Foundation Engineering
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Lecture – 39
Pile Foundation - XIII

Last class I have discussed about the settlement of Pile Foundation how we can determine a settlement of pile in a group which is which are installed these piles are installed in different types of soil. So, today I will discuss about the design of a pile group considering both bearing capacity as well as the settlement criteria.

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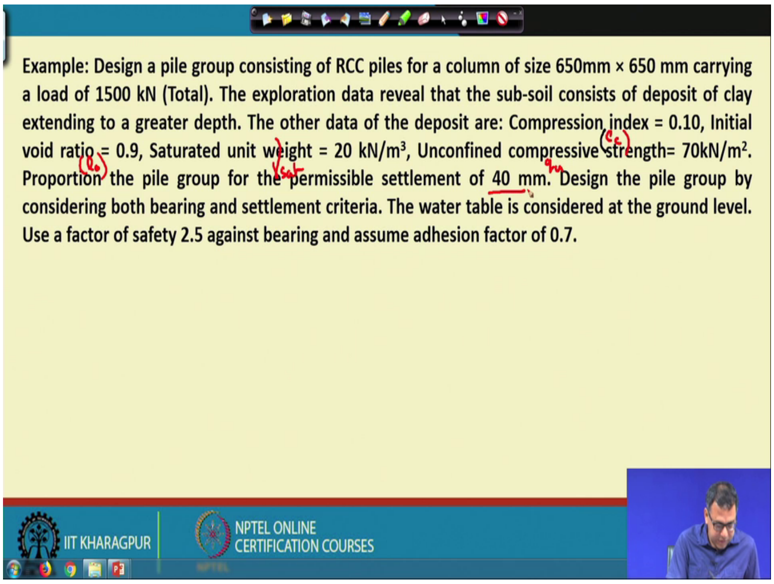

So, this is the design problem. So, design a pile group consisting of RCC pile for a column of size 650 millimeter cross 650 millimeter and this column is carrying a total load of 1500 kilonewton, so that amount of load is coming to the pile group. So, the soil data reveal that the sub-soil consists of deposit of clay extending to a great depth, so that means, the piles are install in a homogeneous clay bed. And the total the other data are the compression index which is that c c is 0.1 of that soil initial void ratio e 0 is 0.9, and saturated unit weight gamma sat is 20 kilonewton per meter cube. And unconfined compressive strength q is 70 kilonewton per meter square. Now, we have to design the pile group such that the permissible settlement is 40 mm. Now, design the pile group by considering both bearing and settlement criteria the water table is consider at ground level. Use a factor of safety 2.5 against bearing, and assume adhesion factor is 0.7. Now, as this data you can see that it is unconfined compressive strength of the soil.

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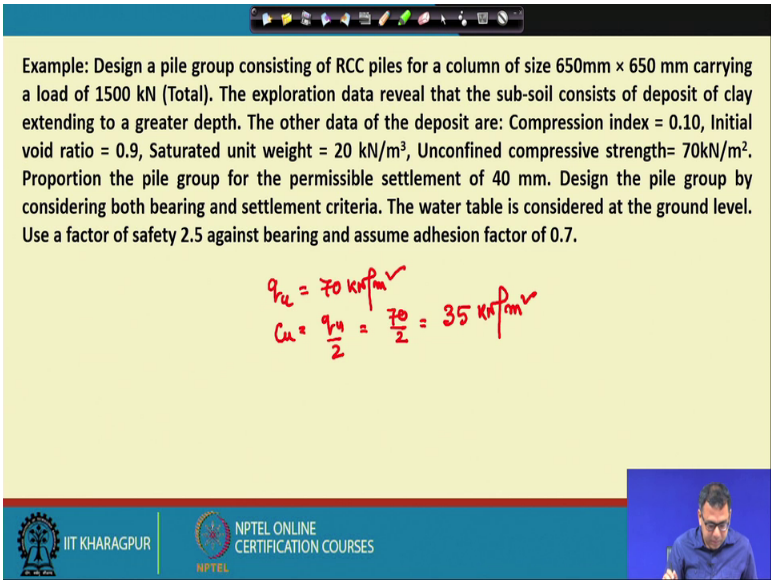

So, that means as I mentioned that unconfined compressive strength of the soil is 70 kilonewton per meter square. So, the un drained cohesion C u will be q u divided by 2. So, this or be 70 divided by 235 kilonewton per meter square. So, cohesion is 35 kilonewton per meter square.

