Foundation Design
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Lecture - 8B
Settlement Analysis- Part 2

Last class, I have started settlement analysis example before application of building load. Actually total settlement is settlement due to heave it may be negative if I am considering settlement of immediate as well as consolidation settlement downward is positive. So, total settlement is settlement due to heaves immediate settlement and consolidation settlement considering heave settlement is very small it has been neglected.

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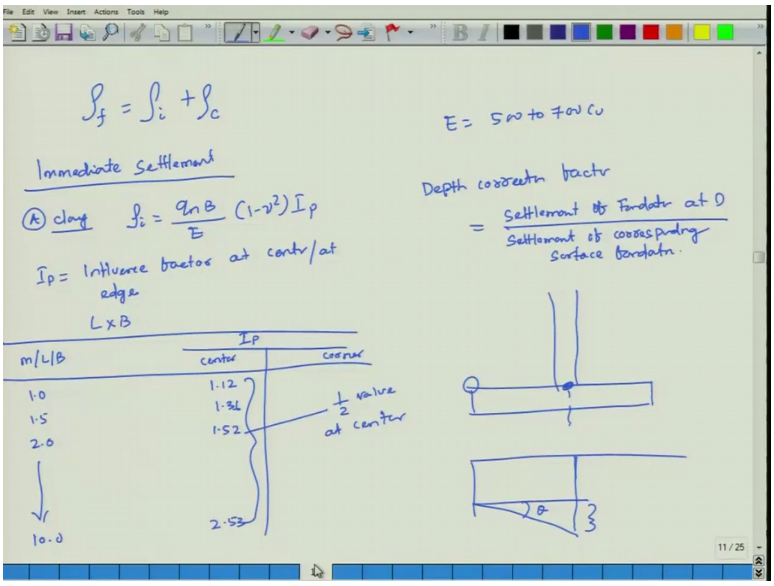

So, it is immediate as well as consolidation settlement then immediate settlement for cases of clay.

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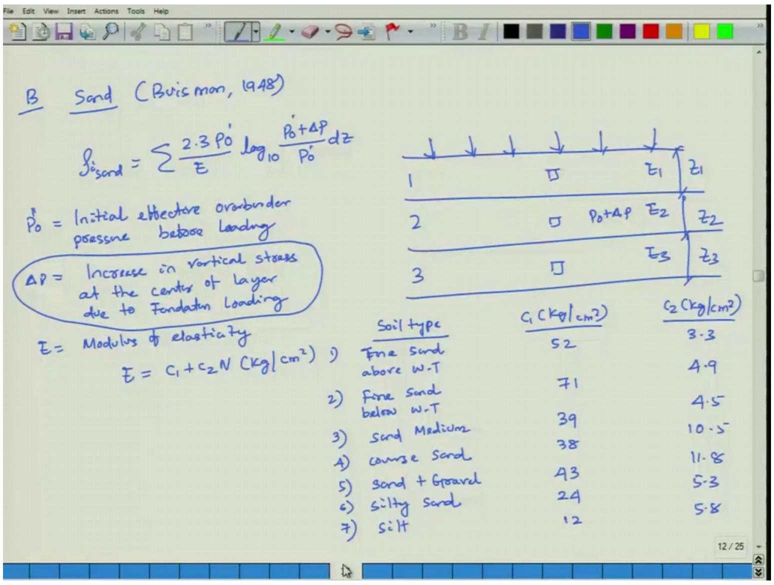

And for sand we have considered 2 theories Buisman 1948. Then another one is your Schmertmann and Hartman 1978.

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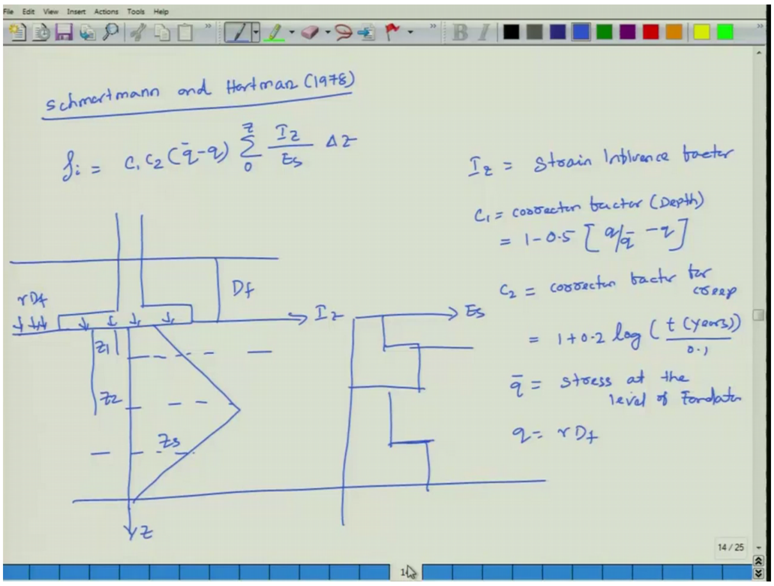

So, these we have covered. Now come to consolidation settlement consolidation settlement. Consolidation settlement if I write it rho c is equal to epsilon z into d z integration.

