Soil Mechanics/ Geotechnical Engineering I
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Lecture – 43
Compressibility of Soils (Contd.)

So, let me continue with the consolidation or compressibility of soil. We have just completed all theoretical aspect of consolidation what is consolidation, how this consolidation happens, what is the mechanism we have discussed. And then how to estimate the total consolidation settlement different methods, what are the parameters involved, then how to determine those parameters, how to find out, how long it takes to consolidate particular soil, different soil obviously will take different time, it depends on what there is a parameter called coefficient of consolidation. Again different soil will have different coefficient of consolidation, how to determine those coefficient of consolidation there are different methods again all those thing I have discussed.

Now, I will take one one or two problems and then of course, in the subsequent lecture also few more problems. So, the first problem let me see the problem is something like this.

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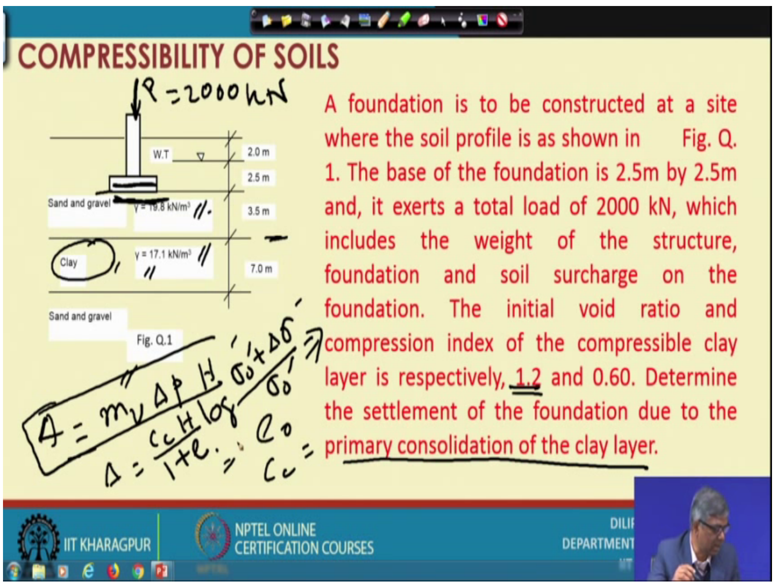

You can see though you have not learned a geotechnical engineer or foundation engineering, but this is the thing one has to understand that for at the end of every column there will be a enlarged base which is nothing but footing. Why we enlarge this? To reduce the pressure. So, this column suppose carrying some load and if it directly put it here then it will not be able to be at the soil, will not be able to be at the at most pressure to reduce the pressure we enlarge this one this is the footing size. So, footing will be much bigger than the column size.

So, typically this is the foot one particular footing suppose and some load is there I will I will see that, and you can see the soil profile here, different types of soil are there actually above at their up to this much depth actually this is 2 3 5 6 to up to 8 meter depth actually sand and gravels are there. And then there is a after 8 meter there is a 7 meter thick clay layer is there and water table location is somewhere here or foundation base is somewhere here it is everything is given. And under this condition actually what is the for the given condition whatever we have learned we have to apply and find out what will be the if I load then this foundation how much will settle ok.

If I load from here through building load is applied through this then this foundation after sometime it will be go down at some depth ok. So, that amount actually you have to find out how much will be the total consolidation. This consolidation again we see settlement again we will have two component which I have mentioned, one component is that because of the elasticity of the soil material. So, this soil sand etcetera because of its elastic properties there will be some compression and then this soil also will because of its elasticity we will have some problem compression.

But second part is this is the clay soil which will undergo consolidation. This soil will not undergo any consolidation so that means, to find out total settlement we need to find out elastic settlement for this layer, elastic settlement for the (Refer Time: 03:50) layer and then consolidation settlement of this layer. But this problem to make simple we have eliminated all those things and we have learned just now how to calculate the consolidation settlement.