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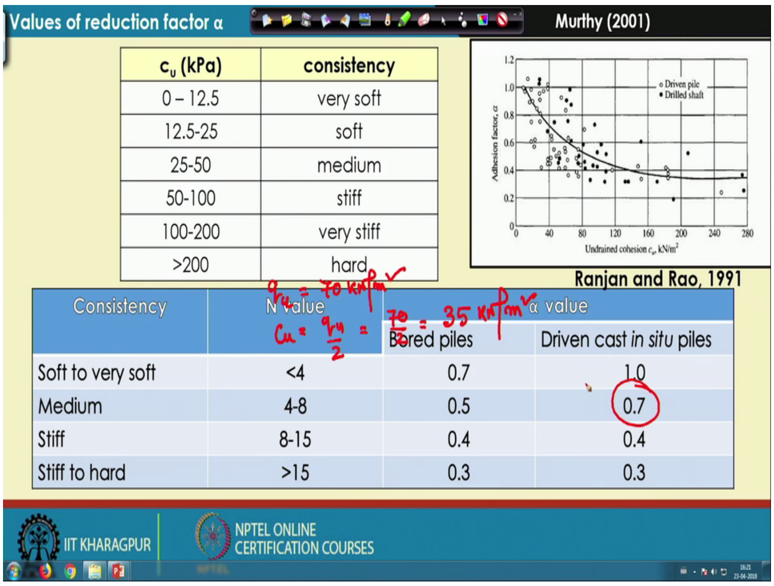

Now, if you go back to the next slide. So, 35 kilonewton per meter square C u value it is a medium clay ok. So, for the medium clay RCC pile, it is adhesion factory is 0.7. So, this is the adhesion factor which is 0.7. And that is the adhesion factor we have consider for this design.

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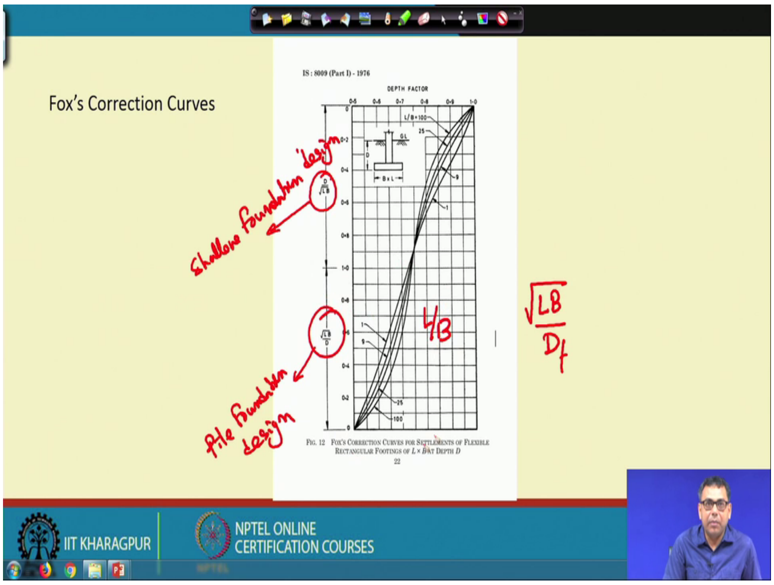

And one more thing that in this design we will use this chart we when we determine the Fox's depth correction, because in the in the shallow foundation design we use the upper portion of this curve that we use this value for the shallow foundation designs. So, this is we used for the shallow foundation design. Now, here in the deep foundation design or the pile foundation design, we use the lower part of this curve ok. This is remember that root over LB divided by D f or D. D f is the depth of the foundation. So, you will lower part and then this is the depth factor that we will calculate and these values as usual this is for L by B so, but you will use the lower part for the pile foundation.

