Geotechnical Measurements and Explorations.

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Module No. # 01

Lecture No. # 04

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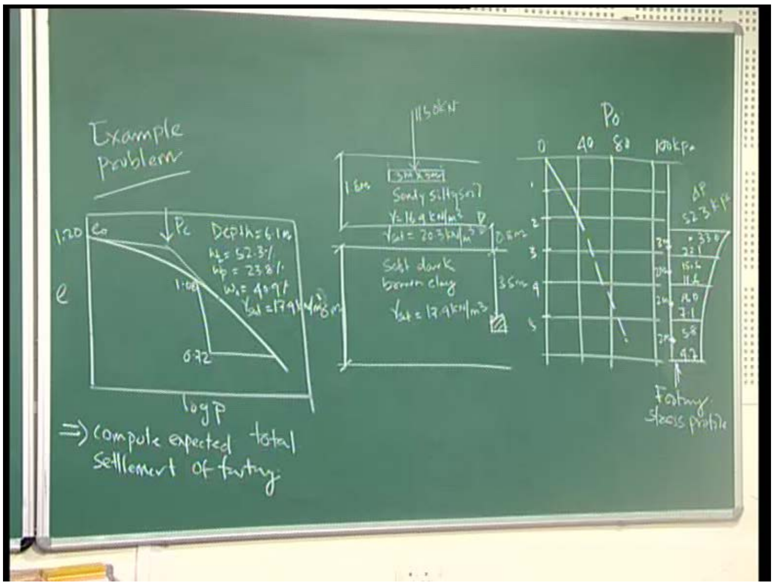

Today we will solve one example problem on consolidation. So, sandy silty this is your 1.8 meter, then this is water table is there, 0.8 meter gamma saturated is equal to 20.3 kilo Newton per meter cube. This is eight meter soft dark brown clay gamma saturated is equal to 17.9 kilo Newton per meter cube and at a depth 3.5 meter the soil has been collected. Now, this is a typical result of 1 2 3 4 5 this is 40 80 100 k p a. Now, it will start at zero then this is 33.0 15.6 9.0 and then this is 5.8 footing stress profile. Another part is given, this is your consolidation problem. Consolidation means set consolidation diagram is it is given. Now, e zero is equal to 1.20. Now, this is your p c e versus log p, this is a 1.08, this is your 0.72.

Now, the question is compute expected total settlement of footing. Now, this is a case where this footing is of size three meter by three meter. So, acted upon this footing is 11.50 kilo Newton and this soil consist of first 1.8 meter is sandy silty soil and water table is located below the ground surface at 1.8 meter, this is your water table and gamma saturated is given. Then below 1.8 plus .8 below this this entire depth is your eight meter. Total is your eight meter. This depth is your eight meter and it is a soft dark and brown clay and soil sample has taken at three meter from here. 3.5 meter from here so gamma saturated is equal to17.9 kilo Newton per meter cube.

This has been soil sample has been taken here and this is given expected means earth pressure means sorry it is not earth pressure, this is p zero. Variation of p zero calculated or may it is given. Then footing stress profile this is your footing stress profile. Below the footing it is called delta p and this is your k p a. Every two, two meter interval it is given so at the surface it is 52.3, at below two meter it is 22.1, then below two meter it is 11.6, then two meter it is 7.1, then two meter it is 4.7, then the middle at the middle this stress has been also been given. At middle it is 33.0, here at middle at 15.6, here at middle is 9.0, here at middle is 5.8. Also, the consolidation graph is given. With this consolidation graph e zero got it 1.20 p c also got it and for depth 6.1. How come depth has come 6.1? 3.5 plus .8 4.3 plus 1.8. So, it will be 6.1. From here to here is 6.1. Liquid limit is 52.3, a plasticity index is 23.8 and natural moisture content is 40.9 percent and gamma gamma saturated is 17.9 kilo Newton per kilometer cube. So the question has been asked compute the expected settlement of footing because of your soft brown clay.

