Soil Mechanics/Geotechnical Engineering I
Prof. Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 38
Compressibility of Soils (Contd.)

Let me continue on compressibility of soil and soil mechanics and geotechnical engineering. And this compressibility of soil I have just taken one problem and I have try to show how to calculate void ratio corresponding to the particular pressure increase or at a particular pressure and we have shown from the back calculation from the back.

And after getting the void ratio and pressure how to calculate coefficient of volume compressibility mv I will continue and then I will show one or two methods again.

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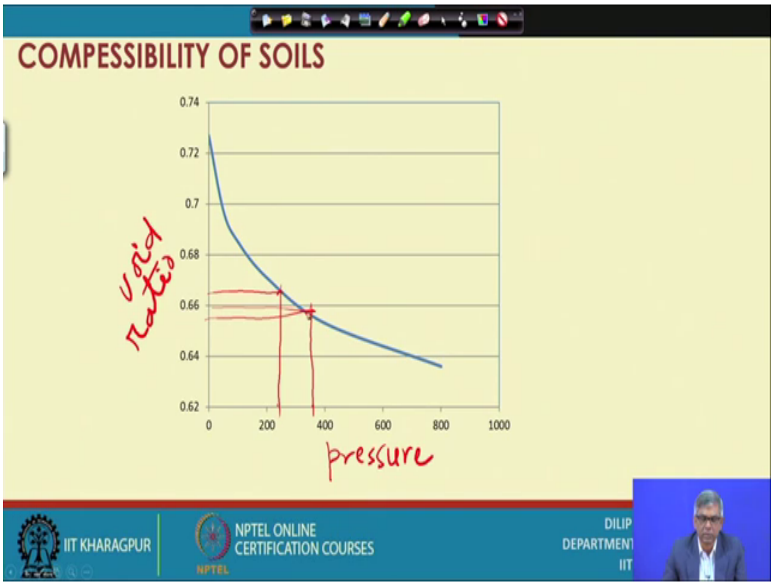

So, let me this is the one we have tabulated previous lecture that pressure versus this is actually your pressure. And this side is your void ratio and this void ratio versus pressure and perhaps it is asked to find out the coefficient of volume compressibility at the pressure range of 250 to 350.

So; that means, I have to find out first void ratio corresponding to pressure 250 somewhere here and I will may get some of value somewhere here. And similarly 350 this is somewhere here I will get the corresponding value from here. So, I will get b e one here another e from here another e from here. So, these two values of e we calculate sorry estimate for or read from this graph. And then I will go back to the equation for volume compressibility and using that I can find out the coefficient of volume compressibility.

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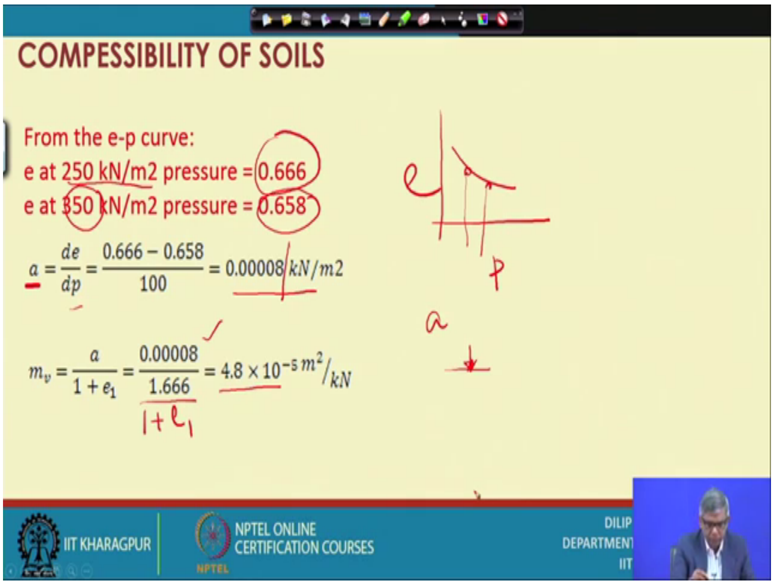

So, let me see that we can see that we have got from the e-p curve corresponding to pressure equal to 250 kilo Newton meter square kilo Newton per meter square pressure we have got e equal to 0.666 and similarly at 350 kilo Newton per meter square pressure we have got e value equal to 0.658. So, it is decrease because with the increase of void ratio your sorry with the increase of pressure the actually soil will be compressing and soil compressing means what it will happen that will be reduction in void ratio. So, void ratio will be reduced.

