Foundation Engineering
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Lecture - 33
Pile Foundation - VII

In the last class I have discuss about the bearing capacity of pile in granular soil, and have solve problems related to the bearing capacity of piles which is in the granular soil. Now this class I will discuss about the bearing capacity of piles in cohesive soil or in clay. Then I will discuss about the others bearing capacity determination techniques like the plate load test. And before I discuss the bearing capacity of pile in clay, I want to discuss one thing that in the IS code recommendations of bearing capacity of pile in granular soil.

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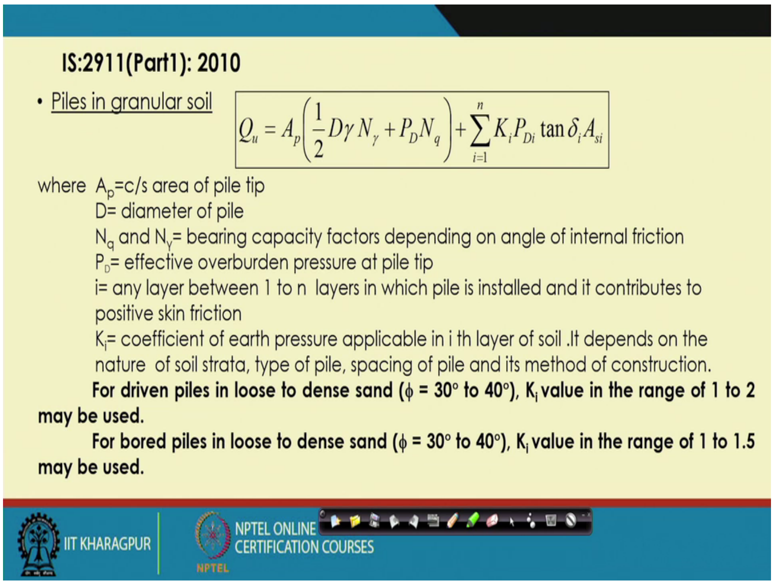

So, here I have used this expression for homogeneous soil calculation. But, that can be use for the layer’s soil that I have done for the other methods for the problems that I have solved in the last class.

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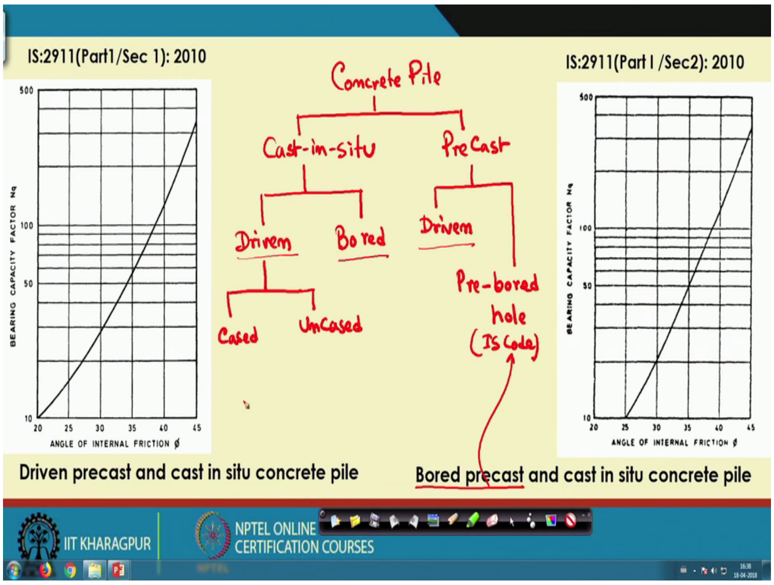

Now, one more thing that here that these 2 charts we have used that one is driven PreCast and Cast-in-Situ concrete pile, and bored PreCast and Cast-in-Situ concrete piles, ok. So, driven PreCast and Cast-in-Situ concrete piles are common, I have discussed that cast in situ piles can be bored or can be driven and driven, also can be cased or uncased. But bored PreCast concrete piles. So, bored piles are generally Cast-in-Situ, but bored PreCast concrete pile also mention in this IS code.

So, let me just discuss about what are the different types of piles is based on the installation techniques. So, as we know that piles are in terms of materials a concrete piles, steel piles and timber piles, and the concrete piles of frequently use. So, that is why if I discuss about the concrete piles only so, in based on the installation technique concrete piles are, so, concrete piles are mainly 2 types.