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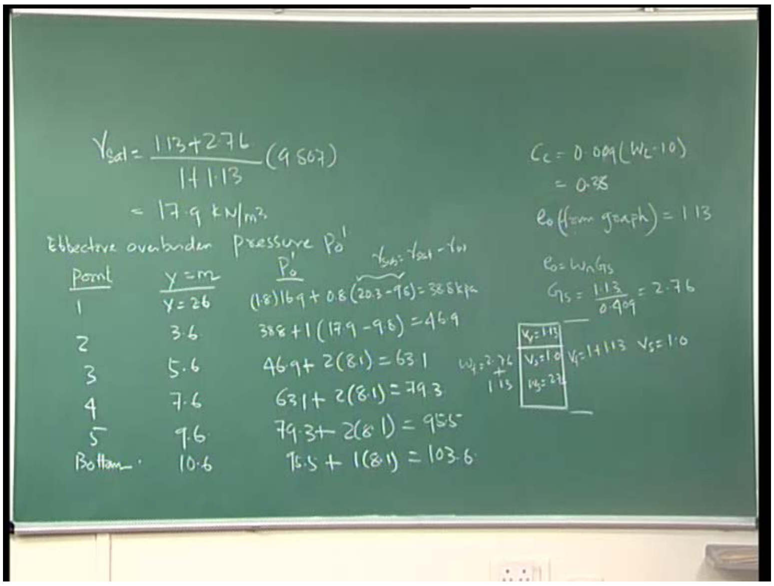

Now c c from co-relation, c c 0.09 009 into w l minus ten so which is equal to 0.38, e zero from graph, 1.13. So, e zero is equal to w n g s. So, g s is equal to 1.13 by 0.409

which is equal to 2.76. Then taking a block diagram, this is a block diagram. v v is equal to 1.13, v s is equal to 1.0, w s is equal to 2.76 and one plus 1.13 w f is equal to 2.76 plus 1.13. Taking block diagram where v s is equal to assumption is volume of solid is equal to1.0. So, from there you can calculate gamma saturated is equal to 1.13 plus 2.76 divided by one plus 1.13 into 9.807 which is equal to 17.9 kilo Newton per meter cube.

Now what is this 1.13? 1.13 is your e zero. e zero g plus e zero gamma saturated g plus e zero g is equal to 2.76 by one plus e zero into gamma w. This is your gamma saturated. Now once you get gamma saturated you can find it out what is your effective stress over burden pressure, effective over burden pressure p zero prime. effective over burden pressure p zero prime.

So now, this point and the y is equal to meter p zero. So, this will be1 2 3 4 5 and bottom so y is equal to 2.6 meter. We will start with this p zero effective stress 1.8. This will be 2.6 y is equal 2.6. This layer has been divided divided into five parts, you see from here we will start it now. At y is equal to 2.6 p zero is equal to 1.8 into 16.9 plus 0.8 into 20.3 minus 9.8 which is equal to 38.8 k p a. So, this is giving 1.8 into 16.9 then this water table is at below 1.8. So, it is coming 0.8 0.8 meter into this is your gamma saturated. So here it will be gamma submerged because water table is lying. Gamma submerged is equal to gamma saturated minus gamma water, gamma w. So 20.3 minus 9.8 this will give 38.8.

Now second point is your 3.6 so it will be 38.8 plus one into 17.9 minus 9.8 which is equal to 46.9. Now, every one meter, one meter interval we are finding now here from here to ground surface to here is 2.6 meter then you go upto 1 meter. So, here it will be here it will be 3.6. This is your 1 meter 3.6. With this 3.6 we got it 38.8 one meter. This is your height meter, one meter into 17.9 minus 9.8. If you look at here, here it is gamma saturated is given. 17.9 then minus 9.8. It is your 46.9. Then third part is your 5.6 so it will be 46.9 plus two into 8.1 which is equal to 63.1, then fourth is your 7.6. So, it will be 63.1. Similarly you can calculate two into 8.1 which is equal to 79.3. These are all k p a's. So, fifth layer is 9.6 which is equal to 79.3 plus two into 8.1 which is equal to 95.5 and bottom is equal to 10.6. So, this will be 95.5 plus one into 8.1 which is equal to 103.6. So, these are the values effective over burden pressure p zero prime, we got it point wise. It is given one two three four five bottom.

