**Soil Mechanics/Geotechnical Engineering I**
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**Lecture – 45**
**Compressibility and Settlement (Contd.)**

Let me continue with application on consolidation calculation and time rate of calculation. I have shown three different types of application and let me take a few more, so that you will be familiar with all types of problem so that you do not have to face new problem ok.

So, this problem I will just take a first problem in this session, you can see in an oedometer test, oedometer test means that the consolidation whatever you do that is name is oedometer that has a at a standard dimension that mean diameter and thickness. This thickness sometime vary, so 12 to 20 millimeter, sometime it can be changed also.

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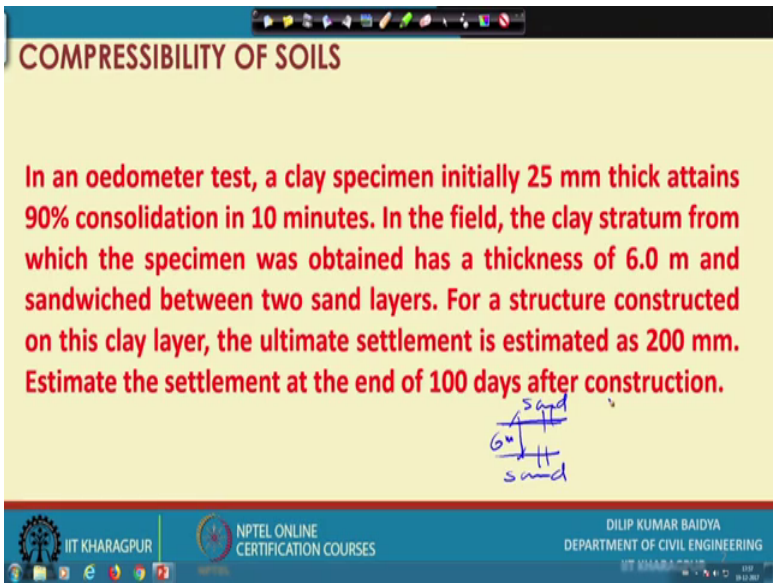


The clay specimen initially 20 millimeter thick attains 90 percent consolidation in 10 minutes. So, by giving that actually what we are getting some information that means, soil some property you will get, in the field, the clay stratum from which the specimen was obtained as a thickness of 6 meter and sandwiched between two sand layers.

That means, you can say in the field the sand consolidating layer was this much and this is actually of 6 meter thick, and below is sand above is sand.

So, instead of saying drained at both sides it is mentioned sand is between two sand layers that means, I from this statement what I have to assume I have to assume that draining from both up and downward direction both that means, this is a both way drainage problem. And for a structure constructed on this clay layer, thus ultimate settlement is estimated as 200 millimeter. End estimate the settlement at the end of 100 days after the construction. So, ultimate settlement is known, and you have to find out in 100 days how much it will be achieved, so that is the problem to be solved. So, let me see that.

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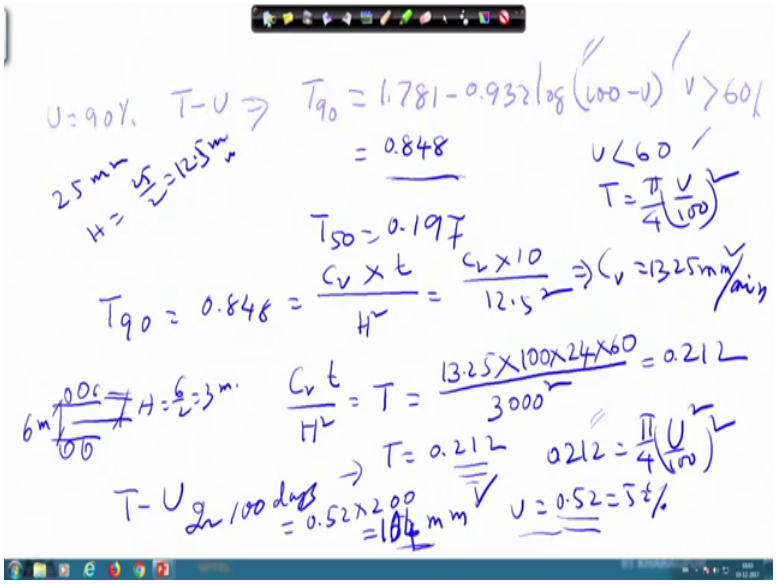


So, you can see in the laboratory test 90 percent consolidation U equal to 90 percent. So, T versus U actually then you refer and then from there you will get T 90. So, T 90 since I know the equation 1.781 minus 0.933 into log 100 minus U, so this is actually when U greater than 60 percent. And when u less than 60 percent your equation is T equal to pi by 4 u by 100 square. So, this is the way.

