cast in situ pile in sand. So, that q pu and f s will be taken same as the driven pile if it is driven cast in situ case pile. Because, I have mentioned that your concrete pile can be precast and cast in situ.

Cast in situ can be 2 types, one is the driven, another is the board. And in the driven cast in situ can be 2 types, one is cased, another is uncased.

So, for the driven cast in situ cased pile the q pu and f s will be same as the driven pile. But, for uncase pile the f s will be equal to 2 to the f s of driven pile if the proper compaction of the concrete is done. And if it is it will be equal to the board cast in situ pile.

If the proper compaction of concrete is not done if the proper compaction of concrete it is not done, then the f s will be equal to then f s of board pile. And if compaction is done then f s will be equal to the f s of driven pile. If it is uncased and cased q pu and f s both are equal to the driven pile.

So, these are the information so, now the next one that I will discuss.

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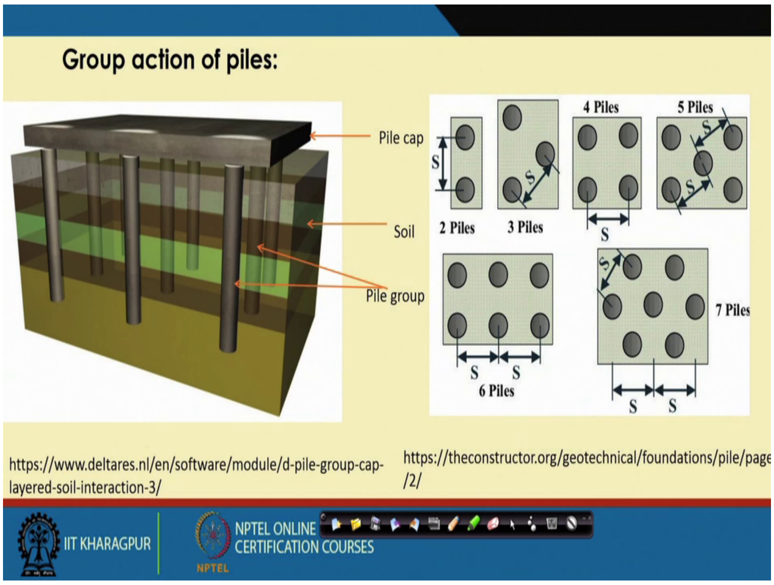

Is the group action of pile, the till now I have discussed the pile load carrying capacity based on a single pile. But, pile will be used as a group.

So, how I will calculate the group capacity of a pile and then how I will calculate the efficiency of a pile group so, that I will discuss in this section.

So, this is the piles in group. So, this can be 2 pile group, 3 pile group, 4 pile, 5 piles, 6 pile, this is 7 piles group. So, you have more number of piles in a group you have them more than 7 also.

So, but the distance between 2 piles centre to centre distance between 2 piles is the spacing between 2 piles. So, depending upon the spacing your efficiency of pile groups will change.

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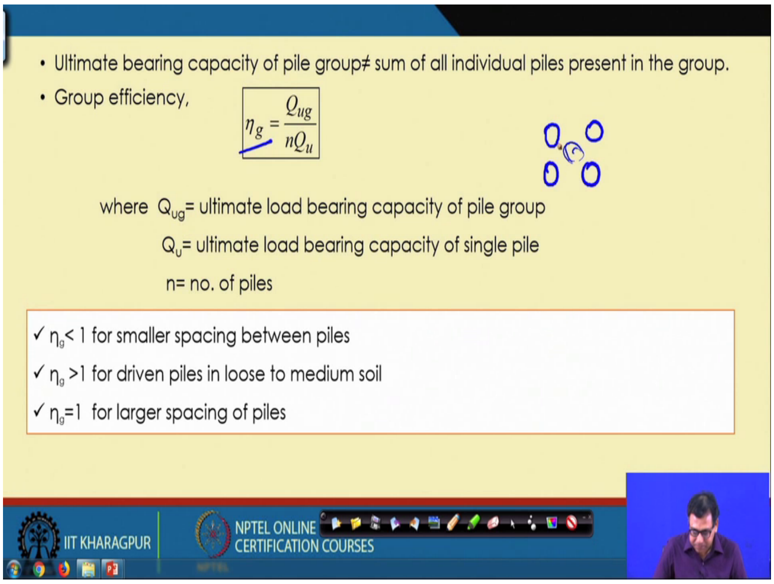

So, now the how we will calculate the efficiency of a pile group that the efficiency of a pile group is the group load carrying capacity of pile divided by number of piles into the single load carrying capacity of pile.