So if you look at here; this has been divided because this settlement has to be calculated in this clay layer. So, this clay layer has been divided into one meter one meter one meter sub layers. So, for each one meter the p zero has been calculated. p zero is effective over burden pressure or p zero prime we write it effective once it is effective it should be p zero prime and in this case also it will be p zero prime. So now, the first calculation I have shown in detail. Now, this second third fourth fifth as per this calculation has been made. Below water table it will be gamma submerged, above water table it will be gamma bulk. Now once you get it your p zero effective over burden pressure versus depth you can plot it there and the plotting has been made there effective over burden pressure versus your depth. This plot already I have shown. This plot has come from these calculations from this calculations.

Now the second stage will be once you get it e zero, first step is find it out e zero c c then g s then gamma saturated. Here gamma saturated is not given at this point gamma saturated initially it is not given. So, once you get it from here gamma saturated we got it from this. This is your e zero this is your e zero plus g s by one plus e zero into gamma w. You will get your gamma saturated once you get the gamma saturated the profile, all the profiles gamma, gamma saturated and bottom of this soil is your clay is your gamma saturated it is given. All the profiles have been given so effective over burden pressure p zero prime you can calculate from here.

So this will be like you see, this this is like, this is the only unknown, gamma saturated here it is the only unknown. So, which is required for calculation of p zero this gamma saturated came from your e versus log p. from your From here you can calculate you c c e zero, you can calculate from here c c from your empirical co-relation, you can get it. Then once you get it then you can find it out e zero is equal w n into g s natural moisture content is given from there. You find it out g s, once you get g s then you go for calculation of gamma saturated. Once you get gamma saturated then, you calculate your effective over burden pressure. So this part is over, effective over burden pressure layer wise we have calculated.

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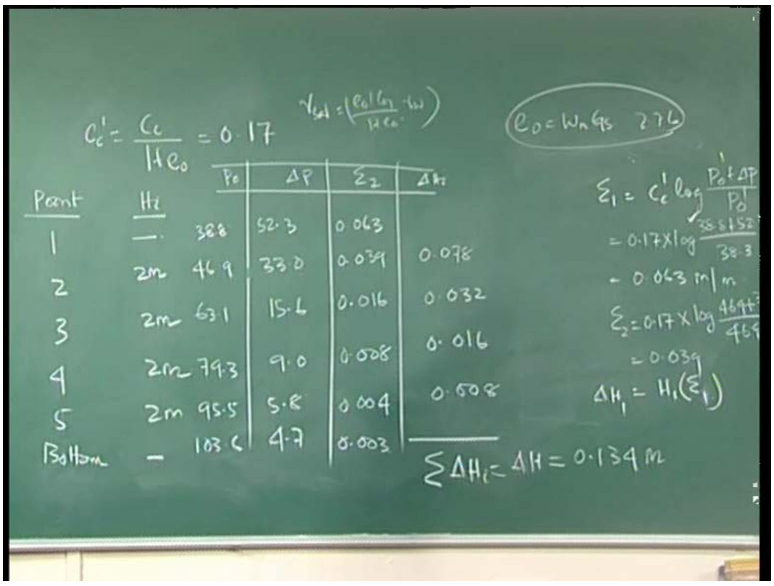

Now, c c prime is equal to c c by one plus e zero. From there c c prime is equal to 0.17. Now, you will calculate obtain delta p increase in stress increase in stress is already given below the footing below the footing. Now, it has been calculated based on Boussinesq's theory. it has been calculated based on Boussini's method based on Boussini's methods Boussini's method.

Now you can calculate the settlement. Here this is in tabular form, this is your point and this is your h i. So, this will be one two three four five then bottom, then h I, this is blank, this is two meter, this is again two meter, this is two meter, this is two meter and this will be blank. So, this is your p zero then delta p then xi two then delta h i. Now first layer p zero is we have already calculated 38.8, second is your already we have shown it 46.9 third is 63.1, 79.3, 95.5 then 103.6, then delta p is equal to 52.3, 33.0, it will be 15.6 then 9.0 5.8 4.7. This increase in stress due to Boussinesq's equation, Boussinesq's method it has been calculated and shown here or particularly here two, two meter it has been shown here 52.3, then at the center it is 33, then at the center it is 15.6, then here at the center it is 9.0, then here at the center it is 5.8, then bottom it is 4.7.

