Geology and Soil Mechanics
Prof. P. Ghosh
Department of Civil Engineering
Indian Institute of Technology Kanpur
Lecture - 56
Tutorial on Consolidation

Hello everyone. So, we are going to continue our fifth tutorial on Geology and Soil Mechanics course.

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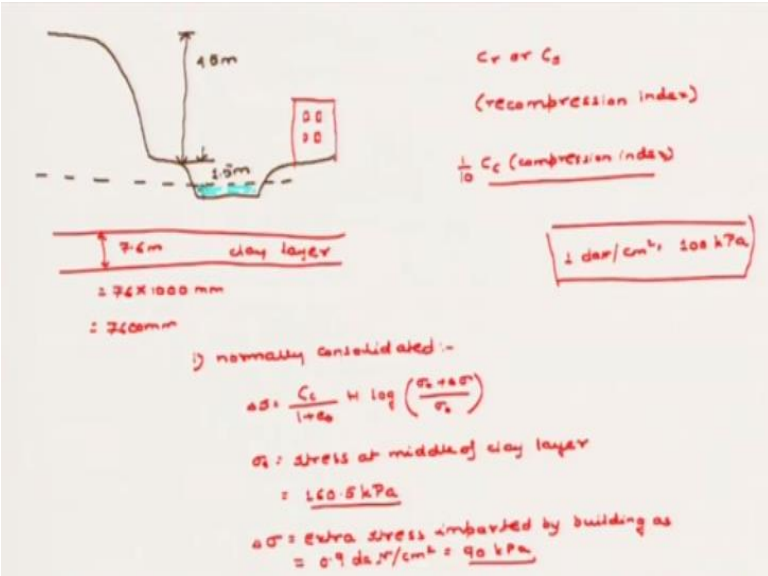

Now we were discussing about the problem of consolidation or the beginning or the starting of the consolidation where basically we told that basically there was a lake that carved a deep valley and we were asked to find out the preconsolidation pressure which I already discussed in the previous lecture how to find out the preconsolidation pressure and now we have to find out the settlement of the clay layer beneath the lake.

Now this is how the present diagram looks like. The water table is here and this site the basically the lake carved a deep valley has been given as 45 m while this site from here to here has been given as 1.5 m and this is the river and this is the building. This is the clay layer of height 60 mm 7.6 m so that means 760 mm 7.6 m 1000 mm 7600 mm.

So, now we are asked to find out the settlement. Now I said previously that if it is a general normally consolidated settlement then we will use the general formula of cc but if it is an over consolidated if the clay layer is over consolidated which it is supposed to be because the lake it was subjected to a greater pressure previously. Now it has been subjected to a less pressure. So, obviously it is an over consolidation settlement.

So, in that case basically we have to find out the value of C r or C s whatever you call it that is the reconsolidation index or recompression index basically the recompression index similar to the compression index and we have to evaluate the settlement. Now as it has been discussed in the lecture that the recompression index is generally taken to be one fourth or one tenth in between one tenth and one fourth so here in this case we will consider it to be one tenth for the case.

So, one tenth of C c or the one tenth of the compression index for our case. So, first let us find out what is the settlement due to the normally consolidated clay layer. Now delta S is equal to we all know it is given by C c by 1 + e 0 into H into log of sigma 0 + del sigma by sigma 0. Now sigma 0 has been already said to be the stress at middle of clay layer which we found out to be equivalent to 160.5 kPa and it has been said that delta sigma that is extra stress imparted by building as equivalent to 0.9 da 0.9 deca newton so basically 0.9 da Newton per centimeter square and we have already said in the previous lecture as well that one da Newton per centimeter square is equal to 100 kPa. So, this is equivalent to 90 kPa.

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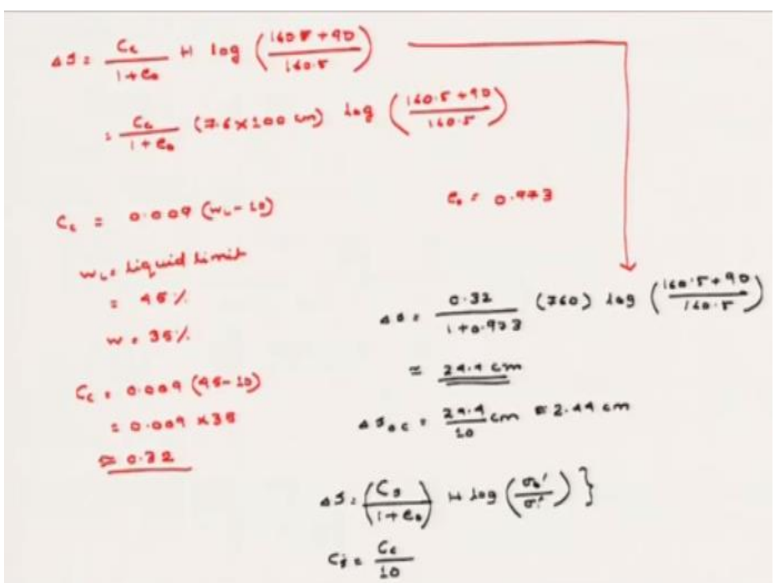

So, from the formula now delta S is equal to C c by 1 + e 0 into H into log of 160.5 + 90 by 160.5. Now H is the height of the clay layer which we have already said to be 76 7.6 m if you find out want to find out in millimeter that means it is 7600 mm. So, C c by 1 + e 0 7.6 or maybe we will convert it into centimeter so 100 cm into log of 160.5 + 90 by 160.5. Now C c can be found out from the general formula of Skempton's compression index which basically says that C c can be given in terms of liquid limit as 0.009 into W L - 10 where W L is the liquid limit.

Now it is already been given in the question that W L is equivalent to 45 for the clay layer and the natural moisture content that is W is equivalent to 35% for the clay layer. This 35% was utilized in finding out the initial void ratio. So, now C c will be equivalent to 0.009 into 45 - 10 which is equivalent to 0.009 into 35 which is equivalent to almost equivalent to 0.32. E 0 we have previously founded out in the lecture which basically is equivalent to 0.973.