So, we generally we because of that I want to just explain how to estimate the consolidation settlement only. Elastic settlement etcetera separately we will discuss later on, some other subject. But here only we just learned about consolidation settlement and this is the clay layer which is saturated. So, definitely if you apply load it will undergo consolidation settlement. So, now, our aim here how to find out the consolidation settlement for this layer whatever applying whatever we have learned just now.

So, this is the problem. The problem once again I read the problem the foundation is to be constructed at a site where the soil profile is as shown in the figure Q suppose. And the base of the foundation is 2.5 meter by 2.5 with this is the dimension of the footing is 2.5 by 2.5 and it exerts a total load of 200 kilo Newton; that means, this is P is equal to 200 kilo Newton P is 200 kilo Newton a pressure will be obviously, 200 divided by 2.5 into 2.5.

So, that I have not that is not given. So, it will be required we will see that later on. So, total load is given which includes the weight of the on the structure foundation and soil structure and the foundation etcetera. So, directly at this there at this level 200 kilo Newton load is transport, that is the thing is given.

The initial void ratio and the compression index of the compressible clay layer is a respectively 1.2, 1.6. So, void ratio initial void ratio is one point e naught which is required for calculation of settlement is e naught is 1.2 and another parameter is required C c which is equal to 0.6, Determine the settlement of foundation due to the primary consolidation only.

As I have mentioned there are elastic settlement, secondary settlement some sorts of soil will have elastic settlement and consolidation settlement both, some soil will have only consolidation, some soil will have only elastic settlement, but ultimately in this problem I will show only how to find out the consolidation settlement of a particular layer ok. So, this if this is the data or information available, so in what method we can apply. So, we have learned two methods, one is actually that is actually a coefficient of volume compressibility method delta equal to delta equal to your m v and delta P into H this is one method and another method is delta equal to C c into H divided by 1 plus e into log sigma naught dash plus delta sigma divided by sigma naught dash.

So, now which equation will be applicable here to you the consolidation settlement? You can see this problem requires C c this problem required e, both the parameters are given and sigma naught see del sigma is not given, but problem is all information is given. So, e base (Refer Time: 07:33) you can calculate so that means, we need to apply this method not this method because m v and other things are not given. So, we will immediately select this method. So, if we select this method, then how to start this problem? We can see this problem like this. So, I will take a new page and so your foundation is something like this.

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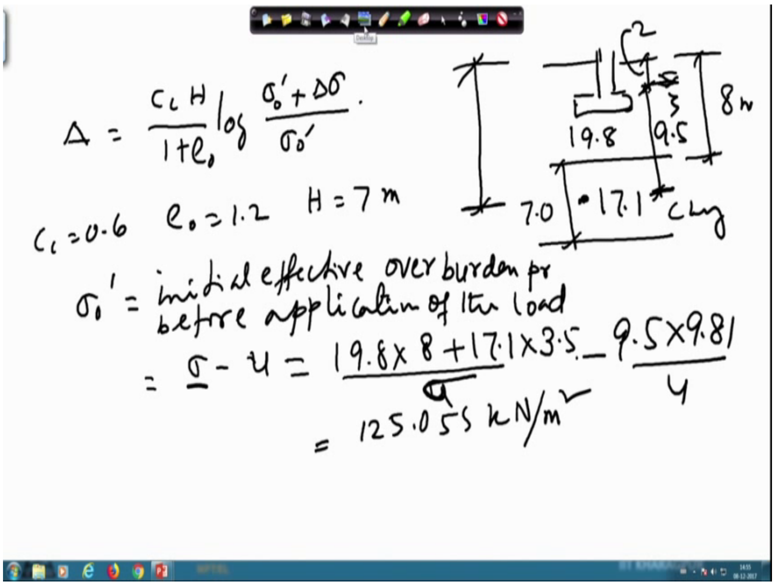

Sorry; and from here this is 7 meter and this is 8 meter and water table is at 2 meter from here, this is 2 meter. So, this is water table and the soil properties given here 19.8 here it is given 19.8 here it is given 17.1. So, this is the information we have. So, what other information we have? As we have decided we will be using the a formula delta equal to C c into H by 1 plus e naught log sigma naught dash plus delta sigma divided by sigma naught dash.