One is Cast-in-Situ, another is PreCast, ok. So, as I mentioned in Cast-in-Situ can be 2 types one is driven and another is bored. And driven piles can be cased or uncased. Similarly, PreCast pile definitely it is driven, and this is the another one where IS code as mentioned, that is the PreCast pile in pre bored hole.

That this IS code as mentioned. So, that mean the PreCast pile is installed in a pre-bored hole, and hole is already created that hole this pile is installed, ok. So, that is call the PreCast bored pile or bored PreCast pile. So, this one; that means, the bored PreCast and PreCast pile in a pre-bored hole and then bored Cast-in-Situ. So, this is the bored Cast-in-Situ and this is driven PreCast, this is driven PreCast and this is Cast-in-Situ driven Cast-in-Situ driven that can be generally cased or uncased.

So, this is the total all the concrete piles based on the installation, ok. So, and driven piles as you know that you are applying a hammer blow with a certain weight of hammer with a certain free fall, and then we are driving the pile into the soil. And in the Cast-in-Situ and PreCast on the PreCast piles are casted in the casting gears, and the Cast-in-Situ piles are casted in the site itself.

So and in the bored piles hole is created into that hole pile is and based on that Cast-in-Situ or PreCast it is being constructed, ok. So, these are the all types of piles and definitely that timber piles in terms of material timber piles and steel piles those are the driven piles which is drived into the soil. And. I have already mentioned where I will use the timber piles steel pile and concrete piles you can use for any type of loading timber piles for the if the loading is very less requirement of loading is very less, and if the steel pile is for the heavy loading all these things I have discuss.

So this is the one information that I want to shear. So, next one I will discuss about the bearing capacity of pile in clay, ok.

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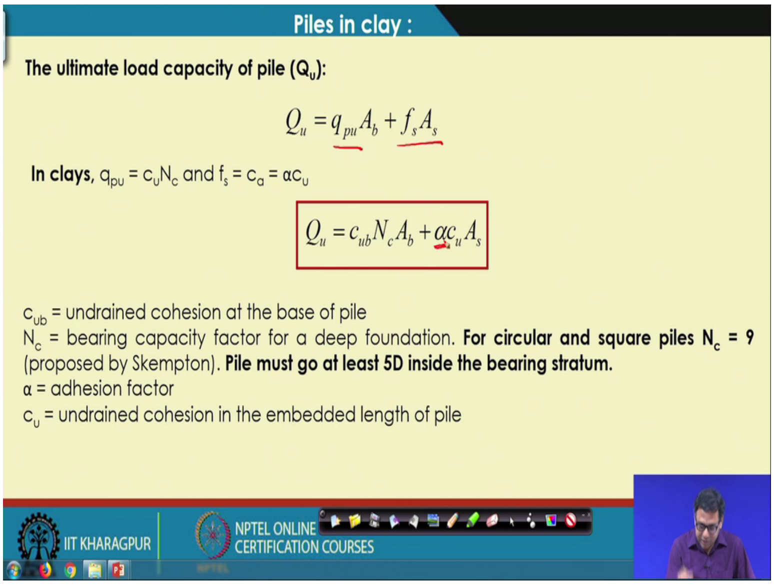

So, similar to the sand bearing capacity of clay the resistance it will get from the tip or the base or and the friction, ok, this is the base and this is the friction. And thus base one will be the c N c, c is the undrained cohesion at the pile tip and N c is the bearing capacity factor A v is the area of base, and alpha C u alpha is the adhesion factor in granular soil it was the delta. Friction angle friction between the soil and any other material, here it is cohesive soil it is the adhesion.

So, this is the alpha is the adhesion factor, and if it is soil versus soil then alpha value will be one in soil versus any other material the generally alpha value is less than one, ok. So now, this a is the area of the surrounding of the pile, ok. So now, how I because the here we have to determine the alpha value.