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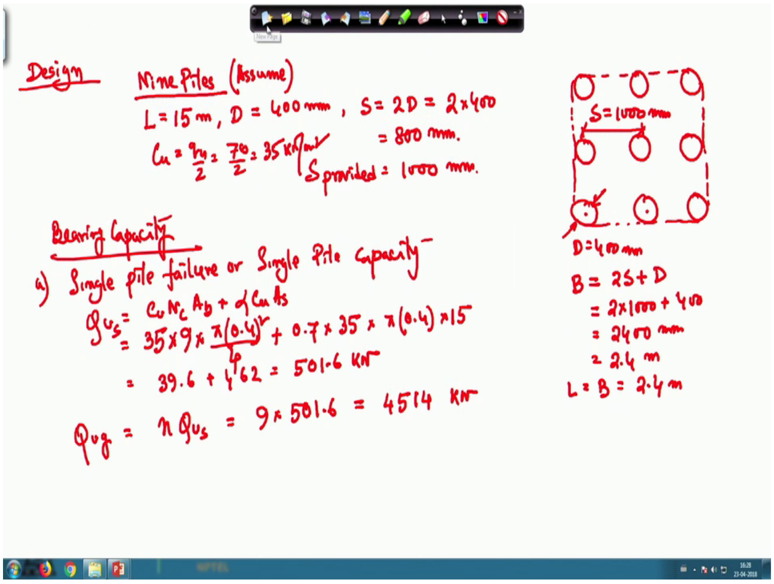

So, now we will start the design of this problem. So, for the design part, so we are assuming that for this total load you are taking first trial that nine number of piles. So, this is the first trial we are considering. So, this is assume so, we are considering the nine number of piles and the distribution of the piles are like this ok, so that is the total number of piles. And we have assumed that that you will take nine piles and the length of the piles that you were taking is 15 meter ok, and the diameter of the pile we are considering as 400 millimeter. So, this is for the first trial.

And the S the spacing between the piles as it is in clay soil, so as per is core recommendation that minimum spacing between the two piles should be the twice D. So, that means, we are considering twice D, so this is for 2 into 400. So, this value is 800 millimeter. So, this is the minimum spacing. So, spacing provided is 1000 millimeter. So, we are taking diameter of the pile is 400 millimeter and spacing we are providing 1 meter or 1000 millimeter, length of the pile is 15 meter. So, first this is the first trial, and we have assumed this value and then you have to check it against bearing capacity and the settlements. And then we will then we will see whether this dimension of the pile or the pile group is or not.

So, this is the diameter of the pile which is we have consider is 400 millimeter. Now, this is the settlement of the spacing between the pile that we are providing as 1000 millimeter ok. So, and we are providing uniform spacing that between all the piles. So, the outside dimension of this pile group is, so if we say this is because it is a square pile group, so we can say that b is equal to twice S plus D because this is the S is between from here to here. So, it will be twice a plus the half diameter for this side and half diameter for this side, so twice D twice S into D, so 2 into 1000 plus 400, so that is equal to 2400 millimeter or 2.4 meter.

Similarly, L is equal to B is equal to 2.4 meter, so that is the dimension of this dimension of the pile group. So, now, first we will check the bearing capacity then we will check the settlement. So, bearing capacity, so we are first we are doing that single pile failure or single pile capacity. So, we are taking Q u is C u N c A b plus alpha C u as ok. So, C u value is 35, because C u value is Q u divided by 2 70 by 2 35 kilonewton per meter square ok. So, C u is 35. N c value is 9, and for the single pile this is pi D square divided by 4, and for the friction part alpha is 0.7, C u is 35 because it is a homogeneous clay, then the single pile pi D L is 15 meter.