So, I have to use this equation. So, 90 percent is there, so it is 90. So, if I do this calculation, you will get 0.848. Sometime 50 percent and 90 percent consolidation many problems will be there. So, and from there actually you find out the coefficient of consolidation in the lab. So, it is better to remember also T 90 and T 50. So, T 50 actually

0.197; and T 90 is 0.848. Sometimes these two value better to remember, sometime it will be useful.

So, since I know T 90, so T 90 is known which will equal to 0.848, which will be equal to C v coefficient of consolidation of the soil into time which is actually 10 minutes here and C v by H square. So, here actually C v into 10, and H here actually will be how much since laboratory sample is 25 millimeter and then both sides, so H become 25 by 2 equal to 12.5 millimeter ok. So, it is 12.5 millimeter square. So, this gives you C v equal to 13.25, 13.25 millimeter square per minute.

Now, the in the field, 6, this is the 6 meter 3 clay layer, sand is here, sand is here. So, this is 6 meter. So, your H become, H equal to 6 by 2 equal to 3 meter. And they are actually we know the time 100 days. Now, I know the time how much time consolidation will be there. So, I know C v t by H square this is nothing but T equal to C v is already I know 13.25, t you already I know 100 days, so 100. Since, it is in minutes, so it will be 100 days into 24 hours into 60 I will put, so it will be a unit will be consistent in minute and so this is T and divided by H square actually 3 meter, so 3000 millimeter square I do. So, this gives you 0.212 so that means, I am getting now T equal to 0.212.

Now, I can refer T versus U curve from there corresponding to T equal to 0.212 what is the U, I can find out. Or a trial and error method I can do, I can assume that U between 0 to 60 percent, then I can use 0.212 equal to pi by 4 into U square U by 100 square. If I do this way and this gives you U equal to U gives you 0.52 or 52 percent. So, I got T, I have for T versus U. I have two equations; this is the one equation, and this is one equation.

So, I am assuming that that maybe U is between 0 to 60 percent. So, the what about T I have got for 100 days time, what is the T I have calculated and that I have equated with this equation, I am getting U 52 percent; that means, whatever assumption I have made that is correct, so within 60 percent. So, that we if suppose by this assumption U comes more than 50 or 60 then that means, your assumption was wrong.

So, in that case, I could have equated 0.212 with this equation. And from there I could have got U, but I do not have to do this because it has matched already. So, U become 52 percent; that means, 100 days whatever C v value was there for the soil for that value of C v, I and then in both side in a 100 days how much actually consolidation will take place 52 percent.

So, if it is 52 percent and total is 200 millimeter, so in 100 days in a 100 days, how much settlement will take place, it will be 0.52 into 200, so that will be equal to 52 millimeter. So, in 100 days how much consolidation is expected, it is only 52 millimeter because time factor you have got 0.21 T, from there we have got degree of set consolidation is 52 percent. So, 52 percent of 200, it will be it will be into 2 so 104, 104 millimeter is it not, 52 into 200, so 104 millimeter.

So, this is the answer ok. So, now let me go to the next problem. You can see in an oedometer test a clay specimen initially 20 so this is the problem I think we already done.

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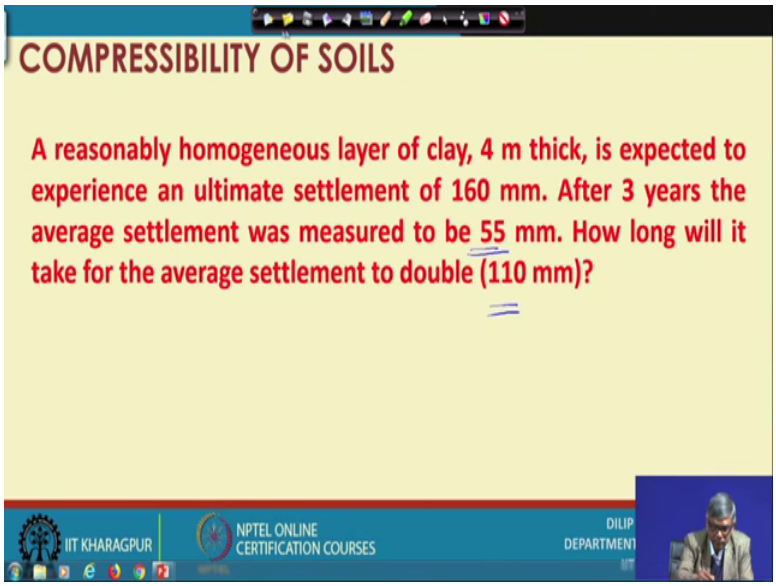