So, once you get these two void ratio a is actually a if I knew get a e-p curve e versus p curve then we are getting a that is slope of e-p curve is a so; that means, you have got two points we have selected on the curve two point we have selected on the curve. So, we have we a equal to de by dp. So, de is a change of void ratio from this two this; so, 0.666 minus 0.658 and the change of pressure that is from here to here.

So, it was 250 it was 350; so, 350 minus 250 it is 100 so; that means, de by dp is this one and de by dp. So, it will it will not be kilo Newton per meter square this will by kilo Newton per meter square. Actually so, mv equal to a by 1 plus e 1 that is the formula we have we have expression we have derived in the last class a by 1 plus e 1. So, a value is this and 1 plus e 1. So, this is 1.666; so, it is nothing, but 1 plus e 1 e 1 is 0.666.

So, then we are getting this one and this unit of mv will be same as a. So, it will be meter square; so, here actually wrongly written it will be a meter square per kilo Newton this is also meter square per kilo Newton. So, or it is one by kilo Newton per meter square. So, this is the value we are getting by one method there are several other ways it can be calculated this is the first one so; that means, you the pressure versus thickness if you get then from there.

Pressure versus thickness means what we are as we have mention that if I apply the pressure on the soil some certain amount of soil under this pressure soil will undergo compression consolidation. And this under con consolidation means what under this pressure when the compression will continue when we will see there is no change of comb thickness; that means, compression is complete under this loading that is then under that loading compression or some consolidation is completed.

So, like that second level of loading third level of H level of loading you have to see till that is no change of thickness. So, from there actually at the end point every time corresponding to each pressure; we are getting at the end what is the thickness. So, that thickness what is the pressure if you know then from there we can find out void ratios and there is a method we have mentioned already.

And in the lecture I have briefly at the table and then from the tabulated data pressure versus e we have plotted the e versus p curve in the previous slide and then from their previous e versus p curve we read at a particular pressure what is the e and a two pressure. So, two e values will be there and expression of de by d a is a d by dp and so, this change of void ratio by change of pressure and then you get this one and mv is a by 1 plus 1 from there we are getting a your coefficient of volume compressibility.

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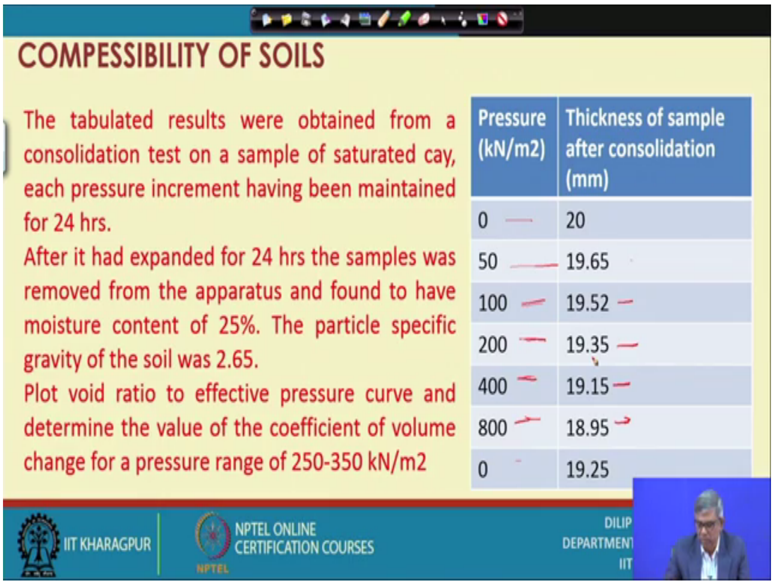

Now, I will try to show another method; in fact, two methods same problem since this problem is there in the previous lecture. So, you may forget; so, because of that I have brought once again this is pressure 0 thickness this 50 thickness then 100, 200, 400, 800 and 0.

Up to 800 pressure is increased and we have allowed to compress with over the suffident log sufficiently log time and we have observe the final thickness. So; that means, 800 pressure corresponding thickness this 400 pressure this is the corresponding thickness, 200 pressure this is the corresponding thickness 100 pressure if this is the corresponding like that we have got.

So, we have expression d by dp two different ways that we done. So, that actually I will I will show with the next slide.