So, we have got C c equal to 0.6 e naught equal to 1.2 and H equal to 7 meter that consolidating layer clay is 7 meter thick. So, what we need? We need to find out sigma naught dash. So sigma naught that that is equal to initial effective overburden pressure before application of the load. So, where we have to find out this effective overburden pressure? Because this formula will be applied at the middle of the clay layer actually this formula is applicable for a small very small thickness so that means, we can divide into number of sub layers and apply instead of here I will just using here only single layer and if you sub divide into a small number actually you will get better accuracy.

But I will show here only considering single layer. So, if I consider single layer then all treatment or application should be done at the middle of the clay layer so that means, sigma naught that you have to find out at this point. So, I have to take effective overburden up to this. So, if I take this now it will be the total stress sigma minus u will be effective stress. So, sigma will be how much? 19.8 into 8 and plus 17.1 into 3.5. This is become total stress and these are actually given saturated unit weight of sand and saturated unit of clay and we are taking that unit weight for calculating the total unit weight. And above water table actually sand also there are two meter thickness this unit weight also can have different, but we are considering that the same unit weight as 19.8.

So, this is become total unit weight otherwise if I take different unit weight here then I should have taken 6 here and 2 into that unit weight should have been used. So, I assume that above water table also unit weight of the sand is almost similar. So, same unit is taken. So, this is actually totals this is nothing but u minus sorry this is nothing, but sigma total minus u will be your how much depth is there up to this will be 2 meter from the top. So, this is actually this from here it is 6 plus 3, 9.5 meters water table up to middle of the clay layer up to the middle of the clay layer water table is 9.5 meter away. So, 9.5 into 9.81 this is actually u.

So, if I do that this value comes actually 125.055 kilo Newton per meter square, this is sigma naught dash. And then you have to find out delta sigma that means I will take new page better oh sorry.

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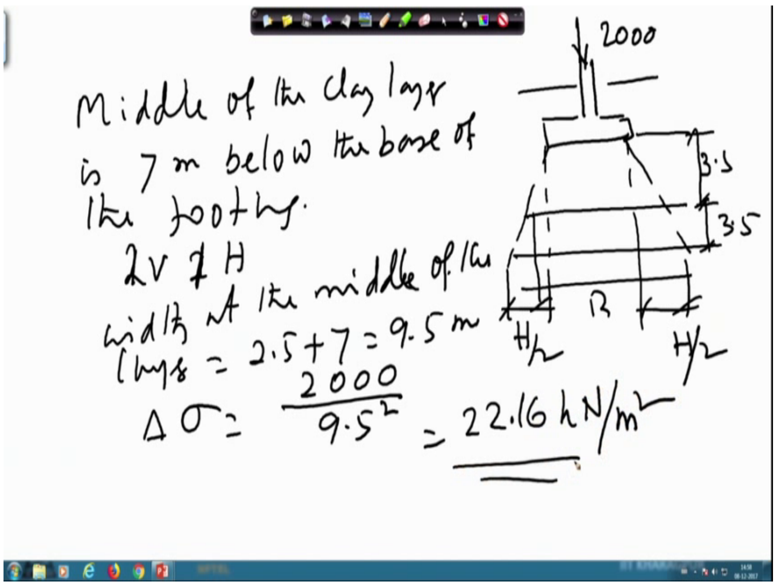

I will take new page suppose you can see this is the footing. here actually your 2000 kilo Newton load is applied and from the base of the footing this is you have to take that this person will be like this you have to consider you have to find out width here.