So, this is the second question, so a reasonably homogeneous layer of clay 4 meter thick is experienced is expected to experience an ultimate settlement of 160 millimeter. After 3 years the average settlement was measure to be 52 55 millimeter. How long will it take for the average settlement to double. So, 55 millimeter in 3 years it has come, so to become double how much time it will take.

So, this is the problem so that means you know a 4 meter thick clay layer, and it was consolidating. So, we have some measurement some mechanism by which suppose you have observed a meter settlement and ultimate settlement expected it is 160 millimeter. And we have suppose observing, and I found that we found suppose in 3 years, it settle

55 millimeter. Then for the same soil how much it will take to settle 110 millimeter, this is the problem.

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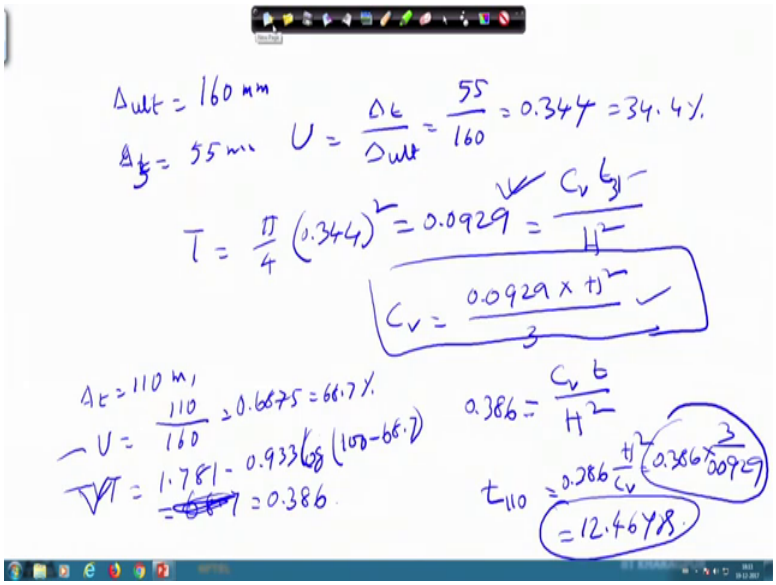


So, we will see that how to do. So, delta total delta actually ultimate equal 160 millimeter ok. And delta t that means, at time T it is 55 millimeter how much time it is 3 years suppose delta 3, so 55 millimeter. So, U become how much, U become delta T by delta ultimate ok. So, it is become 55 by 160. So, it is actually 0.344 and U become this much. So, I can find out, so that is 34 percent is it not, 34.4 percent. So, I can find out T corresponding T equal to pi by 4 into 0.344 square. So, this gives you 0.0929 T, and so that is again equal to C v t 1 or t 3 years suppose and divided by H square.

So, from here actually I can get C v equal to 0.0929 into H square divided by t 3 actually 3 years. Now, you can say H also known. So, you can put the value of course, you can calculate, but I am not doing because I can substitute this. So, you can see then when it is 110 millimeter settlement, when delta T equal to 110 millimeter, so U become 110 divided by 160 that is actually your 0.6875, 0.6875 that means, 68.7 percent. So, your T can be calculated at 1.781 minus 0.933 into log 100 minus U that means, 68.7. And if you do this calculation it comes your 68 point; sorry this will come 0.386, this is 0.386.

Now, for the 0.386 will be equal to again C v t by H square and both the soil actually H is same and C v is same. So, if I substitute from here C v equal to this, C v equal to this if you substitute in this equation, then from here I will get t for 110 millimeter. For t

corresponding to 110 millimeter settlement you will get a you will get T 2 will be equal to your T 2 or this is T 110 will be 0.386 into H square by C v. And then if you substitute, then it will become 0.386 into 3 by 0.0929.

So, this gives you initially in minutes then convert it will be 12.46 years. You can calculate this one. This one if I calculate then I will get 12.46 years ok. So, this is the weight. So, if I know the that means a very important thing is everywhere you can see the application of T versus U is very very important.

