Geotechnical Engineering II / Foundation Engineering
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Lecture - 43
Pile foundation (Contd.)

Let me continue again with the Pile foundation and we have discussed enough on pile foundation. And so far I am not taken any problem, so let us see a few problems which is related to only capacity estimation of single pile. And as I have mentioned or while doing that I have taken the problem separately pile single pile remain in cohesive soil, single pile remain in cohesion less soil.

So, I will take three problems in fact, and try to see they are quite simple actually and I hope it will be clear because I have shown in the form of equation. Now, how to apply them?

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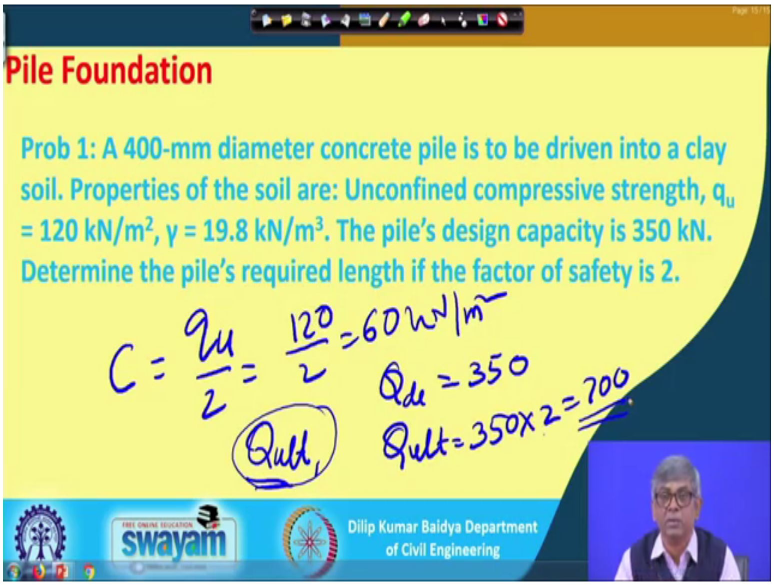

So, let me see two to three problems now. First problem is actually you can see here a 400 mm diameter concrete pile is to be driven into a clay soil. And properties of the soil are unconfined compressive strength q u is 120 k N per m square, unit weight gamma equal to 19.8 k N per m cube. And pile's design capacity is 350 k N. Determine the pile's required length if the factor of safety is 2 ok.

So, two-three things actually there, when this is a pile driven in cohesive soil. And when the pile remaining cohesive soil and we know that the formula that is capacity will be coming total capacity will be coming from the frictional resistance and the base resistance. And frictional resistance comes from the actually cohesion of the clay soil. And here you can see the cohesion is not given ok.

So, how to find out the cohesion, it is instead of the soil un unconfined compressive strength is given. And so in soil mechanics you have learnt that if the unconfined compression strength is known, then we can determine the value of cohesion of the soil is just half of that. That means, C value of the soil is; C value of the soil is just nothing but, q u by 2 that means, 120 by 2; that means, 60 k N per m square. And you can see that the design capacity is given we generally, initially, we whatever formula we derived for capacity, we first we will get Q ultimate is it not. So, here actually design value is there, so, q design is given 350.

So, Q ultimate will be actually generally for single pile. We used factor of safety 2, so it will be 350 multiplied by 2 that means, 700. Now, based on soil property and length of the pile and length and dimension of the pile a dimension of the pile, we have to theoretically find out the Q ultimate and it has to be equated with Q ultimate and then we can find out the unknown that is unknown length.

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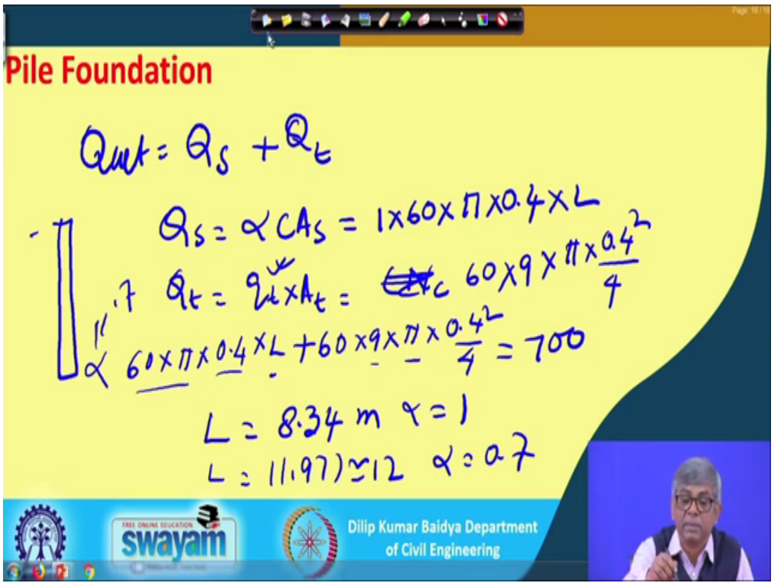

