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Lecture – 50
Pile Foundation: Under Compressive Load - X

So, last class I have discussed about the negative skin friction and I have discussed the negative skin friction for single pile. So, before I start the example problem, so I should discuss about the negative skin friction for group pile.

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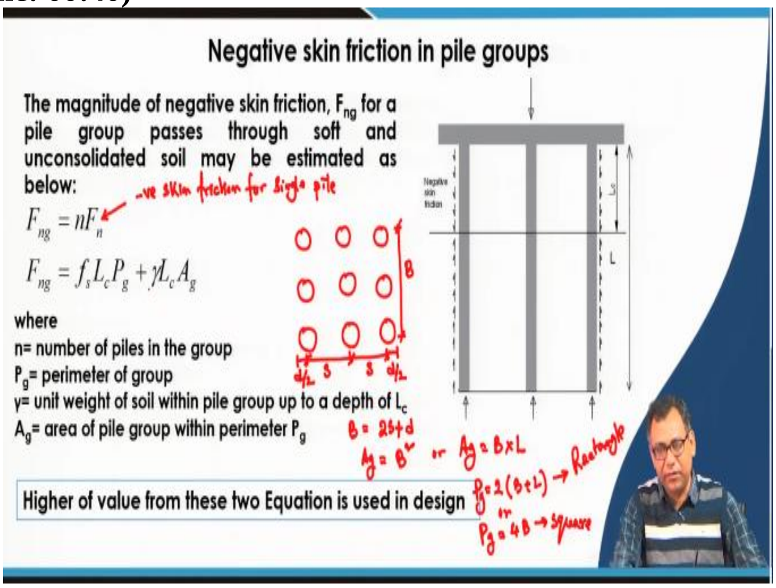

So, this is the group pile. So, the negative skin friction cases are same as I have discussed for the single pile. So, only difference that how we can determine the negative skin friction for the group pile the same way we can determine the negative skin friction for the group pile as we did it for the group pile load carrying capacity. So, first we calculate the negative skin infection for the single pile then you have to multiply it with the number of piles.

So, this is the group negative skin friction that we determine the negative skin friction for single pile and then we multiply it with the number of pile where is the number of pile and this is for the negative skin friction for single pile. So, this is the negative skin friction for single pile. And then we can calculate the negative skin friction as a block for the pile group and that is the expression and where A_g is the area of the pile group, S is the spacing and this is $\frac{d}{2}$ this is also $\frac{d}{2}$.

So, my B will be $2S + d$ for this particular case. And if it is a square pile group then this will be B^2. So, this $B = 2S + d$ and then the area will be A_g which will be this particular case B^2 or if it is a rectangular pile group then $A_g = B \times L$. So, that means, here A_g and L_c is the length of the negative skin friction zone and f_s is the negative skin friction. And then that negative skin friction f_s we can determine the same way that we have discussed for the single pile.

Because we are doing the same technique for the load carrying capacity of the pile also. So, we have to multiply with the perim of the pile group, P_g so, perim will be here and $P_g = 2(B + L)$ for rectangular pile group and or $P_g = 4B$ for the square pile group. So, that we can determine the P_g and A_g and L_c is the length and this unit weight is within the pile group up to a depth of L_c.

So, we can determine the negative skin friction for group and maximum of these two because in load carrying capacity minimum amount of these two values for group block failure and single failure, but here as the native skin friction will give us the negative effect. So, we have to take the maximum of these two as your negative skin friction for the group during the design. So, this example problem is for so first we will go for the single pile then we will go for the group pile.