So, T and U most of the time for calculation at home, you can refer to the table you can refer to the chart graph in T versus U graph you can play refer, but in examination hall sometime, it is not it is not with you. So, that is why you have to remember this equation T versus U whatever different equation I have used the here this one, here I have used this one these two equation always you have to remember and then by different combination I can find out the unknown parameter which is required ok.

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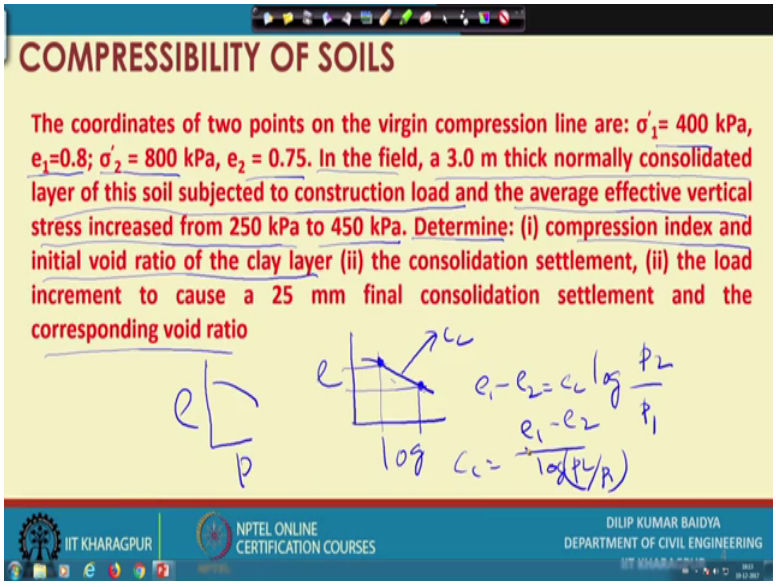


Now, let me go to the next problem. You can see the two the coordinates of two points on the virgin compression line are sigma 1 equal to this, corresponding to sigma 1 dash e 1 is this corresponding to sigma 2 dash e is this. In the field, a 3 meter thick normally consolidated layer of this soil subjected to construction load and the average effective vertical stress increased from 250 Kpa to 450 kpa. Then determine the compression index and the initial void ratio of the clay layer. Second the consolidation settlement, and

third the load increment to cause a 25 millimeter final consolidation settlement and the corresponding void ratio. These are the various things it is given here.

And actually that e log p curve that application of e log p curve what I have shown before. So, you know when you put e versus p, the curve is something like that. And when you put e versus log p, then it becomes straight line and slope of this line is actually your C c. So, you have to find out that, so that means on this bar this is a virgin compression curve, two points are given suppose one point is here what is the sigma dash what is the e 1 and this is what is a sigma 2 and what is the e 2 these things are given.

So, if this is given then your as e 1 minus e 2 will be equal to C c into log p 2 by p 1 that is the formula or the if this is a straight line, so C c will be actually e 1 minus e 2 by log p 2 by p 1. So, this is the if I want to find our slope of this line, this is the if I take two point at p 1 and p 2 and e 1 e 2, so this should be the expression. So, from there, so that is what on the virgin consolidation curve two points are given; using those two points you can find out the compression index. So, after using that I have to do the rest of the thing.

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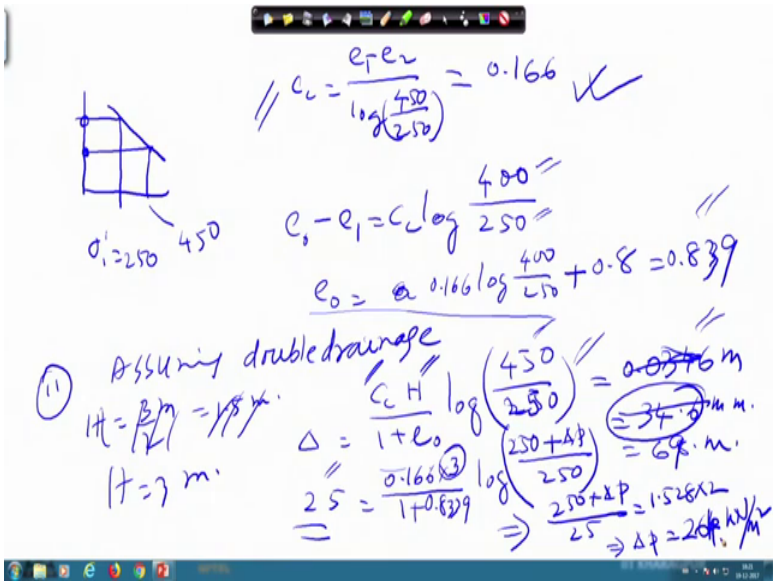


So, you can see now if I put according to given information suppose e versus log p curve and this is sigma 1 dash suppose that is suppose equal to 250. And this is actually suppose 0.8 and 0.75 I think, so this is values given. And another point is here this is 450 and this is corresponding e values there. So, this two is given. So, your C c will be equal

to e 1 minus e 2 divided by log 450 by 250 ok. So, from here we will get C c equal to 0.166.