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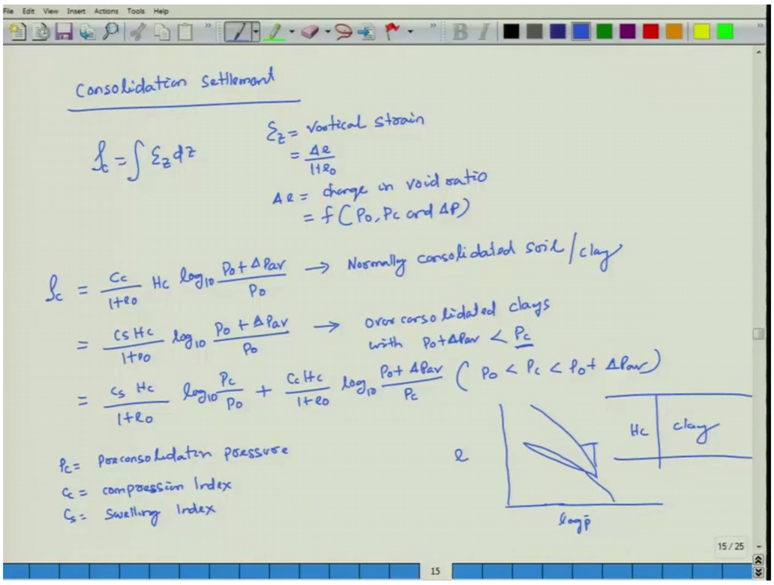

Epsilon z is equal to your vertical strength, which is equal to delta e by 1 plus e 0. And delta e is your change in void ratio, change in void ratio which is equal to a function of P 0 pc pre consolidation pressure and increase in stress due to external loading that is your delta p. So, consolidation settlements general it is Cc by 1 plus e 0, Hc log 10 P 0 plus delta P average divided by P 0. It is for normally consolidated soil. And which is equal to also Cs Hc by 1 plus e 0, log 10 P 0 plus delta P average divide by P 0. This is for over consolidated clays, with P 0 plus delta P average is less than pre consolidation pressure. Pre consolidations pressure how we will get it.

So, that part is has been covered in consolidation in soil mechanics also. Again it is Cs Hc by 1 plus e 0, log 10 pc by P 0 plus Cc Hc by 1 plus e 0 log 10, P 0 plus delta P average divided by pc. So; that means, in this case P 0 less than pc less than P 0 plus delta P average. So, pc is your pre consolidation pressure. Cc is equal to compression index and Cs is equal to swelling index.

Now, if you look at the consolidation theory e versus log p. So, for normally consolidated soil it is Cc by 1 plus e, 0 Cc is your slope of your origin curve right. So, swelling index coefficient of compression, this is a compression curve this is excavations swelling then this is recompression curve. So, s is your height of the layer height of this soil total height of the soil it is your Hc compress layer, if it is a clay log 10 P 0 plus delta P average by P 0 delta P average I will I will get back to you.

This is for your normally consolidated soil or clay normal consolidated soil or you can write it clay. Similarly, for this part from here to here, it is Cs sc by 1 plus e 0 log 10 P 0 plus delta pa v by P 0. This is over consolidated clays particularly when P 0 plus delta pav is less than 0 pre consolidation pressure, then if pc is lying between P 0 over burden and P 0 plus delta P average. In that case it is Cs sc by 1 plus e 0 log 10, pc by P 0 plus Cc by sc divided by 1 plus e 0 log 10 P 0 plus delta pav by sc.

Let me draw layer here, this is your clay layer and there is some errors here it is your ground water table. Then footing is resting here.