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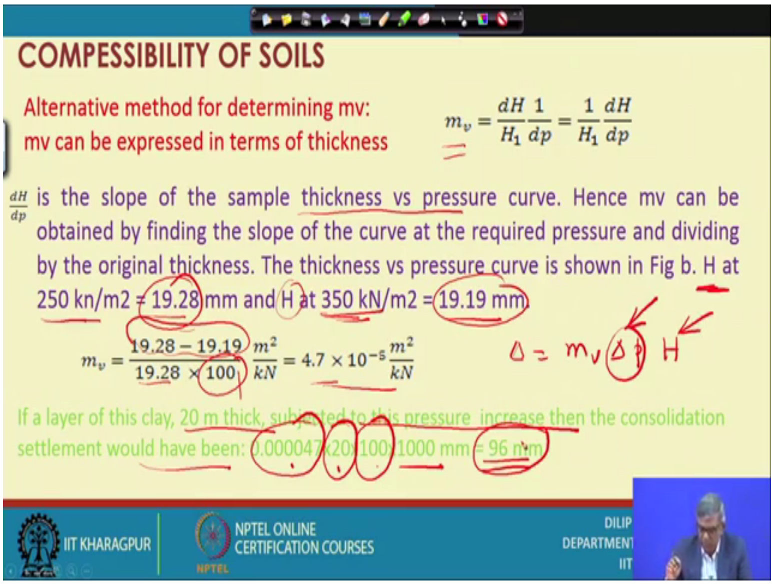

You can see that mv expression can be written in this form actually mv equal to volumetric change divided by u pressure or unit pressure change. So, we can see volumetric change is two expression also we have shown this is also volumetric change if I. So, compression is only vertical direction; so, a constant. So, throughout the d H by H 1 is the volumetric change; that means, change d H over original thickness H and divided by dp. So, this one if I little simplify then 1 by H 1 into d H by dp

So, d H by dp means what actually we in the previous method what we have tried; we have tried to calculate for a particular pressure what was the thickness and based on that thickness what was the corresponding void ratio each stage what is the void ratio we have calculated. But here we can see that if there is a way out without calculating void ratio directly based on thickness also we can do the mv calculation.

So, you can see ultimately mv equal to 1 by d H by dp. So, d H by dp is the slope of the sample thickness versus pressure see d H by dp means sample thickness versus pressure. So, we are changing the pressure and because of the change of pressure thickness is changing. So, that if you plot and slope of that will be nothing, but d H by dp.

Hence mv can be obtained by finding the slope of the curve at the required pressure and dividing by the original thickness; the thickness versus pressure curve is shown I will show in the next slide and each at; that means, thickness H at 250 kilo Newton square is this much and thickness at 350 kilo Newton square this much.

So, del H; so, del H actually 19.28 minus 19.18 19.19 and your del p is sorry del H by dp this is del H 19.28 by 19 point del H and this is dp divided by original thickness. So, H 1; so, 19.28; so, this is the one if you do then you can see we are getting this. So before doing that before doing that I will show. So, I will show the curve for thickness versus pressure it is almost similar to that void ratio versus pressure.

So, I will go back to that pre before that I will just from the curve other from the plot corresponding to pressure 350 thickness is these corresponding to pressure 250 thickness is this. So, if this is the thing you know we want to we have to find out mv in the pressure range of 250 and 350. So, 250 and 350 what is the change of pressure this is 100.

So, del p is 100 and what is the because of this chip change of pressure what is the change of thickness? Whatever what was whatever was originally 19.28 and now become 19.19; so, difference of that will be del e and sorry del H del H by original thickness 19.28 was original. So, this is the calculation 4.7 into 10 to the minus 5 meter square per kilo Newton.

Now, if you know the mv and calculation of settlement already I have mentioned that delta will be equal to mv into del p into H. So, what are those? What is the pressure increase? What is the thickness and mv. So, all three if you multiply then then we will get the consolidation in the 20 meter thick layer subjected to this pressure increase; that means, 100; 100 pressure is increased the consolidation set settlement would have been we can see this is the mv and this is the thickness and this is actually your pressure increase. So, this is del p this is H and this is mv

So, all together and that will come in meter. So, to convert the millimeter I have multiplied by a 1000. So, it is becoming 96 millimeter so; that means, a 20 mili 20 meter thick layer with this mv value if you apply the load in such a way that the middle of the clay layer at the pressure increase a 100 kp then expected consolidation settlement is 96 millimeter. So, if this is the simple expression when the mv is there using mv calculation of settlement is very simple mv multiplied by pressure increase multiplied by total thickness ok.

