Soil Mechanics/Geotechnical Engineering I

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Lecture - 42
Compressibility of Soils (Contd.)

Good morning, once again I welcome you to this lecture on soil mechanics and geotechnical engineering and I will start now exactly where I have stopped in my last class, a last lecture and I was discussing about the determination of coefficient of consolidation by laboratory method and that actually we have.

There are two well known methods are available and one is by given by Taylors method Taylors are sometime called root two method, root t method and another is Casagrandes method that is actually log of time method. And this root t method before going to root t method what it is what was observed that root of time factor versus degree of consolidation plotted and observe certain behavior and when it is the laboratory data, consolidation data root time versus dial gauge reading is plotted the behavior was similar

So, based on that observation there was a method proposed to find out the point corresponding to 90 percent consolidation and once you know the point corresponding to 90 percent consolidation then the you can find out t 90, that is time required to complete the 90 percent of consolidation and once you know that t 90 that is small t the time for 90 percent consolidation. And also you we generally know time factor 90 percent t 90 the actually time factor for 90 percent conso degree of saturation, that is from the relationship we can find out.

So, t 90 and if you once for that is known and t 90 again equal to cv into t 90 by h square where actually t 90 is obtaining from the curve that is time required for completing the 90 percent consolidation and h is a thickness of the sample and that depends of course, whether it is a double rate is a single rate is how much to be h that I have explained I will explained again. So, h also known and time 90 percent consolidation time also known h is known only unknown is c. So, equating these you can one can find out the value of c.

Similar to that there is a another method that is called log time method and it was proposed by Casagrande and these method similar to that similar to the root t method.

This method also initially time factors actually long time factor versus degree of consolidation was plotted and the experimental data also plotted in the same manner; that means, log t versus dial gauge reading or sample thickness and behavior was similar. So, based on that similarity there actually the method is proposed to find out time required for 50 percent consolidation, 0 and 100 is located and then finally, in between 50 percent point is located which is average consider to be average and time required for 50 percent consolidation if it is determined from the test.

And time factor for 90 for 90 percent degree of 50 percent degree of consolidation one can find out from the relationship and then these two to be equated there also similarly we have the only unknown is cv because a thickness and time required for 50 percent consolidation is also known. So, that cv based on that consider comparison or equation from that relationship one can find out the cv.

So, now I will go or the step by step how to do this, how to use this experimental data for determining the coefficient of consolidation cv. So, before going to that step by step procedure I will just show the theoretical curve that is root time factor versus long time factor versus degree of consolidation and the laboratory plot that is root time versus dial gauges. This 2 plot I will show first and what are the observation made first and then I will go step by step procedure what you have do actually when you have the experimental data one consolidation.

So, I will skip initially 2, 3 slide and then again come back. So, this was this is the plot actually 2 plots are shown here, 1 this is actually theoretical plot.

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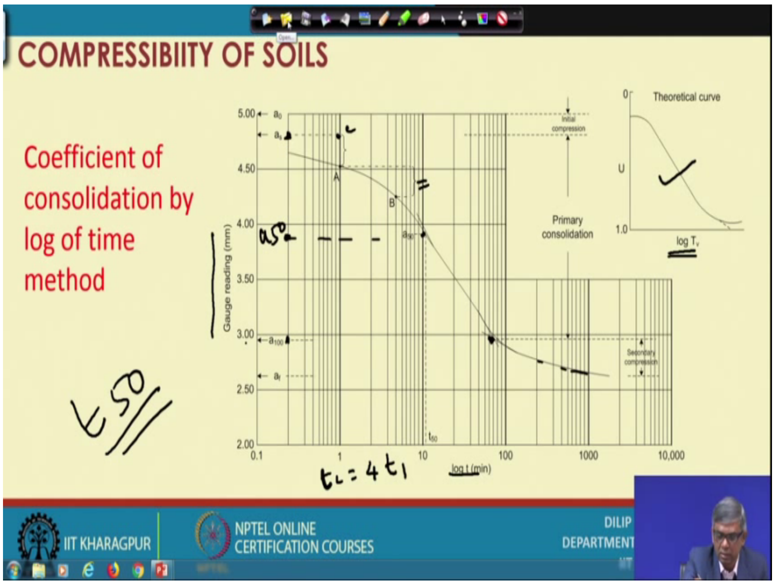

This is the theoretical plot you can see U versus log T v T v is nothing, but time factor sometime use v (Refer Time: 05:24) do not use v. So, this since it is a vertical compression you are talking about. So, t v is used.