So, this is the pile group we can calculate group efficiency like this. Now, if the spacing is small then what will happen? The influence zone of each single pile will overlap each other.

So, your group load carrying capacity will reduce. So, the efficiency of the group pile will reduce. Now, if the pile is driven in a loose to medium sand then what will happen? Due to the pile driven the soil will be compacted.

It is a loose soil, the soil will be compacted. So, your strength of the soil will increase. So, your load carrying capacity of the pile will increase. So, if the single pile if you drive it so, there is a group action. So, so, because if you have a say group pile so; that means,.

When you are driving the piles into the soil so, this portion of the pile will be compacted become dense. So, you have a more pile load carrying capacity in group compared to the single. So, in that case your group efficiency will increase.

But, we never use the group efficiency more than one during the design, we consider it is equal to one 100 percent. But, actually it is more than 100 percent if it is driven pile in the loose sand.

But, if your length of the pile increases, spacing sorry spacing between the pile increases then what will happen? Your influence zones will not overlap. So, that each pile will be a at a singular a single pile.

So, your pile load carrying capacity will be equal to the number of piles into the single pile load carrying capacity. Because, if there is no influence no inference zone is overlap, then one every pile will give you the equal amount of load carrying capacity in the soil because, there is no overlap.

So, now, if you multiply it with the N value, that will give you the load carrying capacity of a group. So, if the spacing is small then your efficiency will be less than 1. If the spacing is more efficiency will be one. If it is driven pile into the loose soil efficiency will be greater than 1.

But, during design we generally considered efficiency is 1 never consider the efficiency is greater than 1 during the design.

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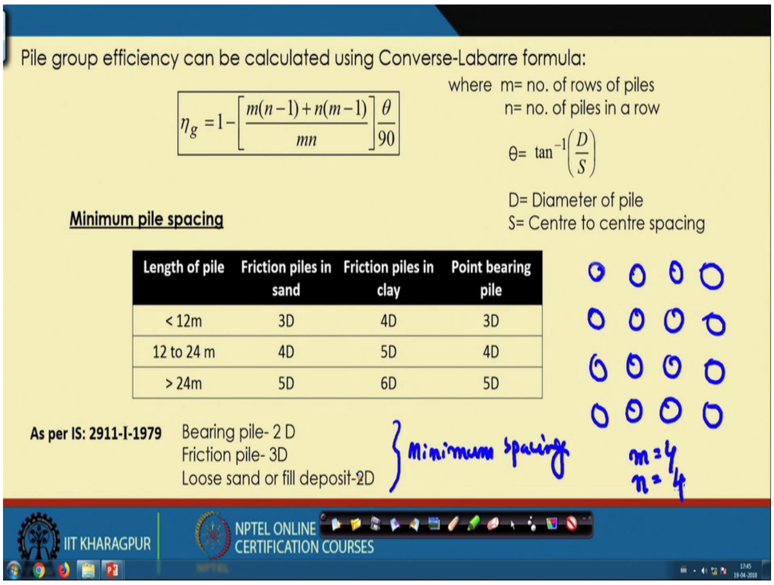

Now, the another way also we can determine the efficiency of a pile group the this is based on the number of rows and the any piles in the number of row.

So, this is the pile number of rows. So, here m is the number of rows in a pile. So, number of rows means 4. So, here m value will be 4 and then per column in a row so, per column in a row is also 4.

So, your n value is equal to 3, number of piles in a in a number of rows is 4 and number of pile in a row is also 4. So, it will be m is equal to 4 sorry this will be n will be also 4 ok.

So, number of pile in a row is 4, number of row is also 4 D is the diameter of the pile S is the spacing between pile. So, you put this a theta value and this way also you can calculate the group efficiency of a pile group.

So, generally that minimum pile spacing is recommendation is like this. If your pile length is greater than 12 meter then friction pile that is in sand it is 3D, friction piles in clay is 4 D and point bearing pile is 3 D. I have mentioned what is friction pile very most of the majority of the contribution due to the friction.

And the bearing pile majority of contribution due to the bearing. And if it is 12 to 25 this is the recommendation, more than 24 which is the recommendation.