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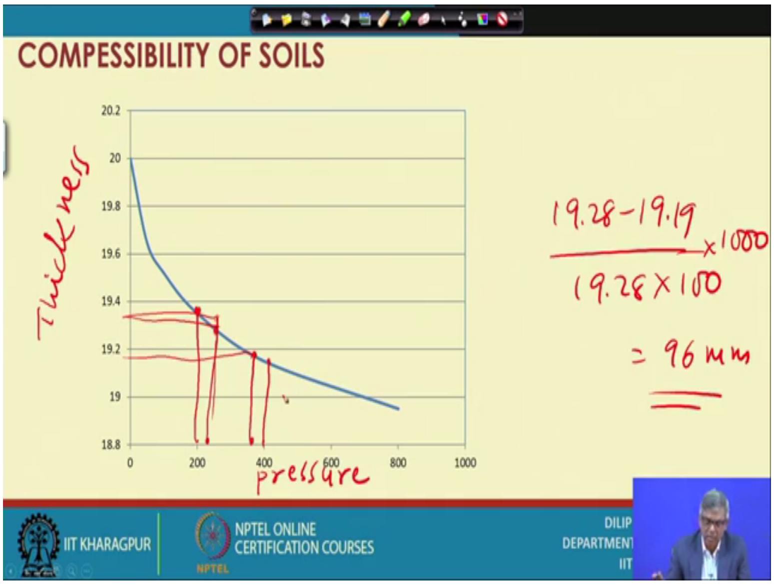

So, let us go to next slide next slide is as I have told you that I will show you the void ratio this is actually thickness and this is actually pressure. So, pressure versus thickness plot and whatever I have done what I have done 250 this is the 250.

So, corresponding thickness we have got and this is about 350 corresponding thickness I have got. So, 19.19 here and a 19.28 here something we have got. So, this two pressure that means, we are getting the expression 19.28 minus 19.19 divided by 19.28 into 100 this will be in meter and multiplied by 1000 that will give you millimeter; so, 96 millimeter.

So, this calculation is shown in the previous slide, but how to do it directly consolidation test we are getting at the end of each pressure increment what is the thickness we know. So, that thickness; so, at the end of suppose 200 pressure what was the thickness I have plotted at the end of the pressure application at the after application of the 400 pressure at the end what is the final value this is the value. So, it like that if you plot and finally, kind of joining them that is giving you thickness versus pressure curve.

So, this is again whether you do form void ratio or from these they are both actually similar almost. So, d H by d p or de by dp you are using. So, once actually we are using directly thickness once actually because of this change in thickness what is the void ratio change that is the thing we have done.

Now, we have one more method V equivalent solid height you may calculate and based on that you can do some calculation that is something like this.

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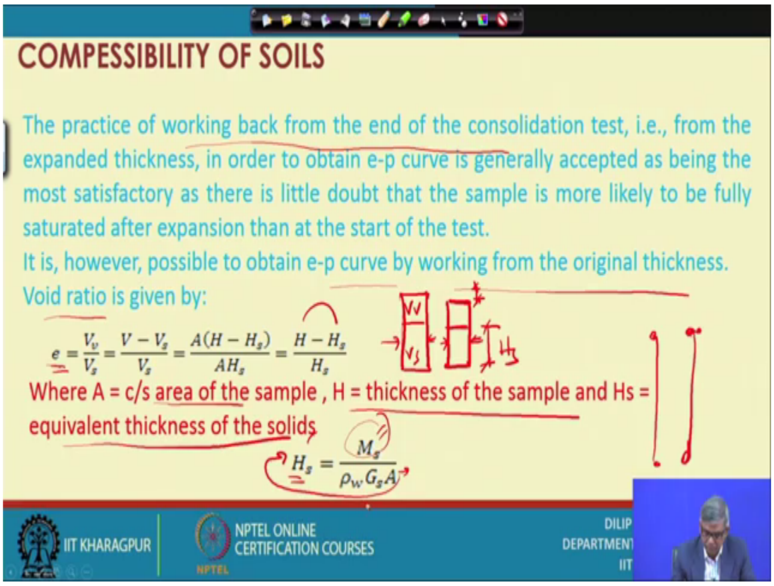

So, before going to this there is some remark the practice of working back from end of consolidation test that is you are well accepted because when you put a prepare a sample and put in the consolidating (Refer Time: 14:53) it is not guaranteed that it will be a saturated, but if I complete the test and at the end of the test this is only some much condition if you allowed to expand actually with 0 loading then that time it is expected that soil will be saturated.