So, what is the distance? So, this is 3 and this is actually your this is also 3.5 from here to here also 3.5, this is also 3.5 so that means, the footing the middle of the layer, middle of the clay layer is 7 meter below the base of the footing. If this happens then this person when you do then at this depth and we take one vertical we take this person one vertical two horizontal sorry, two vertical and one horizontal, one horizontal then if it is if it is 7 meter goes this direction. So, this direction it will be enlarged H by 2 this direction here also this also H by 2 and this is actually equal to B.

So, B plus H by 2 plus H by 2 ultimately width at the middle of the layer middle of the layer will be equal to B is 2.5 plus your depth is 7. So, it is 9.5 meter. So, your pressure delta sigma will be equal to 2000 divided by 9.5 square. So, this gives you this gives you 2000 divided 9 point square it is if you calculate it comes as 22 point, 22.16 kilo Newton per meter square ok. So, this delta sigma we have got.

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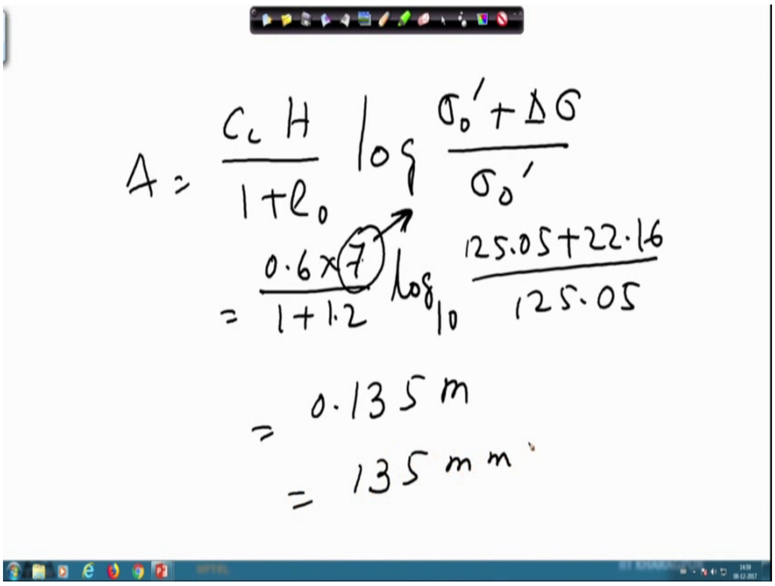

Now, if I sorry now actually if I now our formula was delta will be equal to C c into H by 1 plus e naught log sigma naught dash plus delta sigma plus sigma naught dash. So, if I do that C c is 0.6 into H is 7 divided by 1 plus 1.2 log this is the of course, 10 base sigma not dash actually is your 122, 125.05 plus 22.16 divided by 125.05 and if I do this calculation then finally, we will get 0.135 meter because all it is in meter unit is used. And you can see this is non dimensional, the dimension comes for from this only this is the only thing which has dimension. So, this will give you 135 0.135 meter or 135 millimeter ok. So, this is the entire step.

So, if I see this is the point calculation or delta sigma and this is the calculation of effective stress. So, this is the one step by step you have to do and in fact, if you want to find out delta sigma the trapezoidal way I have done quickly, but we have discussed other method also the bossiness corner formula those thing, if you wish can be applied. But that will take unnecessary long time when you do in the office for design purpose can be used per when solving problem in the classroom or in the exam hall if it is not mentioned always it is better to use this trapezoidal dispersion method two vertical one horizontal. That means, if you go the soil layer is are in depth z from the base of the footing then your base will be enlarge assume that footing base will be widened at that depth and that widened depth in a width will be equal to B width original width plus z that the what depth we are if it is used two vertical one horizontal of course, instead of two vertical one horizontal one can take any the dispersion. But that is the most common dispersion value we generally take.

