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IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

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LectureNo.23

Module -3

Lecture-5 on compressibility
And
Consolidation

Welcome to Lecture series on advanced geotechnical engineering course offered by IIT Bombay. We are in Module-3 compressibility and consolidation. So, this is the Lecture-5 on compressibility and consolidation. And we have introduce ourselves in previous lectures.

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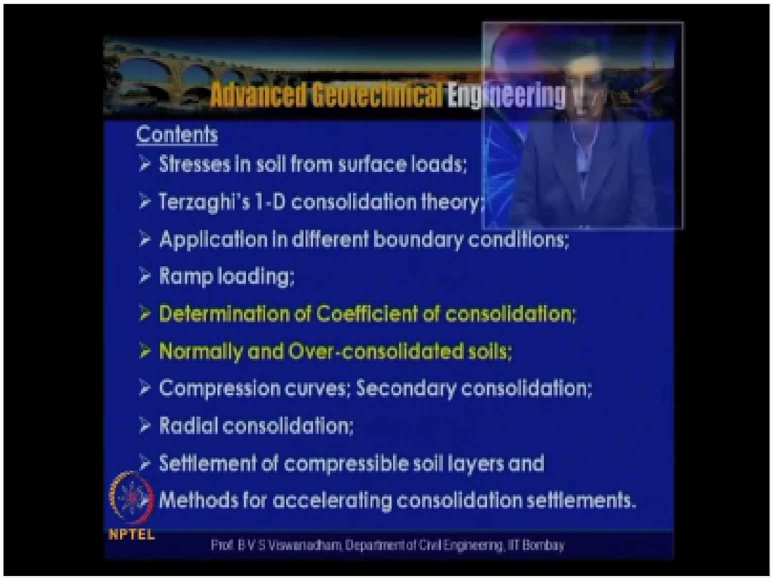

Stresses in soil on the surface looks and we also discussed about the Teazaghi's consolidation theory. And application in different boundary conditions, and what will happen if you're having a constant rate of loading or Ramp loading then we proceed for the how we can active determined the consolidation of characteristics in the laboratory by using the consolidations then we will introduce ourselves to normally and ore consolidated soils and then we will try to discuss about typical laboratory vertical compression curves then we will try to look into the determination of the coefficient of consolidation what are the different method are available in are.

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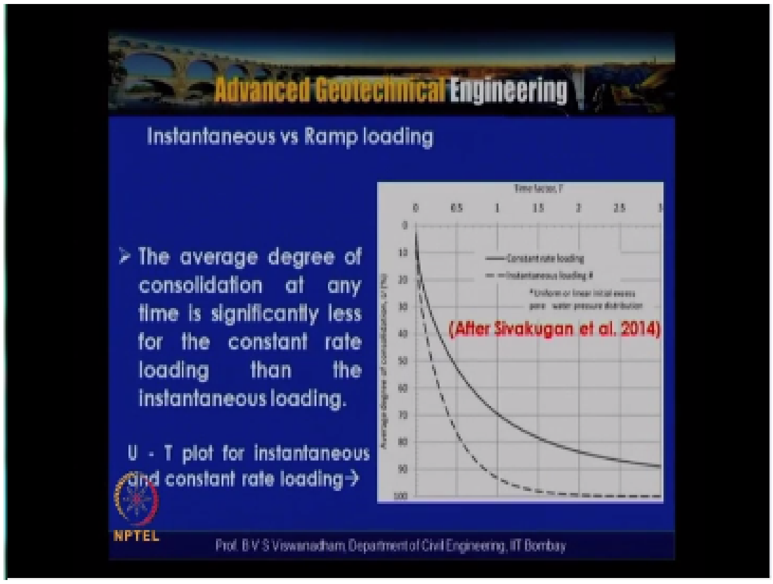

So, in the previous lecture we have discussed about the instant previous loading very now T=0 itself. the load will be a assumed to be acting on the surface of the load. Surface of the soil but interiority or instructor It is this placement of the load takes or occurs pile of time so if that is done in single or constant rate it is called constant rate loading or single stage ramp loading or if it is done in two stages then it is called two stage ramp loading.