So, that is the one we utilize then at the end it was saturated and what is the final thing from there you get void ratio and then we are going back to the original. So, that is the one calculation we have done though it is it is; obviously, because of these advantages people are its well accepted method.

But obtain a e-p curve by working from the original thickness; that means, we have got from back to front. Now you suppose some may prepared the from directly from these to these because it was the first void ratio and this was the last void ratio I will first find out in the first one and last one will be that last. So, that way also it can be calculated; so, to do that we have to do some calculation.

And you can see this is the calculation e actually from the definition e is the VV by V S and V V is actually nothing, but total void minus a total volume minus V S and if I keep constant cross sectional area then you can see suppose the sample is soil is something like this and under compression pressure it is compressed suppose like this.

So, this much compression you took place or thickness changes, but this cross sectional area suppose kept constant in that case V minus V S by V S that I can write a time the H is the total volume a time H is the total solid volume and a in to H S again total volume already. So, I can I can imagine you can I can imagine this soil initially this is V S and this is void. So, these void V S V S will have a height suppose H S.

So, a times H S and this will be this then if you simplify it become H minus H S by H S the void ratio. So, where a is the cross sectional area H is a thickness of the sample and H is the equivalent thickness of the solid. Now again H S equal to actually rho w G S the a into H S is the volume volume multiplied by unit weight will give you the weight or volume multiplied by mass will give you the mass.

So, that is what actually H S equal to total mass divided by rho G S by A the rho G S into A so; that means, H S can be calculated by this if you know the mass rho G S into A or we can say the volume a into H S will be m by rho rho wg s and. So, H s if I take then M s rho w G S into A.

So, this way actually if I know the weight of the mass if you know the mass and if you know the what you the density of what are you know and G S of soil more soil is known if it is not known we can assume 2.65 to 2.7 at cross sectional area. So, this is the way one can calculate the H S.

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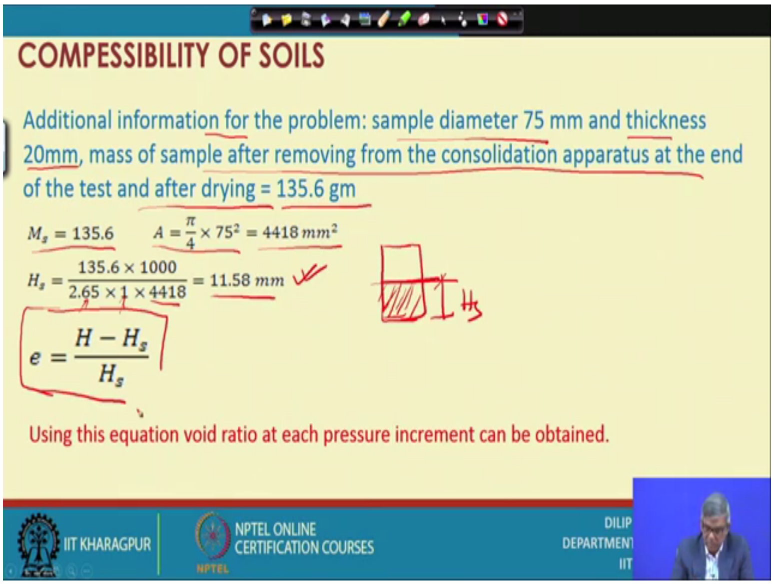

So, this actually to be used in the calculation of void ratio in other methods; you can see now if I want to do this problem by alternative method we; obviously, record some additional information and this additional information is really not additional information during the test we get we have those information.

So, initial problem those information not given because that are not essential if I want to do based on void ratio or thickness e versus p curve; if you use or your or your thickness versus pressure curve if I use then your this calculation; that means, this information was not needed.

Now, if I want to this method we required this information suppose this information is available suppose it is like this the sample diameter was 75 3 inches or 75 millimeter thickness was 20 millimeter and your mass of the sample after drying actually it was 135 point gm 135.6 gm gram; that means, after completion of the test we have kept it oven and then dried and dry volume was 135.6.