IS code as also given the recommendation, if it is bearing pile the minimum spacing, these are the all minimum spacing. This is also minimum spacing is 2D, for fiction pile this is 3D and loose sand or field deposit it is also 2D.

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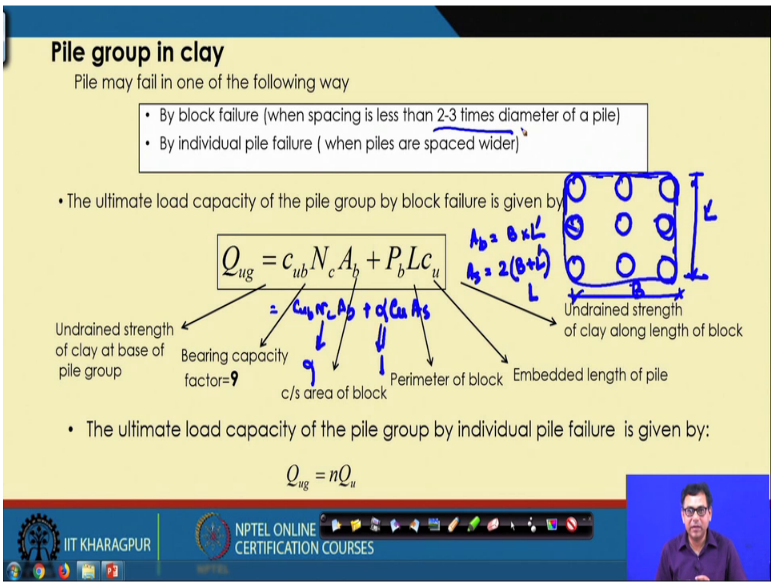

So, next one that how I will calculate the load carrying capacity of a pile group in clay. So, when we are calculating the pile load carrying capacity of a pile group in clay, we consider is as a block failure.

For example, if you have a pile so, suppose this is your pile group. So, this is the outer periphery of this pile group. So, total pile will fail in a block like this.

So, the in such case the our load carrying capacity is same as c u A base N c into A b plus your alpha c u your as. So, that means, here N c is again equal to 1. A b will be here A b will be area of this block. So, if this is the b and this is the L then Lc will be b into L will be the A b

And here alpha value will be equal to 1 why? Because, it is settling as a block and in between that this is the soil. So, most of the interaction when this block is deforming or deflecting then the friction is between soil and soil. Because, this portion is soil, this portion is soil, this is soil, this is soil. So, it is between soil and soil.

So, that is why abrasion factor is 1. So, we will dictate alpha equal to 1 c u is the undrained cohesion and A s will be here A s will be 2 into B plus L into the length, L dash. L dash is the length of the pile. So, here or you can see this is L dash then this will be the L, L is the length of the pile. So, this way we can determine A b and the A s.

And the and next one the this is the block failure when spacing is less than 2 to 3 times of the diameter of a pile. Then there will block failure, then there will be a group failure or the block failure if the spacing is less. Now, if the spacing is more then there will be individual pile failure. And then you calculate the load carrying capacity of a single pile. Then multiply it with the number of pile you will get the load carrying capacity of the group pile, if you re spacing is more.

So, that means, if the spacing is less within 2 to 3 times of diameter of the pile there will be a group failure. So, we have to consider a block failure and if the spacing is more then we have to consider the single pile failure. Now, what I will do?

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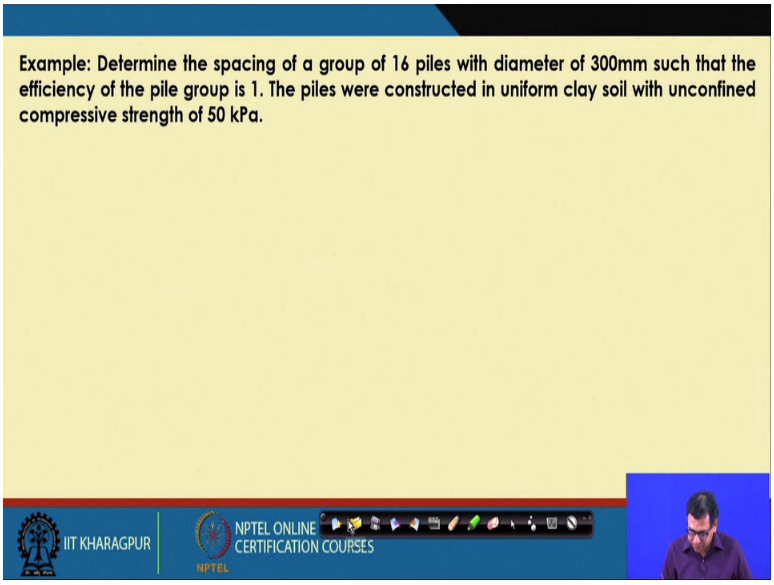

Now, I will solve one particular problem so, where.

