Soil Mechanics/Geotechnical Engineering I
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Lecture - 46
Compressibility and Secondary Compression

Good morning friends and I welcome you all to this lecture on soil mechanics and or previously we have completed the complete compressibility aspect theoretical aspect. And then we have shown application also, but to at the end one or two application early done. Also there was some calculation mistake. So, I will repeat one or two with little slowly. So, that will be clear to you.

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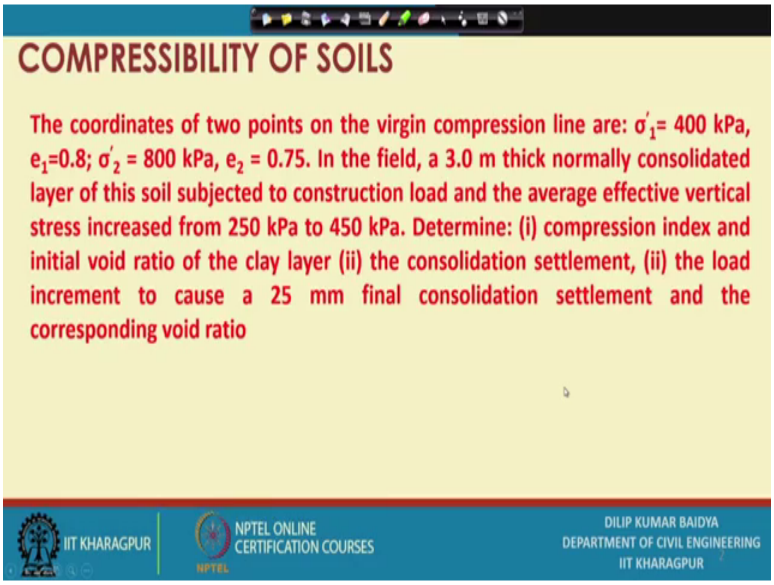

And so this is the problem perhaps I have taken yesterday also before also. But this problem so, let me see once again step by step calculation. And you can see the coordinate of two points and the virgin compression line are: this is sigma 1 and sigma 2 is given, 400 and 800 and e1 and e2 also given; 0.8 and 0.75. In the field, that means this as I have told you before that if you have the e log p curve and e log p curve actually will become finally straight line. And on the straight line if you can fix two points and from there we get we find out the slope of the line. And that slope of the line will be compression index. And in the field a 3 meter thick normally consolidated the layer of this soil subjected to construction load and a average effective vertical stress increased from 250 kPa to 450; that means, the pressure range 250 to 450. Initially was 250 and then finally, become 450.

So, determining the compression index and the initial void ratio of the clay layer; that means, compression index I will get from the the (Refer Time: 02:21) the data that is sigma 1, sigma 2 and e1, e2. But to get the initial void ratio; that means, the point on the curve given 400 and 800, but in the field actual initial pressure wall only 250. So that means, a 250 what was the void ratio that has to be determined. And as we know with the increase of effective pressure the soil will be consolidated and finally, void ratio will be decreased. That means at 400 pressure whatever void ratio was there, 250 were pressure void ratio will be higher than that. So, we have to find out that.

So, that is the one thing that is compression index first and then initial void ratio, then consolidation settlement; that means, there is a if you know the C c and using the log formula you can find out the consolidation settlement if thickness is known. And also the load increment to cause a 25 millimeter final consolidation; that means we may get based on that certain amount of consolidation. But the when pressure is increasing from 250 to 450, but if I want to keep the settlement range are limited, but 25ve millimeter, then what will be the pressure, that we have to find out. So, this is a problem in by a large detail.