So, M s become 135.6 and a become the accents area is given pi by 4 into 75 square; so, this millimeter square. So, H S become one is the rho w 2.65 suppose this and this is area 135. 5.6 by this become H S. And if you want to convert into millimeter then you are getting multiplied by 1000. So, 11.58 is the thickness of the equivalent soil mass thickness.

So, if there is a total soil whatever may be the thickness out of that out of 135 gram soil and if that is the diagram. So, sorry diameter is mentioned and thickness also mentioned total thickness and out of that if it is a dry weight is this. So, what is the equivalent H S; that means, H S when you are considering H S?

That means, you are considering is a solid there is no void in it whatever solid as there I am actually theoretically I am putting together then if it is a total solid mass what is the equivalent height? That is the thing based on that calculation it came 11.58. Then e will be from the derivation in the previous slide we have shown H minus H S by H S. So, this one actually can be used to calculate void ratio at any pressure range start starting from beginning. So, that is the thing done in the next slide.

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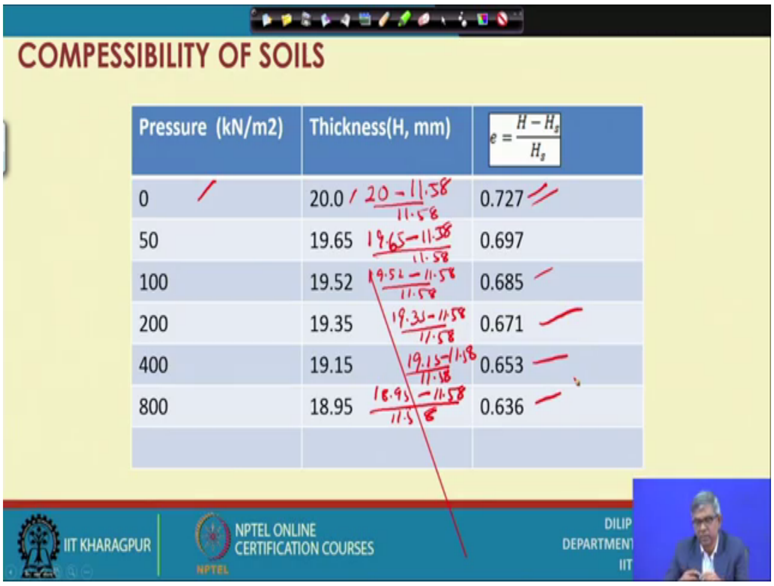

Pressure (kN/m2)	Thickness(H, mm)	$e = \frac{H - H_s}{H_s}$
0	20.0	0.727
50	19.65	0.697
100	19.52	0.685
200	19.35	0.671
400	19.15	0.653
800	18.95	0.636

We can see here 0 pre pressure is 0 and pressure is 0 the thickness is this. So, what is the void ratio this m void ratio H minus H S. So, H minus H S; H was actually H was 20 minus H S 11.58 divided by H S 11.58 if you do this calculation. If you do this calculation then you will get the void ratio equal to this similarly it is 19.65 minus 11.58 is constant everywhere divided by 11.58 this is the one you get if you calculate then you will get 0.697.

Similarly here 19.52, 19.52 minus 11.58 divided by 11.58; they are also will get this value. Similarly here 19.35 minus 11.58 divided by 11.58 will get this value. Similarly for this 19.15 divided minus 11.58 divided by 11.58 we will get this value. And here you will get 18.95 minus 11.58 divided by 11.58. So, if you do this then you will get this void ratio.

So, now we have got again void ratio and using this void ratio and this pressure you can draw e-p curve and from there you can get the volume compressibility. And then you are getting you can see this is a practice problem and the problem whether it is if you take a total a true experimental data then your value may not be. So, close, but here actually to explain this is all you can say just data taken and it will, may not be the experimental data.

And so, here actually you get that theoretically all are giving same results by and large same results, but in if you do experimental using experimental results you may get some venetian in that case you have to take the judgment and put the appropriate value based on your own judgment.

