Geotechnical Engineering II / Foundation Engineering

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Lecture – 22
Settlement of Foundation (Contd.)

Perhaps it would be the last session on Foundation Settlement and I have the very beginning I have mentioned that the settlement will be of 3; 3 components and elastic settlement we have discussed, then consolidation settlement and again soil consolidation settlement, soil can be of two types normally consolidated, over consolidated and accordingly how to modified our equation that also we have discussed. And that is one part to find out total consolidation settlement and after finding out the total consolidation settlement sometime, we may require the over a what time this consolidation settlement will take place or how much time is required to achieve certain degree of consolidation so that also we have discussed.

And we have shown some application also ah but now, I will try to take another problem where so far we have given either in a some problem I have taken that where we have CC is calculated based on empirical formula which is nothing but 0.009 multiplied by liquid level minus 10 that is one equation that is one problem we have done and but I have mentioned that, the CC typically can be obtained by using laboratory test data. Laboratory test data means you have to collect the sample and then you have to test it consolidation test you have to carry out, consolidation test means what you have to apply load and then you have to see when there is a no change in the dimension or compression is not taking places or so sorry if you apply the load and then you see that at some time there is no change of thickness; that means, under that loading consolidation is complete.

So, like that again after that if we apply another load p 2, then you will see what is the end of consolidation part that load and then if you apply p 3, then you see what is the end of consolidation under p 3, now apply p 4 and find out what is end of consolidation for load p 4. Like that we will get different pressure and for corresponding different compression and then from there we can find out pressure versus void ratio and that pressure versus void ratio data. If have, then if you plot in a similar curve a paper then

we generally we know that it will be a straight line particularly for normally consolidated soil and from the slope of that line we can find out the CC.

So, that is the another aspect I have mentioned that you can find out the CC from the laboratory e log p curve, but we have not taken any problem. So, now, I will be taking one problem where the complete application; that means, suppose a clay layer is there, from the clay layer some soil is sample is collected, the soil sample is tested, consolidation test is carried out and pressure versus void ratio is curve is given and then details of the clay layer is given. So for that what you have to do then to find out the consolidation settlement, we need to find out initial pressure one that is p naught, then because of the loading or the footing we have to find out a delta p that is increase of the pressure and then while applying the log formula then we need another term that is CC; that means, whatever e versus pressure data is given I will plot again and find out what is the value of CC.

once you get all those things then I can apply finally, log formula and get the total settlement and I will take this problem, then again it is another problem ask another question was asked that how much time it will take to achieve this much percentage of consolidation that; that means, application of the degree of consolidation also will be seen here.

So, all those three aspect in consolidation will be shown here. So, this problem so let us go to the problem.

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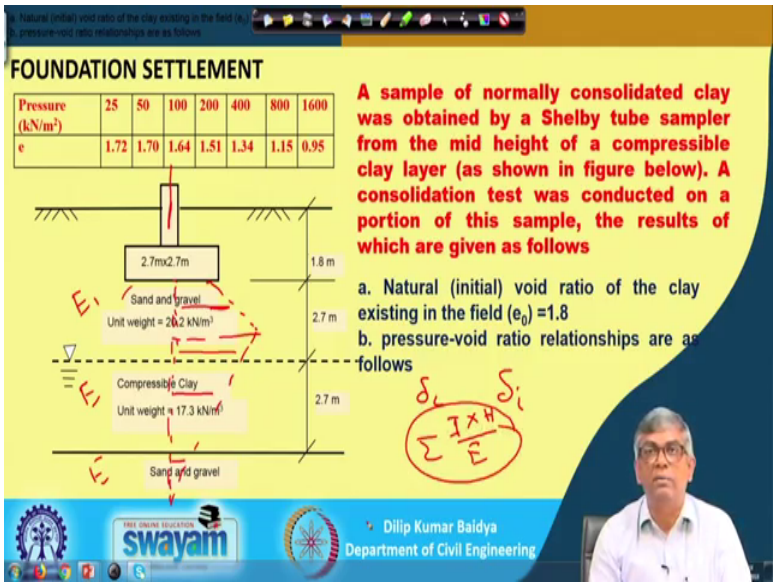

The problem is like this, we can see here a sample of normally consolidation clay was obtained by a Shelby tube sampler from the mid height of a compressible clay layers. So, that means, this is the clay layer actually this is the clay layer and from the mid height suppose sample is collected and and then tested, a consolidation test was conducted on a portion of the sample.