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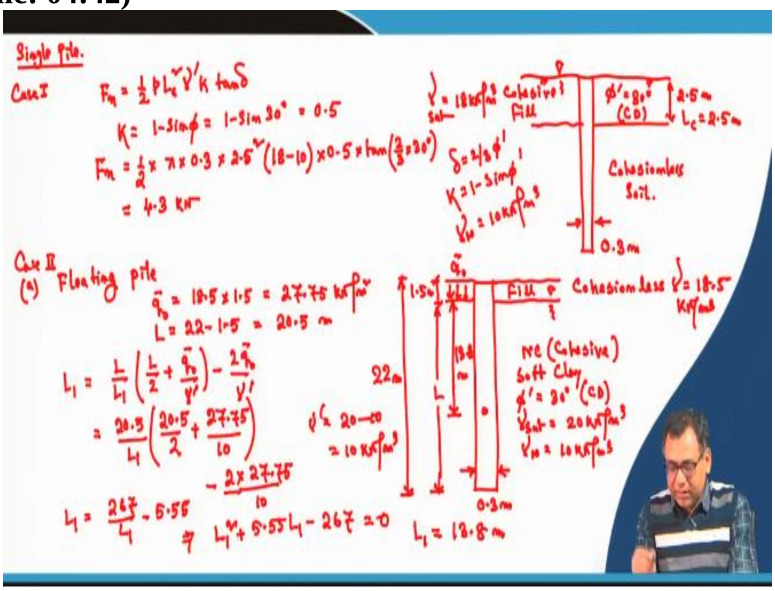

The single pile, we have that profile, so this is the pile. It has diam of 0.3 m; it is uniform cross section and fill zone is 2.5 m thick. So, that means $L_c = 2.5$ m, it is a cohesive fill whose $\phi' = 30°$. So, under CD test we have determined that. And the unit weight of the soil is 18 kN/m^3 and water table is at the top of the fill.

And we can consider δ value is $\frac{2}{3}$ of ϕ' because δ is given 0.5 to 0.9 here we have taken $\frac{2}{3}$ of ϕ', K we know that is $1 - \sin\phi'$ and unit weight of water is taken as 10 kN/m^3. So, you have to determine what would be the additional load on the pile due to the negative skin friction. So, this is the cohesionless soil. So, here the water table is at the ground surface, so we can use the linear distribution.

Because if the water table is not at the ground surface it is some depth below the ground surface then we cannot use the linear distribution and there will be bilinear type of distribution. So, but here we can use the distribution considering the submerged unit weight. So, directly we can use that expression in such case F_n will be $\frac{1}{2}$ perimeter × $L_c^2 K\gamma' \tan\delta$. So, $K = 1 - \sin\phi'$, so that will give you $1 - \sin 30°$, so that is 0.5.

So, finally, the F_n value is $\frac{1}{2}$ perimeter will be πd, where d is 0.3, L_c^2 is 2.5^2, unit weight is 18 - 10 because γ_{sat} is 18, then K value is 0.5 × $\tan\delta$, $\tan\delta$ is $\frac{2}{3}$ of ϕ' which is 30°. So, this is the negative skin friction and that value is 4.3 kN. So, that is the additional load which is acting on the pile due to the negative skin friction.

So, now I will go to the second case this is the case number 1, now for the second case, case 2 the problem is slightly different. So, in case 2 we have the fill which is cohesionless and this is normally consolidated soil, this is cohesive, this is a soft clay with $\phi' = 30°$ and we have done it for the CD test, γ_{sat} is 20 kN/m^3, γ_w is 10 kN/m^3, diameter of the pile is same as 0.3 m.

The fill thickness is 1.5 m and total length of the pile is 22 m, so we have to determine the negative skin friction for two cases, one case is floating pile and another case is point bearing pile and water table is at the fill base level. So, unit weight of the fill is 18.5 kN/m^3. So, first case is that floating pile. So, we know that here q_0 value which will act as a surcharge here, so that is $\bar{q}_0$.

But here the water table is below that fill or the base of the fill so $\bar{q}_0 = q_0$ and that value is 18.5 × 1.5 so, that q_0 is 27.75 kN/m^2. Now, the effective length of the pile will be 22 - 1.5, because 1.5 m is the fill. So, this is 20.5 m. So, now, for the floating pile we know the expression of L_1

which is developed. So, this is the case where the negative skin friction is due to the movement of the downward movement of the lower soil that is the soft clay soil.

So, $L_1 = \frac{L}{L_1}\left(\frac{L}{2} + \frac{\bar{q}_0}{\gamma'}\right) - 2\frac{\bar{q}_0}{\gamma'}$ and $\gamma' = 20 - 10 = 10$, kN/m^3. So, if I put L = 20.5 because L is this one and L_1 we do not know. So, we can write that $L_1 = \frac{20.5}{L_1}\left(\frac{20.5}{2} + \frac{27.75}{10}\right) - 2 \times \frac{27.75}{10}$.