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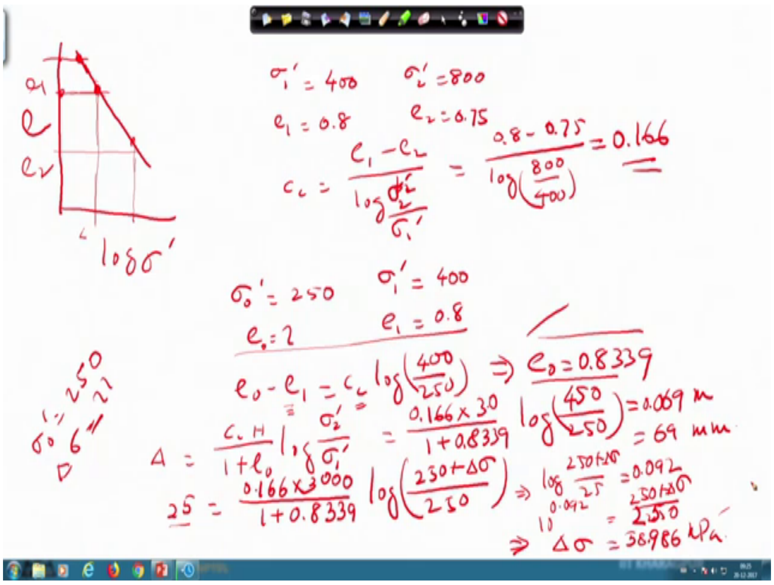

So, we can we can see I can see that sigma 1 dash will be 400 and sigma 2 dash is 800 all are kPa and e1 equal to 0.8 and e2 equal to 0.75. Then your C c will become C c will be e1 minus e2 by log p2 or sigma 2 dash by sigma 1 dash and if you put that then 0.8 minus 0.75 divided by log 800 by 400 and if you calculate this one by calculator you will see 0.166.

Now actually is a compression curve, suppose this is the compression curve. Ok this is e and this is log sigma dash. So, this is the point suppose 400, this is the point suppose 800 and this is now e1 and this is suppose e2 and this is 400 and this is 800. So, from there we have got. Now, this is 400 but initial pressure was 250. So that means, I can take this is one point and this is another point. From here if I know the void ratio of these I can find out the void ratio of this. So, how to do that? You can say sigma naught dash will be equal to 250 and e is unknown e naught and sigma 1 dash will be equal to suppose 400 and e1 equal to 0.8. And we can write e naught minus e1 equal to C c into log 400 by 250; that means, we are setting we are writing equation between these two points.

So, if you do C c already calculated from here you put there and e1 is unknown this is also known. So, if you calculate this then you will get this gives you e naught equal to 0.8339. So, it is obvious that 400 kPa pressure whatever the void ratio. If you pressure is 250; that means, less pressure than void ratio be higher. So, that is the thing we have got. Now, this is delta to be found out. So delta; that means, settlement will be equal to C c into H by 1 plus e naught log sigma 2 dash by sigma 1 dash. And you can see C C c is 0.166 into H is 3 meter and this is 1 plus 0.8339 and log sigma 2 dat dash is 425 450 450 divided by 250 so if you do this calculation and it comes 0.069 meter or 69 millimeter.

So, this is the step clearly you have to follow. So, first you have got C c based on given information. Then an initial pressure means less than that then how to find out e that we have calculated by this setting this equation. The total consolidation settlement is this now. now I had to find out that when the limiting settlement is 25 millimeter and I do not know sigma naught dash maybe 250 and delta sigma suppose not known ok. So, then 25 millimeter I can write 0.166 into 3 meter mean 3000 millimeter divided by 1 plus 0.8339 log 250 plus delta sigma by 250.

So sigma naught plus delta sigma by sigma naught, this is the formula generally or sigma 2 by sigma 1 or sigma 2 is nothing, but sigma 1 plus delta sigma. So, you can see this is the formula and from here you can see that we can get ultimately log this gives you log 250 plus delta sigma by 250 will be equal to 0.092. So that means, 10 to the power 0.092

will be equal to 250 plus delta sigma by 250. And from here I get delta sigma equal to by simplifying I get 58.986 kPa.