So, let me see in the next page. Let me go. So, here actually Q ultimate will be coming from Q s plus Q t. And Q s will be equal to alpha C A s ok. And alpha is not given, I can assume 1 here. So, if it is 1 multiplied by C is actually 60 multiplied by A s pi times d, d is actually how much 0.4 and L a surface is what if the pile is something like this. So, pi d times the length is the pi A s, so, multiplied by suppose L.

And your Q t will be equal to your q t multiplied by A t and Q t how to find out that is nothing, but C N c that is nothing but C N c and so directly I will put the value C is actual 60 and N c for the single pile actually your for deep foundation actually your N c value for cohesive soil. Normally in bearing capacity problem of shallow foundation you have taken 5.1. And I have mentioned that when you consider deep foundation then your N c value is 9.

So, it is 9 multiplied by pi multiplied by 0.4 square by pi d square by 4. So, this is actually your Q t, so that means, you will be having 60 multiplied by pi multiplied by 0.4 multiplied by L plus 60 multiplied by 9 multiplied by pi multiplied by 0.4 square divide by 4 that is nothing but 700 Q ultimate is it not, 60 pi 0.4 into L and 60 9 pi d square by 4. So, if you do that, then you will L will be coming out actually 8.34 meter.

Suppose, in this problem I have taken alpha value is 1 and if I take suppose alpha value something different because of if it is a steep soil then alpha value will be reduced less than 1. If I take suppose 0.7, then if I multi here actually alpha value suppose, if I take as 0.7 which is taken as 1. So, it will be actually you can see that will be 700 minus, 60 multiplied by 9, multiplied by pi, multiplied by 0.4, multiplied 0.4, divided by 4.

So, divided by 60, divided by pi, divided by 0.4, sorry divided by further 0.7 suppose, then it will be if I take alpha equal to 0.7, see alpha equal to 1 that is the value and L equal to 11.977 or suppose 12 meter when alpha equal to 0.7. So, this is actually the your freedom it is not freedom actually depending on soil type you have to assume that. So, this is one very simple application.

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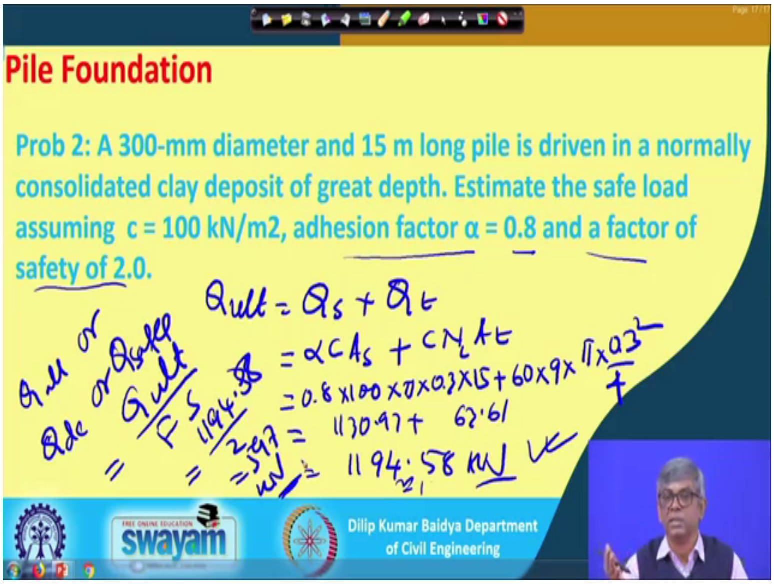

Let me go to the next problem. So, next problem also similar the pile is driven in again clay soil instead of L is unknown now I am this is giving you L and you have to find out the design capacity of the pile. You can see here that a 300 mm diameter and 15 m long pile is driven in a normally consolidated clay deposit of great depth that mean the soil up to sufficient depth beyond 15 meter also same soil, so that I can use the value of property of that layer.