So, you will get $L_1 = \frac{267}{L_1} - 5.55$ or we can write $L_1^2 + 5.55L_1 - 267 = 0$. So, after solving this I will get $L_1 = 13.8$ m, so L_1 value is 13.8 m, so this is 20, so 13.8 will be somewhere here and so the neutral point will be here. So, this will be the neutral point which is 13.8 m below the fill level.

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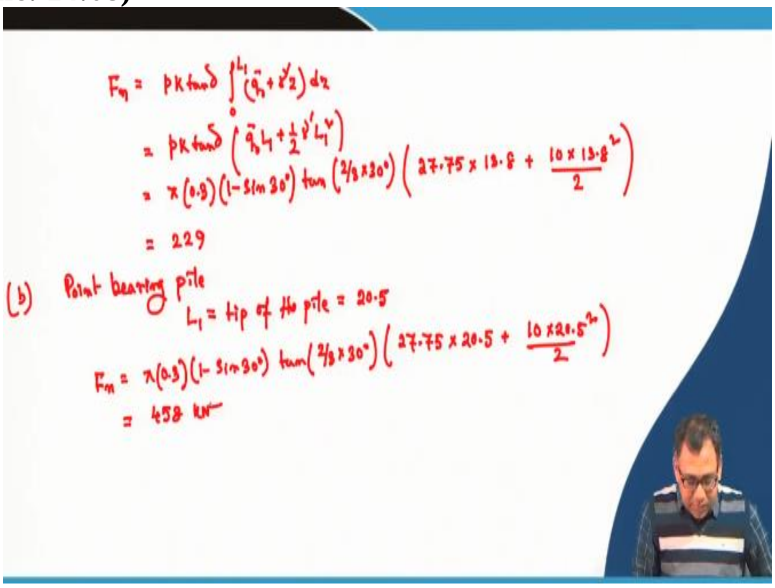

So, I have determined that 13.81 m is the L_1 value, so F_n I can calculate the expression is given if I integrate so I will get that expression that is $pK \tan\delta \int_0^{L_1}(\bar{q}_0 + \gamma' z)dz$. So, now if I put the limit so, this will be $pK \tan\delta \left(\bar{q}_0 L_1 + \frac{1}{2}\gamma' L_1^2\right)$. So, now we will put this value p is the perimeter which is πd.

So, this will be d is 0.3 $K = 1 - \sin\phi'$, so $1 - \sin 30°$ which is 0.5. So, δ again we are taking the same value $\frac{2}{3}\phi'$ then $\bar{q}_0$ is 27.75, L_1 is 13.8 + γ' is 10, $\frac{L_1^2}{2}$ is $\frac{13.8^2}{2}$. So, this value is 229. So, 229 is the negative skin friction that is acting in the pile, so that we have determined. So, now for the case b which is for the point bearing pile. So, point bearing pile L_1 is taken as the tip of the pile, so L_1 is equal to tip of the pile.

So, for point bearing pile L_1 is the neutral point is at the tip of the pile so that means, the total pile length is giving negative skin friction, but the tip resistance is so high, so that negative skin friction is counterbalanced because it is a point bearing pile. So, we can consider to L_1 in this case it will be 20.5. So, the F_n will be here is equal to $\pi(0.3)(1-\sin 30°)\tan\left(\frac{2}{3}\times 30°\right)$ then this will be $27.75 \times 20.5 + \frac{10\times 20.5^2}{2}$.

And here also we are neglecting the contribution of the tip resistance during the mobilization of the frictional resistance. So, that is why we can use this equation or here we can use that equation also whether you considered it or not. That is not mandatory because we do not need to calculate the L_1 because directly we have determined the L_1 at the tip so, that is I mean important thing here.

So, we can directly put this L_1 in the equation of F_n and we will get the value so, that is 458 kN. This is 229 which is double because even if without putting this value in the equation we can get so, that it will be double because that is the neutral axis we have considered. So, that mean if the total one is giving the negative skin friction for the tip bearing pile and for floating pile, so the equal amount of negative and positive. So, that is overall this will be almost the double.