So, this is actually I am a ask actually; that means, if I want to limit my settlement it is initially asked how much is the settlement, if this is the C c and the pressure increase from 250 to 450 how much is that is done one part. Now second part is asked if the if I want to limit the settlement then what will be the pressure increase. So, that actually I have taken unknown and by solving this I get this. Now, one question of also asked that corresponding to this pressure what will be the void ratio? That also can be obtained. So, you can see that that void ratio can be obtained again similar way.

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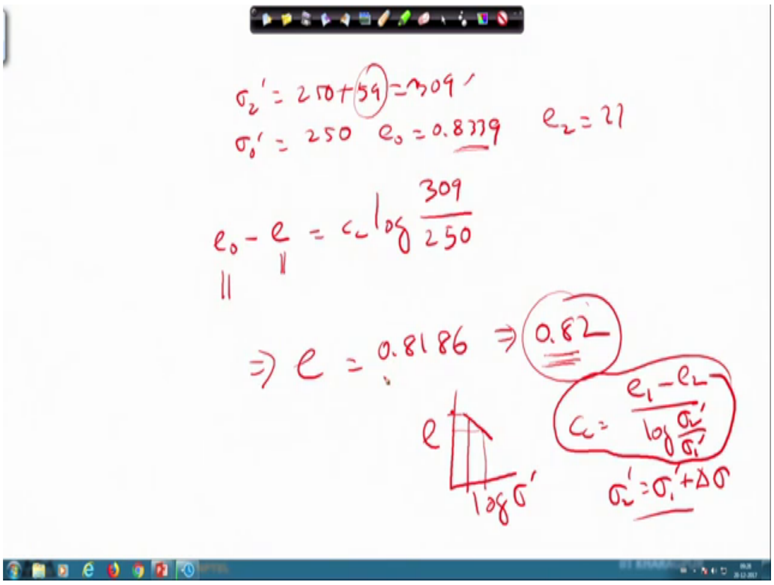

You can see that your sigma 2 dash equal to 250 plus 59 that is actually 309, 309 and the sigma naught dash equal to 250 and then e naught equal to 0.8339 and e2 is not known. So, you can find e2 minus e equal to C c into log 309 divided by 250. So if I do this C c value is known. So, I can e naught is known and only unknown is this one. So, from here I can get e equal to zero point 0.8186 and nothing, but 0.82.

And you can see now that that 450 pressure this is 309 pressure actually this is the void ratio. So 839 and from there it is decreasing actually 82. It was initially 8399 and when increasing of pressure this that this much pressure is increased then what this was decreased from this to this. So, this is the complete problem only it is understanding of this e log p curve. This is the e log p curve and e log sigma dash supposed; then equation,

equation it will be actually C c will be equal to e1 minus e2 by log sigma 2 dash by sigma 1 dash, where sigma 2 dash equal to sigma 1 dash plus delta sigma. So, this is the this formula if you remember this problem can be solved very easily.

So, step by step this has to be remember; another thing when pressure is increasing this direction then your void ratio will be decreasing. And when pressure is decreasing void ratio will be increasing. So, that is the thing. So, here void ratio if the pressure this is the pressure void ratio is higher, this is the pressure the void ratio will be lower. So, that is the way in calculation also you could find. So, this is the problem we have done.

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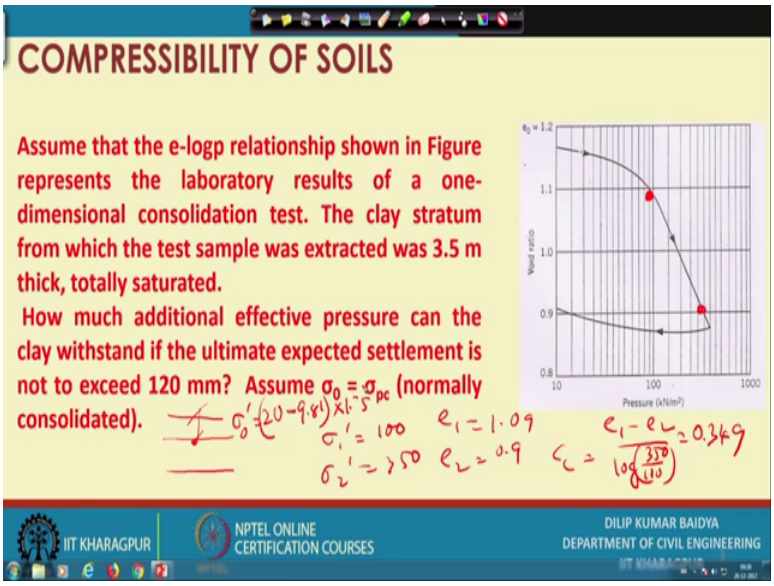