So, this formula now comes out to be delta S is equal to0.32 by 1 + 0.973 into 760 log of 160.5 + 90 by 160.5. So, if you solve this then it will come out to be eventually 24.4 cm which is the normally consolidated settlement for the clay layer. Now if you consider an over consolidated settlement that is delta S o c this will be just one tenth of this because if you remember the formula that is delta S is equal to C s by 1 + e 0 into H into log of sigma 0 dash by sigma dash. Now C s is equal to C c by 10. Now both this term may change but it comes out to be almost like one tenth of this formula because this is the major factor that is governing the settlement. So, in that case delta o c will be equivalent to 2.44 cm approximately equivalent to.

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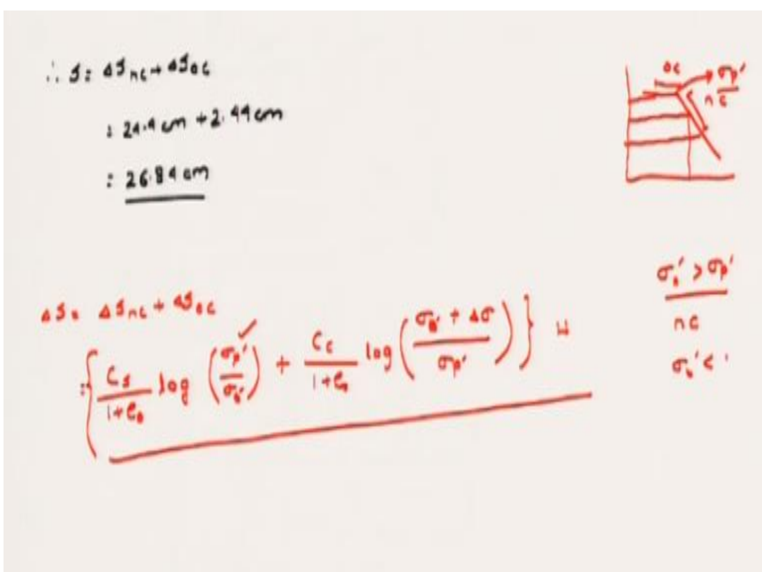

So, in that case the total settlement will be equivalent to delta S n c plus delta S o c which is equivalent 24.4 cm plus 2.44 cm which comes out to be 26.84 cm. Now remember this is all an approximate calculation because neither the graphs are given here nor you are nor basically the you know what is the preconsolidation pressure. If you obviously know the preconsolidation pressure then obviously you have to find out the over consolidated settlement from the pre consolidation pressure because as you all know from the lecture that total settlement is given by delta S n c plus delta S o c which is given by as C s by 1 + e 0 into log of sigma P dash by sigma 0 dash where sigma P dash is the pre consolidation pressure sigma 0 dash is the present particle stress which basically is less than the pre consolidation pressure + C c by 1 + e 0 into log of sigma P dash + sigma 0 dash + delta sigma divide by sigma P dash into H.

So, here you have to know sigma P dash previously either from the Casagrande method which we will discuss in the next problem. Delta sigma is known to you and sigma 0 dash is also know to you because it is the present particle stress and H is the height of the layer. So, in taking all these factors in account you have to find out the total settlement considering both the normally consolidated and the over consolidated soil depending on where your initial settlement where your initial stress lies.

So, if your initial stress lies here and you are subjected to a stress here then basically you can easily see that it is a sum of over consolidated plus normally consolidated soil but suppose let us say your initial stress lies at this point. Then there is no over consolidated settlement because you see that it has already covered the over consolidated settlement if at it has already covered the preconsolidation pressure.

So, since it has already crossed the preconsolidation pressure that is sigma 0 is actually greater than sigma P dash so in that case only normally consolidated part would come into view while basically if sigma not dash is less than sigma P dash then both the normally consolidated and over consolidated part would come in view. So, keeping all these factors in mind now let us move to the next problem.

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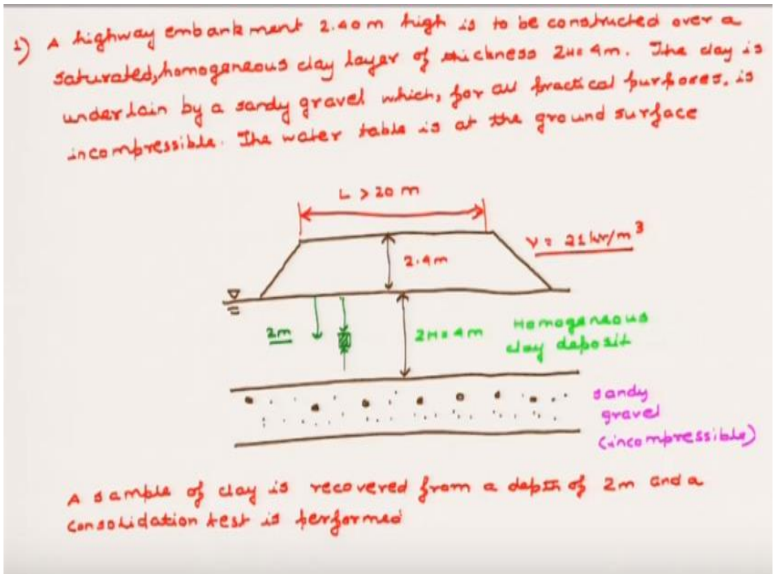

Now the next problem says that a highway embankment 2.40 m high is to be constructed over a saturated homogeneous clay layer of thickness 2 H equal to 4 m. The clay is underlain by a sandy gravel which for all practical purposes is incompressible. Now this term itself indicates the term incompressible itself indicates that basically there is no settlement for the sandy gravel layer.

The water table is at the ground surface. Now let us construct this. So, this is suppose the ground surface. The water table is here. So, this is the clay layer. So, this layer has a thickness of let us say how much is given as 2H equal to 4 m. So, this is the homogeneous clay deposit. Now this is the sandy gravel layer and as it has been already said that this layer is practically incompressible.

Now the embankment is to be constructed at its top. So, this is the embankment this is a high embankment it is like a railroad and this height of the embankment is given as 2.4 m and this height is given as 2.4 m and the length as it has been described in the figure is greater than 20 m. Now this is of not importance. This is of not much importance the length because you are only interested in the depth of the embankment and one more thing that is given here is the density of the embankment.

So, the density of the embankment is given as 21 kN/m cube is given. So, now it is said that a sample of clay is recovered from a depth of 2 m. So, the sample of clay is recovered from let us say a depth of 2 m. So, basically this is the point from where basically the sample of clay is recovered. This height is given as 2 m and a consolidation test is performed.