So, this is the plot the it is parabolic and then it is going this side and this is the plot when it is time versus consolidation time versus dial gauge reading, dial gauge reading means what when the soil is compressive if the dial gauge indicate how much settlement or consolidation took place. So, that the dial gauge reading is if it is taken and time is noted then log time versus dial gauge reading. So, this is plotted at this shape and this shape almost similar.

So, because of that and if you have these and then actually we can this parabolic part actually will have a standard way of variation. So, because of that procedure is to find out from this curve you have to find out 0 consolidation point and 100 percent consolidation point and this is actually after 100 percent consolidation and whatever con that is actually secondary consolidation and secondary consolidation of course, we will not discuss right now this is a separately I will discuss later on.

But, the so the before start of secondary consolidation; that means, end of primary consolidation; So, how to locate that you can see that this part this is this is the there is a point of inflection that will change and then here actually to become to towards a due the become straight this side.

So, what you have to do you have to extend this state portion backward and from these there is a point of inflection from there actually we have to straight line and extend then it will meet a at a point that is here suppose at this point. So, this point actually indicates the end of primary consolidation. So; that means, it is a 100 percent consolidation. So, this is actually a 100 and ah; that means, 100 percent compression this is suppose and then to find out 0 compression.

So, what you have to do we can choose two points this is a parabolic portion of the initial parabolic portion of the curve, we can choose two point in such a way that t 2 equal to 4 times t 1. This is the way you have to take and then if you take these then the distance or ordinate between a and b suppose some value then from a will select another point suppose c c here and look at that point and through that point it make a horizontal and intersect this ordinate at that point indicates actually 0 consolidation.

So, we get 0 and we get 100 so; that means, from here to here this is actually the consolidation settlement. So, this rate may not be uniform, but. So, if I take at a 50 percent we supposed to get the average.

So, because of that what you do between these and these will find out the midpoint of it and from there I will project on this curve and that will give you the this is some a 50, then this will give you corresponding t 50. So, like a Taylors method what you have tried to find out, we find out try to find out time required for 90 percent consolidation that is t 90 and in Casagrandes method that is by log time method what you are trying to find out, we are trying to find out t fifty; that means, time required to complete 50 present consolidation. So, this is the point.

So, the outcome of this plot is ultimately determination of t 50. So, this is the by large the curve or how to plot and there are different steps, but now I will go back to the original slide that the first pro right from beginning and try to show you the procedure how you have to follow to find out the cv

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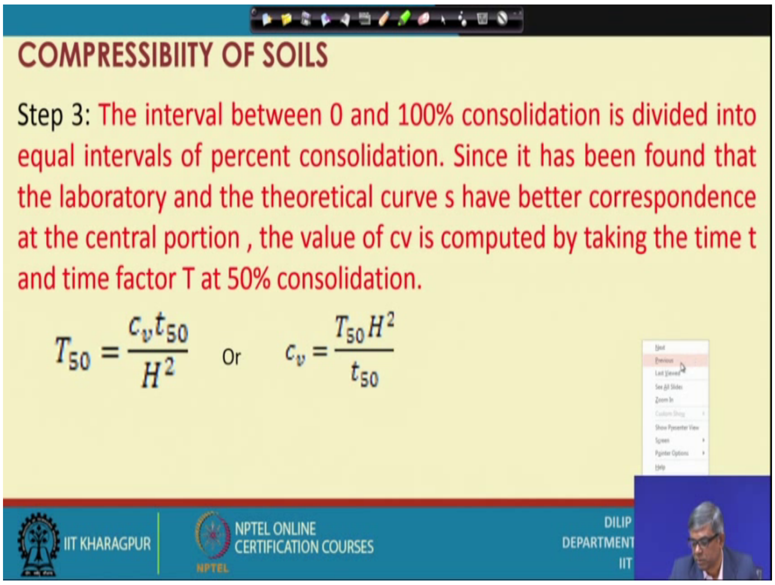

You can see that coefficient of consolidation by log time method.