So, sample might have collected and some portion and then test was conducted on a some portion of the sample the results of the which are given as follows that is actually natural void ratio of the clay existing as the natural void ratio that is 1.8 and pressure void ratio relationships are as given as follows means, its table could have been here, but kept because of the space adjustment I kept here and you can see pressure 25 kilo Newton per meter square, 50, 100, 200, 400, 800, 1600. So this is the procedure we follow in consolidation test, then each pressure increment will be doubled from the previous one. So, initially 25, then 50, then 100, then 200, then 400, then 800 and 6 like that and when that 25 kilo Newton per meter square pressure is applied corresponding void ratio is 1.72, when 50 is applied then corresponding void ratio 1.7 100 corresponding at the of course, after application of the 100 pressure. At the end what is the void ratio that is the one is given here.

So, in 200 one point like that from 25 to 1600 pressure variation was there and for that e versus p is given and next actually still we are described the problem, that problem what is asked is not has come. So, I will go to the next point next slide.

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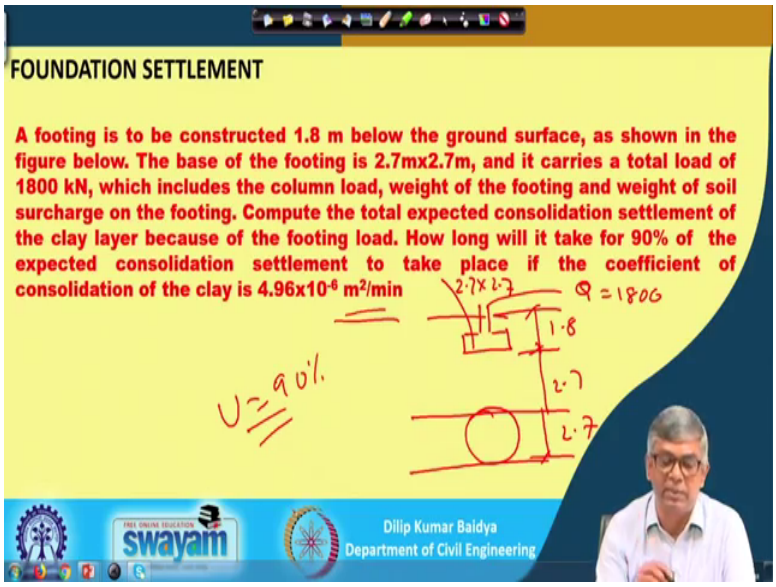

You can see here a footing is to be constructed 1.8 meter below the ground surface that means, so this is 1.8 meter one point meter below the ground surface as shown in the figure.

The base of the footing is 2.7 by 2.7, this footing dimension is 2.7 by 2.7 it is shown in the figure actually and it carries a total load of 1800 kilo Newton Q; become 1800 kilo Newton it is there in the previous slide and then compute the total expected consolidation settlement of the clay layer because of the footing load, there clay layer was somewhere here and some thickness was 2.7 meter and this is 2.7, this is also 2.7. And water table was; water table was at the let me see settlement of the clay layer because of the footing load.

How long will it take for 90 percent of the expected consolidation settlement to take place? If the coefficient of consolidation of the clay is 4.96 multiplied by 10 to the minus this one. So that means, because of this loading what is the consolidation settlement, we have to find out and for 90 U 90 percent how much time will take. So, this is the two parts so 3 parts are there. CC is not given, so from the e p plot e versus log p I will get CC then using that I will get consolidation settlement, after getting the consolidation

settlement next what I have to do? I have to find out again u ninety percent how much time it should take.