So, this is the calculation of del sigma and if it is I want to find out finally, after going those C c, then e, then your value of sigma naught dash then delta sigma then you can next can be used formula finally, use this formula to get the total settlement, so this way actually one can calculate the settlement. This is a very practical problem because any foundation design before design is how many how much pressure to be given that to be first design and there is then at that and that much pressure is applied how much settlement it will undergo that has to be estimated, because in the code we have some restriction; that means, you would not allow to settle more than certain value there is a recommendation. So, you have to see that the value comes here it much below then the recommended or restricted value given in the code. So, that is what this is another important step to check or check in the design.

So, this is one problem we have already done. The next problem I will take something like this.

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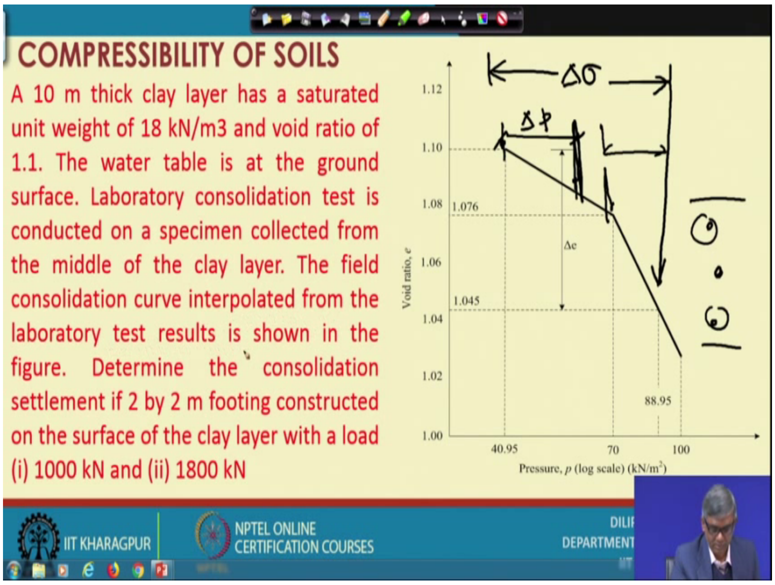

Whatever problem I have discussed that is actually normally consolidate soil we have not exactly investigated whether it is over consolidated or not we have given a footing we have bought a C c value, then we have calculated using those.

Now, I have another thing I have mentioned that soil can be over consolidated. That means, over consolidated means the soil at present whatever activity what water pressure is the existing the soil has been subjected to a higher pressure and consolidated before. So, that is called pre consolidation, consolidated soil. And how to determine pre consolidated pressure that method also I have explained. But now suppose we have a over consolidated soil and the data are plot for the consolidation data also available e versus log data is available and when is the over consolidated soil generally to make it simple we get the e log P curve in two segment from present to pre consolidation pressure one one one one part and pre consolidation pressure to further consolidation then another part.

These two part using, these two part when you find out the consolidation settlement there also I have mentioned that after with respect to present over effective overburden pressure when we increase the pressure because of the foundation load you have to see where is the point now. So, that point suppose if I apply delta P and because of the delta P point comes here. So, this is initial overburden and this is delta c, delta P suppose then;

that means, because of the foundation pressure you can go up to this much; that means, we are to go not going beyond that. So that means, this is a recompression only.

So, we have to find out consolidation settlement using this part only and for that that is the equation. If suppose delta sigma is such that it is coming somewhere here this is the delta sigma suppose, if this is the delta sigma you can see it will have two component the compression up to this; that means, you have to apply the formula from here to here and then you have to apply formula again from here to here, so in two parts. That is also I have shown before today also in the first a previous lecture I have shown the I have highlighted how to do it.

So, application of that I will show through this problem. You can see here 10 beta thick clay layer has a saturated unit weight of 18 kilo Newton per meter cube and void ratio 1.1. The water table is at the ground surface. Laboratory consolidation test is conducted on a specimen collected from the middle of the clay layer suppose there is a thick clay layer and from the middle. So, due to the why it is middle because it is a representative if it is taken from here or if it is taken from here it will give some value it will give some value, so different point give different values and values generally changes with depth. So, because of that if you take at the middle it will be correctly representative value.