Next is this problem also I have just discussed before, but I am not sure the calculation. Instead of giving two points from the e log p curve, here e log p curve e log p curve itself can be given. And to find out C c you have to pick up two point on the straight line. So, this is a portion straight portion from. Here to here if I consider two points and then you can see that sigma 1 dash will be suppose 100. This is the 100 and e1 will be suppose 1.09 and sigma 2 dash will be 350. If you read from here and e 2 will be actually 0.9 and from here actually again C c will be e1 minus e 2 by log 350 by 100, from there you can get this value will be actually 0.349.

So, this C c once you get the C c then another problem is there that is also quite easy. You can see double tendence is given. How much additional effective pressure can the clay withstand. So, it is actually the clay stratum from which the test sample was accept three point 3.5 meter thick. So, 3.5 meter thick. So at the middle of the clay layer I will apply the formula. So, at this middle what is sigma naught dash? It will be gamma is not given here. So, gamma I can assume suppose 20. Effect is minus 9.81 into multiplied by suppose 1.75. So, let me take one new page.

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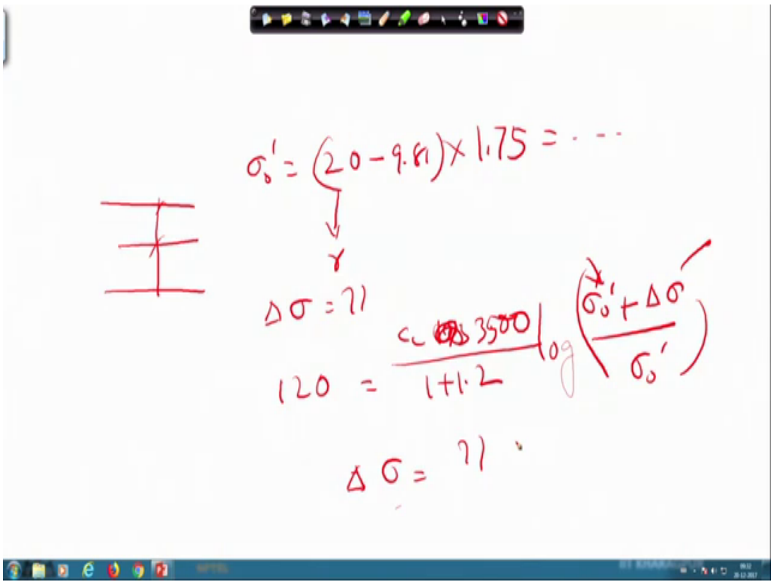

So, it will be if it is this is the one. So, at the middle of the clay layer it will be sigma naught dash will be suppose if I take gamma equal to 20 minus 9.81 into multiplied by 1.75. So, whatever value will be there and delta sigma actually not known you have to find out. And settlement is total settlement is given 120. So, 120 will be equal to C c into H is 175 not 1.750 this will be 3500 divided by 1 plus 1.2 the initial void ratio and log, log whatever value it comes that value sigma naught dash plus delta sigma divided by sigma naught dash. If I do this from here of course, this is known. You can find out and we can find out delta sigma.

So, this is the problem already in the previous problem this is this part is there we have done. So, here this the delta sigma can be obtain. Ok so, this is the second problem.