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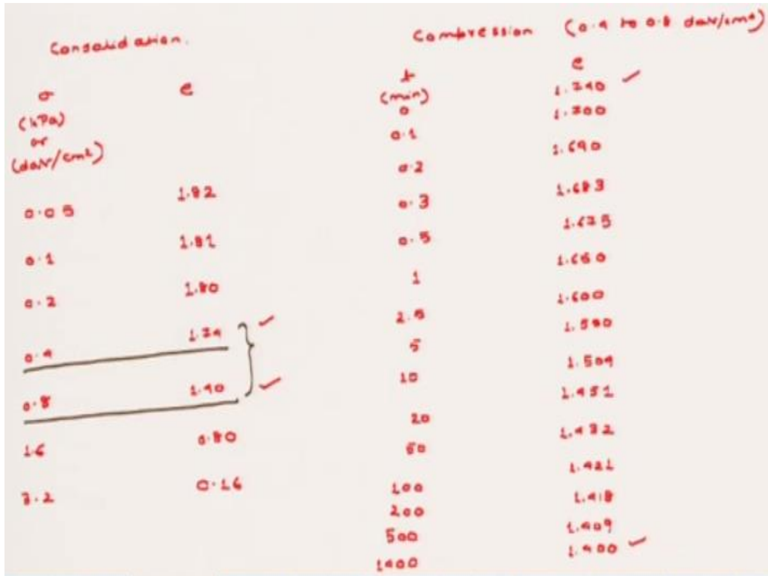

So, this results of the consolidation test are given here so this is the consolidation test where this is the stress and this is the e so this is given in kPa or deca newton per centimeter square and as we have already said in the beginning that 1 deca newton per centimeter square 100 kPa so if I am going to use deca newton per centimeter square just multiply into 100 you will get the value in kPa and e has no units so 0.05 deca newton per centimeter square 1.82 void ratio; 0.1, 1.81; 0.2 1.80; 0.4, 1.74; 0.8, 1.40; 1.6, 0.80; and lastly 3.2,0.16. Now this is the consolidation that is given.

There is also a compression given with respect to t in minutes in order to plot the coefficient of consolidation and e so 4.1. Now this is for 0.4 to 0.8 daN/cm square. That means basically for this value and for this value in between these 2 values when basically the load was increased from 0.4 to 0.8 then how with respect to time the void ratio changed. This is how this table explains.

So, for 0.1 it was 1.700 then for 02 it was 1.690 for 0.3 it was 1.683 for 0.5 it was 1.675 for 1 it was 1.650 for 2.5 it was 1.600 for 5 it was 1.550 for 10 it is given as 1.504 for 20 1.451, 50 1.432, 100 1.421, 200 1.418, 500 1.409, and lastly 1400 given as 1.400 and at 0 minutes obviously this is 1.740. So, see the first and the last readings correspond to the void ratios 0.4 and 0.8 respectively and this is in between how the void ratio change.

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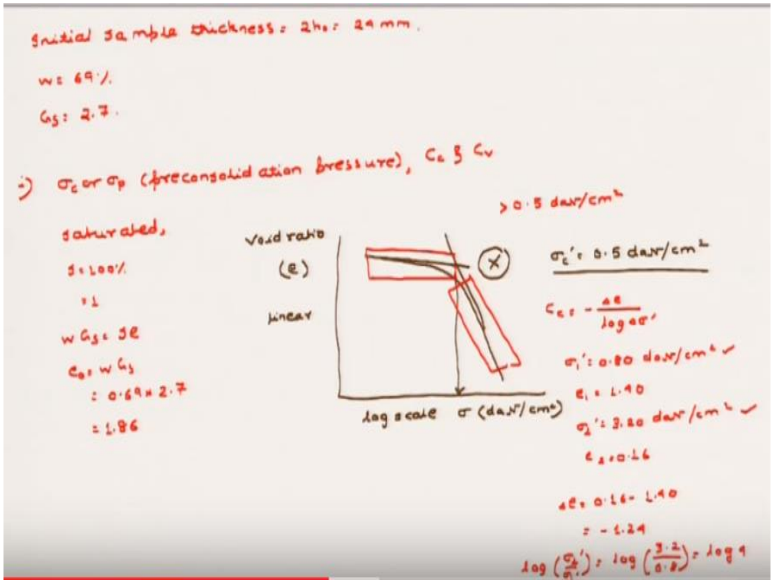

So, the first question that is asked is the initial sample thickness is equivalent to 2h 0 that means for the oedometer sample or the consolidation ring sample it is equivalent to 24 mm and the water content of the initial sample is 69% G s or the density of the soil solids is considered to be 2.7. So, the first question that is asked is find out sigma c or sigma p which is basically the preconsolidation pressure then C c and C v.

Now we all know that C c is the compression index C v is the coefficient of consolidation. So, that is what is the first question is asked. So, the first thing that you have to do is plot all both the consolidation as well as the compression curves. Now initially in order to plot the consolidation as well as the compression curves you have to first find out that at 0 pressure what was the e 0 or the initial void ratio.

So, for this you have already been given w and G s 2.7. Now we will consider for that we will consider that in consolidation basically since it is only the removal of water and nothing else not air it is only the removal of water so basically, we will obviously the sample has to be saturated. So, the sample is fully saturated in the beginning. If the sample is fully saturated in the beginning then S is equal to 100% or 1.

So, from the initial lesson that is w G s is equal to S e, e 0 is equal to w into G s which basically is equal to 0.69 into 2.7 and comes out to be 1.86. So, this is the void ratio at a pressure of 0 kPa. Now moving to the next void ratios because it has already been given how the next void ratio varies. So, 1 after 1.86 it becomes 1.82, 1.81, 1.80 and like that. So, the plot now looks like this where this is in log scale and this is in linear scale.

This is e or the initial void ratio and this is e or the void ratio and this is the sigma which is da newton per centimeter square. Now you have to find out the preconsolidation pressure. Now the best way to plot the preconsolidation pressure is by Casagrande method. So, I am not going to elaborate the Casagrande method here but there is there are other methods as well. The most useful method is the Casagrande method but there are some method that gives a rough idea about the preconsolidation pressure is going to be.