So, because of that the field consolidation curve interpolated from the laboratory test curve results is shown in the figure that is the thing shown here. Determine the consolidation settlement if 2 by 2 meter footing constructed on the surface of the clay layer with a load 1000 kilo Newton, another is 1800 kilo Newton. So, two cases I will show one case when we will handle it will see that it is within the recompression zone and when it will apply the second load it goes to consolidation zone, the compression zone.

So, first one we can we may have to do by using a formula with C r that is recome; coefficient of recompression and when you apply the second problem we may see that recompression and compression both will be there. So, we will see one by one.

So, let me see this problem from this problem actually there is a chance of having recompression and compression also be because of that let me from the graph itself we can see sigma p c pre consolidation pressure is 70 kilo Newton per meter square it is given ok.

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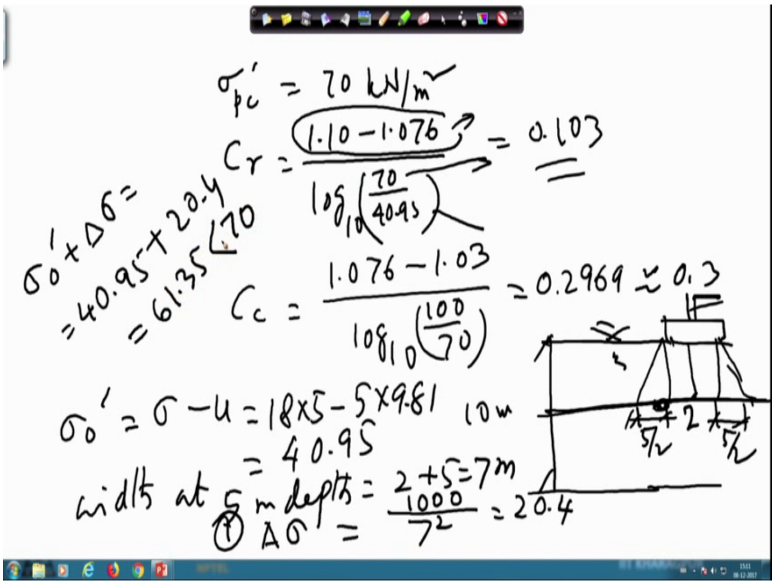

And C r can be calculated which will be equal to can see two points pressure is given and void ratio is given. So, deltas void ratio or delta e 1.10 minus 1.076 and their corresponding pressure is log 10 base 70 by 70 by 40.95. Actually at 70 pressure we have this void ratio around 40 pressure this is a void ratio. So, because of this two pressure void ratio changes. So, this is delta e divided by log P 2 by P 1. So, this gives you C r that value if you calculated comes actually 0.103.

Similarly C c will be p c to beyond it will be a portion if you use you will get the C c. The C c will be used I will be equal to corresponding to pressure 71.076 minus 1.03 when pressure equal to when pressure equal to 100. So, this will be log 10 base 100 by 70. So, you will get from here 0.2969 which will be equal approximate equal to 0.3. So, C c is 0.3 and C r equal to 0.1.

And now you have 10 meter thick clay layer suppose 10 meter thick clay layer this is 10 meter and it water table also here and foundation is size 2 meter by 2 meter applied on the surface and because of that you have to find out the consolidation. Now, we have to apply the formula at the middle of the clay layers. So, you have to find out delta a sigma naught dash at the middle of the clay layer means at 5 meter depth. So, 5 meter depth what will be the sigma minus u which will be sigma will be equal to your total unit weight saturated unit weight is given 18. So, 18 into 5 and minus u is actually 5 into 9.81. So, this will be your value 40.95. So, initial effective overburden pressure is 40.95.