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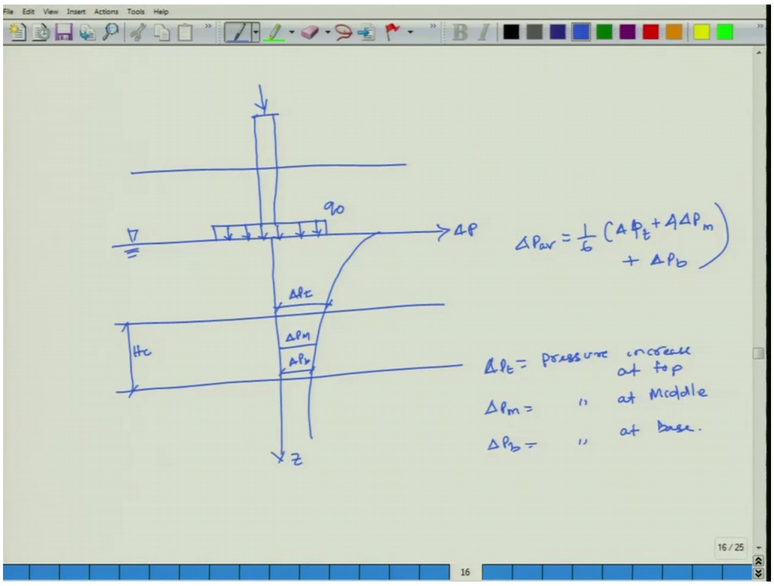

So, this will be q 0, and this layer particularly this layer is your sc or clay soils. Here if I draw it here, load intensity and this is your delta P, then this comes out to be here. This part is your delta P L delta PM. This is you delta Pb. And this is your depth Z. So, from how do get the average value generally average increase in increase of pressure may be approximated delta P average is equal to one-6th of delta L, delta P top delta P top, plus 4 delta P middle, plus delta P bottom. The increase in stress particularly in this soil layer it is not a constant with your depth. Rather it is decreasing at the bottom if I write it delta P t is your pressure increase, pressure increase at top. And delta PM is your pressure increase at middle, then delta P b is your pressure increase at base.

So, delta P average you can calculate considering increase particularly if this is your clay soil. This layer you want to find it out consolidation settlement, then find out in increase in stress at the top of the layer, at the middle of the layer, at the bottom of the layer; that means, b then you can find it out delta P average is our 1 6 delta P top plus 4 delta P m plus delta P at the base.

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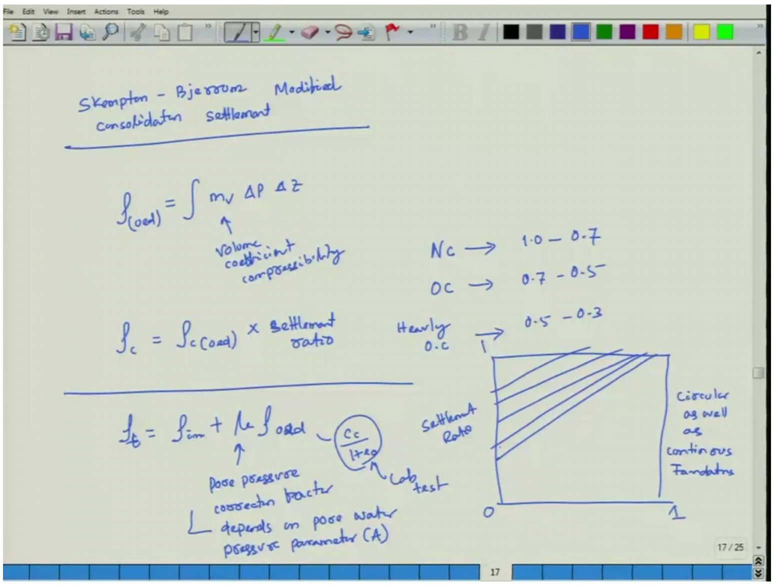

Next part is your Skempton, modified your coefficient (Refer Time: 10:34) means particularly consolidation settlement this is your skempton and Bjerrum modified consolidation settlement. So, it will be rho odometer. That means, consolidations settlement from your odometer test; that means, from your consolidation test suppose to be integration of mv, delta P into delta z mv is your mv is your volume coefficient compressibility volume coefficient compressibility.

So, then you can find it out in the field taking into consolidation of in the consolidation settlement in the field, it will be consolidation settlement in odometer in to settlement ratio. So, you can get it this mb from your consolidation test, I hope this as covered primarily in soil mechanics particularly in our consolidation part. So, he further said they further particularly based one their laboratory study they further said consolidation settlement is your immediate settlement plus your mu into rho odometer. Rho odometer test from consolidation test mu is called pore pressure correction factor, mu is your pore pressure correction factor pore pressure correction factor and it depends upon your pored pore pressure parameter A, depends on pore water pressure parameter A.