Now xi two, you can calculate this is your strain c c prime log p zero plus delta p by p zero so which is equal to 0.17 into log 38.8 plus 52.3 divided by 38.3 which is equal to 0.063. Now xi two is equal to also 0.17 into log 46.9 plus 33.0 divided by 46.9 which is equal to 0.039. The typical calculation is given for xi one xi two xi three xi four xi five xi six. If you look at here, this train one means at .1, first layers train at .1 so it is c c prime log p zero plus delta p by p zero. So this will be 0.17 into log 38.8 and the plus 52.3 divided by 38.3. This will be 0.063 zero six three.

Similarly for xi two, for second point 0.17 log if you look at 46.9 plus 33.0, so it will be 46.9 increase in stress is your 33.0 divided by 46.9. So, this will be p zero prime, p zero prime plus delta p divided by p zero prime. So p zero prime is p zero prime is forty-six p zero prime is your in this case second case is 46.9. That means increase in stress. First case it is 38.8, so it is 38.8, so increase in stress by means of Boussinesq's; it is 52.3. It will be 52.3. So now this values I have written 0.063, this is a typical calculation. So, 0.039, then 0.016, 0.008, then 0.004, then 0.003. Now, increase in means particularly change in height change in height will come from your strain. So, this will be this minus this. So, it will be coming 0.078, then this is coming 0.032 0.016 0.008 sorry this delta h is coming delta h is coming height h one into xi two or xi. Delta h one is equal to height h one into xi one.

So change in height delta h is equal to what is your height? H one is equal to that is your two meter into xi one how much is your xi one? 0.63 So, from there it is coming 0.078 0.032 0.016 then 0.008. Now, with this delta h i is equal to delta h which is equal to 0.134 meter. This is nothing but, delta h change in height is nothing but, a change in this is nothing but, your total settlement. Total settlement, expected settlement is equal to 0.13 meter below the footing. So this problem is a kind of solved one. Example problem, how the consolidation how the consolidation is going to be used for particularly settlement calculations. If you look at this consolidation particularly used for settlement calculations initially this e versus change in height versus log p is given from this because this soil sample is taken at a distance 3.5 meter below particularly this layer of soil. Once soil has been taken and consolidation consolidation test has been done this graph obtained. With this graph once again you can get it your e zero value. You can get it e zero as as well as also you can find it out what is your also c c. c c you can get it either you get it c c from here or you can get c c from empirical co-relation.

So here c c we got it from here. I have written earlier c c by means of empirical co-relation. With this you can get it also empirical co-relation if it is not given 0.009 into w l minus ten. If this is not given this e versus log p is not given then you can get it here if it is given do not use, you can get it from your slope this is called virgin curve from this slope you can get it. What is your c c? Once you get c c e zero you get it then, c c you got it. Once you got e zero and c c you can find it out your g. You see e zero is equal to w n into g g s specific g s.

So this e zero you got it from here, natural moisture content of this soil at this depth it is given w n is given. So, from there you can find it out g s. So, g s is coming 2.76 two point seven six. Once you get the g s from here, then your next step is initially the gamma is not given. Initially gamma saturated was not given so, with this value with this value e zero g s with this value you have to calculate your gamma saturated. So then, what is your gamma saturated? Your gamma saturated is equal to this is your e zero plus g s by one plus e zero into gamma w. This is your gamma saturated you can calculate. Once you get your gamma saturated this comes from particularly e zero g gamma saturated whatever the available data for this consolidation test from there and c c you can find it out consolidation. Once you get it gamma saturated, then find it out second step is your find it out p zero prime over burden pressure at this from here to here.