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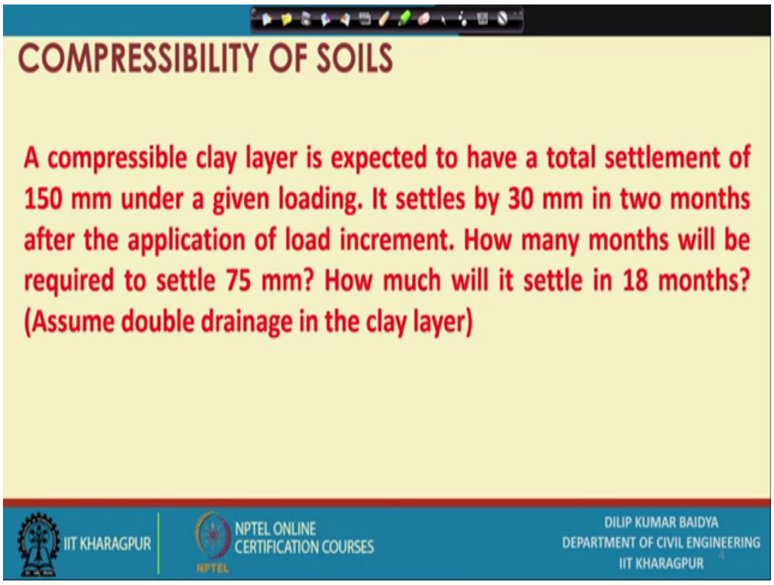

And now suppose the third problem. Third problem you can see a compressible clay layer is expected to have a total settlement of 150 millimeter under a given loading. It settles by 30 millimeter in two months after the application of load increment. How many months will be required to settle 75 millimeter? How much will it settle in 18 months? Assume double drainage in the clay layer ok.

So, this is the problem we have to do. Actually you can see and out of total 150 in two months it has got 3 millimeter. And now you have to find out for 75 millimeter how much time will be required? And an 18 months also it how much it will settle that the other things we have to find out.

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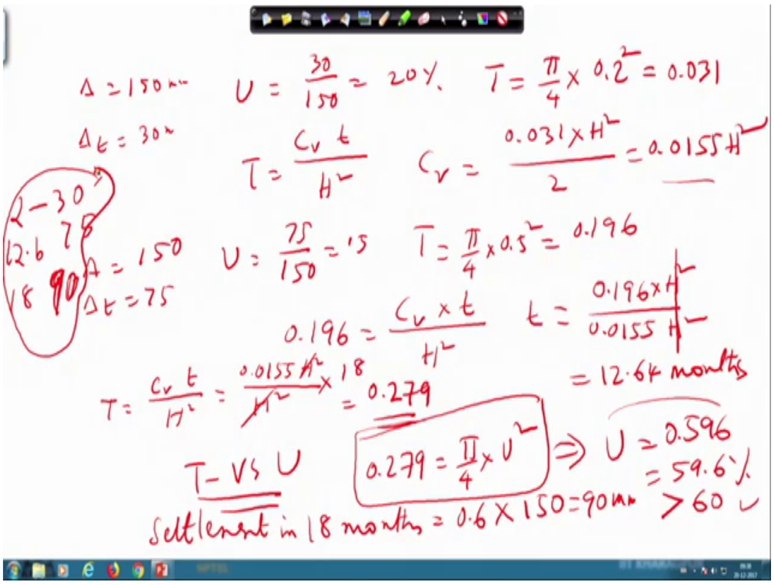

So, let me see this one. So delta actually 150 millimeter and your delta t; that means, in two whatever may be two months 30 millimeter. So, U will be equal to 30 by 150. So, this will be 20 percent. Now, if it is there then I can find out T equal to pi by 4 multiplied by 0.2 square. So, this will be your 0.031, 0.031. And then I know T equal to C v t by H square and here actually I can find out C v equal to C v equal to 0.031 into H squared divided by T is 2. So, this is the 1 so it will be 0.0155 H square suppose. H is not known or if it is there also you can put value, but it will be canceled I am not use suppose.