One of the method is the double tangent method. In double tangent method, what you do is that you just draw a tangent from here you just draw a tangent from and thus find out the intersect points intersection point and you find out what is the preconsolidation pressure but remember that this preconsolidation pressure may be over overestimated or underestimated. So, that is why this method is not preferable.

If you have time obviously you are you must go for the Casagrande method. So, if you follow Casagrande construction then sigma c dash comes out to be 0.5 daN/cm square and C c we all know is delta e by log delta dash sigma dash. So, for sigma 1 dash is equal to 0.80 daN/cm square e 1 is equal to 1.40 this one and for sigma 2 dash is equal to 3.20 daN/cm square e 2 is equal to 0.16.

We will take any 2 points after 0.5 daN/cm square. That means 0.1, 0.5 means 0.8, 1.6, 3.2 any one of them you can take basically to find out the value of C c. You cannot take any value beyond before 0.5 because before 0.5 it would resemble to the C a or the decompression index or basically you can also say the preconsolidation part okay that means in this part. We cannot take any value in this part.

We have to take every value after 0.5 in order to find out this so we have to take every value greater than 0.5 daN/cm square. So, that is what we took. We took 2 values after 0.5 daN/cm square. One of them is 0.80 and the other one 3.20 the last point and the first point. So, 1.40 and 0.16. So, delta e then comes out to be 0.16 - 1.40 which basically is equivalent to - 1.24 and log sigma 2 dash by sigma 1 dash comes out to be log of 3.2 by 0.8 which comes out to be log of 4.

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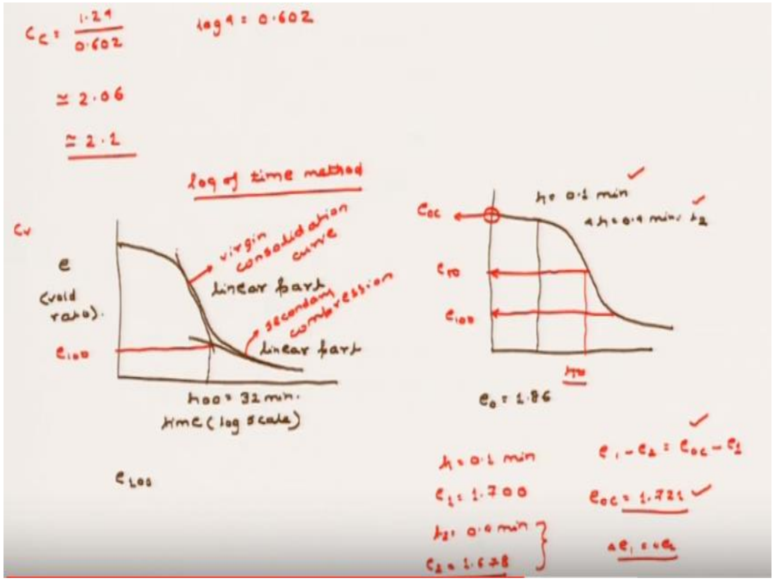

So, finally we get the value of C c as 1.24 by 0.602 because log of 4 is actually equivalent to 0.602 so this comes out to be 2.06 or equivalent to 2.1. So, that is the C c value. This is how you find out the C c value. Now you are also asked to find out the C v or the coefficient of consolidation. Now coefficient in order to find out the coefficient of consolidation you all know that there are lot of methods available like T 90, T 50 but today actually we are going to discuss a different method from all of these methods. It is called T 100 method. Now at T 100 method is kind of a different method from both the T 90 and T 50 methods.

So, here also you first plot the graph that means plot the compression graph. So, the compression graph looks somewhat like this. Now in order to T 100 T 100 we follow the T 100 method because it is a very easy method than T 90 and T 50. In order to find out T 90 and T 50 you have to go through a lot of construction procedures but in T 100 actually it is pretty easy because it is similar to the double tangent method like the one that I spoke previous during the construction of the preconsolidation pressure but like the previous one this also is less accurate method but today actually we are going to follow this method T 100.

So, T 100 means you have to construct a double tangent form the linear part of this curve and a linear part of the compression curve. Now this tangents when they intersect at a specific point this point is termed as a T 100 point. You all know that this is the void ratio and this is the time which is again in log scale. So, this T 100 comes out to be 32 minutes. Now once this T 100 now once this T 100 is found out now find out the e 100 that is the void ratio at the 100% consolidation.

You can also use we can also use a different procedure by taking the 4 times of the length that is T 50 procedure that we generally follow the log method. That also I am going to discuss so this is how it looks like. Now first you have to find out the initial void radio e 0. Now you all know that the initial void ratio e 0 is actually given as 1.86. Once the initial void ratio e 0 is know then you have to find out a time year origin.

So, let us say we take a time like here let us say we take a time like t 1 equal to 0.1 minute. Origin means near the initial void ratio. You have to take another time that is exactly 4 times longer than the initial time. So, 4 times of t 1 equal to 0.4 minutes that is let say that is equivalent to t 2. Now for 0.1 minute we have the value of e as 1.7. So, t 1 equal to 0.1 minute we have e 1 equal to 1.700 and for t 2 equal to 0.4 minutes we have e 2 equal to 1.678. Now remember this value is not given here. So, the best thing that you can do is find out interpolation between 0.3 and 0.5 and find out what is the value of e at 0.4 okay.

This is what it has been done here also a linear interpolation between 0.3 and 0.5. I am not going to discuss the details here but this is how you are going to find out the e 2 value. That means basically you are found out you will find out a linear interpolation simple linear interpolation between the 0.3 and 0.5. Once you know this part so basically now you find out the value of e 1 - e 2 equivalent to because we know that delta e because it is a linear portion so basically e 1 - e 2 must be equal to e o c - e1. So, from there we get e o c or the initial over consolidated part to be 1.721.