I am taking the determine the spacing of a group of 16 pile with diameter 300 millimetre such that the efficiency of the pile group is 1 ok. Piles were constructed in uniform clay soil with unconfined compressive strength of 500 for 50 kPa ok.

So, now, if I solve this problem then. So, I can solve this problem that this is a 16 pile.

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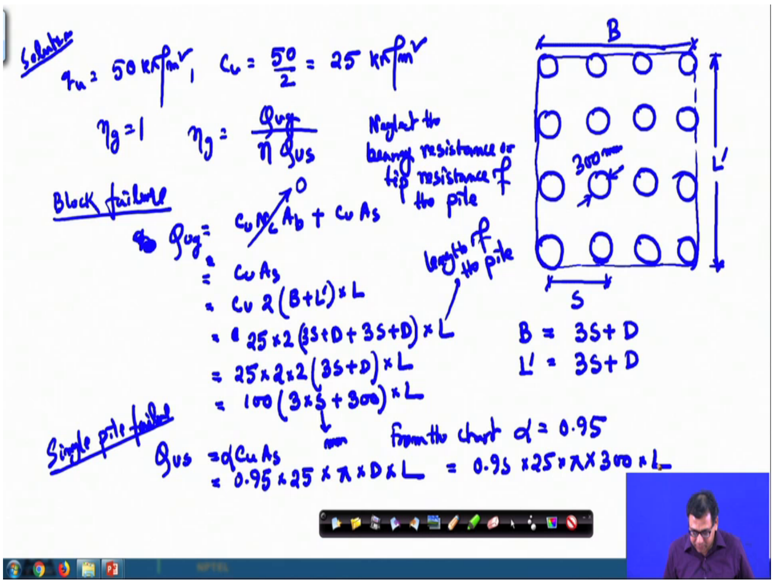

So, 16 pile is like this 1, 2, 3, 4, 5, 6, 7, 8, 12, 16 whatever 4 cross 4.

So, spacing between each pile is you have to calculate. And say suppose that is S and diameter of each pile is 300 millimetre. So, that the this outer dimension of this outer zone will be the dimension of the with direction B.

It will be 1, 2, 3, 3 S plus D. And for the L if this is the L dash and this is the B then L dash will be again 3 S plus D.

Now our q u is given 50 kilo Newton per meter square. So, as I mentioned c u will be 50 divided by 2 25 kilo Newton per meter square.

So, now, our group efficiency will be 1. And the group efficiency is Q u in group divided by N number of pile into Q u single. So, first I will consider the block failure. So, in the block failure Q u or Q u in g that is the group it will be equal to c u N c into A B plus alpha is 1. So, c u A S.

So, we can write that our q u N c value is N c Q and A B. And one condition is given that that you neglect the bearing resistance on tip resistance of the pile. So, we are neglecting the tip resistance of the pile. So, that portion we are neglecting ok, that we are consider as a 0. We are we will consider only the frictional part to c u into A S for the group [FL].

So; that means, here that condition was given in the in the problem. So, this is the condition you are considering only the frictional resistance using is that it is the floating pile, it is not resting on a on a hard strata. So, the majority of the contribution will be from friction. So, that is why we are neglecting the tip resistance that is the logic.

So, that means, the c u into A S A S will be 2 into B plus L dash into L. So, that is a group perimeter into the length. So, I can write that your cu value is 25 into 2 into S 3S plus D plus 3S plus D into L. L is the length of the pile.

So, I can write that your that your this will be the 25 into if I take 2 into 2. So, this will be 3S plus D. Because, 3S plus D so, another 2 into the L. So, this will be your equal to 100 into 3 into S plus 300 millimetre into L.

So, S is in millimetre here because we have taking B is in millimetre. So, this is for the block failure. Now, for single pile failure that your single pile capacity Q u s single again we are neglecting the tip resistance.

So, it will be c u into A S into alpha, because now for the single pile capacity it is not alpha is not equal to 1, alpha is equal to some value. Now, from the chart we will get alpha is from 9. 0.95.