So, they have given graphical values also from there you can take it, generally for rough design per nc normally consolidated clays the value of the correction factor is taken as 1.0 to 0.7 for hour consolidated clay oc the mu value has been taken as 0.7 to 0.5. Then for heavily over consolidated clay over consolidated clay this value will be 0.5 to 0.3. They have given certain charge you can collect it in a book foundation design in a analysis by bowels as I said. From there it is your settlement ratio, and this is varying from 0 to 1. Here also settlement ratio this is varying from 0 to 1. And they have given for this chart is there it is for circular foundation circular as well as for continuous foundations.

So, this is how it has been modified in the consolidation settlement if I put it in summary. The consolidation settlement rho c is your epsilon z into d z. And this is your vertical strength and it is delta e by 1 plus e 0; that means, change in void ratio delta is your change in void ratio it is a function of over burden pressure, pre consolidation pressure and increase in your stress. And consolidation settlement has been given for normally consolidated soil over consolidated clay and over consolidated clay particularly P 0 plus delta pav is less than pc. If pc is lying between P 0 to this P 0 plus delta pv, and these are all 3 sets of equations.

And from there this is your compression index Cc is your compression index Cs is your swelling index. Cc this compression index you can get it from your origin curve Cs you can get this slope of swelling and recompression index you can get it slope from here. You can write it Cs sorry Cc, Cs crc recompression or Cs some time z. This you can get it from your consolidation graph e versus log P.

Then how to calculate delta P average it is one-6th of increase in stress at top then 4 times increases in stress at middle, then increase in stress at the bottom then again it has been modified by skempton considering your mb, this is your volume coefficient compressibility you can get it directly from your consolidation odometer test and finally, they have suggested total settlement total settlement is your immediate settlement plus mu into odometer settlement considering consolidations means your pore water pressure correction factors. Whatever the value you are getting for these case Cc by 1 plus e 0 this is from your laboratory test.

So, from the odometer test you can find it out a settlement that is basically from your laboratory test and the pore water pressure corrections has been applied to simulate into true fact of your field for normally consolidated clay it is varying between 1 to 0.7 for over consolidated clay it is 0.7 to 0.5. Heavily over consolidated clay it is varying 0.5 to 0.3. Before I go to your stress part and other part settlement by these stress part methods.

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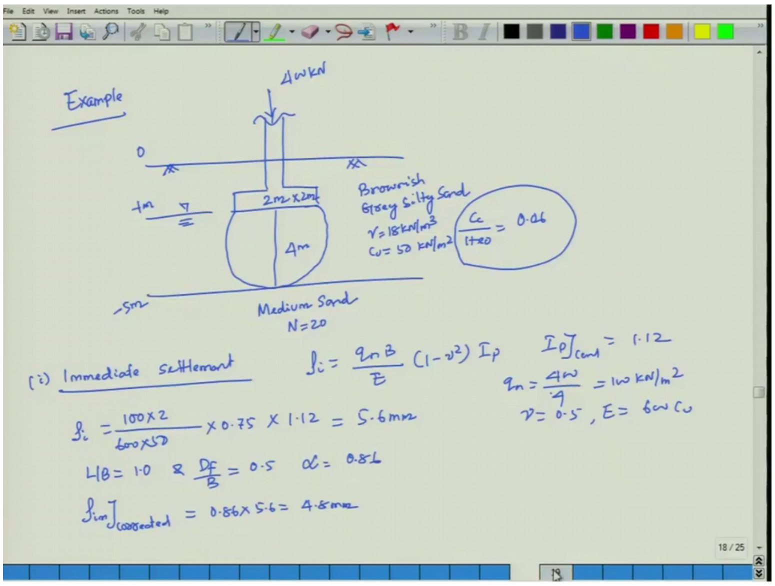

Let us solve one problem, and then only try for different methods one example. There is a case here; 0 meter here this is your ground surface. And there is a footing. Here it is your minus 1 meter water table is lying here. This is your minus 5 meter and beyond this it is a medium sand, n is equal to 20. And this width is your 2 meter. And this soil is brownish grey silty sand, silty sand gamma is equal to 18 kilonewton per meter q. Ogden coefficient is your 50 kilonewton per meter square from laboratory test Cc by 1 plus e 0 this parameter getting 0.06. And find it out your settlement total load coming one to the footing is your 400 kilonewton. This is what is your example: there is a proposed side of 0 to 5 meter water table is located at 1 meter below your ground surface footing size is 2 meter.