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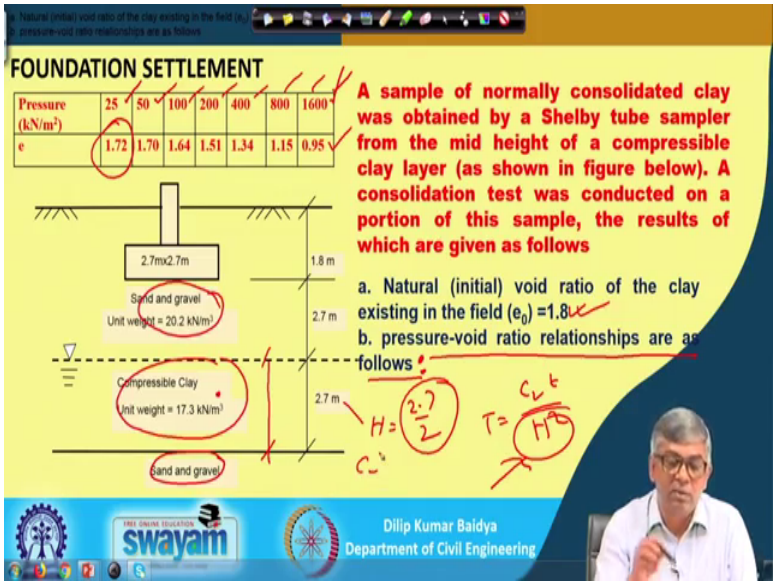

So, these are the different parts of this problem and you can see and you can see the problem here that your 2.7 by 2.7 meter and then your here actually sand and gravel, here also sand and gravel. So, this is another point while calculating the time in you need to use this one sand and gravel here, sand and gravel here. So, both top layer and above and below the sand and gravel is there. So, because of that it has to be considered as double drainage and if you have double drainage, then H will become in the equation would be 2.7 by 2. While calculating total settlement will be H equal to 2.7, but while calculating the time that T equal to c v t over H square these will be equal to this one, that is one thing to be observe and so with this detail actually, then let us and when I will find out the consolidation settlement we required CC first. So, let us go to that first and you can see now.

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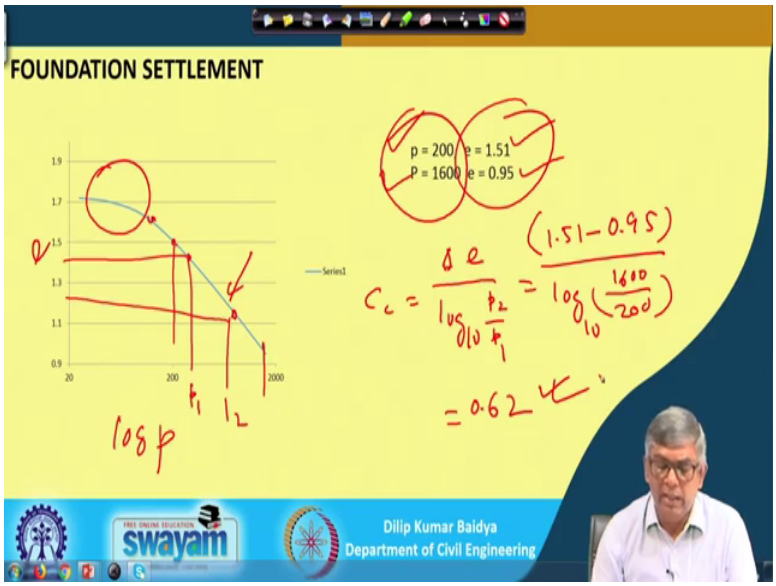

So, this is actually I have just plotted in the excel and you can see this is actually e and this is actually log p and e versus log p actually you can see as I mentioned that initial portion will be little curved and after sometime it will be straight line. So, it must be; that means it must be a normal consolidation case. So, then how to find out CC that mean I have to find out slope of this portion to find out CC and then what I will do? I will find out at this point what are the pressure and at this point what was the pressure, at this point what was the pressure ok.