Now, another condition is there when 250 c when pressure is 250, what is the void ratio you have to find out. So, pressure is 250 and 450. So, initial void ratio e naught suppose e naught minus e 1 equal to now C c into log that we had 400 pressure 400 pressure divided by 250 ok. So, from there actually you can see e naught equal to C c which is the value is known. So, I can put 0.166 log 400 by 250 plus e 1 is suppose 0.8. So, this gives you e naught will be equal to 0.839 ok, 83 8339. And. So, this is the first part compression index and initial void ratio ok.

So, the next is second part. Second part is assuming double drainage, it is not mentioned so always we assuming double drainage. And you can say H equal to [FL] meter 3 meter. So, H equal to 3 meter 3 by 2 so that means, double drainage, so it will be 1.5 meter and then your total delta will be equal to C c into log formula by 1 plus e into log 450 by 250 450 by 250. So, this will give you so all values C c can be up put here sorry H cannot be this, H will be thick full thickness here H will be full thickness. H equal to 3 meter and C c into H by 1 plus e e naught to be used e naught. And then if I do this calculation, then you will get 0.0346 meter or 34.6 millimeter.

And another problem is asked that what is the pressure required if you want to the 34 millimeter is the total called expected consolidation settlement. But I want to find out how much pressure required to have 25 millimeter of consolidation. So, I will see 25 millimeter consolidation, it is C c 0.166 into H actually it will be I think if I do this will be it will be double actually if it may become 68, 69 millimeter, it becomes 69 millimeter. And 0.166 into H equal to 3 meter and divided by 1 plus 0.8339 log. And we do not know delta p, so initial pressure is 250 plus I suppose delta p I have to find out divided by 250 because of what pressure we will have this much pressure settlement.

So, if I put in this way equation, and if I solve this so I will take this side then by simplifying we will get 250 plus delta p divided by 250 plus delta p by 250 will be equal to 1.528, 1.528 into 2 I think. So, by mistake I think I have taken a half of that before. So, if I do it will be this, and then from here I will get delta p will be something 132, it is it maybe 264, 264 it will be 264 kilo Newton per meter square.

So, the pressure will be so that means, what I have done I know the initial e log p curve just using that I have got the C c. Now, at a different pressure what was the initial pressure to find out so e naught minus e 1 400 by 250 from here I got e naught. So, 400 to at 400 I know e value and a 250 actually what is the e value I do not know suppose. So, I have to find out. So, I have got this way. And then after knowing that I have to find out the total consolidation, total consolidation settlement will be C c into H by 1 plus e naught log this is the formula. And this is the final pressure and this is the initial pressure. So, I will get this calculation, this will be maybe wrong. So, I will be multiplied by 2, so it will be 69 is the correct.

And then next second problem is what will be the pressure required to have 25 millimeter of consolidation. So, same formula I will be using initial pressure is 250 and delta p is the additional pressure required suppose then from there simplifying I will get delta p equal to this.

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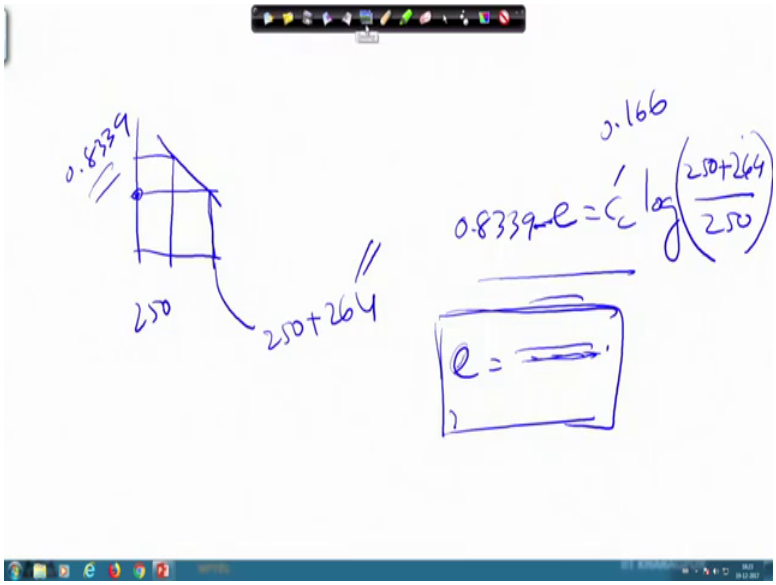