So, then the load excepted load from the column is your 400 kilonewton. And it is a brownish grey silty sand gamma is given 18 kilonewton per meter q; Ogden coefficient 50 kilonewton per meter square. Cc by 1 plus e 0 from your consolidation test it comes out to be 0.06. Now calculate because this is a silty sand calculate immediately settlement part one, immediate settlement. In these immediate settlement what is your formula, qn into b by e 1 minus mu square into ip, ip is given, ip at the center ip at the center it is your 1.12 then you calculate your values calculate your values.

So, this is your rho I is equal to qn what is the value of qn. So, qn you can always find it out 400 by 4. It is a 2 meter by 2 meter, it is a square footing 400 by 4, it is hundred kilonewton per meter square. Mu value is given 0.5, e you assume 600, cu based on the cu you can calculate e modulus of elasticity. And from there this is your 100 into 2 divided by 600 into cu value is your 50 into 0.75 into 1.12.

So, this is coming about to be 5.6 mm. Then depth correction factor has to be calculated. So, this is your L by b is equal to 1.0 and df by b is equal to 0.5. So, depth correction factor alpha is equal to 0.86. So, immediate settlement corrected, it is your 0.86 into 5.6 which is your 4.8 mm.

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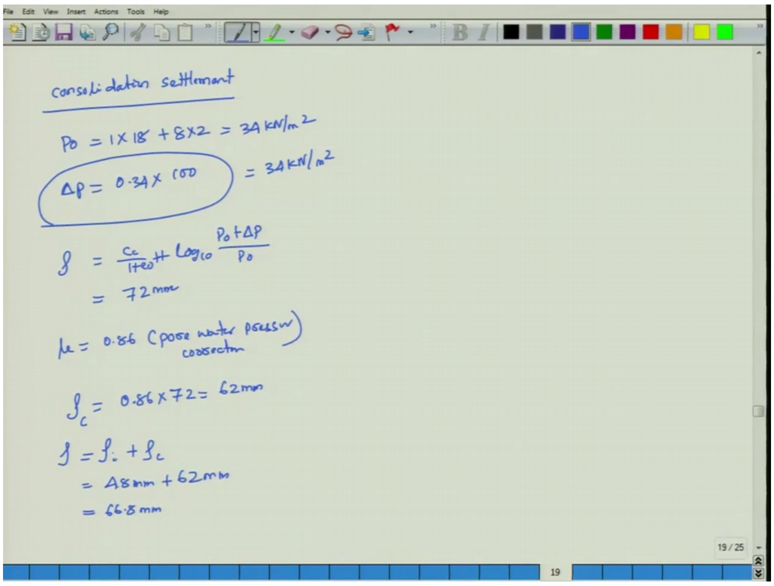

Now, come to your consolidation settlement. So, calculate P 0 if you look at here P 0 water table is at 1 meter and bellow 1 meter, 1 to 5 meter how long your pressure ball you can calculate you can take it into 2 times b. So, it will be 2 into 2 times it will be here 4 meter exactly it is at here. So, then calculate P 0. So, P 0 is equal to 1 into 18, 1 into 18 above of the water table bulk unit weight consider plus 8 into 2, where is your 8 into 2 submerged unit 8 minus 10. Gamma saturated assuming this is your gamma saturated. So, gamma saturated minus gamma w 10 or 9.81, it is come out to be 8 then here it is 18 plus 16, 34 kilonewton per meter square.

Delta P increase in stress because of your rectangular loaded because I have not covered that one stress increase in stress because of your external loaded that will be after your settlement. I just put it here for rectangular loaded delta P is equal to 0.34 into 100. 100 is your load intensity hundred kilonewton per meter square it is your 400 kilonewton here it is 2 meter by 2 meter. This part I will discuss after your settlement then again I come back to this problem.

So, this comes out to be 34 kilonewton per meter square. So, delta is equal to Cc by 1 plus e 0, Cc by 1 plus e 0, into h then log 10 P 0 plus delta P by P 0, which comes out to be 72 mm. Then you are considering pore water pressure corrections mu is equal to 0.86 this is your pore water pressure correction, then it comes out to be rho is equal to 0.86 into 72 which is your 62 mm. Now, immediate settlement is your 4.8 mm. So, total settlement is equal to immediate settlement plus consolidation settlement 4.8 mm plus 62 mm: so 66.8 mm. So, I will stop it here.

Next class I will go by means of stress path method to find it out your settlements.

Thank you.