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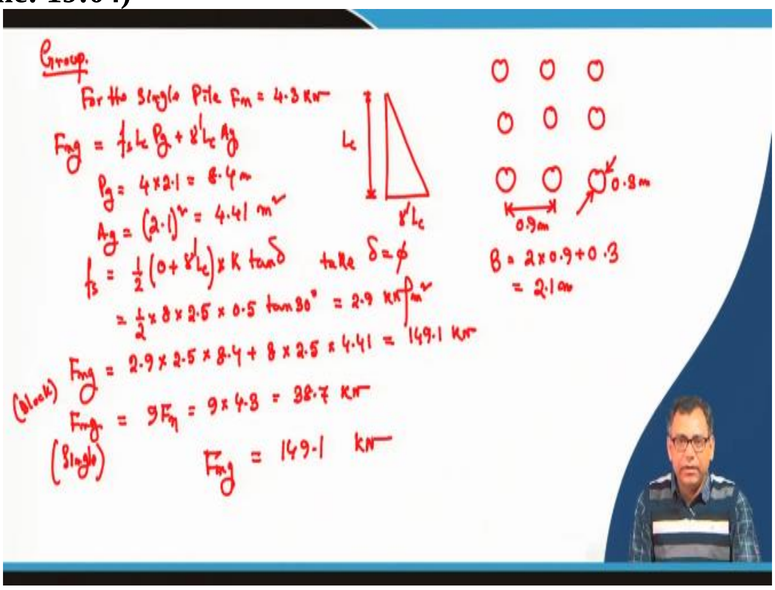

So, now I will calculate the last example problem this is for group, so we have 9 piles in square group. So, spacing between the pile is 0.9 m diameter of the pile is 0.3 m. So, my B is 2 × 0.9 + 0.3 that is equal to 2.1 m. So, the same problem I have done for the single pile the same problem that I am taking so this problem case 1 so, this problem I am taking here for the group pile. So, for the single pile it was 4.3 kN. So, same problem I am taking here.

So, for the single pile, F_n is 4.3 kN, so $F_{ng} = f_s L_c P_g + \gamma' L_c A_g$ that is given. So, P_g is 4 × 2.1 here that is 8.4 m, A_g is 2.1^2, so that is 4.41 m^2 and f_s is we are taking that same value because here f_s is the frictional resistance and then now we can draw in a linear friction. So, f_s will be suppose this is your L_c so, f_s contribution without perimeter and the length. So, that is nothing, but this is your $\gamma' L_c$.

So, it will act at the middle and you have to take average, so you can take this $\frac{1}{2}(0 + \gamma' L_c)$, so that is acting at middle $\times K \tan\delta$ that is the total resistance f_s. So, if I get this value and take this case $\delta = \phi$ because the interaction is between soil to soil. So, we can write this value is $\frac{1}{2} \times \gamma'$ is 8 because $\gamma' = 18 - 10 = 8$ kN/m^3.

So, γ' is 8 $\times L_c$, L_c is 2.5 in that problem K value is 0.5 and this is tan 30°, so these will be 2.9 kN/m^2. So, now we have to multiply with that value so, you can write F_{ng} as f_s is 2.9, L_c is 2.5, P_g is 8.4 + we are assuming the same γ within the pile group also and that is 8 × L_c is 2.5, A_g is 4.41. So, that will be equal to 149.1 kN. And for single pile consideration this is for block and this is for single, this is equal to 9 × F_n.

So, 9 × 4.3 that is 38.7 kN. So, final F_{ng} is 149.1 kN because higher of these two values. So, this way we can determine the negative skin friction for the group pile as well as for the single pile for different cases. We have discussed the case 1, case 2 and case 3 straight forward which is same as the case 1. So, one thing I want to mention that for the tip or the point bearing pile.

The negative skin friction basically influenced the bearing capacity of the pile and for the floating pile it influences the settlement of the pile. So, this is one information. So, I have finished the pile under compressive load part. So, in the next class, I will start a new topic that is laterally loaded pile then we will discuss the pile under uplift and then remaining two topics we will discuss. So, basically there are three topics remaining one is laterally loaded pile and pile under uplift load.

So, these two will be combined as one module and the next module will be the well foundation and third module our last module will be pile foundation in difficult soil, mainly foundation in collapsible soil and swelling soil. So, these topics will be discussed during the coming lectures. Thank you.