So, these two points actually if I locate p is 200, e was 1.51 and p 1600, e was 0.95, then what would be the our what would be our CC? CC will be equal to delta e divided by log 10 base p 2 over p 1, so that means, I will put 1.51 minus 0.95 divide by log 10 base, p 2 will be sixteen 1600 and p 1 is actually 200. So, if you do this you will get a value of CC equal to 0.62. First job is done; that means, either you can take a graph sheet generally you have to take graph sheet even you are in exam hall because you may not have the plotting facility the exam hall or you can take excel when you will normally you practice and then put the value and fit in this form, then you will get a straight line by observing the curve you have to first decide whether it is a over consolidated case or normally consolidated.

Normally consolidated case how to know that you know that initial portion will be curve, but the major portion will be straight line. So, it happens from here to here actually the

straight line. So, when it is so, then any where two points you can locate and from there you can find out what is p 1, what is p 2 and corresponding what is e 1 and what is e 2. So, I two pressure value and corresponding to e value from there I got CC equal to 0.62.

And now if you want to find out consolidation settlement then, consolidation settlement let me draw the footing first.

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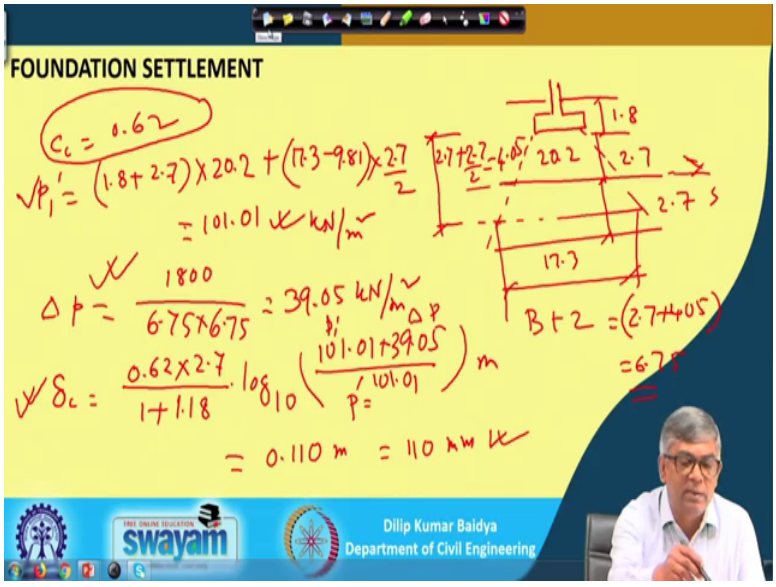


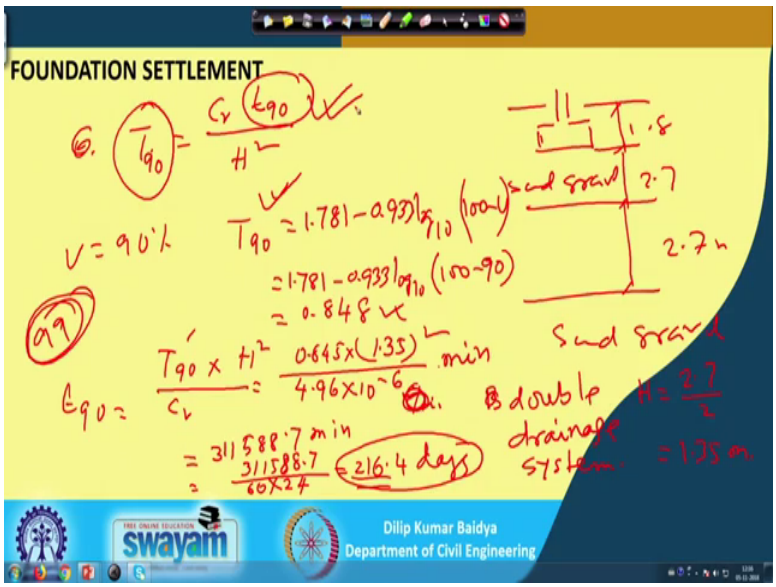
1.8, 2.7, 2.7 and water table is here only and if I put dispersion like this and add these level what is the width I have to find out this will be equal to B plus Z and Z will be how much from here to here it will be 2.7 plus 2.7 divided by 2 and that gives you 4.05. So, this will be equal to B is 2.7 plus; plus 4.05 and that becomes 6.75. That is one thing and here actually your 20.2 sand and gravel, this was gamma is 20.2 and here actually it was 17.3.