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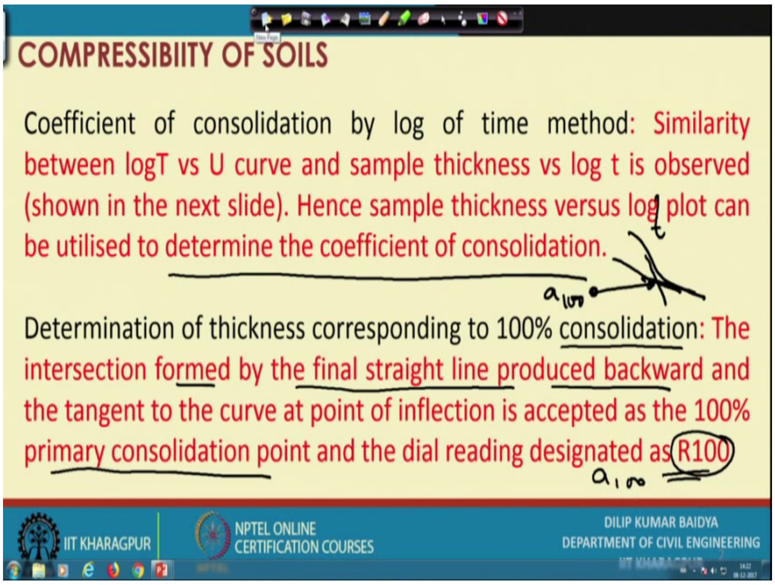

So, the similarity between log t versus U curve and sample thickness versus log time log t is observed and we have shown already, there is the sample thickness versus log plot or log t plot actually log t plot can be utilized to determine the coefficient of consolidation.

So, since there are similarities there. So, that can what similarity should be. So, two things determination of thickness corresponding to 100 percent consolidation to be determine first the intersection of, intersection form by the final straight line produced backward which I have shown already the towards this side I will back produce back and the tangent to the curve at point of inflection is accepted as the 100 percent primary consolidation.

So, already I have shown once again I will show that. So, the curve is coming like this. So, I will produce back this one and I will something like this and I will produce this one this intersecting point and this will be your a 100 I will go back to the figure again and the and the dial reading designated as r 100 or a 100 r reading 100 or a 100. So, in figure it is a, but this is written as. So, do not get confuse there are same.

So, this is actually once you got the 100 percent consolidation point next thing to determine of the thickness corresponding to 0 percent co primary consolidation.

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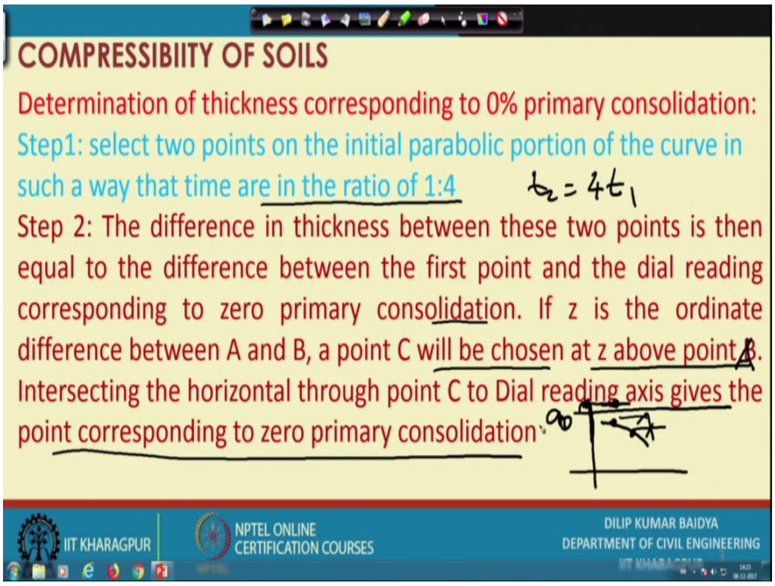

So, in this actually what you have to do select two points on the initial parabolic portion of the curve in such a way that time are in the ratio of one is to 4 that mean t 1 t 2 will be 4 times t 1 this is the way you have to choose.

The difference in thickness between these two point is then equal to the difference between the first point and the dial reading corresponding the 0 primary consolidation. So, this is the observation if z is the ordinate difference between A and B, a point c will be chosen at z above point B or point A actually a per figure intersecting the horizontal through point C, to dial reading access axis gives the point corresponding to zero primary consolidation.

So, I have shown already 0 or the suppose it was it was like this and this curve was something like that one point is here another point is here and then I will get the difference distance between this the from here actually same distance point I will look at here and go horizontal that this give you a 0. So, I will show again

So, this is the way you locate the point corresponding to 0 percent consolidation.