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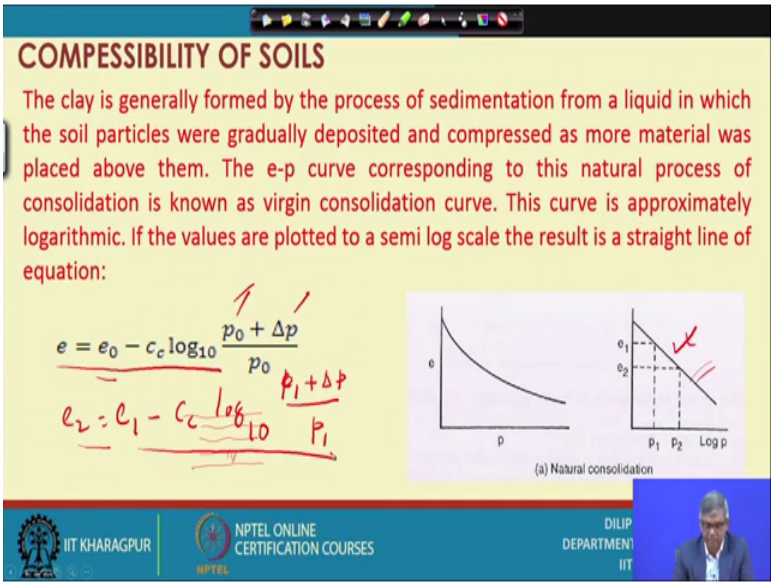

Now, here actually you have to find out final compression some other way also. The that mv method we have discussed now you will be measuring compression method compression index method and for that you have to observe the clay behavior under loading behavior of the clay under loading or consolidation behavior of the clay under loading. And for that we you can see that the clay is generally formed by the process of sedimentation from a liquid in which the soil particles were gradually deposit and compressed as more material was placed above it.

Suppose there is a flowing fluid and soil is deposited here today the thickness was these tomorrow these tomorrow like that. So, it will be accumulated height will be increase. So, if I do then under this loading this soil below will be consolidated. So, like that this is the process and the e-p curve corresponding to these natural process of solidation consolidation known as virgin consolidation.

So, that this is the natural way consolidation. So, if you do a e versus pressure corresponding to that then whatever you get that is called virgin compression curve. And the this curve is approximately logarithmic actually sorry the this curve is approximately logarithmic; that means, if the values are plotted to a semi log scale; that means, e versus p you are getting this, but if I put e versus log p.

Then we get a straight line this and if this is actually p 1 p 2 means it is log p 1 log p 2 and here actually if I scale put it in the logs log scale directly I will put the values or if it is a linear scale and then you have to calculate log p 1 log p 2 then you have to put it

Generally we use semi log graph and then if you use semi log graph then you will see that p 1 p 2 directly read from there and then e 1 e 2 e d directly from here. So, e you will be to equal to e will be equal to e naught here actually e one in to in terms of e 1 e 2. So, e 1 will be or e 2 will be equal to e 1 minus cc into log 10 base p 1; p 1 plus del p by p 1.

So, this is the way one can one can write the equations. Since this is written in general form p naught; that means, that the originally when that that is p naught and then del p. But here in this plot we have shown in terms of e 1 and e 2; then if you put in this way then e 2 equal to e 1 minus cc into this formula you can write.

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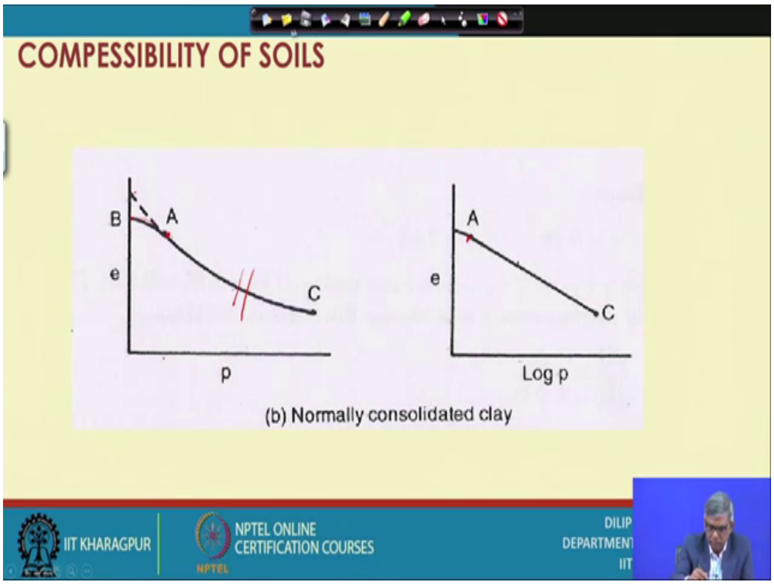

And you can see the compressibility this e versus p curve generally will have some point here and there this is a continuous, but if you extend this curve it will meet somewhere else. So, there is a mechanism and if I put corresponding curve is the log scale up to this is a straight line compression line this there is a small curve.