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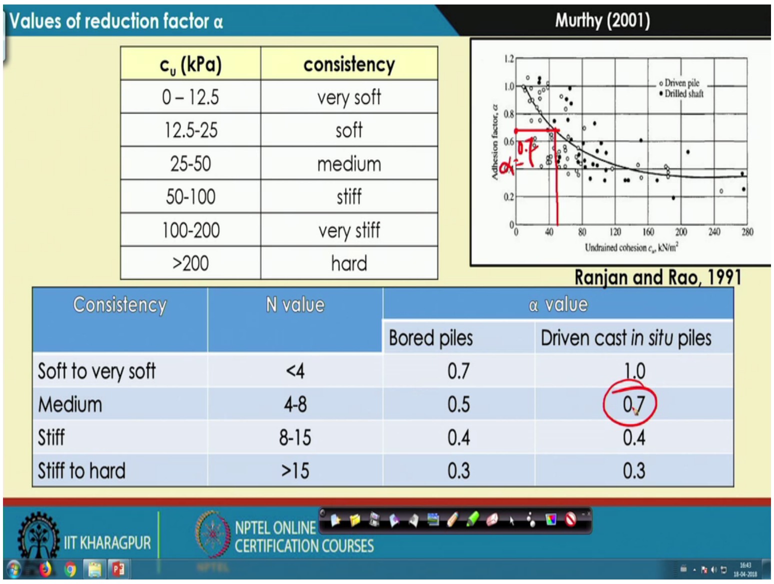

So, how I will determine the alpha value? So, this is the table we can use a or we can use this chart where it is applicable for driven an driven or your drilled shaft both and here this is the undrained cohesion, this is the adhesion factor, and or you can use this chart for different consistency of soil soft to very soft medium stiff to hard. And this how I will identify which type of soil is soft based on the C u value. So, I will get this information from this table also.

So, this table or these chart we can used determine this adhesion factor alpha.

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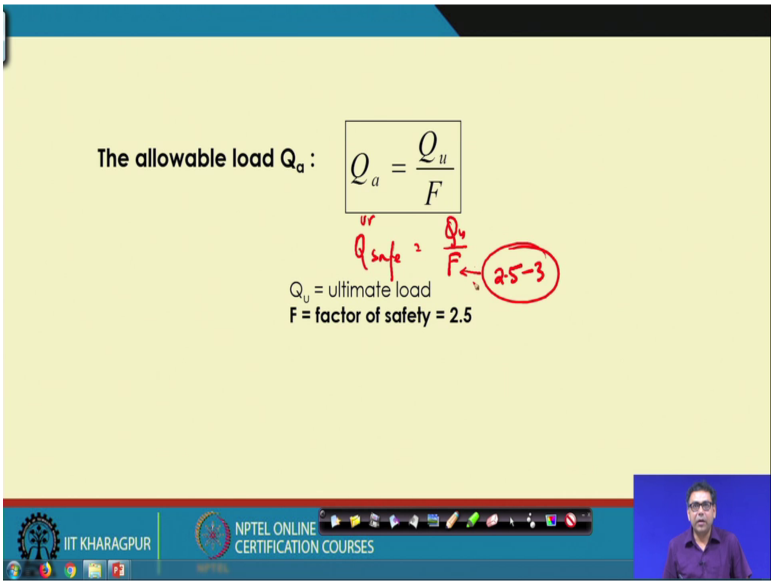

And then once we get the Q u then if I divided by factor of safety then I will get the Q allowable or sometimes it is call Q safe ok. So, this is Q safe Q ultimate divided by the factor of safety generally this is 2.523, ok. So, this is the factor of safety value 2.5 to 3.

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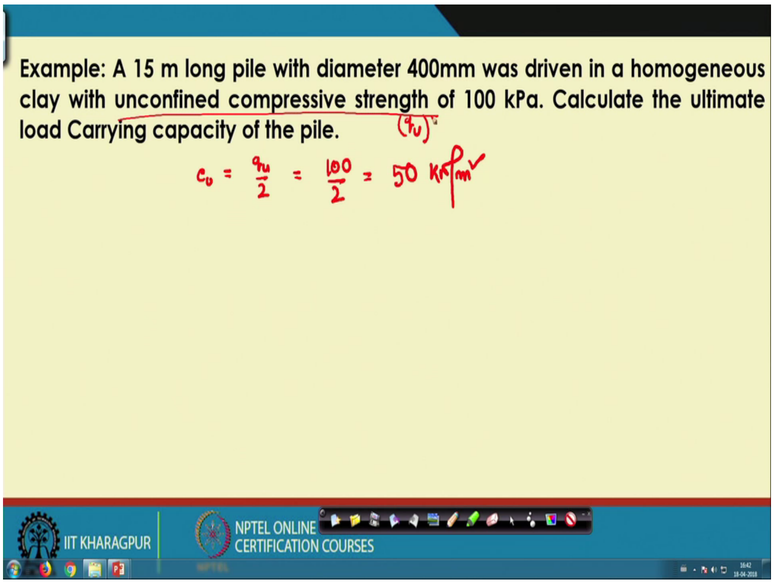

So now, I will solve one problem that a pile of 15-meter length with a diameter 400 millimeter was driven in a homogeneous clay with unconfined compressive strength of 100 kPa. Calculate the ultimate load carrying capacity of the pile.