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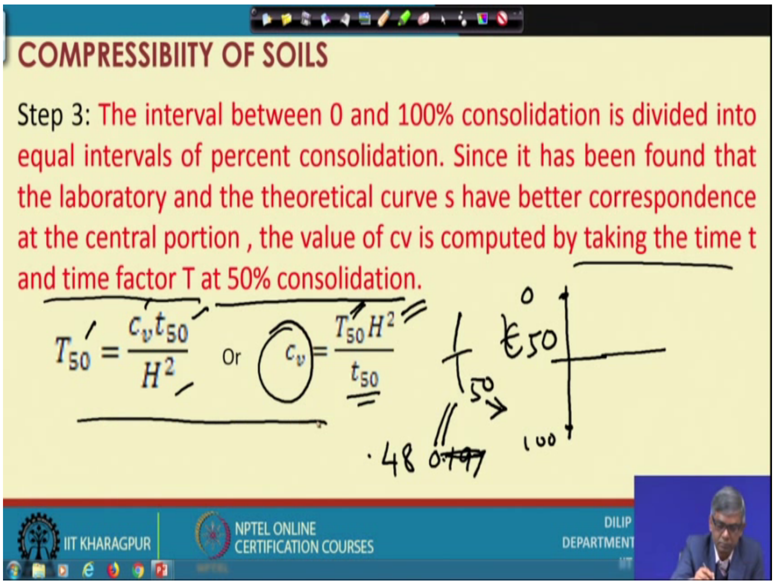

And next is the interval between 0 and 100 percent consolidation is divided into equal intervals of percent consolidation. So, suppose I have 0 here and 100 here. So, I uniformly distribute. So, if I want to find out 50 percent it will be just exactly at the midpoint, since it has been found the laboratory and the theoretical curve v have better correspondence at the central portion; that means, and the average the value of cv is computed by taking the time t and time factor t at 50 percent consolidation time t. So; that means, I will find out t 50 and I will from the curve I will find out small t 50.

So, this 2; So, t 50 from the relationship between t versus u; that means, t 50 means what time factor corresponding to 50 percent degree of consolidation that is actually I will get and that value will be 0.197 most likely no 0.48.

So, this is actually so, if I do not know the value then I can write t 50 equal to cv t 50 by a square. So, ultimately cv is unknown because this can be obtained from the relationship H actually think h length of the drainage path and if it is single drainage it is equal to the thickness and if it is a thickness of the sample and if it is a double drainage then you have the thickness of the sample and t 50 to be obtained from the graph. So, this is the way one can find out the cv.

Once again we are coming back to this curve.

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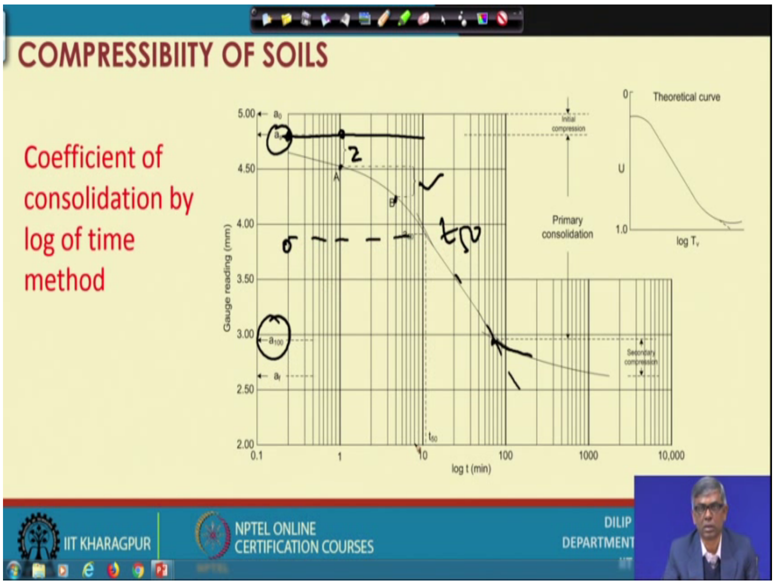

You can you can see same thing as I have mentioned that you have produce this back and you have produce tangent here the intersecting point here a 0 and you have chosen a point here and here then between these distance is z then I will draw on point above this z.