So in this particular slide the comparison of constant rate of loading and instantaneous loading which is actually discussed by Sivakugan et at. 2014. We are in this side the average degree of consolidation at any time it is significantly less for constant rate loading done the instantaneous loading so the average degree of consolidation at any time significantly less for the constant rate loading than for the instantaneous loading.

So, this is for the instantaneous loading theoretically which is what we get but constant rate loading we get the U verses T plot or U degree of consolidation verses TVA plot for instantaneous or constant loading shown here. This is the time factor and this is the degree of consolidation so the average degree of consolidation at any times significantly less for the constant loading than the instantaneous loading.

Now we try to look into the response of soil for the you know the stress control verses which are applied having sandy soils we said that you know the pants undergo compression faster so, in the particular slide E verses σ' compression time plot verses sand are shown here. So, as can we seen here within a short span of time of one or two minutes the sand under goes the compression. If you are having a loose sand and dense sand you can see that the loose sand reduces its wide ratio from 0.75 to somewhere around 0.52 or so in case of dense sand there will be less you know reduction in the wide ratio but at ultimately that the larger effective stresses they tend to be toward the same wide ration.

So the sand deposit compresses immediately on loadable sand deposit the response is very instantaneous and loose sand compresses more than dense sand and loose and dense sand posses strength toward the same wide ratio. So, this particular slide you know illustrates the response of you know the sand particularly loose for the applied loading. IF you look into for a clay fine grain soil where the soil having very low perimeter they compression varies with time and it takes place for a very long period of time.

So, even after ten minutes you know the degree of compressions actually very less .so ,it can be seen that you know it takes long time for under going compression for a given load .similarly here, the wide ration reduces 50kilo Pascal pressure and tries to reduce you know when we start increasing the pressure and even that 250kilopascal that is the wide reduction only 0.5 ,you know the ratio actually shown just to as a n example how the Eσ' compression time plots will be there for clay and the time dependent compression takes longer time compare to sand and the magnitude of compression also large for clays.

So, we need to understand that the magnitude of compression is large and also it takes long period of time. So, if before looking into the odometer or consolidation test let us read into definition once again. If the soils off low perimeter the application of the surface load as an increase in pressure. So the resulted increase in pour water pressure cleans raise to hydraulic radiant and it response top pour water flows out of the soil forms.

And it has the water flows soil the pour water pressure gradually returned to equilibrium values and which know for the deformation place. This is what we are actually discussing about. The consolidation phenomenon. So, the process of deformation of the soil over time due to the execution of the non equilibrium pour water pressure turned as consolidation. and again the compression due to the curve changes in volume due to changes in σ' prefix the occur.

So, compression and consolidation here in case of consolidation the process of deformation of the soil over the time due to the dissipation of non equilibrium pour water pressures is turned as consolidation. And compression is used to describe the changes in volume due to the changes in σ' that is effective stress, without differs from the time scale for which they occur so ,in order to determine the consolidation characteristics in the laboratory the test which is used is called Oedometer test. And in this slide typical.

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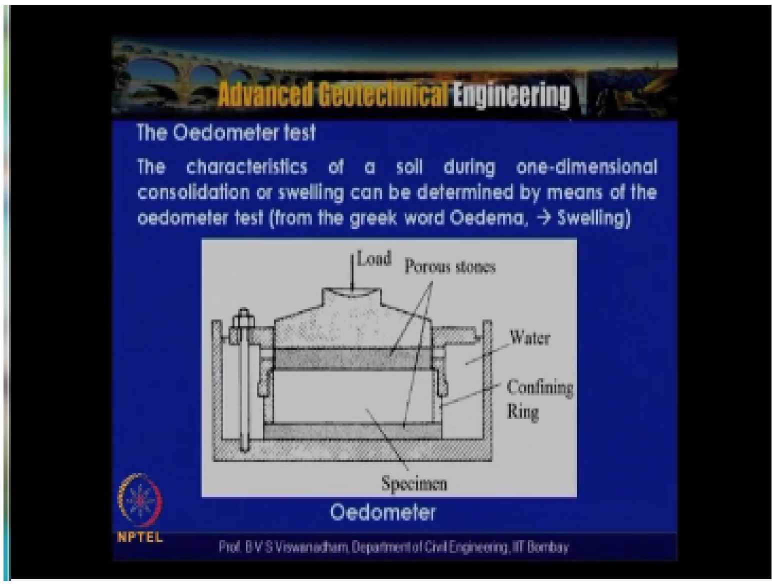