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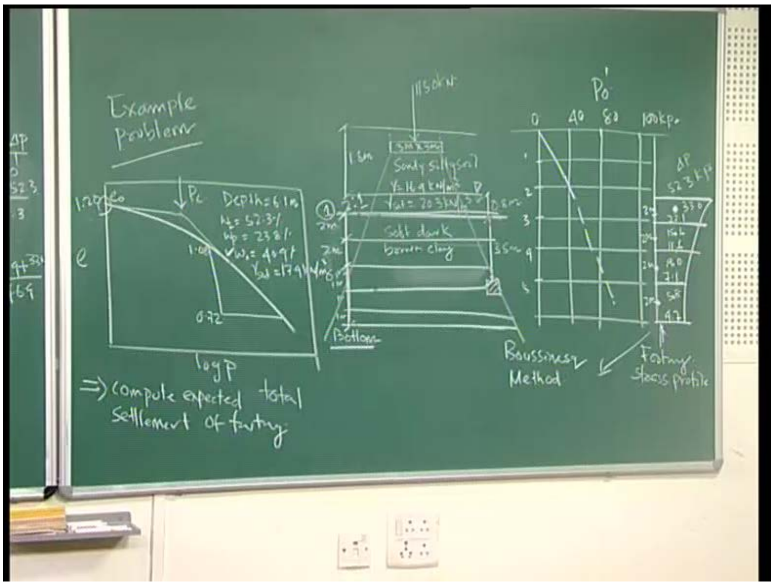

So that means p zero prime I have shown the calculations particularly here because this is your clay layer where this consolidation settlement is going to happen. So, this means this clay layer has been divided into equal number of layers of one, one meter of one meter. With this one meter at this, what is your p zero prime? If you look at the calculation p zero prime has been done this is your particularly this, this is above this soil has no water table effects. So, that is why 1.8 into gamma 16.9 and below this 1.8 there is your water table. So once water table is there, you have to use submerged unit weight. So that means your gamma saturated is given 20.3. So, submerged is equal to gamma saturated minus gamma w you calculate particularly this layer this layer this layer and you proceed.

So, this is your typical plot I have shown this plot variation of p zero versus the depth how this effective over burden pressure is varying. Once you get effective over burden pressure next step for settlement calculation you have to find it out increase in stress delta p. So, delta p increase in stress delta p from Boussinesq's theory you can get it. Either boussinesq's theory you can get it or by means of two is to one distribution or by means of two is to one distribution two is to one distribution you can get it.

So here, because this is a lower point load acted upon this footing; Boussinesq's theory has been used to find it out increase in stress because of footing in this clay layer. Because consolidation settlement is going to occur in this clay layer so increase in stress because of footing in this clay layer so this has been calculated so every two, two meter interval how much is your increase in stress? So, if this is the two meter interval so increase in stress here 52.3 that means increase in stress here is 52.3 then two meter interval 22.1. So, we are going to calculate the settlement at the center of the layer so that means this is your 33.1. So, here it is going to be 11.6 then 22.1 and at the center it is 15.6 then another two meter it is 7.1 and here 11.6. So, it will be 9.0. So, last layer is your 4.7 and 7.1 at the center it is 5.8.

Now, once you get the delta p increase in stress either from Boussinesq's method or by means of two is to one distribution then, write it column wise. So, every two, two meter interval we got our increase in stress. So, this is not one, one meter interval this is every two, two meter interval because stress increase also we got it every two, two meter interval. So you write it .1 .1 is at this point. This is your surface you are writing at the point, not surface. This clay layer starts from 0.8 to this is your this is your at here 0.8 here, it will be eight meter total clay layer is eight meter. So, this is your .1 and this is your bottom. Now, .1 height of the solid is 0 and p zero has been written 38.8 and delta p is written 52.3 and from there this strain has been calculated though the strain formula is c c prime log p zero prime p zero prime plus delta p by p zero prime.

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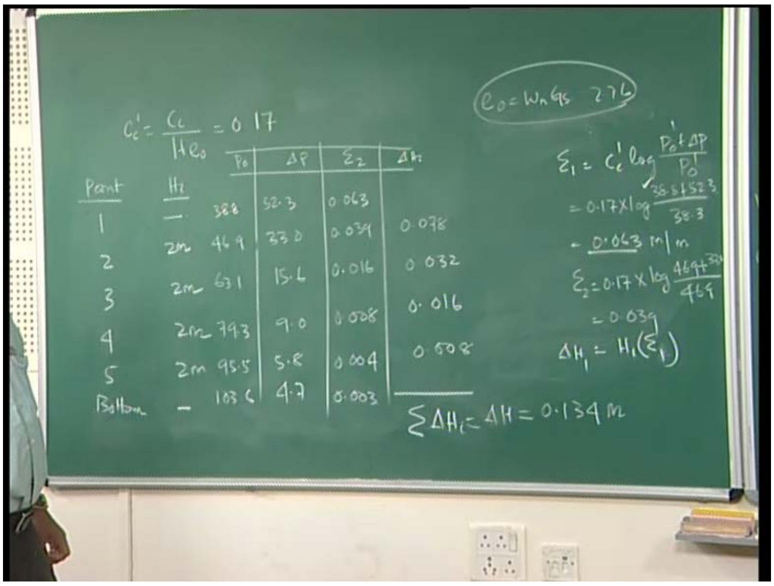