So that points above c and then, draw an horizontal passing through these intersecting this that is in a 0 and this is a 100. So, a 50 will be midpoint of that from there we will get the t 50 this is will give you t 50 from here. So, that finally, will equate to get the coefficient of consolidation.

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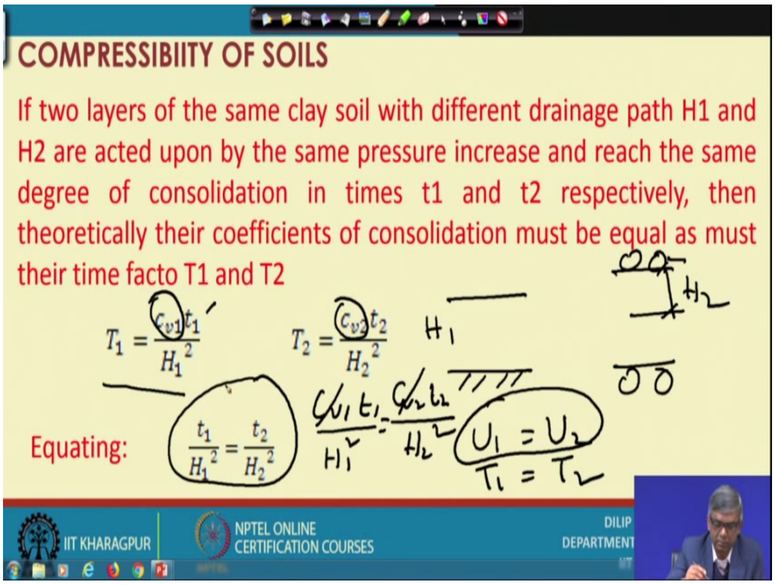

Now, if two layers of the same clay soil is same, but with different drainage condition and. So, drainage path H 1 and H 2 are acted upon by the same pressure increase and reach the same degree of consolidation in terms of t 1 and t 2. So, drainage path is different thickness of the laver layer is different, but soil is same, but again degree of consolidation is same so; obviously, time will not be same; So, T 1 and T 2.

Suppose respect then the theoretically how will be the relationship suppose t 1, suppose t 1 will be cv 1 someone layer 1 t one time required for time for the layer 1 and H 1 square. So, drainage path suppose one layer is something like this single drainage and this is suppose H 1 another layer is something like this and this is double drainage and this is suppose H 2 ok.

So, that is the thing, but since soil is same though initially I am writing cv 1 and cv 2 separately, but since the soil is same coefficient of consolidation will be same. So, ultimately this 1. So, t 1 and t 2 time factor since for both cases we are we achieved suppose same degree of consolidation; that means, U 1 and equal to U 2 then t 1 will be equal to t 2. So, if t 1 equal to t 2 then ultimately you will have cv 1 t 1 divided by H 1 square equal to c v 2, t 2 divided by H 2 square.

So, see we both the cases we achieved that same degree of consolidation then your corresponding to t 1 and t 2 they are equal. So, t one or t two also will be equal. So, if they are equal then this 2 can be equated and once again you can see, since it is same soil the c v 1 equal to c v 2. So, ultimately what is left t 1 by h 1 square equal to t 2 by h 2 square.

So, from for a particular soil when laboratory test is conducted on a particular thickness and if it is asked to find out the actual (Refer Time: 18:37) is the thickness is this much, what will be the time to be time required. So, directly one can use this relationship to find out the timing. So, this is another observation or important information which can be used in solving the problem.

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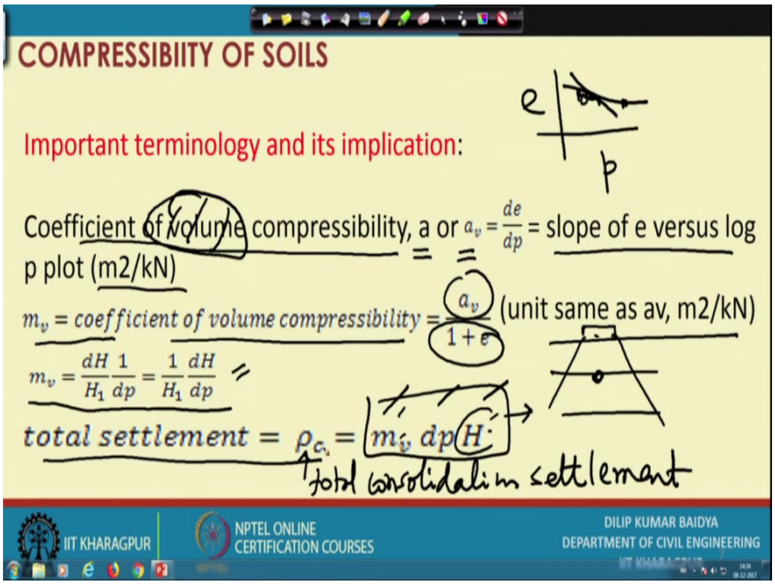