So, we can see this is 39.6 plus 462, this is 501.6 kilonewton. So, the single pile capacity is 501.6 kilonewton. So, pile group capacity in terms of single pile failure will be n into Q u or Q u s single. So, n is 9, and Q u is 501.6, so that is equal to 4514 kilonewton ok. So, this is the bearing capacity as for the single pile failure.

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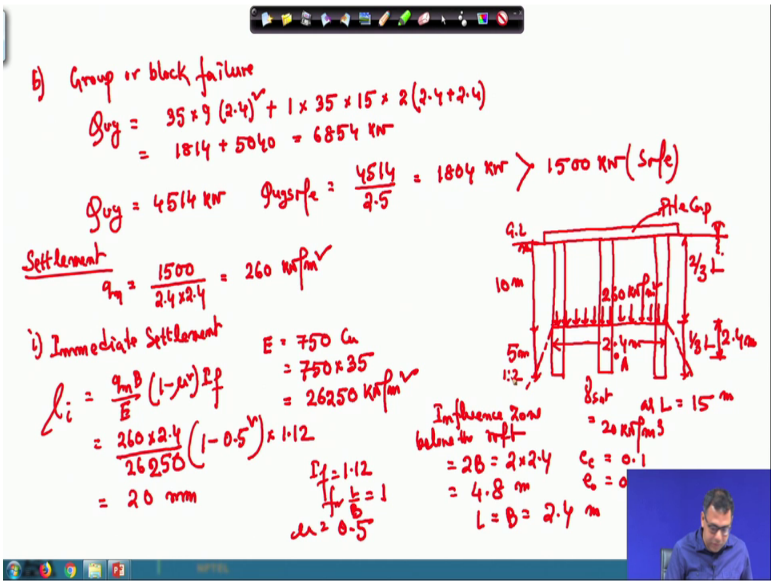

So, next we will do for the group pile failure. So, bearing capacity we will calculate for group or block failure ok. From the block failure, again Q ug will be that Cu N c, Cu is

35, N c is 9, but in that case area will be 2.4 meter square, so because the dimension of the pile was 2.4 meters. So, area of this base will be 2.4 meter square. And then alpha value will be equal to 1, because as I mentioned for the group block failure, the adhesion between the soil and soil, so alpha value will be 1, 1, and then C u is 35 and then the length of the pile is 15 and then the perimeter of that block. So, perimeter of that block will be 2 into 2.4 plus 2.4 ok, so that is the perimeter of this block 2.4 plus 2.4 into 2 because your B is equal to L.

So, now if I get this value if I calculate these values, then it will come it will come 1814 plus 5040, so that is 6854 kilonewton. So, as far the block failure it is 6854 kilonewton as for the single pile failure it is 4514 kilo newton. So, the minimum value is this one 4514 kilonewton. So, pile group carrying capacity u g will be 4514 kilonewton. So, the Q u g safe is 4514 divided by 2.5 that is the factor of safety and that is coming out to be 1804 kilonewton, and which is greater than 1500 kilonewton. So, it is safe, because your total load is coming 1500 kilonewton and your pile can pile group can take 1804 kilonewton so, it is safe.

The next one we will calculate the settlement of the pile settlement of the pile group. So, as I have mentioned that if you have a pile group, and this is the pile group and the pile cap, and then this is total three piles because you have a three cross three pile group. So, this is three piles then and this soil is a homogeneous clay. So, in that condition as I mentioned that we will assume that this is a raft foundation, and this raft load or the stress is acting at a distance two-third of L from the top of the pile. So, this is the ground surface or G L. So, this is the raft is acting here and this is one-third of L. So, L is 50 meter. So, this will be 5 meter and this will be 10 meter as L is equal to 15 meter.

So, we are assuming that your apt is acting here at a depth of 10 meter below the ground level because for the homogeneous clay that is the condition. So, the unit weight or saturated unit weight gamma sat is equal to 20 kilonewton per meter cube. And C c is equal to 0.1, and e 0 value is equal to 0.9 ok. So, the width of this raft width of this raft will be again 2.4 meter ok. So, width of this raft will be again 2.4 meter. So, the influence area will be the influence zone below the raft will be twice B, so 2 into 2.4. So, this will be 4.8 meter. And up to this is pi 5 meters. So, we will take this 4.8 meter below this raft, this is the influence zone ok, because we are calculating settlement. So, this will be twice B.