Meter is shown and very this is characteristic of the soil during the consolidation swelling can be determine by the means of the Oedometer the name Oedoma is actually you know derived from Latin or the Greek word that is Oedoma means swelling. So, the characteristic of a soil during one-dimensional consolidation or swelling can be determined by Oedometer test.sao hence the name Oedomete come like this and the Oedometer test or consoled meter test is actually used for the you know getting the compressibility characteristics or consolidation characteristics are soil samples in molded state or in undisturbed state.

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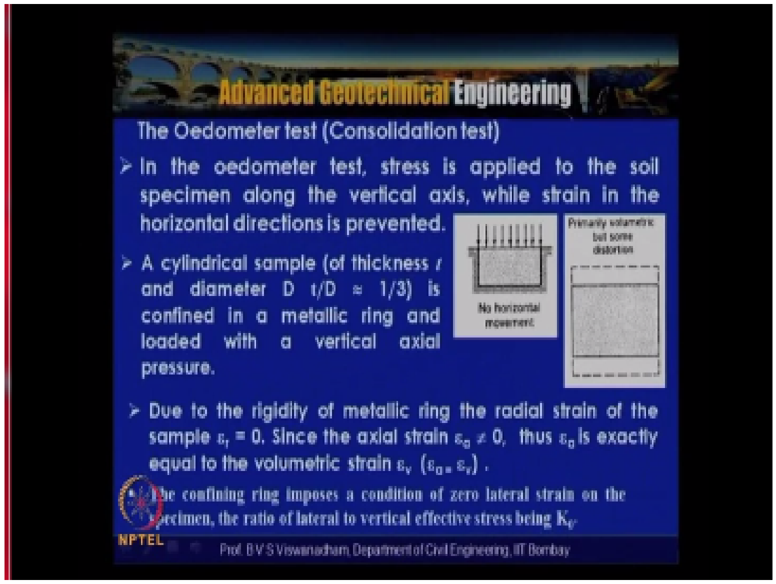
εB.



So, generally the samples are actually they having ideally forest down here the forest zone you know the pour water pressure increased in forest zone is 0. Which is actually similar to open layers at top and bottom and this is the moving loading plate and one interesting thing we note her is that this confining ring which is actually received enough and will not allowed the lateral deformation hence, you know whatever the strain is actually under goes is actual strain so, if you are not allowing the radial strain then it also to be R=0 so eps along B.

And in order to the water all these water is actually filled up here and the sample is allowed to consolidate under a given volume, under given load so, load is also in order to apply large meters up to let us say 800kilo Pascal or 600 kilo Pascal. In the lever of technique actually used in the laboratory. So, the Odeometer or consolidation in this test the stress is applied to the soil specimen along the vertical axis and while strain in the horizontal direction is fluent that is actually shown here.

The no horizontal movement and this sample to thickness to the diameter is normally maintained as 3D/D is a word of the ratio is 1/3or diameter to thickness ratio is maintained as three and so, the cylindrical sample of thickness T and diameter that T/D approximately equal to 1/3 it confined in metrically and loaded with vertical axial pressure. so, the resduality of the metallic ring the radials train sample of R=0 so, epsilon R is means that the radial direction will be 0 since the axial train is not equal to zero thus the ƐA is exactly equal to the volume strain ƐA is equal to ƐB.

And the confining ring is imposes the condition of zero and the ratio of lateral to vertical effective stress being kv. So, σV =σA=KvσR. There is the σR is the so, there are attempts by the several investigators to measure the lateral stress offered by the ring by placing some loads. In the odeometer test we need to looking to the two types of odemeter is there one is called fixed ring odeometer and floating odeometer or odeometer with fixed confining ring for odeometer floating confined ring.