Now, I am almost at the end of compressibility topic, but once again what I will do I will summarize the important points what I have discussed. So, far and then how to utilize that using by applying to the different problems in 2, 3 lectures actually I will devote to solving the problem mainly because the different types of problem possible a different exam different types of problem comes. So, for all varieties of problem I will try one after one maybe 2 to 3 module I will take on solving problem addressing different aspect of the cons compressibility of soil.

So, this is the summary what we have done actually you can see first we have defined coefficient of volume compressibility sorry this is not this is the yeah, coefficient of compressibility actually not volume compressibility will come later on if this is co. This is not the coefficient of compressibility coefficient of compressibility is a sometime you write a v either by it can be written. So, this is de by dp and it is nothing, but slope of e versus p curve. So, e versus p curve if you plot. So, it comes like this. So, if you select 2 points sorry this is not come it will not come like this. So, if you select 2 points then from this 2 point, we can find out the slope between these 2 point and that is nothing, but de by dp and you can see unit will be it will be meter square per kilo Newton because e does not have why does it does not have any unit and dp is the below.

So, inverse of pressure unit will be the coefficient of compressibility and another term we have defined mv coefficient of volume compressibility which is nothing, but av by one plus e; that means, unit will not change only coefficient of compressibility divided by original volume. So, that is then it become coefficient of volume compressibility the unit will be same meter square per kilo Newton and mv. So, different ways it can be expressed mv also av by 1 plus e that is also can be expressed d h by h 1 by 1 by dp.

So, change of volume volume compressibility over unit pressure. So, from that definition if you use d h by h 1 where h 1 is the original thickness and dp is the pressure change. So, if I simplify it become 1 by H 1 d H by dp. So, this is another way of defining mv volume compressibility. So, if you know the directly thickness versus pressure or pressure versus thickness change from there also we can find out the dh dp like da dp and they divided by original thickness, that also give you a volume coefficient of volume compressibility.

Once you know the coefficient of volume compressibility one can find out the total settlement and that is shown here rho c total consolidation this is actually that nothing, but total consolidation settlement consolidation settlement and this is actually mv into dp into h and you can see it was meter square per kilo Newton. So, dp kilo Newton square meter. So, it get cancel ultimately thick the entire unit of this entire thing will be a a unit of h. So, you suppose to get settlement in meter or millimeter. So, that is thing is that things are coming.

So, mv dp into h this is the relationship when you use the mv method for of finding out the consolidation this is a simple formula. So, how to do that if there is a layer here and you know to find out the e versus p curve and from there we can get a v and then av by 1 plus e will get mv and how to find out dp if this is a layer and you have applied load here then what is the pressure increase in the middle of the clay layer that is del p. That can be obtained by either by bossiness or by trapezoidal distribution like this one can find out and then finally, multiplied by thickness that gives you the total consolidation settlement by mv method.

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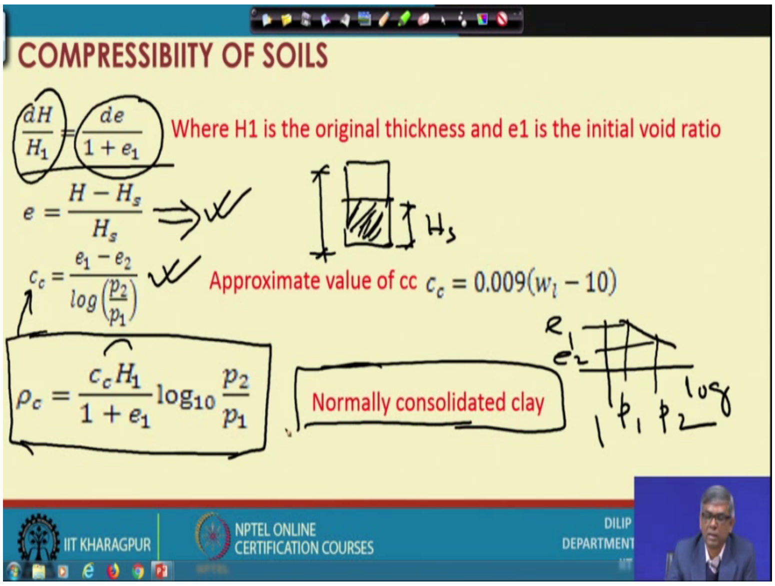