So, the unconfined compressive strength of the clay is 100. So, you know that the C u value I will get from q u divided by 2 is unconfined compressive strength is the q u, so, q u divided by 2. So, this will be the 100 divided by 250 kilo Newton per meter square. So, my C u value is undrained cohesion is 50 kilo Newton per meter square. Remember, that if it is unconfined compressive strength it does not mean that it is a cohesive C u value, C u value will be half of that. So, in some problem a directly C u value can be given in some problem is only Q value will be given? So, we have to divided by 2 to get the C u value, ok; so if the C u value is half, then from this table or I can use this table so, from this table that you can see that if it is 50 to 100.

So, this will be equal to your coming 50 to 100 stiff or 25 to 50 is medium so, our case C u value is 50. So, here I am considering it is the medium range and the medium the driven Cast-in-Situ pile is 0.7, alpha value is 0.7, ok. So, that is why I am taking that 0.7, if I even the use this chart, here also 50 will be somewhere here. So, corresponding to the 50 so, it is also around 0.7, ok. So, from the chart also I am getting it is 0.7.

So, from chart also I am getting 0.7 from the table also I am getting 0.7. So, that is why I am taking the 0.7 as the alpha value.

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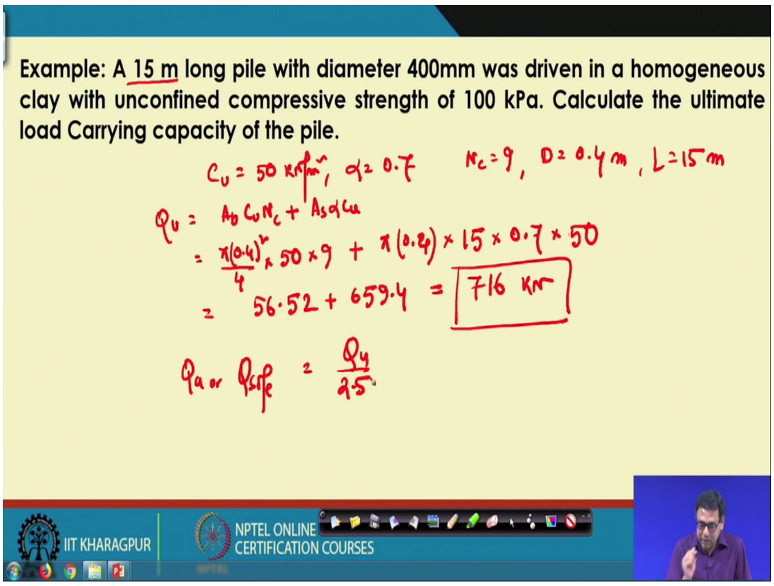

So, my C u value is C u value is 50 kilo Newton per meter square, alpha value is 0.7, ok. So, my q value will be q u will be A b C u N c plus A s alpha C u.

So, A b is the area of the pile base. So, which is pi D is 0.4 square divided by 4, C u is 50 and N c value is because N c value is always 9 based on the skempton recommendation for dip pile you are taking 9, and D is here 0.4 meter. And this is 9 plus Ac is pi D 0.4 into the L, L is 15 meter. L is 15, then adhesion factor is 0.7, and C u is your C u value is 50 kPa.

So, C u value is 50 so, I will get the total 56.52 plus 659.4 that is equal to 716 kilo Newton. So, it is a homogeneous clay, that is why that the cohesion value in the friction and the bearing we are taking same. But if it is the layer soil, then we have to take it in segment wise, depending upon the different layers and that case C u value for base and the side friction may be different, ok. So, this is an if you want to determine the Q allowable or Q safe, then if you have to divided it by 2.5 of this Q u then you will get the Q safe.

So, this is the one problem, we have solve for the homogeneous soil, ok.