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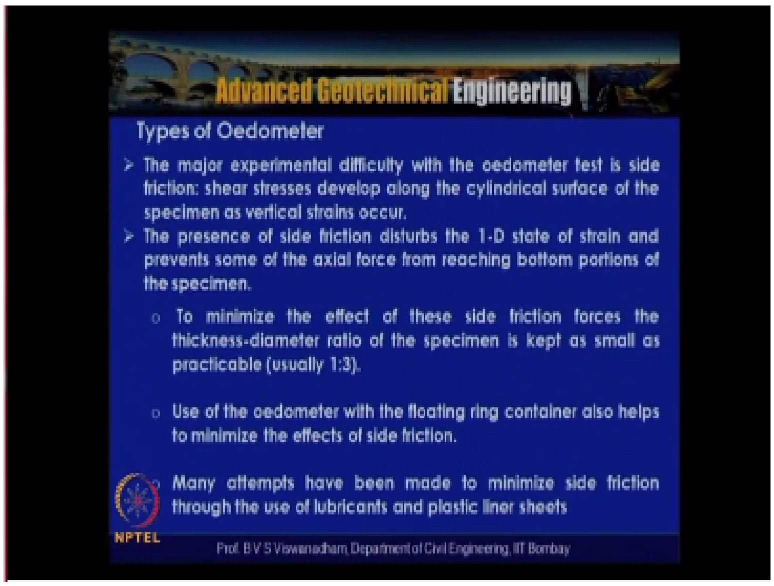

The major experimental difficulty with odeometer test is slight friction that is the so the shear stresses develop along this cylindrical surface of the specimen as vertical strain occurs. so, as the vertical strain occurs you know the cylindrical surface of the specimen the shear stresses is actually develop along the cylindrical surface of the specimen as the vertical strain occurs. so the presence of the die friction disrupts the one dimensional state or strain and prevent some of the axial force from reaching the bottom portion of the specimen.

So the presence of the side friction disrupts the one dimensional space of the plain and prevent some of the axial force from reaching the bottom of the portion of the specimen so, to revise you know the effect of the side friction forces the thickness diameter ration so, one of the reasons why you know the diameter to thickness ratio is maintained as 3 is that knew to minimize the side forces to be minimize the side friction forces the thickness to diameter of the specimen is kept as small as practicable.

So, that is maintained as 1:3 and use of the odeometer with floating ring container also minimized to containing the effect of the side friction so that you know the ring will not offer any resistance sop use of odeometer with floating ring container also minimize the effects of side friction and many attempts made to minimize the use of lubricants and plastic liner sheets.

So, by using the plastic liner sheets or by using the lubricants can be reduced this was actually attempted by several researchers. So, basically many coats, recommended fixed ring odeometer and with thickness to diameter ratio as 1:3 basically this helps to you know to limit the side friction forces in addition to this, the walls of the interline confining ring can be lubricated so that you know the side friction for case can be minimized.

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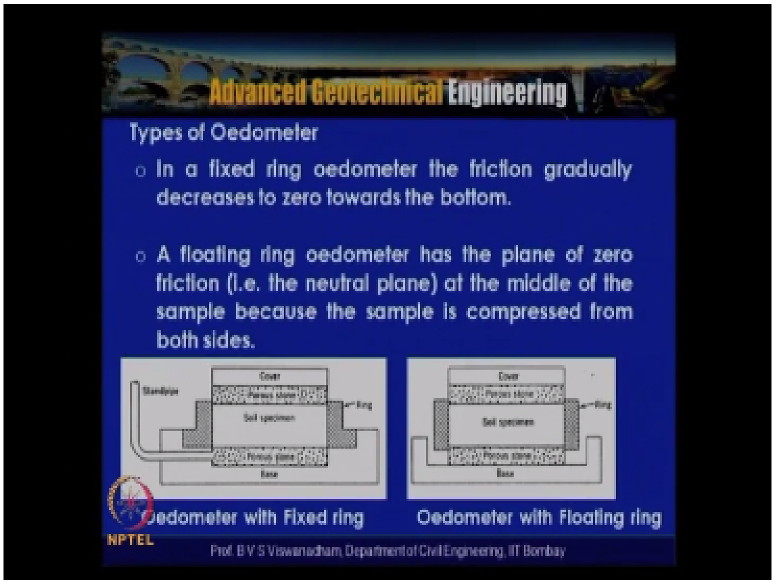

So, here the in this particular slide this is odeometer with the fixed ring so the ring actually fixed hereon in this case odeometer actually provided with floating ring you can see that odeometer provided with the floating ring so, there is no connection between the base plate and floating ring in this case the ring attached rigidly to the base plate, so, the fixed ring odeometer friction gradually decreases to 0 towards the bottom the load is actually high here.