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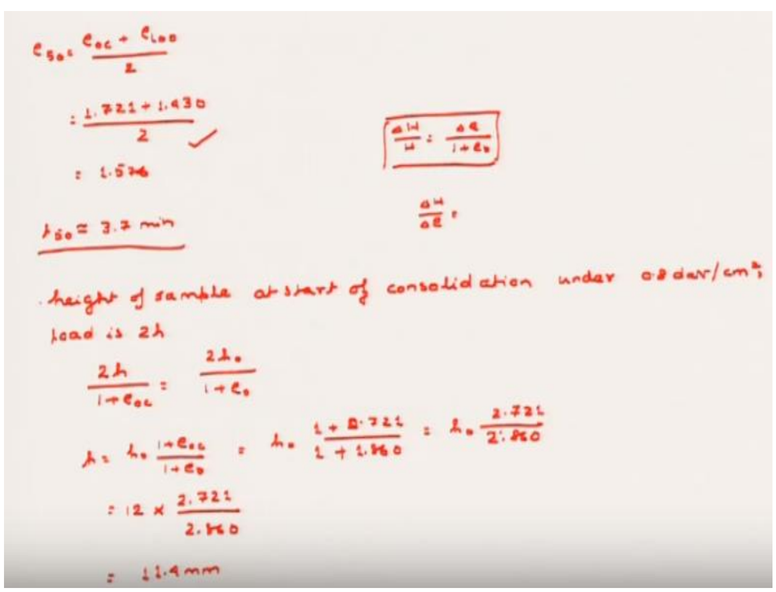

Now e o c once it is 1.721 so we find out the e 50 as e o c means the original the initial part and e 100 means the final part divide by 2 so 1.721 plus 1.430 by 2 which is equivalent to 1.576. Now I hope that I have I hope that I okay the e 100 here is obviously at 32 minutes is 1.421 it is given here okay. So, e 50 is 1.576 so from there you can calculate the T 50 as 3.7 minutes. Now this is all possible because the scale of e is linear and the scale of T is in log okay so that is why you just linearly interpolate all the e's that you get and find out what is the value.

Again, let me discuss this T 100 procedure because it has been not been covered in the lecture so in T 100 procedure what we do is that we just do a double tangent method from the linear part of the secondary compression because you all know that this is a secondary compression and this is the virgin consolidation curve. So, what we do is that we draw a linear we draw our linearly we draw a linear interpolation or basically we draw a linear part of the virgin consolidation curve and the secondary compression curve and extend that so that they intersect at a certain point.

That point is considered to be T 100. So, T 100 in this case comes out to be 32 minutes. If it is given what is the value of e 100 corresponding to T 100 that is good otherwise you have to linearly interpolate to find out what is the value of e 100. So, once you know e 100 now you just take a point that is near to the origin T 1 and you find out a point that is 4 times of that of the origin that is 0.4 in this case we have taken.

Now for 0.1 the e 1 was given for 0.4 it is linearly interpolated between 0.3 and 0.5 to find out what was the value of e 0. So, once the value of e 1 and e 2 was found out not from the original relation we all know that since e is linear in that part so delta e 1 must be equal to delta e 2 that is what we have found out in order to find out the e o c. e o c means the initial void ratio at the over consolidated part that means at this part.

So, e 1 - e 2 equal to e o c - e 1 so from there we founded out e o c to be 1.721. Now we know what is e here that is at the start of the test we know what is at 100% of consolidation what is because T 100 corresponds to 100% of consolidation so we know what is the e 100 here. This is the e o c and this is e 100. So, once e 50 once we know e o c and e 100 e 50 will be between them.

So, it will be half of e o c plus e 100 by 2 that is what we have done and corresponding to e 50 we have founded out what is the value of e 50. So, this is how you find out the coefficient of consolidation c v or in a different procedure or T 50 in a different in a different procedure not considering T 90 or T 90 part okay or this is the T 100 type of scale. Now for T 90 also you can find out T 90 in that case what you have to do is that you have to find out you have to first draw a line that is 1.15 times of the x part and basically you have to see that where it intersects the curve and then basically from there you can find out what is the value of the T 90 part.

So, now how to find out the coefficient of consolidation. Now coefficient of consolidation can be found out because the height of the sample at start of consolidation under 0.8 daN/cm square load is 2h. We will consider this that the height of the sample at 0.8 daN/cm square load is 2h.

Then we have 2h by 1 + e o c means e o c means the original I have told you that in the beginning when basically we started the consolidation this remember that this should not be confused with the this should not be confused with this 0 and e 0 because this 0 and e 0 means it is the consolidation it is the consolidation time it is the void ratio at the time when basically there was zero pressure but this is not corresponding to the point where basically this is 0 pressure.

It is basically at 0.4 daN/cm square and then the load has been increased to 0.8 daN/cm square. So, that is why we get a e o c of 1.721. Remember this very carefully. Because this is quite different from the fact that this e 0 okay do not confuse this e 0 with the compression part because compression when it is in compression part it is already been loaded so that is why you have to find out this e o c value otherwise this value would have been given to you or you have to find out from W g equal to e s.

So, during that part when basically it was subjected to a load of 0.8 daN/cm square then its height was 2h. So, 2h by 1 + e o c must be equivalent to 2h 0 by 1 + e 0 because now we are reverting back to the original consolidation curve that means we are reverting back to this original consolidation sigma e. So, from sigma e curve we can say that because we know that delta H by H is equal to delta e by 1 + e 0.

So, from this relation we can also say that 2h by 1 + e 0 c that is h by 1 + e 0 must be equivalent to 2h by 1 + e because delta H by delta e is supposed to be same in both the cases. So, we get h is equal to h 0 into 1 + e o c + 1 + e 0. So, basically it was 12 into 2.721 by 2.860 or maybe I can write it in a more elaborate way like 1 + 0.721 because e o c is 1.721 1.721 and e 0 we have already found out to be 1.86.

So, 1.860 so that means h 0 into 2.721 divide by 2.860 and this 12 is basically the height of the sample that also has been discussed here see 2 h 0 is equal to 24 mm so h 0 is 12 mm because we considered the half of the sample. So, in this case it comes out to be 11.4 mm.