We are giving the figure of or photographs of the alpha or the chart of the alpha the graph of the alpha corresponding to c u you. So, c u value is 25 kilo Newton per meter square. So, alpha I will get 0.95.

So, here again this I can write the 0.95, c u value is 25 A S is pi into D into L. So, or I can write 0.95 into 25 into pi into 300 into L. So, now, I have mentioned that our.

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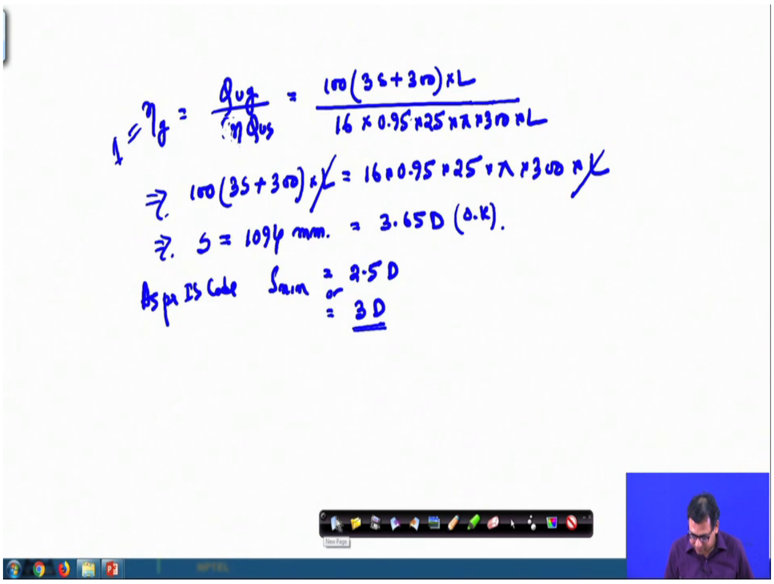

Group efficiency is 1. So, this is u g and N or the number of pile that is N into u s. So, u g I can write the that is equal to the u g value is this 100 into 3 S plus 300 into L.

So, 100 into 3 S plus 300 into L divided by N is 16 and then single value is 0.95 into 25 pi 300 L. So, 0.95 into 25 into pi into 300 into L. So, finally, I will get that 100 into 3S plus because these value is equal to 1, because in the case of 1.

So, I mean we have checked it if the spacing that I will get if I provide the spacing less than that then there will be a group failure. If I provide greater than that they are the single pile failure. But, we have taking the optimum spacing so, that or efficiency is 1.

So, A S plus 300 into L that will be equal to 16 into 0.95 into 25 into pi into 300 into L. So, this L, L will cancel out. And then if I take the simplify these things or solve this one then we will get my S will come 1094 millimetre ok. And so, the spacing if I provide that spacing is 1094 millimetre then the efficiency will be exactly 1 or 100 percent. And as per IS code the minimum spacing S minimum for clay or friction or point bearing is we get 2. This for the IS code is 2.5 D and or 3D.

So, this is the minimum spacing here it is coming out to be 3.65 D. So, it is as for the requirement of the is code the 2.5 or 2. So, because 3D is the maximum requirement for minimum spacing. So, it is giving 3.65. So, it is safe. So, that the spacing that you will get is 1 0 9 4 and that will give you the spacing that should be used to get the 100 percent efficiency.

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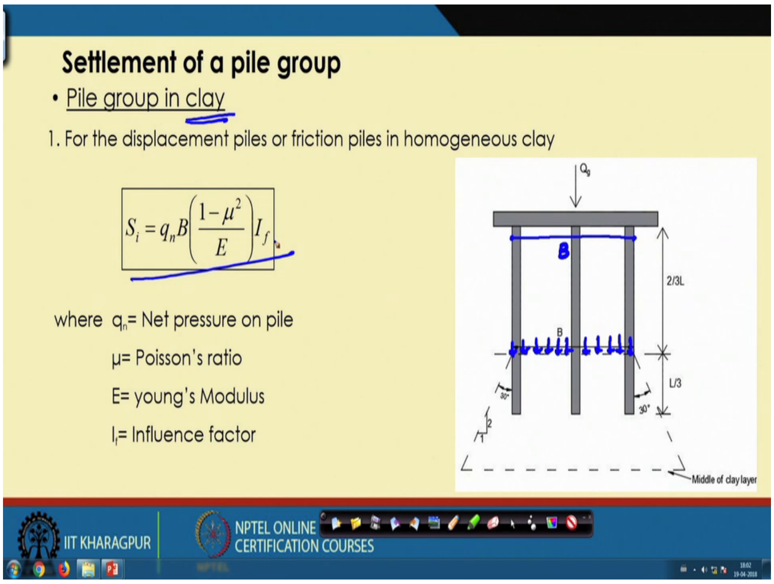

So, next one the settlement calculation of pile group it is also very important. So, till we are talking about the load carrying capacity of the pile group. Now, this is a settle how we will calculate the settlement of a pile group.