Next thing is we have considered another is another important thing some many times will be useful d by 1 plus this is the volume compressibility and coefficient of volume compressibility change of volume over original volume. In fact, and this is also change of volume of over original we have to considering one dimensional consolidation, if you consider the consolidation is one dimensional; that means, there is no other change in the lateral dimension only compression because of the compression in the vertical direction then this relationships valid.

And another definition of void ratio if I know the soil volume is v and then cross sectional area is not changing. So, if I think that idealized that thickness of the solid is H s then and total thickness is h then I can define void ratio H minus H s by H s. This is the way sometimes solving some problem this is important and required.

Another thing we will discuss that e versus p curve is a curve, but when you plot e versus log p it becomes a straight line and mostly straight line there will be some observation; obviously, initial portion that I have discussed. One second I do not want to discuss again, only thing of what I have to mention that the major portion of the e versus log p curve will be straight line and the slope of the straight line will be cc compression index and that cc equation will be e 1 minus e 2 by log p 2 by p 1.

So, if it is a something like this your curve is like this and this is p 1 then this is p 2 then this is e 1 and this is e 2 and this is this is p 1 and this is p 2 then and this is this is in a log scale then your expression for compression index is c e 1 minus e 2 by log p 2 by p 1. And then if you know the cc then we can find out the consolidation by compression index method by using this formula cc into H by 1 plus e log p 2 by p 1 and this is actually this formula is applicable only for normally consolidated soil and when it is a over consolidated soil that will be a treatment will be little different and that is also I have discussed, but I will once again summarized that is 1.

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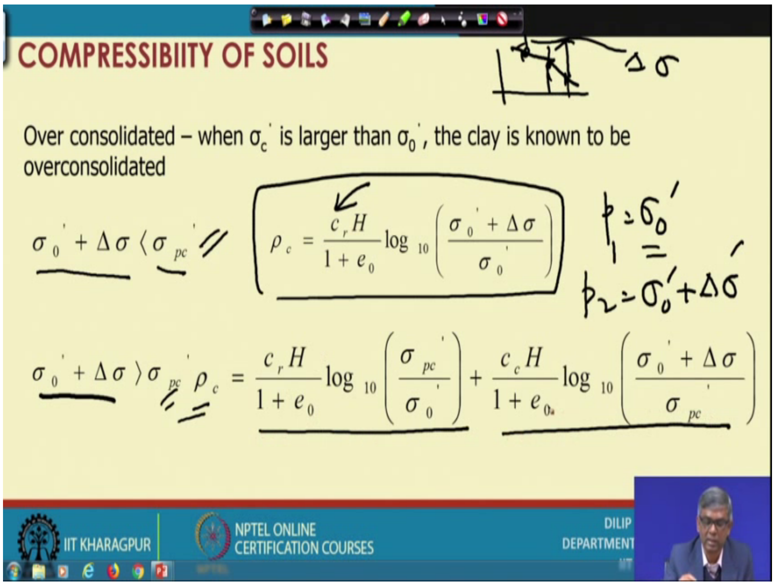

So, again your we have defined in general actually p 1 and p 2 in mathematically, but when we talk about soil mechanics then p 1 is nothing sorry p 1 in the soil mechanics actually when we apply p 1 is nothing, but sigma naught dash which is that actually it is the effective over burden pressure before application of the load. So, p 1 is nothing, but sigma naught and p 2 equal to sigma naught dash plus delta sigma delta sigma dash. So, that is the way it is mentioned.