So here you are getting 0.063. So calculated 0.063 next point is your .2 if I mark it here, this is my .1, this is my .2, this is .3. It will continue and this is your bottom. So, .2 particularly, .2 height is equal to two meter and p zero is equal to 46.9 whatever we calculated and increase in stress delta p if you look at here delta p it is your 33.0. Initially it is 52.3 at the surface. At the center it will be 30.0. Now, from there you calculate your xi two. Then similarly, your .32 meter 63.1 15.6 all you calculate p zero and delta p you just calculate one by one. Then once you calculate p zero delta p then you calculate your xi two, then find it out settlement. The settlement is nothing but, your h one into what is your strain. So, every cases h is equal to two two two two two meter. So, it is two into what is your change in strain, you can multiply you can calculate your strain, calculate your settlement then add it. So, total settlement consolidation settlement will be 0.134 meter.

So this is one one of this example, solved example problem. I just solve it so it may helpful particularly this assignments problems later on. One more problem I am giving this as an assignment may be student can practice. You can practice this one more problem as an assignment so, you try at your home. This is simple assignment problem. It is given p kilo Newton per meter square versus void ratio, different void ratio from the laboratory. This value has been given so first load unload and reload. So, plot first e versus log p diagram, e versus log p. Once you get e versus log p from there you find it out what is your c c. Then c r , then you find it out p c.

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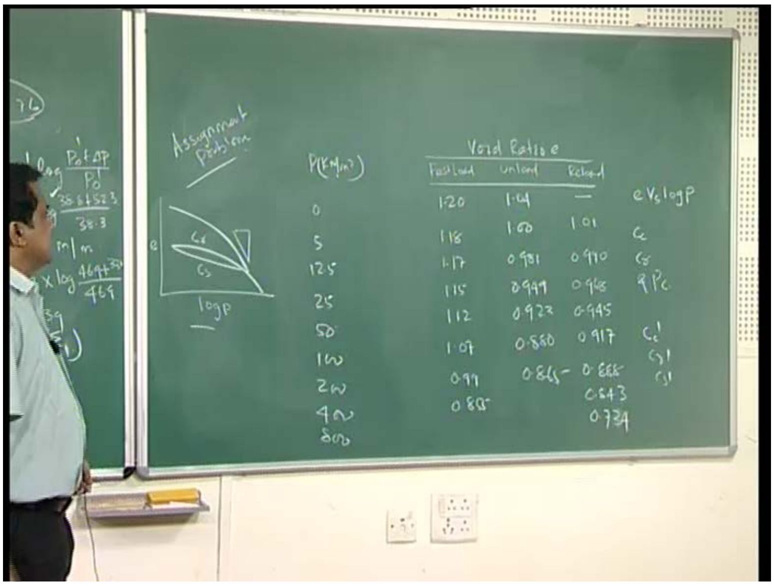

So this kind of curve will come e versus log p, this type of curve will come once you get it once you get it then find it out your c c slope of this. Then find it out your c c s find it out your c r, then once you get it, then find it out pre consolidation pressure from this curve you can find it out pre consolidation pressure and you do it in the graph paper and do it very neatly so that you can you will you'll get the appropriate results. Use your scale, proper scale it will be e versus log p diagram. So this is one assignment. So try and do it. Once you do it from there you can find it out what is your c c prime c c prime, c r prime, c s prime that you can do it. Suppose this is e versus log p is there from this diagram can you plot strain versus your log p. That you can think strain versus log p if you can do that would be fine. Thank you.