So, there are 3 possible conditions I have selected that one is your pile is installed and it is in the clay remember that it is in the clay. So, your pile it is in the clay, pile is install in a uniform clay then what is that?

That it is assume there is a raft you are placing on the pile. So, the dimension of this raft will be this one ok. From this edge to this edge this is the B. So, you place this raft here which is two third of the length of the pile. So, we place this raft here then the calculation is exactly similar to the raft foundation calculation.

This is the immediate settlement equation. But, you have to place the raft here then distribute the load with 2 is to 1. And then from here up to the twice of this width you have to consider the influence zone for settlement calculation. But, remember that this raft is placed at two third of length if it is a uniform clay. And then the rest of the calculation is exactly same as the raft foundation calculation ok.

So, these the terms are same as we used for the raft foundation calculation, this is for the immediate settlement then similarly.

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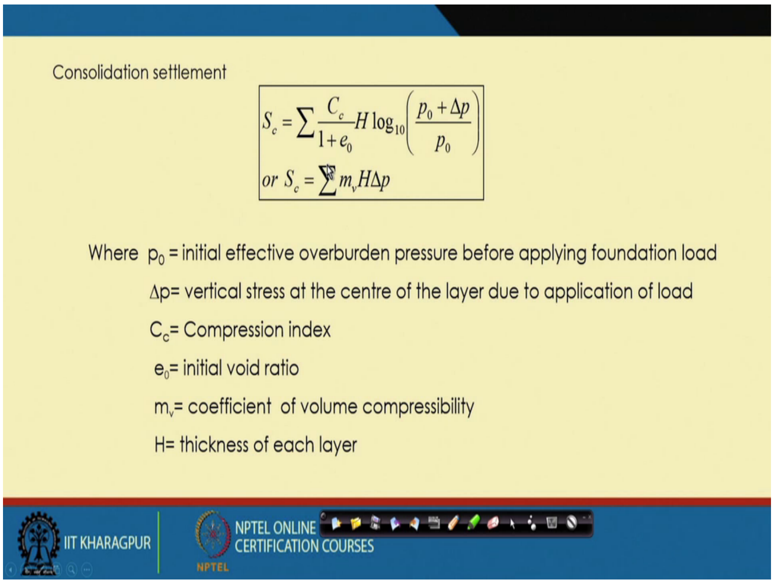

This is for the consolidation settlement and these terms are same exactly that we used for or sallow foundation calculation. But, remember that the raft you have to place at two third from the top of the pile cap. And then influence zone will be twice of the width of the pile from that two third of the a length.

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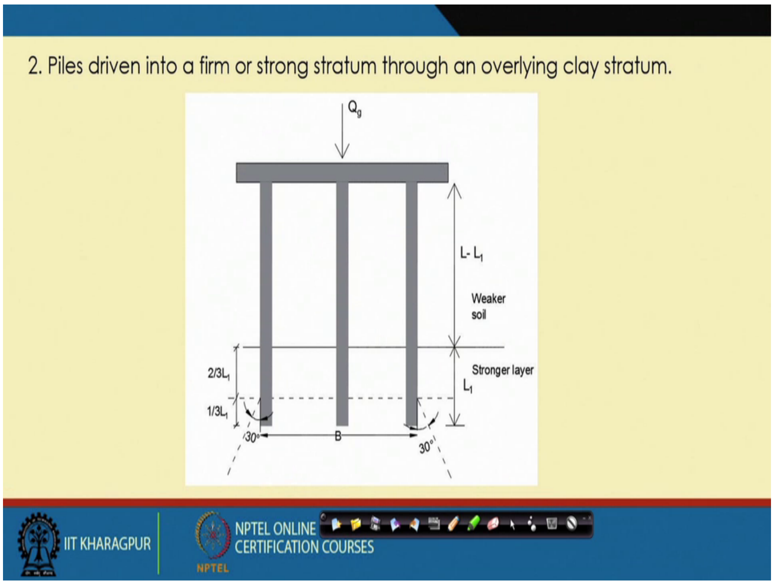

And then if suppose this upper layer is very weak soil lower layer is very strong soil. But, previous one is the homogeneous clay but, here the upper layer is very soft but, the lower layer is very strong ok.