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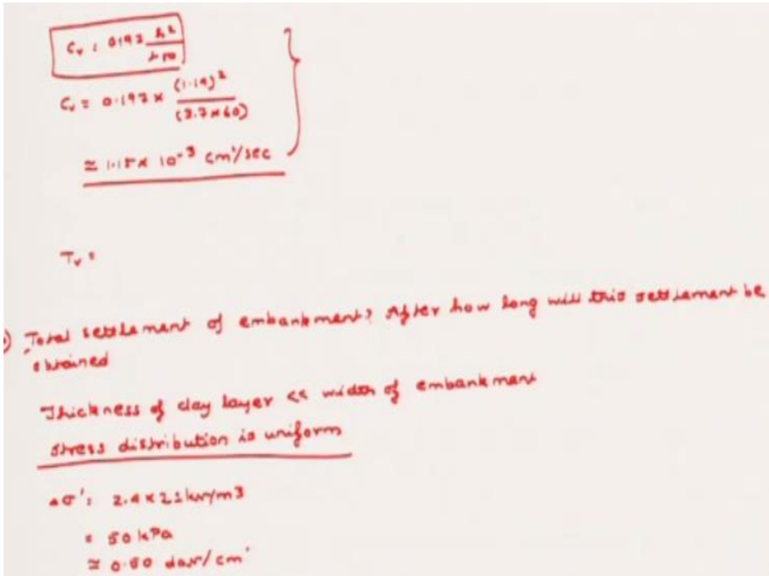

So, now C v is equal to 0.197 into h square by T 50 so C v equal to 0.197 into 1.14 square divide by 3.7 into 60 which comes out to be 1.15 into 10 to the power - 3-centimeter square per second. Now this method like T 50 method this method is also known as the log of time method. Like the square root of time method okay just like the part that is covered in the lecture this is termed as the log of time method because in this case you consider the log of time okay.

So, initially what you do is that you just intersect the initially you find out the T 100 and then basically from there you find out the T 50 and once you find out the T 50 then basically you find out the coefficient of consolidation from the T 50. So, in this case it finds out to be 1.15 into 10 to the power of - 3 cm/sec and this formula is already discussed that about how you find out the this coefficient called 0.197 because this 0.197 is from the time factor T v or consolidation.

Now after this part has been done so the first question has been done because the first question is said that you find out the preconsolidation pressure which you found out from the Casagrande construction then C c which is the compression index that also you find out from the that also you find out after finding out the preconsolidation pressure then we founded out what was the value of the C v.

Now moving to the next question which is said that total settlement of embankment and after how long will this settlement be obtained. So, this is second question. Now in order to find out the total settlement of the embankment now we have already we have already found out that what is the value of C c C v and all those factors. So, now in this case we are going to find out that what is the total settlement of the embankment so the first thing that you have to consider is that the thickness of clay layer.

Now as you can see the thickness of the clay layer is less is the thickness of the compressibility layer is small compared to the width of the embankment because the width of the embankment is considered to be 20 m while the thickness of the clay layer is just 4 m. So, thickness of clay layer is much less much less than width of embankment.

So, in this case it may be assumed that the stress distribution due to the due to the embankment or due to the embankment on the clay layer is considered to be uniform because if the width is like comparable with the thickness of the clay layer then in that case basically the stress distribution maybe non-uniform but in this case since the thickness of the clay layer is much less than the width of the embankment so in this case the stress distribution is uniform.

This is a very important thing. If this if the stress distribution is non-uniform then we will see that how basically if the stress distribution is non-uniform in that case how the settlement is evaluated for the different stress distributions. In that case basically you have to either divide the section or you have to adopt some another method in order to find out the stresses at different levels.

So, basically in this case the stress distribution is uniform so we can easily find out what is the value of delta sigma dash because as I have said that only the depth of this embankment is required in order to find out the delta sigma dash because we all know that the bload at any point is 45 it is going to come out is gamma into z. So, in this case the gamma into z comes out to be 2.4 which is the height of the embankment into 21 kN/m cube. So, this comes out to be approximately 50 kPa. Now since we are doing everything in da newton so this is 0.50 daN/cm square. So, once this has been done then following just like the previous day we said that we have to find out the stress at the middle height of the clay layer.

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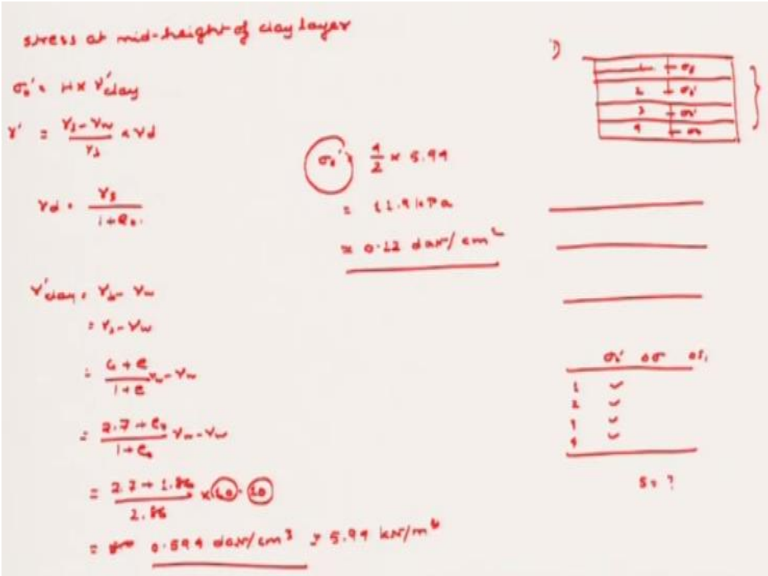

Now here one thing I want to mention that basically it may be also have been covered in your assignments that if basically the clay layer is a very is has a very great depth or basically let us say that the clay layer is has a very extensive depth in that case basically in order to make the settlement calculation all more equivalent to the field conditions what we do is that we just divide the clay layers into a number of subsections.

So, suppose you divide it into 4 subsections. So, in that case what you find out is that you find out you just form a table and you find out what is the you just form a table and you find out what is the 1 2 3 4 you just find out what is the stress at each of this sections. Let us say that for the 1 what is the stress in between. For the second layer, what is the stress in between. For the third layer, what is the stress in between.

What is the fourth for the fourth layer what is the stress in between. Then the stress increments in between for all this 4 layers and you calculate the settlement for each of this layer individually. At the end you add up the settlements for all this layer to get the total settlement. This is a very important fact. You must remember this that basically if the clay layer has a greater depth in that case basically you have to divide the clay layer into a number of subsections so that according to appropriate to you it may be 2 it may be 4 whatever it is but generally if it is like but generally you should divide it into as many small sections as possible so that basically the settlement becomes more close to the equivalent field conditions or the settlement that is observed in the field.