Now because of this footing this dispersion will be there ok. So, this is actually 5 meter depth and this was 2 meter. So, this will be 5 by 2 and this is also 5 by 2. So, ultimately this is 2, 2 plus 5 by 2 plus 5 by 2; that means, the base width at 5 meter depth will be equal to your 2 plus 5 equal to 7 meter. Then delta sigma will be equal to the first case delta sigma will be equal to a 1000 kilo Newton divided by your 7 square and that gives you 20.4 this is 20.4 and that means, your sigma naught dash plus delta sigma will be equal to this 2 2 together equal to 40 point 40.95 plus 20.4 that gives you your 61.35 which is less than 70. So that means, first problem will be there on the recompression zone.

If it is recompression zone corresponding formula will be your delta will be equal to C r into H by 1 plus e log and that is 40.95 plus 20.4 divided by 40.95. So, that gives you the value equal to 96 millimeter.

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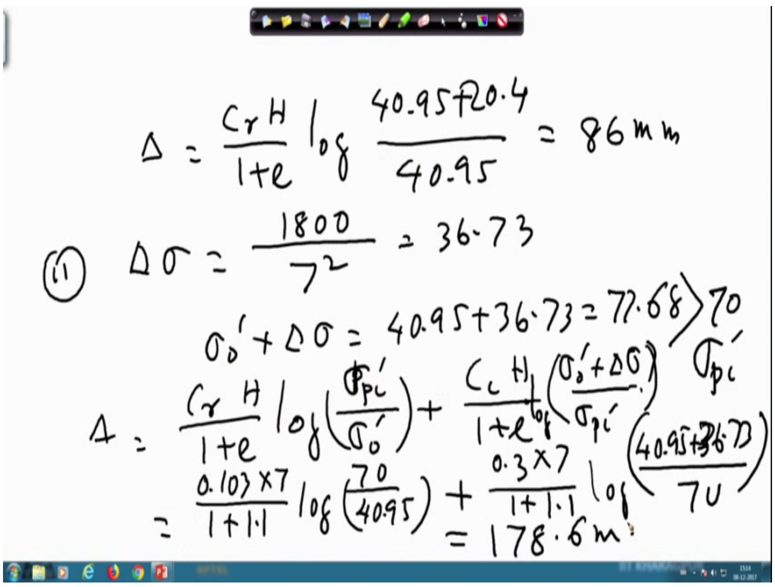

For second case delta sigma will be equal to 1800 divided by same 7 square and that is equal to 36.73. So, sigma naught dash plus delta sigma will be equal to 40.95 plus 36.73 will be equal to 77 point, 77.68 which is greater than 70 that is sigma p c.

So, we have to use two formula that means, delta equal to C r into H by 1 plus e log p c sigma p c dash by sigma naught dash plus C c into H by 1 plus e and this will be your sigma naught dash plus delta sigma by sigma p c dash. So, all everything is known. So, if I put those value c are equal to 0.103 into H is 7 divided by 1 plus 1.1 log sigma p c is 70 and this is 40.95 plus C c is actually 0.3 into 7 divided by 1 plus 1.1 and log, this is log is there log 40.95 plus delta sigma is 36.73 divided by p c is 70. So, this two part if you calculate and finally, we will get a value which will be equal to 178.6 millimeter.

Now this problem I have used to explain that if the foundation load is applied on a soil then how consolidation, how settlement can be calculated and if it is a normally consolidate in one part over consolidated soil again it can be a one part or two part that depends I have shown the two part. And of course, sometime a better when you will understand a learned foundation engineering for a this type of soil so much of load is not actually suitable that practical aspect we are not considering only to explain the method of calculation of consolidation I have taken this problem, otherwise this much load for those foundation may not be suitable that of course, we should not we do not know assume that we do not know that. When you understand foundation engineering that part again will come and we will see that.

But otherwise this is whatever load is there based on that what is the pressure, based on that pressure, whether it is greater than pre consolidation pressure or less than pre consolidation pressure that to be decided. Based on that whether the single calculation or two calculation that to be seen and based on that it would be applied. So, two problems I have shown here and that is all, maybe. Thank you, I will see in next the subsequent class.

Thank you.