So, I can find out now already I have got CC equal to 0.62 and then your p 1 will be; your p 1 will be equal to 1.8; 1.8 plus 2.7 this is sand and gravel and unit weight is 20.2 plus your clay layer that is 17.3 that is actually 17.3 minus 9.81 multiplied by what is the depth actually 2.7 by 2. So, then if we do this one, then how much it comes this is this will coming 101.01. So, p 1 dash effective stress effective 1 1 pressure before application of the load is this one.

Now I have to find out delta p, delta p will be equal to how much I know the load applied was 1800 kilo Newton per meter square; 1800 kilo Newton divided by footing size, footing size at the level of the middle of the clay layer was is become now based on calculation B plus Z it becomes 6.75 its square footing so 6.75. So, this gives you a value equal to 39.05 kilo Newton per meter square this is also kilo Newton per meter square. Now if this is the one then you will have delta consolidation will be equal to CC that will 0.62 multiplied by H actually 2.7 divided by 1 plus actually your e value is given 1.18, 1.88 1.18 multiplied by log 10 base; log 10 base your 101.01 plus 39.05 this is p 1 dash and this is delta p divided by p 1 dash that may equal to 101.01.

So, this one if you calculate it gives you zero point this will be in meter 0.110 meter. So, it will be nothing but 110 millimeter. So, this so already I have taken one or two problem similar only the up to this only what is the difference in this problem, I have a CC was not given. So, what I have done, I have plotted e versus log p and from there I have calculated the slope and that slope is nothing but CC, that CC I have taken here otherwise p 1 dash calculation is similar delta p calculation also similar and equation also the same by using this I will get a settlement equal to 110 millimeter.

So, this is actually first part of the problem is done. Now I want to now second thing is mentioned that, if the coefficient of consolidation is this much what will be the time required to achieve 90 percent degree of consolidation for that actually I will take second step. So, let me go to the second part let me erase this and go to the second part. (Refer Slide Time: 18:38)



So, your you know that footing was something like this once again let me draw this is 1.8 and this is 2.7 and this is 2.7, this is also 2.7 and this is and then sand and gravel here ; sand and gravel here.

So, so that mean this is a both were drainage or double drainage system; double drainage system. So, double drainage system then your H equal to; H equal to 2.7 by 2 equal to 1.35 meter this is one part. Second thing is our calculation depends on T, T equal to or T 90 equal to C v t 90 by H square so that means, T 90 means what degree of consolidation time factor corresponding to 90 percent degree of consolidation and T 90 means what? Time required to achieve 90 percent degree of consolidation. So, I have use additionally instead of T, I use T 90 this capital T also I have used T 90.

Now, degree of consolidation U is 90 percent. So, I have to find out T 90 and as I have mentioned that T versus U there are two sets of equation. So, it is 90 percent degree of consolidation that means, above 60 percent. So, I will use second set of equation that that T 90 will be 1.781 multiplied by 0.9333 multiplied by log 10 ; log 10 100 minus U. So, if I put that 1.781 minus 0.933 log 10 100 minus 90, then we will get a value equal to 0.848 you can see exactly for 90 percent it is the value 848.

Now,so, I go back to this equation; if I go back to this equation then I will get T 90 will be equal to T 90 multiplied by H square divided by C v. So, this will be T 90 become 8.848 and H square become 1.35 whole square divide by C v is actually given your 4.96; 4.96 multiplied by 10 to the power minus 6 and this is actually given meter square per minute so; that means, you can see here actually there is a meter square and here there is a meter square get cancelled. So, all the this minute will come. So, ultimately this unit of this expression will be in minute. So that means, it T 90 I am getting this in minute. So, this calculated value if I put this value comes in the range of 311; 311 ah, then 588; 588 0.7 minute.

When I am express in minute is a large value so then, I what I will do divided by 311588.7 divided by if I multiply; if I divided by 60, then it become minutes to hour. Again further if I divided by 24, then it become days and if I do if I want to get in days, so I if I do this much then you will get in days and if the days become very large again I can convert into month or it can be into year also. So, if further I can divide by 30 then it will be in month, then again further if I divided by something then it will be year also, if

I divided by 365 then it will become year also. So, by doing this I will get it will be 216 ; 216.4 days.