So, in this case since the settlement height is less like 4 meter so in this case we have to find out the stress at mid depth or at mid height of clay layer. Now sigma 0 dash is equal to H into gamma dash into clay. So, now you have to find out the gamma dash of clay. So, gamma dash is equal to gamma s - gamma w by gamma s into gamma d where gamma d is equal to gamma s by 1 + e 0 or you can easily adopt a way gamma dash of clay is equal to gamma b - gamma w that is gamma s - gamma w where gamma s is given by G + e by 1 + e - gamma w into gamma w.

G has already been given in the problem which is equivalent to 2.7 so 2.7 this is e 0 by 1 + e 0 into gamma w - gamma w. Now e 0 for the problem has also been given 1.86. So, 2.7 + 1.86 divide by 2.86 into 10 - 10 which comes out to be equivalent to 0.594 because remember this is again in I am doing everything calculations in da newton per centimeter cube. So, this is also in da newton per centimeter cube. So, this may not be 10. So, sigma 0 dash that is at mid height of the clay layer which is obviously 4 by 2 into 5.94 so this comes out to be 11.9 kPa.

If this is in if this is in 10 this comes out to be 5.94 kN/m square meter cube sorry. So, this is equivalent to 0.12 daN/cm square. Now if you do it in kPa then this comes out to be 5.94 kN/m square meter cube sorry and obviously multiply with 4 by 2 because at the mid height you have to find out so it comes out to be 11.9 kPa. Now you can proceed according to kPa or because all my units are in da newton per centimeter square so we have converted this into da newton per centimeter square. So, now you have founded out the value of sigma 0 dash and you also know what is the stress increment.

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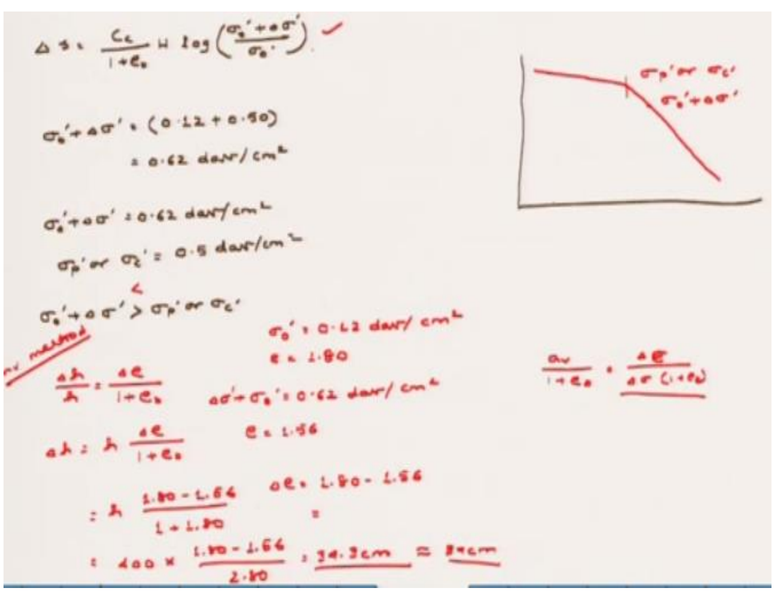

So, just referring back just like the previous problem we have said referring back to the original definition of consolidation delta S is equal to C c by 1 + e 0 into H into log of sigma 0 dash + del sigma by sigma 0 dash. So, what is the value of sigma 0 dash + del sigma dash. This is equivalent to what is the sigma 0 dash sigma 0 dash is 0.12 so 0.12 + what is the del sigma dash 0.50 so 0.50 adding both of them we get 0.62 daN/cm square.

So, now as I have said that in the first problem that you have to check this part that whether your present sigma 0 dash is greater than the preconsolidation pressure or less than the preconsolidation pressure. Depending on that here sigma 0 dash + delta sigma dash is equivalent to 0.62 daN/cm square and if you remember correctly then sigma p dash or sigma p dash whatever you call it, it is equivalent to 0.5 daN/cm square okay.

That is the preconsolidation pressure. So, obviously sigma 0 dash + del sigma dash is greater than sigma p dash or sigma c dash. Now let us refer that to the consolidation curve. So, this is my consolidation curve. So, this is my preconsolidation pressure. Now you are lying somewhere here. So, obviously the effect of preconsolidation settlement is gone. That means only you have to find out the virgin settlement from the virgin consolidation curve.

So, if that is the case then you can find out since the compression curve is given to you instead of using this formula you can directly apply the compression curve. That is delta h by h is equal to delta e by 1 + e 0. So, if that is the case then delta h is equal to h into delta e by 1 + e 0. Now you have to find out from 0.60. Now so let us find out the corresponding values. So, sigma 0 dash is equivalent to 0.12 daN/cm square stress at the mid height of the clay layer.

Corresponding e is equal to 1.80. Now how do I find out the corresponding e? So, from here you have to linearly interpolate. That is the only option, 0.2 it is given as 1.80 so like that you have to linearly interpolate in order to get that value and for sigma 0 dash is equal to 0.62 daN/cm square that is the present stress condition this is delta sigma dash + sigma 0 dash. We have e is equal to 1.56.

Now this also you have to linearly interpolate between 1.7 and 1.40 in order to get the value of 1.56. So, all this results are neglecting here but as I have said previously that you can just find out the linear interpolation it is very easy to find out. Just find out the linear interpolation between sigma 0 between sigma 0 dash and delta sigma to find out the value of e. So, e is equal to 1.56. Now just put the values. Now you see what is the change in delta e. So, delta e has been changed from 1.80 to 1.56. So, it comes out to be 1.80 - 1.56 and your original e was obviously

1.80 and h is the height of the clay layer which we have already said is 4 m so 400 cm into 1.80 - 1.56 by 2.80 which is equivalent to 34.3 cm or this is equivalent to 34 cm. So, this is the settlement.

Now you can also refer to this definition delta h is equal to C c by 1 + e 0 h into log sigma 0 whatever you prefer you will see that the settlement is same in both the cases or it comes out to be 34 cm. This is an easier method because it just uses a linear method rather than using a long procedure okay and it is more easier in that way this is called mv method okay. Either of them you can either of them you can use mv you know which is coefficient of volume compressibility and it is given by a v by 1 + e 0 where a v is given by delta sigma delta e by delta sigma into 1 + e 0.