Now, this is in two months calculation, I get suppose C v. Now in 75 millimeter consolidation how much time it will take that to found out so that means, your delta is 150 and delta t is 70 75 then U will be 75 by 150. Then it is actually 0.5 is not it? So, T will be equal to pi by 4 into multiplied by 0.5 square. So this will be equal to 0.196 where, 0.196 equal to C v multiplied by t and divided by H square. So, t will be equal to 0.196 t equal to 0.1 0.196 multiplied by H square and divided by C v. C v I can write 0.0155 H square. So this get cancel. So, t become this by this. It becomes 12.6 4 months 12.6 4 months.

Now, in 18 months how much would be the settlement that to be obtain? Again you know that T equal to C v t by H square and it will be equal to C v suppose 0.0155 H square divided by H square into 18 months. So, H H get canceled, 18 into this that become 0.279, 0.279. So, we get T equal to 0.279. So, I have I find out what is the corresponding value of your degree of consolidation. So, T versus U plot I can refer or I can use equation. Then I assume that degree of consolidation within 60 percent. Then I can write 0.279 equal to pi by 4 multiplied by U square and that gives you U equal to 0.596 or it is 59.6 percent. So, still it is less than still it is less than 60 percent. So, this equation is valid up to 60 percent. So, I can assume this is valid. So that means, whatever value I get that means, 59 percent near about 60 percent will be your degree of consolation.

So, if it is so then in 18 months what we will be the settlement? So, settlement in 18 month, settlement in 18 month will be equal to 0.6 we can take 50, 60 0.6 into 150. So, it will be equal to 90 millimeter. So, you can see now in 2 months it is 30 and it is in 12.6 month it is 75 and it is 18 month, it is actually 90. So obviously, they are not linear. Initially the settlement rate will be very high, 2 months 30 and it is time is 12 months 6 times, but settlement is only you can see 2 and half times.

So, that is the beauty that settlement initially will be faster rate, but slowly with time it will be rate will be reduced. So, this is another problem that how to find out the rate of consolidation; that means, at different time how much is the settlement or if I know the time then another thing then how to find out the expected settlement? So, this is one application.

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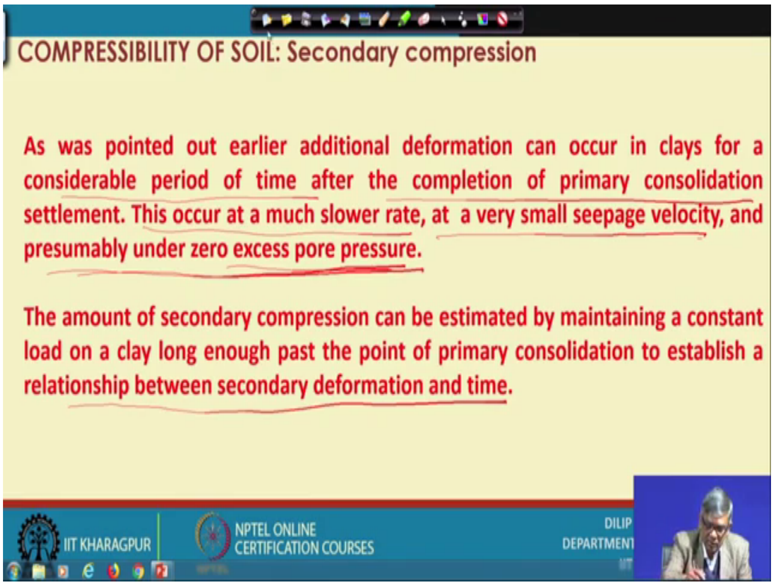

So, now I will take one small aspect which we have not discussed yet. Perhaps discussed before loosely that there are consolidation will have three components. One is elastic component of elastic compression another is consolidation settlement, another is secondary. And we have devoted quite a bit time on consolidation settlement and we have shown so much of application. Now, what is secondary application by a secondary consolidation just one very briefly I will just mention here, that you can see.