So, again when the total load is coming Q n the stress intensity is 1500 is the kilonewton is the total load coming on this pile group, and then the dimension of this raft is 2.4 cross 2.4. So, this is 260 kilonewton per meter square. This so this intensity of loading is 260 kilonewton per meter square ok. So, the dimension of the raft again it will be L is equal to B is equal to 2.4 meter ok. So, I can right that how I will calculate the settlement. So, you know that there are two types of settlement, one is immediate settlement and immediate for the immediate settlement we are considering that as I mentioned if nothing is given then E is equal to 750 C u is reasonable e value for normally consolidated clay. So, this is also 750 C u we are taking, so this will be equal to 750 into 335 that is equal to 26250 kilonewton per meter square.

So, the immediate settlement is q n B divided by E 1 minus nu square I f ok. So, q n is 260, B is 2.4, E value is 26250 and nu value we are taking 0.5 square, and I f for square putting is 1.12. So, from the table will get I f equal to 1.12 for L by B is equal to 1, and mu we are taking 0.5 ok.

So, from here we are getting that settlement is 20 millimeter ok. So, settlement we are getting 20 millimeter and then next one will get ok. So, now, we have to apply corrections. So, it is a raft we are assuming. So, it is a rigid foundation so, we have to apply two corrections one is rigidity correction another is the depth correction for immediate settlement. So, we will apply this correction.

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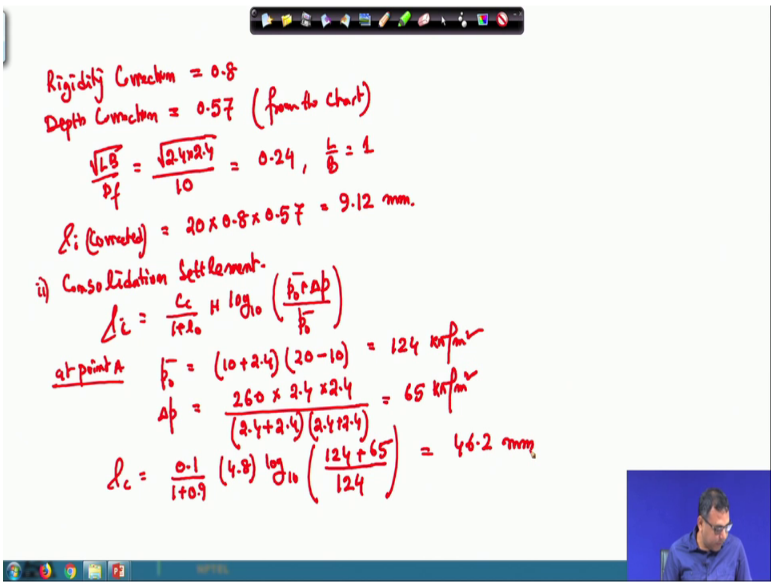

So, first correction is the rigidity correction, so that is equal to 0.8, and depth correction is equal to 0.57 from the chart. So, as I mentioned you have to use the lower part of this chart. So, my root L B divided by D f is equal to root 2.4 cross 2.4 L B and D f value is 10. Because if you look at this figure here you are raft is place at the 10 meter below the ground or ground level. So, the depth of the raft have to consider as 10 meter.

So, this is the 10 meter so, this value is 0.24 and your L by B is equal to 1. So, the correction factor will come 0.57. So, the corrected immediate settlement will be 20 into 0.8 into 0.57 that is equal to 9.12 millimeter. So, next one will do the consolidation settlement ok. So, you know the expression is C c 1 plus e 0 log h log 10 p 0 bar plus del p p 0 bar ok.