Why it happens actually this is actually when this is suppose originally consolidated list up to this and while sampling because of that decreasing pressure or pressure release it may volume expand may be there. So, if I if may reach there; so, when I will load again it will compress in the different way instead of this way it will different way and when reach a. And then if you load further then it will be smooth line which actually like normal consolidation.

So, beyond that actually it was a decompression and because of that if we put this data how this data BA and C this data you put in a log scale then up to A; we will get a small curve and then A to C we will get a straight line because we know that the behavior is actually a logarithmic.

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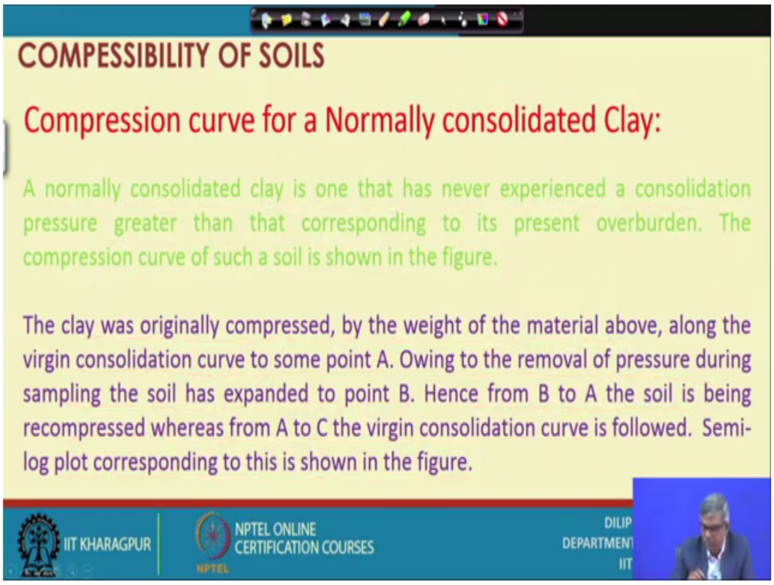

So, this one once again explained here and normally. So, compression curve for a normally consolidated clay you can see here I have already defined perhaps during shear strength chapter what is normally what is consolidated what consolidated; because I have mentioned that time that the behavior will change because of this when if it is a normally consolidated soil the behavior is something and over consolidated soil behavior is different from that.

So, now once again I have repeating and I have also mention that appropriate place I will repeat it and I will explain why it is different. And you can see a normally consolidated clay is one that has never experienced a compression or consolidation pressure greater than their corresponding to its present overburden pressure.

Suppose at a particular side I can calculate present overburden pressure, but if the history of the soil layer never means subjected to higher pressure than this; that means, this is a normally consolidated; that means, this is consolidating uniformly it is never consolidated by a higher pressure. At the compression curve such soil is shown the figure I have shown there and the clay was originally compressed the finger whatever you have shown; the clay was originally compressed by the weight of the semi material above along the virgin consolidation curve to some point a. So, that is that is that the point I have shown from the vertical axis to up to a that is actually the point.

Owing to the removal of the pressure during sampling the soil has expanded to a point B that I have shown I will I will show it once again. Here is the from hence from B to A the soil is being recompressed that is recompression whereas, from A to C is a virgin consolidation curve.

So, semi log plot corresponding to these shown is the figure so; that means, I will show you there once again that one. So, we can see here as I have mentioned here this is this is the path reached up to this and at suppose at this point the existing overburden present there and, but suppose it is a 10 meter depth. And from 10 meter depth I have taken the sample when you are remove the sample then there is a pressure release because of that suppose the volume the sample is increased to a volume suppose we reached here.

Now, if I start pressurizing from here. So, up to this to this it is a decompression and from when pressure increased beyond this then normal consolidation that is actually your virgin consolidation. So, this curve we have plot when in that log scale you will get up to A; the little curve and then straight line.

So, this is about the behavior of consolidation normally consolidated soil and this that is all I will take now over consolidated soil and their behavior and how to use the consolidation settlement using that in the next slide next lecture.

Thank you.