So, that is what we have done here the same thing because delta sigma is the increment and we have considered the increment to be constant. So, this is the best way in which basically you can find the settlement and basically and basically in order to find out the if there was a preconsolidation settlement previously or basically if this was less then in that case you have to refer back to this definition of settlement that means basically you have to find out the preconsolidation settlement first then moving to the next part the virgin consolidation settlement and add up together to find out the total settlement.

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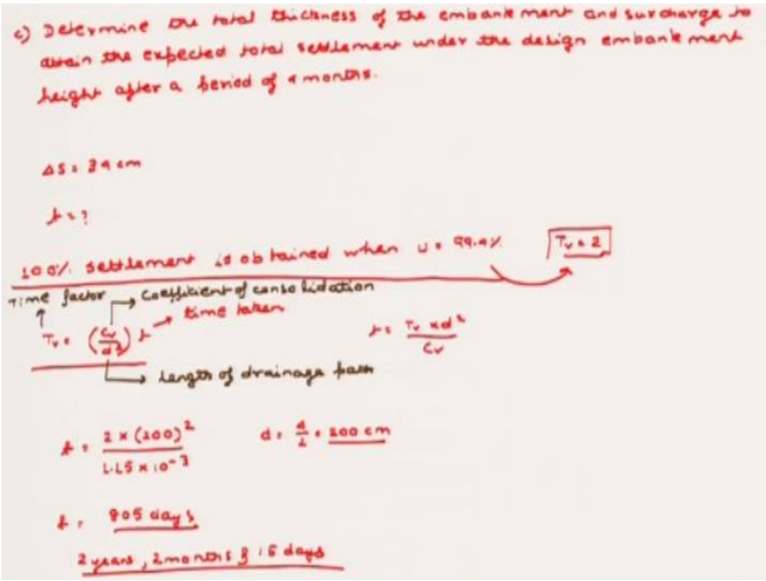

Now moving to the final question which is said that determine the total thickness of the embankment and surcharge to attain the expected total settlement under the design embankment height after a period of 4 months. So, let us first see that 34 cm is the consolidation settlement that you have obtained. So, delta S equal to 34 cm. So, let us see what is the time taken to achieve this 34-cm settlement.

Now theoretically you can say because you all know from the consolidation curve that the time taken is infinite because this is the infinite long settlement. But general practice is that a 100% settlement is obtained when U is equal to 99.4%. This is a very important part. So, if anybody asks you that basically what is the time taken for the settlement it is not 100% but actually U is equal to 99.4%.

This is generally theoretically considered okay. This is practically considered, theoretically it is like infinite but practically it is considered that when U or the degree of consolidation is actually 99.4% then 100% settlement is obtained. So, now T v as we know is equivalent to C v by d square into t where d is the drainage path C v is the coefficient of consolidation and t is the time taken for the consolidation this is time taken this is time factor this is length of drainage path and this is coefficient of consolidation.

So, now t is equal to 2 into 200 square by 1.15 into 10 to the power - 3. So, t because this 200 comes from the fact that this is the drainage path so obviously it is d is equivalent to I should have said this that 4 by 2 which basically is 200 cm that is 2 m so half of the drainage path because there is an because there is a sandy gravel below which basically subsides the drainage as well as the top there is a drainage so basically it is a half it is the double drainage path.

So, that is why double drainage means it is half the drainage path. If it has been a single drainage that means below there was no drainage was permitted then basically it had been a single drainage path that means written 400 cm. So, t we can write as T v into d square by C v. Now obviously T v is 2 because for 99.4% if you find out what is the time factor then it comes out to be 2.

So, 2 into drainage path is 200 cm so 200 square by C v the coefficient of consolidation which comes out to be from our log of time method it comes out to be 1.15 into 10 to the power - 3 cm square per second so that is what I have written and this comes out to be 805 days. So, this is equivalent to 2 years 2 months and 15 days. This is the time that is taken to reach a settlement of 34 cm but here it is said that how much total thickness of the embankment is to be considered so that the settlement consolidates within 4 months. Now it is obvious that if you have a settlement height of 2 that height means settlement height of 2.4 m then obviously it is going to take 2 years 2 years 2 months and 15 days to settle.

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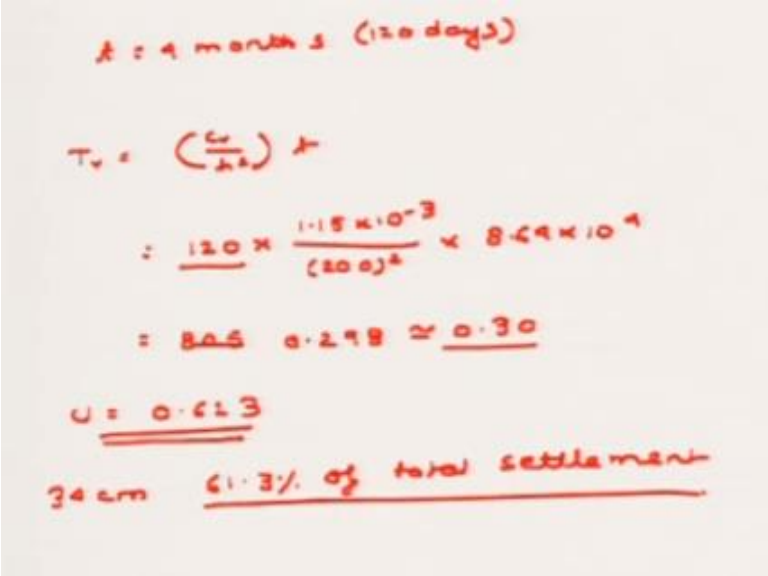

So, in order to attain a settlement time that means now the t has been given to you as 4 months or it is in 120 days. So, what should be the time factor? The time factor you can find out again from the given relation like C v by h square into t so now this is given 120 days into C v which is 1.15 into 10 to the power - 3 and h which is 200 square. Now in order to convert this into second so 8.64 into 10 to the power 4 this 120 days I have converted into second so it is 8.64 into 10 to the power 4.

So, 800 and sorry so 0.298 or that is equivalent to 0.30 so this is the time factor for the consolidation and if you see the value of U it comes out to be 0.613. So, for a settlement of 34 cm it corresponds to 61.3% of total settlement. Now we will stop here today and we will continue with this problem in the next lecture and we will also discuss other aspects of consolidation in the next lecture. Thank you.