So, estimate the safe load assuming, safe load means design load or allowable load. c is 100 and adhesion factor actually alpha 0.8 and a factor of safety of 2.0 ok. So, again same thing Q ultimate will be equal to Q s plus Q t and Q s will be actually you can see adhesion factor alpha times c multiplied by A s plus Q t actually C N c and it will be A t. So, here if I put the values, alpha is 0.8 multiplied by 100, multiplied by pi, multiplied by d is 0.3, multiplied by L is 15, plus c is actually 60, N c C N c N c actually 9 9 multiplied by pi, multiplied by 0.3 square by 4.

So, if I calculate this, this value will come this will come actually Q s come eleventh 1130.97 plus this comes 63.61. So, total co mes actually your 1194.58 k N. So, ultimate capacity of the pile 15 meter long and 3 milli meter 300 milli meter diameter pile driven in a clay soil whose cohesion value is 100, then your ultimate capacity is around 1200. So, you can approximately take as 1200 actually 1200 k N.

So, Q allowable or Q allowable or Q design or Q safe which will be equal to Q ultimate divided by factor of safety. And if I take 2, then it will be 1194.58 divided by 2. So, it will be so it will be your 597 k N. So, approximately 600 k N also can be taken, because already we have factor of safety. So, 597 otherwise are most specific, but approximately it can be taken 600 also. So, this is the second problem and of course, it is quite simple. Now, I will go to the third problem.

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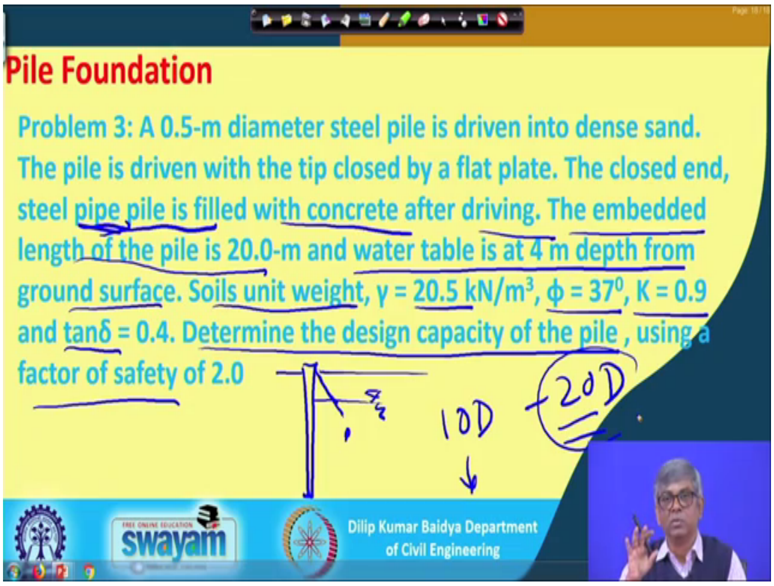

So, third problem actually you can see here the pile driven in pile driven in sandy soil. And you can see that a 0.5 m diameter steel pile is driven into dense sand. The pile is driven with the tip closed by a flat plate ok; that means, it is a hollow actually, bottom is closed initially while driving. And the closed end, steel pile is filled with that is pipe pile actually closed end the closed end steel pipe pile steel pipe pile is filled with concrete after driving.

The embedded length of the pile is 20 m and water table is at 4 m depth from ground surface. The soil unit weight is 20, pi is 37 degrees and K is the that means, lateral pressure coefficient 0.9 and tan delta that means friction between the surface and the solid is 0.4 determine the design capacity of the pile using a factor of safety of 2. What actually you have to do, 20 m pile is there, so, this is 20 m. And actually this is the 120 m at 4 meter depth water table is there ok. And then so it is a sandy soil and dense sand soil actually driven into dense sand. And for these actually for when the pile is driven in the sand then the friction depends on lateral pressure actually. A lateral pressure depends on vertical pressure.