As was pointed out earlier additional deformation can occur in case for a considerable period of time after the completion of primary consolidation. So, primary consolidation in end of primary consolidation locate after that also with time it will compress or settle by it is very slow rate. And this occur at a much slower rate, at a very small seepage velocity, that means water movement almost negligible and presumably under zero excess pressure. That means, consolidation mechanism actually first of all it develop pore water pressure, excess pore water pressure and slowly it dissipate the pore water pressure and transfer the load to the soil grain which caused the soil grain conclusion and it has a consolidation settlement whereas here mostly excess pore as a zero excess pore pressure ok.

The amount of secondary compression can be estimated by maintaining a constant load on a clay long enough past the point of primary consolidation. So, you have to locate we have to locate the primary consolidation point and then from there if you apply a load for a long time then it will undergo some compression and from there we can some calculation some the structure suggested and that we can see.

The primary consolidation to establish a relationship between secondary deformation and time so that actually we can that means, after completion of primary consolidation you keep the load for a long time and from that loading for the time and loading plot one can find out relationship between the secondary compression and time. So, that one actually you can show in the in the next slide.

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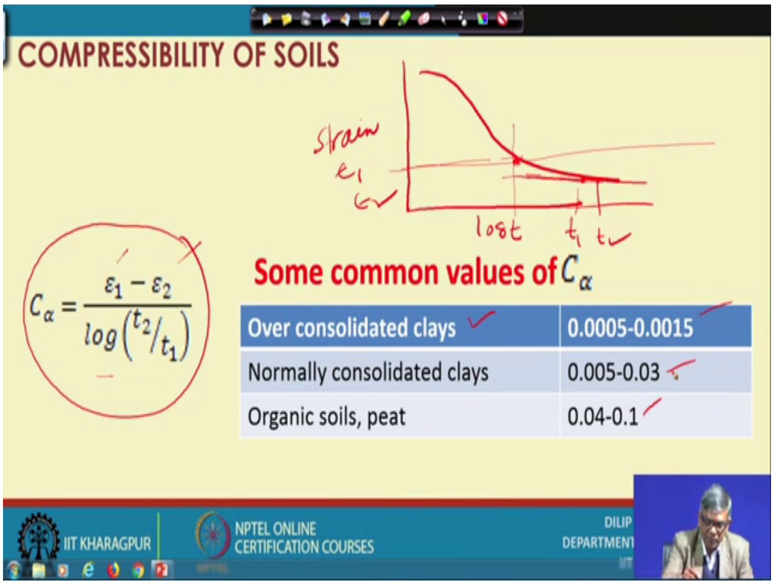

You can see. So, we have shown (Refer Time: 25:43) versus strain versus log time. And we have a curve something like this. So, somewhere maybe the end of primary consolidation and it will keep the loading here continuously, then you get a curve like this. So, from here this is suppose end of primary consolidation ok. And now suppose I extend this one, a straight portion I extend.

So, I will I will take two points from there and I get Epsilon one and corresponding this is t1 and t2. Suppose t1 and t2 and they are corresponding Epsilon 1 and Epsilon 2. If I get from this curve and two point I will select on this secondary curve and then t1 and t2 I mark at corresponding Epsilon 1 and Epsilon 1 Epsilon 2 by 2. At the end from there I can find out the expression similar to the compression index C alpha will be Epsilon 1 minus Epsilon 2 divided by log t 2 by t 1.

So, this is giving you the secondary compression coefficient and from if you know that then at different time how much will be the secondary compression I can find out, one can find out. And for a guideline we have some the value for different soil what will be the C alpha? You can see Over consolidation soil it is given 0.005 to 0.0015. And Normally consolidation soil it is 0.005 to 0.03. And Organic soil peat it is 0.04 to 0.1. So that means, for organic soil and peat will have more secondary compression than normally consolidated and over consolidation soil. So, this is actually a very a lot of research may be there. But at this level this must will be enough. For what is secondary compression? How to estimate? Another one simple method and what is the values range of values if you know this much for this level it will be enough. So, with this, I will close here right now. I will go to next topic may be.

Thank you.