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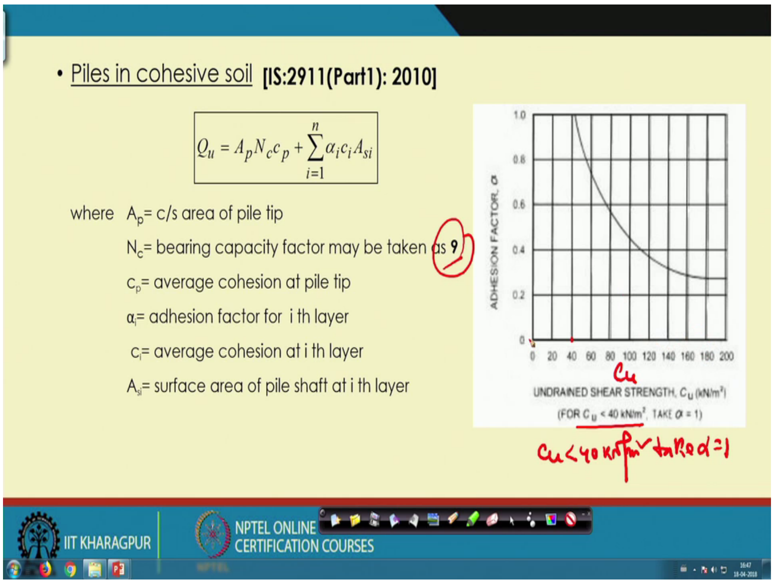

And IS code also recommended the similar type of expression, this is for different layers so, that is why they are given the summation. And this is a p is the a cause section of pile tip, N c is again here it is 9, and N c again 9 and the c p is the average cohesion as the pile tip, and c i is the average cohesion of the different layers.

And here alpha value I will get from this chart. The IS chart different is that if you are phi value is less C u value, if you C u value is less than 40, you can see then your alpha value is always 1. So, if you are this is the term is C u value is if C u value is less than 40 kilo Newton per meter square, then take alpha value is equal to 1 for the IS code method for the, but generally will follow the previous method.

So, that means, IS code method if you have following then we have to take C u value if it is less than 40 than alpha value is one after that you can follow this chart, for this curve and the this depending upon the differency you will get the adhesion factor.

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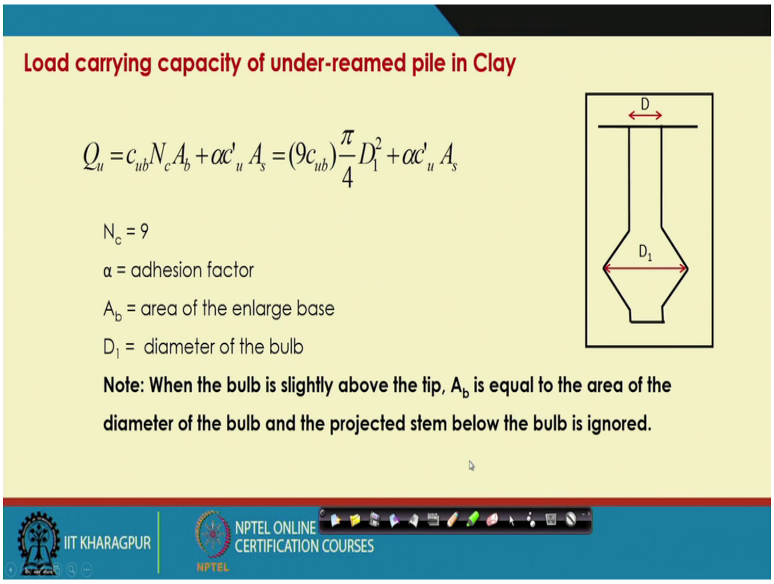

So, now, I will solve problems for layer soil, for the clay of the layer's soil. Because I have now solve the problem for only single layer homogeneous soil.

Now, if I solve the similar problem for the layer's soil.

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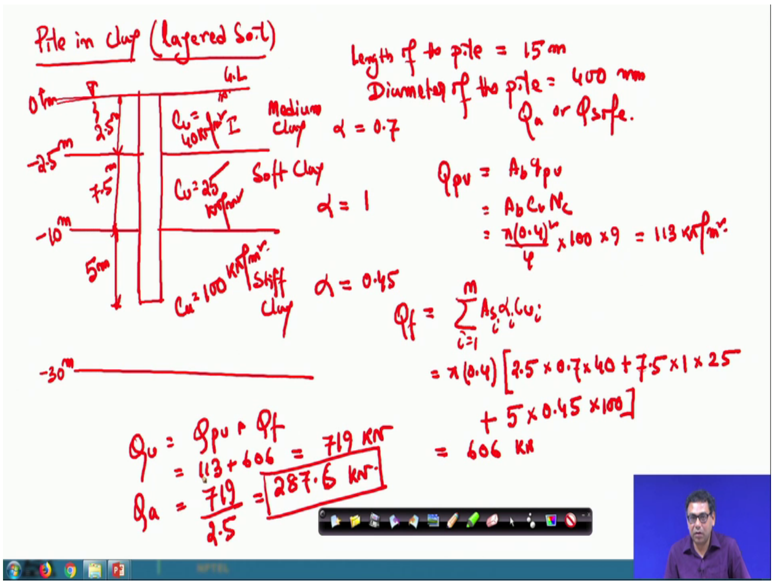