Or stiff layer or hard layer then you will place the raft as twice the two third of the length of the lower layer. So, this is the L1 two third of to third of L1 you have to consider, two third of L1. Remember that this condition.

The third after that it is same as 2 is to 1 distribution. From here it will go up to the twice of the influence zone.

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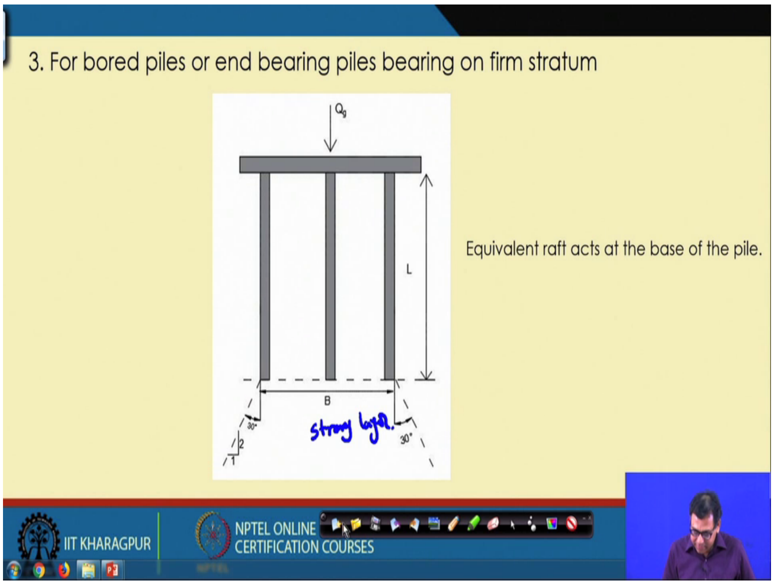

And then if this pile is rested on a very strong layer because, this is the very strong layer. The soil is very strong and pile is rested on the strong layer. Then form that base you have to place the you have to distribute the load and at that base you have to place the raft.

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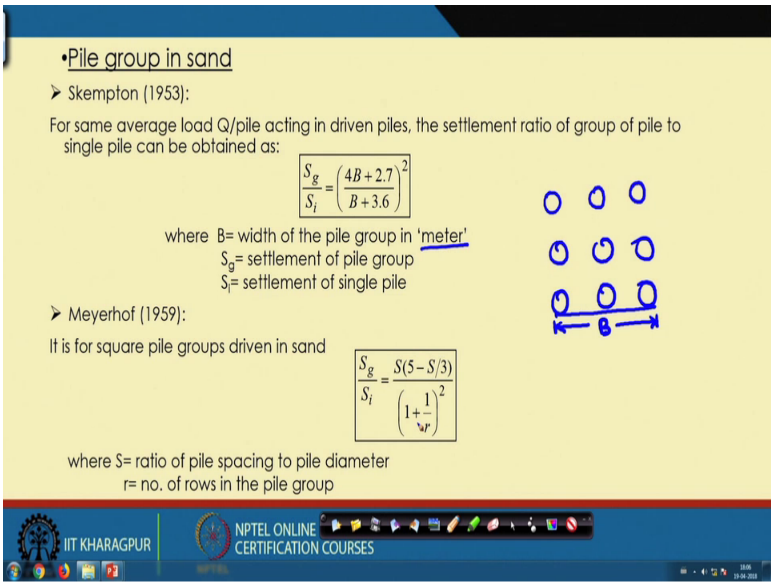

So, and then for the, these are the settlement for the clay and similar to the settlement for the pile group in sand also I we can calculate that this is the settlement of a group pile and the settlement of a individual pile. And this is the expression which is proposed by Skempton. And this is the expression which is proposed by the Meyerhof.

Here B is the width of the pile in group in group that is in meter. So, here B is the width of the pile in group means suppose we have a pile group like this. Then B will be this one width of the pile group.