That means this problem whatever is asked and you can see because of double drainage I have use this half the thickness. So, that ultimately; that means, the whatever problem was given for that problem through you will get a total settlement of 110 millimeter and 90 percent means 90 to 110; that means, 90 multiplied by 110 divided by 100 we get 99 millimeter so; that means, ; that means, in 216 days; 216 days will be required to achieve 99 millimeter of settlement and similarly, if you want to find out 50 percent settlement how was time it will required at you can you can change only this instead of T 90 I can use T 50, if it is mentioned that 70 percent then instead of T 90 I can use T 70 like that any percentage it mention accordingly I find out the T and then I use this equation to find out the time required. So, this way one can find out the time also. So, this problem actually is a complete application of all those thing consolidation data from their calculation of CC and then applying log formula, find out the total settlement and then further applying the time factor equation I can find out the time required to achieve certain degree of consolidation settlement in the particular layer.

So, like this I we can do the problem, but once again I let me go back to the problem ah. So, this problem also similarly so this problem also in addition actually sorry, this problem in addition that here actually it is mentioned only total consolidation settlement delta c.

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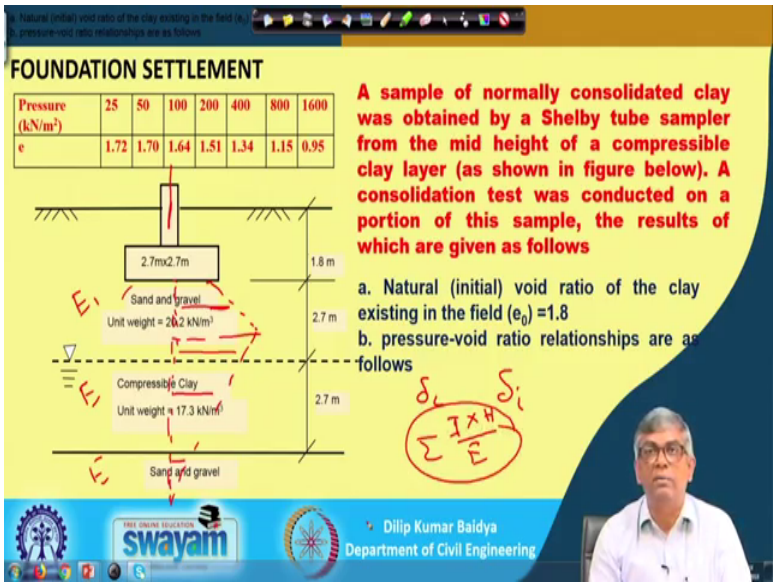

So, we may need to find out delta i also, if you want to find out delta i then again I keep could have drawn the Schmertmann influence chart and from there I find out i here, I find out I here, I find out i here, I find out i here and then if I know the e value here, e value here and e value here then again I can find out the delta i.

So, then calculating this two together I can find out the total consolidation total settlement of the of the; of the total settlement of this footing; that means, load is applied through this footing; that means, whatever settlement is taking place because of immediate or consolidation that will be ultimately that much amount footing will be settling that will going downward. So, the if you want to find out the total, then you have to find out in addition to that whatever we have done you have to use as a Schmertmann method which I have initially discussed and this is the way first corresponding the footing size, draw the influence diagram, then find out I at respective places, then sigma I multiplied by H divided by e and by that I can find out the settlement.

So, this the way one can find out the complete problem. So, with these I willa only one part is left actually that that may take a very 1 or 2 minutes that not much information available that is I have initially mentioned that settlement is a combination of three parts initial ah, then the consolidation and then your secondary compression; that secondary compression not much things are available I could have brought today, but there is some imperial method to calculate and sometime I will take that one and is not very that

important also. So, there is another part in the otherwise the constant settlement of footing considering various aspects I have already done. So, with this I will end here consolidation chapter and in the next class onwards I may take the soil exploration and different test, field testing etcetera I will take in the next class ok.

Thank you.