So, pile in clay and this is for the layer soil. So, you have a pile of length 15 meter. So, this is the pile, and this is the ground surface G L, water table is at the ground surface itself. So, this is the sign of water table. And so, this is the first layer, this is second layer and this is the third layer. So, this is minus 30, this is minus 10 meter this is minus 2.5 meter and this is 0 meter.

So, this clay is the medium clay. This clay is the soft clay, and this clay is 100 kilo Newton per meter square, that is this it is stiff clay. So, C u value for this clay is 40 kilo Newton per meter square, and C u value this clay is 25 kilo Newton per meter square, and C u value for this clay is 100 kilo Newton per meter square. Because these are solve medium clay. So, C u value and the length of the pile is equal to 15 meter, and the diameter of the pile is 400 millimeter.

So, we have to calculate what would be the Q allowable or Q safe, ok. So, here we have 3 layers of 3 different are the C u value. So, first we have to determined what would be the alpha value for the first layer what would be the alpha value for the second layer, what would be the alpha value for the third layer?

Now, if I go to the chart that here, ok. So, for the alpha value is given first layer is 40 kilo Newton per meter square. So, 40 kilo Newton C u value is 40 kilo Newton per meter square so, it is 25 to 50 so, it is medium. So, for the medium this is the driven pile is alpha value is 0.7, next one is 25 is your C u value. So, it is in the soft range so, for the soft soil it is one, and third one is the 100. So, 100 will be the stiff range so, for the stiff soil 100.

So, we are taking it is 0.45, because in the in the stiff soil it is 0.4 for the 100, because and but from the chart also if I get with form the chart if it is 100, then this value is around 0.45. So, because this is the 100 and so, from the chart this is 100 this value is also 0.45. So, from the chart I am taking 0.45 from the table also it is 0.4 so, I am taking 0.45. So, if I so, this is the problem. So, alpha value I am taking for the first layer is 0.7, and here second layer it is the soft soil. So, we will get the table will it will all the from the curve, a chart that is given, it is one alpha for C u 40 kilo Newton per meter square it is 0.7.

And here it is taking 0.45, ok. And here the length of the pile for the first layer it is 2.5, then second layer it is 7.5, 10 then 15. So, this layer is another 5 meter, because total length of the pile is 15 meter. So, my now I will first calculate the Q u, Q p u; Q p u is A b into Q p u, and it is Ab C u Nc, ok.

And this A b is the area of the pile base so, 0.4 square divided by 4. And C u is pile is the basis and third layer where C u value is 100. So, we will take 100 is the C u and N c is 9, ok. So, this value is coming out to be 113 kilo Newton per meter square. Similarly, now I will calculate the Q f and Q f for the all the layers. So, it is the summation of A s into alpha in to C u alpha i C u i, s i, i equal to 1 to n here n is 3, because we have 3 layers.

So, for the A s it is the uniform diameter pile. So, A s will be same for As area outside diameter is same for all the layer. So, I can write pi into D is 4 and L will change for different layer. So, first layer the L value is 2.5 meter where first layer. Alpha is 0.7 and C u is 40 kilo Newton per meter square, for the second layer your length is 5 7.5 meter.

For the second layer length is 7.5 meter, this is the length is 7.5 meter, alpha value is one and C u value is 25. For the third layer length is 5 meter, then alpha value is 0.45, and C u value 100. So, the total Q f is coming out to be 606 kilo Newton is a total Q f.

So, Q u will be Q p u plus Q f so, this is Q p u is 113 plus 606 is equal to 719 kilo Newton. So, Q allowable is equal to 719 divided by 2.5. So, this is equal to 287.6 kilo Newton. So, the safe load carrying capacity of this pile is 287.6 kilo Newton's. So, you can see here because this pile is not rested to any forms data. So, it is a within the clay.