So, if I look at this figure, so the influence zone is 4.8 meter and so homogeneous layer. So, we will take our layer or the point is at A, which is 2.4 meter from the base of the raft, because total thickness of the layer is 4.8 meter, and the middle of that layer is 2.4 meter below the base of the raft. So, a 2.4 meter below the base of the raft, so the p 0 bar at point A the p 0 bar is equal to because water table is at ground level. So, water table is also at ground level. So, water table is ground level. So, you have to consider the submerged unit weight of the soil. So, p 0 bar will be for the so that means, total thickness or the total depth will be of this point A 10 meter plus 2.4 meter. So, 12.4 meter from the ground level ok.

So, we can write that p 0 bar is because water table is at the ground level. So, finally, I can write 10 plus 2.4 meter and unit weight is 20 minus 10; 10 is the unit weight of water 10 kilonewton per meter cube taken as the unit weight of water. So, we can write this is 124 kilonewton per meter square. And del p again we will consider as 2 is to 1 distribution at 0.2 points at 2.4 meter below the raft. So, this is the same 1 is to 2 distribution we will consider, so it will be 260 into 2.4 into 2.4 divided by 2.4 plus 2.4 into 2.4 plus 2.4 ok. So, this is 65 kilonewton per meter square.

So, the finally, the consolidation settlement will be C c is 0.11 plus e 0 is 0.9 and h will be 4.8 meter because that is the influence zone and log 10 p 0 bar is to 124 plus 65 divided by 124 ok. So, this is 46.2 millimeter. So, here the correction factors for consolidation settlement is depth correction factor, rigidity correction factor, and the correction factor due to pore water pressure ok.

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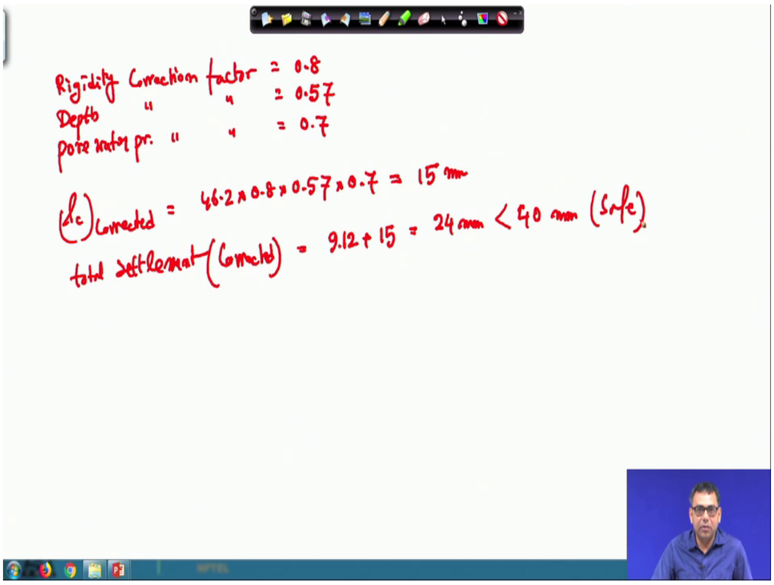

So, the correction factors first the rigidity correction factor is 0.8. Then depth correction factor again 0.57, and pore water pressure correction factor as I mentioned that for the normally consolidated clay if nothing is given, so 0.7 is a reasonable value for the pore water collection factor. So, 0.7 we have to consider if this value is given you have to consider that value. So, the pc corrected is 46.2 into 0.8 into 0.57 into 0.7, so that is equal to 15 millimeter. So, the total settlement or corrected settlement is equal to 9.12 plus 15 millimeter. So, this is 24 millimeter which is less than 40 millimeter that is the permissible settlement so, it is safe or ok, ok.

So, from here we can see that not only we have to check the bearing capacity we have to also check the settlement of a pile foundation. So, this is the total design procedure, you have to check the bearing capacity first as a single pile failure then as a block failure, then the minimum one you have to consider as a load carrying capacity of the pile group, then you have to consider the or calculate the settlement. And then we have to check whether that settlement is within permissible limit or not. So, in the next class, I will discuss about the negative skin friction of pile which is also a very important topic.

Thank you.