This will be the B and B is in meter remember that. And then we will get the settlement from this equation. Now, the question is how I will get the settlement for the individual pile? So, the individual pile settlement I can get from the pile load test. So, we can do the pile load test we will. So, from there we can get the allowable load carrying capacity of the pile.

Now, form that load carrying capacity corresponding what will be the corresponding settlement that I will get from the pile load test data. Or the curve that settlement we can use here and we can get the load settlement of a pile group. So, this is the equation we can get the settlement from here.

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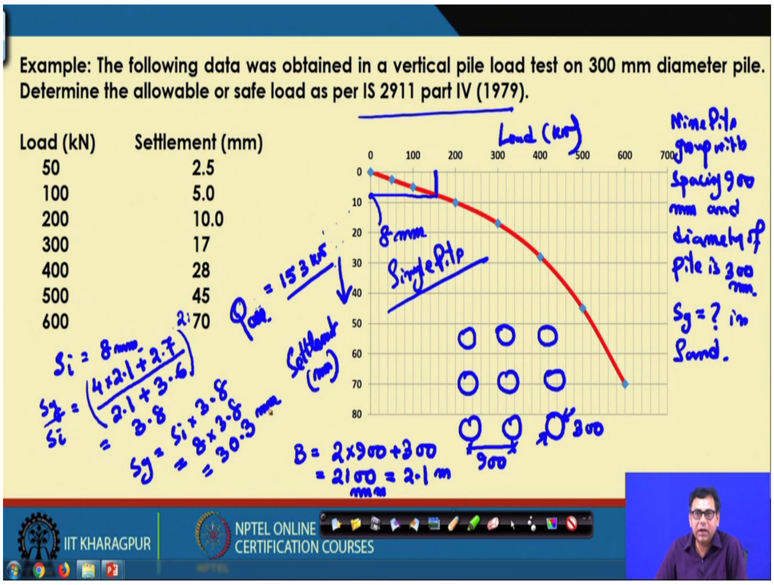

The similar way if I use the same pile load test data, that we used in the previous single pile calculation and if I use that data for the pile load test calculation of or settlement calculation of a group pile.

Then in the previous problem in the single pile load test that we have used that our Q allowable was coming out to be 153 kilo Newton per meter square. Oh sorry this is the kilo Newton 153 kilo Newton. So, that is the Q allowable based on the IS code.

If you look at this problem that I have solve for the single pile single pile load test. When I discussed the single pile load test that time I solve this problem.

So, this is the load versus settlement curve and based on the IS code recommendation we got that that Q allowable is was 153 kilo Newton. So, this is the load in kilo Newton this is the settlement in millimetre.

So, initially we applied 2 clauses and then we got that Q allowable was 153 kilo Newton. One clause was 2 third of the load at which settlement attains 12 millimetre. And second clause was 50 percent of the load at which settlement attains the 10 percent of the pile diameter.

So, we apply these 2 clauses and we got this 153 kilo Newton is the allowable load. Now, corresponding to 153 so, this is your 110, 100 140, 150 3. So, 153 your settlement is coming out to be 8 millimetre that is for single pile. So, because this was the single pile load test data. So, I can write that my S i is 8 millimetre.

Now, if you have a 9 pile group 9 pile group with spacing 900 millimetre and diameter of pile is 300 millimetre. Then what is the S g? Settlement of the pile group in sand. So, the b value is if we have a 9 pile group. So, this is the 9 pile group and the spacing is 900 millimetre and diameter is 300 millimetre. So, B value will be 2 IS into 900 plus 300.

So, this will be 2 1 0 0 or 2 1 meter 2 1 0 0 millimetre or 2.1 meter. So, if I use the Skempton equation that S g by S i that is equal to your 4 into 2.1 plus 2.7 divided by 2.1 plus 3.6. So, we will get that is equal to 3. 8. You are using the Skempton equation. So, from here S g will be S i into 3.8. So, that will be equal to 8 into 3. 8 that is 30. 3 millimetre.

So, this way if we have the pile load test data from there also we can calculate what is the settlement of a pile group. Ok, by using this Skempton equation or the others available equations or directly if you have a pile load test data for pile group from there directly you can get the what will be the settlement corresponding to allowable load carrying capacity of the pile.

So, with this I am finishing today's class. In the next class I will design a pile foundation in clay. In that case I will check both bearing as well as the settlement. And then we will decide, what will be the dimension of the pile, I mean spacing diameter and the length of the pile. And then next I will discuss the last topic of this pile foundation that is the negative skin friction.

Thank you.