So, it majority of the contribution is from the friction, which is 606 compared to the t p is 113, but if the pile is rested on a. So, in the on a hot stratum likes sand, then majority contribution may come from the bearing tip resistance as compared to the friction though those type. So, plies a call the bearing piles and this type of piles are called the friction piles.

So, the next problem that, I will solve that if this pile is on layer soil, but the layer may be both sand sandy soil as well as the clay soil. Then what will happen? Ok, so that means, in layer soil the pile in sand clay layer soil, ok.

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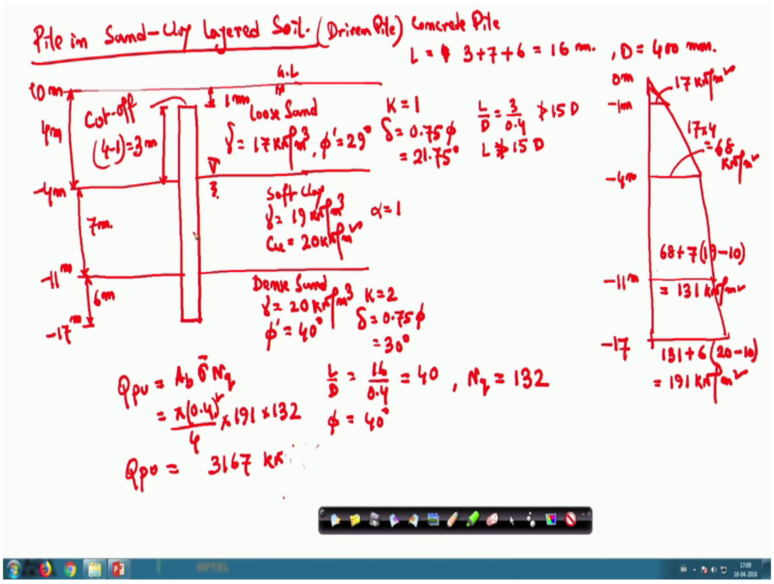

So, I have done the only sand layer soil case, I have done the only clay layer soil case. So, this example I will solve if pile is in sand and clay both the layers, ok. So, the problem that I have taken is that this is the ground surface, and sometimes your pile cut off level may where the pile is in may be below the ground, or sometime it can be above the ground also.

So, but you have to take the length of the pile which is within the ground. So, here the length of the pile this is the cutoff level, and which is one meter below the so, below the ground level. So, this is the cutoff point, and pile is end here ok, but your ground level is one meter above the pile. So, if this type of situation is happened then what you have to do. So, that means, here this first layer is 4 meter ok, but the length of the pile, in the first layer is, 4 minus 1 that is 3 meter.

And this first layer is a loose sand layer with the unit weight is 17 kilo Newton per meter cube, and phi 0 or phi dash is 29 degree, ok. And water level is at the 4th meter. So, water level is 4 meter. So, this is minus 4 meter, this is 0 meter, then we have clay layer this is the clay layer of soft clay layer, where unit weight is 19 kilo Newton per meter cube, and C u value is 20 kilo Newton per meter square, and phi value is 0, because it is a soft clay layer. And the thickness of this clay layer is 7 meter ok.

So, this is 7 meter so, this 1 minus 11 meter, then the next layer which is dense sand; which is dense sand unit weight is 20 kilo Newton per meter cube, and phi value is 40 degree, and the length of this layer other of the pile in this layer is 6 meter, ok. So, that is minus 17 meter the base of the pile.

So, total length of the pile is 3 meter, plus 7 meter plus 6 meter. So, this will be the 16 meter will be the total length of the pile. So, because one meter we will not consider because it is in the cutoff is at one meter below the ground level. So, but when you calculate the effective overburden pressure then you have to consider that way, but during the pile length calculation we will not considered that length. And the diameter of the pile is taken as 0.4 or 400 millimeter, ok. So, what will be the load carrying capacity of the pile?

So, from the table you know that for the soft soil, your alpha value is equal to 1, you can see the table or the chart that I have given I am just putting those value I have taken also these values from the table or the chart. So, that means, for the dense soil, my k value is equal to 2 and delta value it is a concrete pile a remember the all the problems that I am solving is for driven pile, ok. So, this is also driven pile, the previous problem was also in the driven pile. Solve the problems that have solve till now is all are driven pile.