So, at any point I can find out vertical pressure, then multiplied by lateral earth pressure coefficient, then will be the horizontal pressure, then multiplied by the frictional coefficient then I will get the friction. And since sandy soil the vertical pressure is varying, so friction also will be varying, so that is the because of that you have to draw the pressure diagram for first, and then find out the pressure diagram area from there you can get the total capacity frictional capacity. And while drawing this diagram already I have shown that this though this vertical pressure linearly increasing so lateral pressure will also supposed to be linearly increase can increase.

But for the calculation per purpose we have seen that if you do that then there will be over estimation, so it has to be that distribution will be restricted at a depth of equal to critical depth. And that critical depth is nothing but generally is given some recommendation 10 time diameter to 20 time diameter, whereas actually soft soil where loose soil 10 times diameter and then dense sand it will 20 times diameter.

So, here actually our problem is actually dense soil. So, I will take critical depth as 20 times of the diameter. So, that mean 20 times of the diameter of the pile that means 20 multiplied by 0.5 is actually 10 meters. So, this is the initial things actually you have to decide and then you have to go for the calculation.

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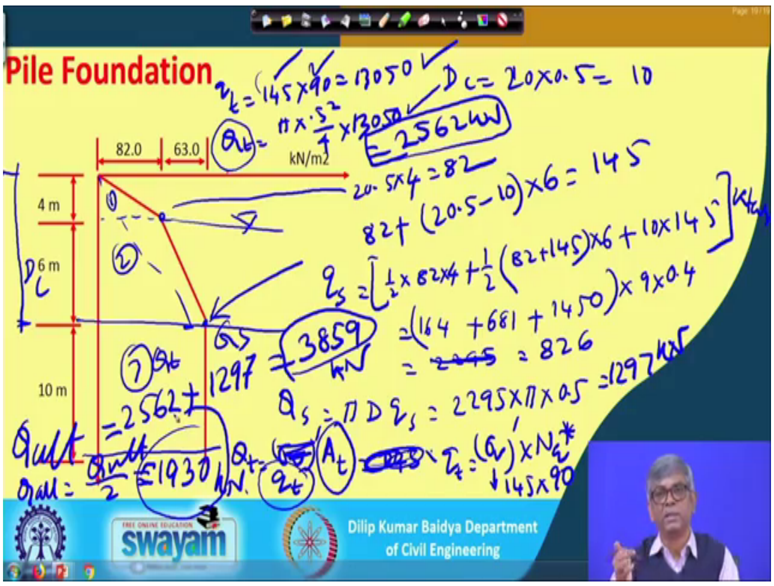

So, let me see the calculation in the next slide. You can see here that this is up to this actual 10 meters. So, D c your D c will be equal to 20 multiplied by 0.5 actually 10 m. So, this is the D c. And up to D c your earth pressure or lateral pressure diagram will not be linear, because water table is here. So, above that actually your unit weight of the soil is 20.5. So, full unit weight will we can calculate use up to this. And from here actually when we will go, you have to use submerged unit weight for calculating the lateral pressure.

So, if I do that, then this point actually your value will be 20.5 multiplied by 4 that is 82. And when I will come here then this 80 this will be 82 plus this will be 82 plus your gamma is 20.5 and taking unit weight of water as 10 multiplied by 6. So, this two together will come actually 145 ok.

So, the easiest way to find out actually when you will draw the vertical this is the vertical pressure diagram. And if you find out the vertical pressure diagram and then you multiplied by the lateral earth pressure coefficient ok, then you are getting lateral pressure diagram or lateral force. Then if you multiply the frictional coefficient, then you will get the friction along a line friction along the line, what how much frictional load.

And if you want to find out the wall around the surface, then you have to multiply the by a pi times d so that is the concept I will be using. First I will try to find out the q s that means, along a line along, along the pile is a circular pile suppose, and if this is a circular pile suppose along this line how much the fictional force I will try to find out that I suppose denote by small q s.

So, that means, it will be area of this diagram multiplied by k multiplied by tan delta so that if I to. So, how to find out this diagram I can divide into three parts 1, 2 and 3. So, first part actually half multiplied by 82 multiplied by 4 plus second part actually half trapezoidal area actually it is 82 plus 145 this plus this multiplied by half multiplied by height actually 6 this is the area of trapezium plus this area of this rectangle that will be actually 10 multiplied by 145.