So, the two cases will be sigma naught plus delta sigma when less than pre consolidation pressure then this is the formula to be used where instead of ccc r will be used and cr if it is not given it is one-third to one-fifth of cc can be taken and sigma naught plus delta sigma if it is a greater than sigma p c; that means, the if the curve is something like this and you have applied initial is here and del sigma is here if this is the del sigma then c sigma naught plus del sigma is greater than sigma p c. So, this is the case when you are here in that case it will have to part from here to here 1 part and here to here another part. So, c naught part is these and cc part this these 2 together will be the total consolidation settlement this is again I have repeated I have explained before so once again repeated here.

Then determination of time factor this is the well known formula for time factor cv t by h square.

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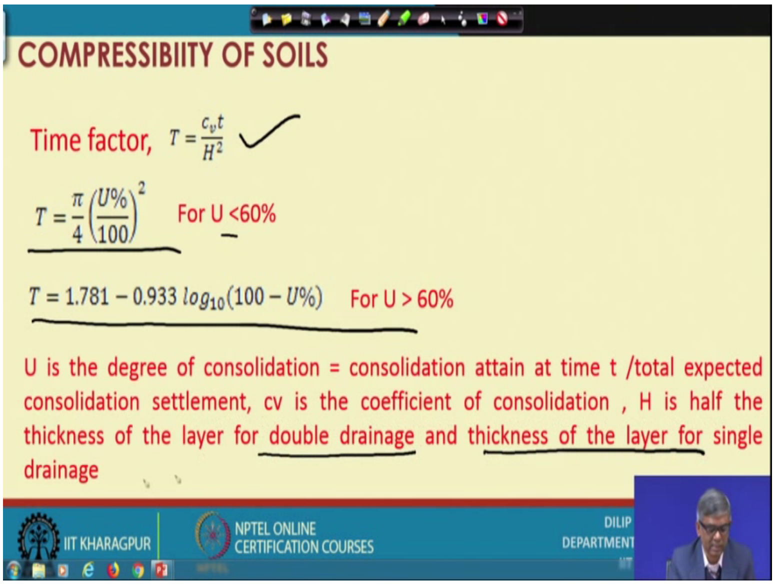

And this is can be related with U when it is less than 60 percent this is the formula can be used for finding out T and if we U is greater than 60 percent this is the formula can be used for determining U and then degree of consolidation is the consolidation attained at time T divided by total expected consolidation settlement and cv is the coefficient of consolidation and h is the half the thickness of the layer for double drainage condition and thickness of the layer for the signal drainage condition.

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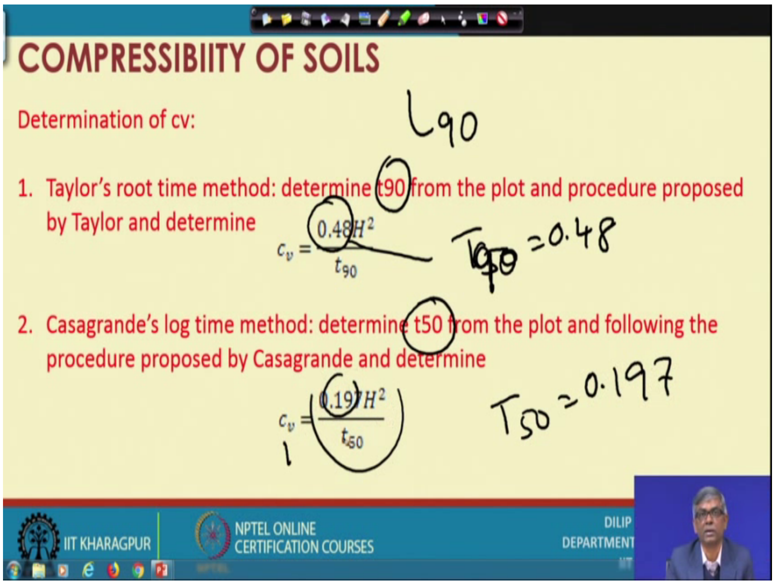

So, all those things I have explained before one second I am giving summary here and for determination of cv the two methods actually the root time method and log time method, root time method we get t 90 this is t 90 we get and once you get t 90 then cv can be related to tv, t 50 actually is nothing, but 0.48 sorry t 90 actually 0.48 and so, this is the way I can put t 90 and then we can get the value and what is a log time method we get t 50 and t 50 corresponding to t 50, t 50 is 0.197. So, that value if I use then cv can be related to these and from there one can find out the cv. So, both way cv can be obtained.

Thank you, with this I will stop this one next one I will try to sources some application different theories whatever I have discussed and try to explain one by one the application.

Thank you.