And this is the delta values for the concrete 75 0.75 phi, which is equal to 30 degree. For the loose soil k value will be one, and the delta is again concrete pile; so 0.75 into phi this is also driven and concrete pile. So, all the piles I am solving are driven piles, and concrete pile. So, this is 7.75 phi. So, this will be equal to 20, 1.75 degree.

So now I will calculate the value. So now, let me do the may this art pressure distribution on this is a vertical pressure distribution. So, we have one-meter cutoff. So, up to one meter these value is 17 kilo Newton per meter square, because your unit weight is 17 and up to one meter 17 into 1. So, 17 kilo Newton per meter square, then we have so, this will continue and up to this.

So, here it is 17, this is the one meter, minus 1 meter this is 0 meter, and this is minus 4 meter. So, at the 4 meter, it is 17 into 4 so, this is equal to 68 kilo Newton per meter square. Then this will change, and this is the distribution up to 11 meter, minus 11 meter and this value is 68 then plus 7 into 19 minus 10.

So, this is equal to 131 kilo Newton per meter square. Then it will then up to the base of the pile so, that is minus 14 meter sorry minus 17 meter. So, this is minus 17 meter, and minus 17 meter these value is 131 plus 6 meter into unit weight is 20 for the saturated and affected is minus 10, and that will be equal to 191 kilo Newton per meter square.

So, first I will calculate the tip resistance then I will calculate the friction resistance. So, Q p u will be because it is in a sand. So, it will be equal to sigma bar N q into A b, ok. Sigma bar is 191 and N q I will take that for L by D is equal to 16 meter divided by 4, as I mentioned you will take the total length, but the phi value I will take corresponding to the base of the pile.

So, 16 point so, this is 40 so, corresponding to the chart, and I am using this is the tomlinson solution so; that means, where I will get the N q value from that chart is equal to 132, ok. So, my Q p u pi D square by 4 sigma bar that is the base is 191, 191 and then N q is 132. So, this value is equal to 3167 kilo Newton per meter, sorry, this is kilo Newton. So, this value is the kilo Newton is the is the Q p u.

Now, one thing I want to share that we have solve the problem in sand considering critical length concept or without considering critical length concept, where one case we have consider the reduce stress or the uniform stress, as it is suggested by critical length in the critical length concept. Another one we have solve considering the effect, total effective overburden pressure. Because different researchers have suggested that a some researchers are suggested you consider the critical length concept, some researchers are suggested you consider with you do not you do not consider the critical length during the pile calculation, because you consider full effective overburden pressure.

But for the sand layer this critical length concept is recommended, I would also recommend that, when you calculate the stresses, homogeneous all layer sandy soil, then you use the critical length concept,, but if the it is within the clay layer then another sand layer in this case, first it is sand layer then a clay layer.

Then it is another sand layer then it is doubtful whether that soil archin will really happen or not, ok, because in that case you are not sure because in the clay this arching phenomena will not happen in that way which is been occurred in the sand. So, in that case I would recommend that if it is this type of layer soil you take the full effective overburden pressure.

So, my recommendation that if it is sandy soil homogeneous will layer you considered the critical length concept. And if it is this kind of layer where clay sand layer then clay dense sand then use the total effective overburden pressure. Because there is no guarantee is doubtful whether these soil arching will happen or not critical length will developed or not.

It is some cases people also check it the critical length check it for the individual layer. For example, that here this is a loose sand. So, you check for this sand whether the it is within the critical length or not. For example, that here for the loose sand my L by L y D value is, for the here the L by D value L is 3 meter, D is 0.4 meter.

So it is definitely it is it is not greater than 15 D. It is not greater than 15 D so, or your L is if you take the L, it is 15 D it is basically the L is not greater than 15 D. Because your D is 0.4 so, it is not greater than. So, here your critical length, it is within the critical length. So, we can take the full effective overburden pressure.

But is sometimes it is recommended, if suppose this top layer is this there is a critical length, existing in the top layer is greater than the critical length. Then what will happen? That you apply this concept in the top layer then you continue that thing for the second layer also. But my recommendation that you use as it is the doubtful. So, in this case, who use the total effective overburden pressure that I have done in this case. So, this is the Q u p 3167.

And so here I am stopping this class here. And the next class I will solve the friction part, I have so determine the tip resistance that is 3167 kilo Newton. In the next class I will calculate the friction resistance then I will add that, ok.

Thank you.