So, you will get this value equal to this value will be equal to I can find out anyway. So, you can see that 4 multiplied by 82 sorry 4 multiplied by 82 multiplied by 0.5, this is 164 plus this one 82 plus 145 this one multiplied by 0.5 multiplied by 6 this is actually 681 plus this is actually 10 multiplied by 145 that become 1450.

So, this together will be equal to 1450 plus 681 plus 164 that is actually 2295. So, that means, Q s actually along this line. So, Q s will be equal to pi D times q s. So, it will be 2295 multiplied by pi multiplied by a 0.5 so that will be equal to multiplied by pi multiplied by 0.5, so that gives you 3605 sorry I have not multiplied here another thing this is actually q to get the q s you have to multiplied by K tan delta.

So, these multiplied by K is 0.9 and tan delta is 0.4. So, this will be equal to 164 plus 681 plus 450 this multiplied by 0.9 multiplied by 0.4 that become 826.2. So, 164 plus 681 plus 1450 multiplied by 0.9 multiplied by 0.4, this become your 826, this become 826.

And if I multiplied by pi D so multiplied by pi multiplied by 0.5 so that become 1297. So, this value become 1297 k N. So, Q s because of friction you have got a load of 1297. Whereas, your Q t; Q t will be sigma v dash multiplied by A t and sigma v dash actually here is nothing but 145, so 145 no sorry not sigma v. So, this is q t multiplied by A t and Q t will be equal to sigma v dash prime multiplied by N q star. So, if I do that sigma v dash actually this is actually nothing but 145 and N q star for the particular pi is given is suppose 90.

So, your q t become 145 multiplied by 90. So, it will be 145 multiplied by 90, so 130, 13050. So, then your Q t will become pi multiplied by 0.5 square by 4 multiplied by 13050. So, that become you can see 0.5 square multiplied by pi divided by 4 multiplied by 13050. So, that gives you of 2562 this is 2562 k N ok.

So, now that means, your total Q Q ultimate will be equal to 2562 plus your here it was 1297, so that gives you 2562 plus 1297 that become 3859 k N. So, that means if you now find out want to find out Q allowable; that means, Q allowable will be equal to Q ultimate divide by 2. So, if you would do that then divide by 2, so it become 1929. So, 19 approximately you can say 30 k N ok. So this is actually the third problem.

And if there is so here actually I have taken comparatively little difficult problem, suppose I have taken water table. And if it is a completely dry then you could have got one line ok, then the diagram could have been of two parts. But I have taken water table because I have wanted to see always complexity in this calculation. So, you can see it has pressure diagram varied from here to here, then varied to here to here then you have divided into three parts.

So, first I have calculated skin friction, resistance because of the skin friction and then I have calculated base resistance. Base resistance Q t actually equal to bearing capacity of the t multiplied by your base area. And then q t actually how to find out, q t is nothing but sigma v dash prime will be N q star sigma v dash prime is what whatever pressure actually at the base of the pile. And what are the base of the pressure of the base of the pile this is at whatever pressure is the critical depth same pressure will be there at the base of the pile same thing I have taken so that is 145 I have taken.

And N q star corresponding to pi equal to given value is 90, so that means, Q t is obtained this. And once you get q small q t then capital Q t is that means, total base resistance will be equal to pi A t into Q t. So, pi D square by 4 multiplied by. So, it will be 2562 k N is a Q t. So, Q ultimate will be Q s plus Q t this is Q t and this is Q s and these two together become 3859 as a ultimate. And then if you know the Q ultimate, then Q allowable will be just nothing but divided by the; divided by the factor of safety which is generally considered as 2.

So, we have taken 2. So, ultimately your capacity become 1930 k N, so that means, you can see that when the pile driven granular soil both based resistance is quite significant, skin resistance is also quiet significant and as a result your total capacity will be quite high compared to the capacity of the friction pile or pile driven in cohesive soil. So, these are the things also one can remember.

So, perhaps with this better to stop today and I will take some other application like group capacity, group efficiency I have discussed further discussion as I have mentioned that when the pile group pile is space spaced in very closely, then sometime pile instead of failing individually it may fail as a whole as a block how to find out the capacity of the block, and then finally, how to arrive at the design capacity. Perhaps all those things I will discuss in the next few classes ok.

Thank you.