And then there is a last part of it that is if I know again e log p curve suppose the initial is 0.8339, and this is actually 250. And this is actually suppose whatever pressure I get, so 250 plus 264, this pressure is p 2, and this is unknown. So, I can find out 0.8339 minus e minus e equal to C c into log this will be 250 plus 264 divided by 250 from here C c is known 0.166 I can get e value. So, this can be calculate.

So, there is a error in my calculation perhaps. So, I will not be able to give the value this can be completed. And you can see from this equation, what is the value coming here you can refer. So, in my calculation look like there is a error here. So, because instead of 264, I have used in my calculation 132, so I do not have calculator right now. So, this calculation can be checked and then you can find out what is the value of e.

So, this value will be significantly smaller than that whatever value we have here. So, this is the third application. Then one more application is there let me explain the problem and this way that I can solve or not let me see.

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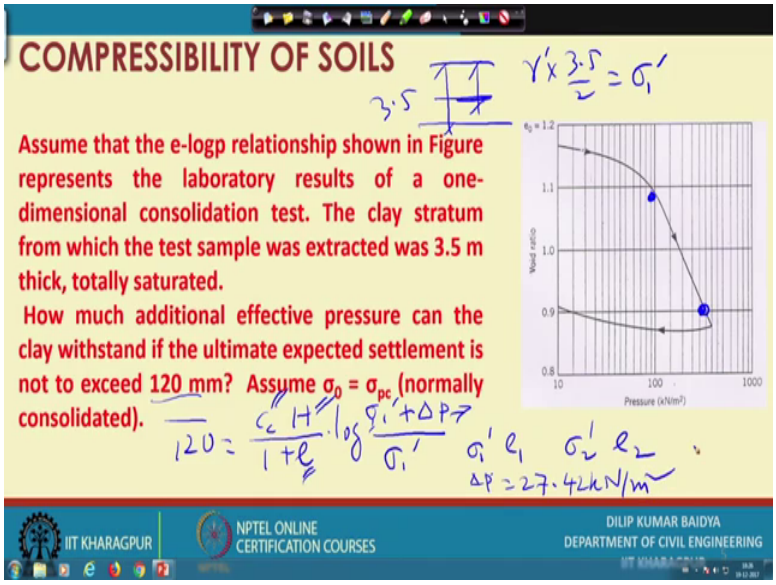


So, this is the problem actually. Sometime, the problem will be given like this assume that the e log p relationship shown in the figure represents the laboratory results of a one-dimensional consolation test. The clay stratum from which the test sample was extracted was 3.5 meter totally saturated. How much additional effective pressure can the clay withstand if the ultimate expected settlement is not to exceed 120 millimeter.

So, this problem actually earlier problem what happened I have given a two I have in the e log p curve I have not given there actually I have from the e log p curve one actually sigma 1 dash and e 1 sigma 2 dash and e 2 I have given. So, here actually I can find out this is a straight portion, I can find out one point here, another point here. I can read what is the value of sigma what is the value of sigma here, what is the value of e here, what is the value of e here by that I can find out the value of C c.

Once you get the cc and then I can again apply the formula similarly that delta is actually 120 maximum and C c is known, H also known 3.5 meter by 1 plus e I can find out from here. And into log actually as you can see additional can be so it has initial pressure is how much suppose the so soil layer is 3.5 meter thick 3.5 meter thick. So, then at the middle what is the effective stress, I can find out gamma submerse into 3.5 by 2 that will give you the sigma 1 dash. So, this will be sigma 1 dash plus delta p is unknown divided by sigma 1 dash.

So, everything will be known. This is known; this is known from here; this is known this is also known. So, only delta p the like previous problem one can find out. So, I am not calculating the all steps. You can please do the calculation and complete and find out what is the del p required. So, answer probably will be p del p will be equal to 27.42 kilo Newton per meter square. So, you can verify this and with this, I will stop here ok.

Thank you, I will not take this problem also.

Thank you.