The friction you it will be very high here and reduce to the 0 of the bottom of the specimen. In case of floating odeometer the plane of 0 friction that is the neutral plane is that the middle of the sample because the sample is compressed from the both the sides the reaction is actually offered from here and here. In the case of the floating ring the neutral plane the it is between the plane soothe floating ring odeometer has the plane of 0 friction as the middle of the sample because of the sample is compressed from the both the sides.

As a sample is compressed from the both the sides so floating ring odeometer has the plane of 0 friction at the middle of the sample because the sample compressed from both the sides. In the case of fixed ring odeometer the friction gradually decreases to 0 towards the bottoms the maximum here and reduced to 0.
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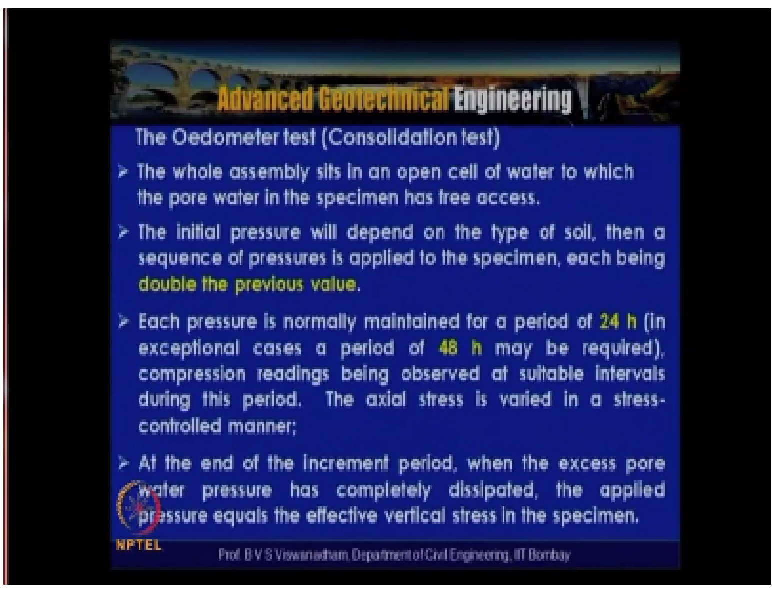

So, the process of the or procedure of the odeometer testing described in the slide the whole assembly with confining ring and the other accessories the with sits in the open cell of water to which the pour water specimen has the access and the initial pressure will depend upon the type of soil then the sequence of pressure applied to this specimen and each being double the previous value.

So, why it is required to be double why not you know what will happen actually having more than the double value what will happen it is less than the you know the designated if suppose σ1 pressure of p1 is applied if its not applied 2p1 or it will applied with less than 2p1 what will happen all those things we discussed subsequently but here we can take it has the initial pressure depends upon the type of soil so the example the soil is actually in liquid limit and you know we cannot actually very high pressure so the has to be as slow as possible.

Then sequence of pressure is applied to the specimen each being double to the previous value. And each pressure is normally maintained for the 24hours. So, here also discussed about what will happen the same load maintained for more than 24 hours or 7 days what will happen or it is you know removed within 24 hours what will happen. See exceptional cases period of 48hours maybe required so for some certain type of soils exceptional cases 48 hours required otherwise 24hours period you know actually maintained. And a compression reading being observed during the period for each load what we need to apply is that we need to observe the compression the time verses compression. And the moment the end of the 24 hours before applying the n new load only to note down the compression value and the load need to be applied carefully and the axial stress is varied in a load maintained.

So, the odeometer test and the consolidation test axial stress is varied in a stress control manner. So, at the end of increment period when the excess pour water as completely displaces the applied pressure is equal to effective stress in the specimen. So, at t he end of the increment period when the excess pour water pressure completely disappeared the applied pressure is equal the whole stress in the specimen.

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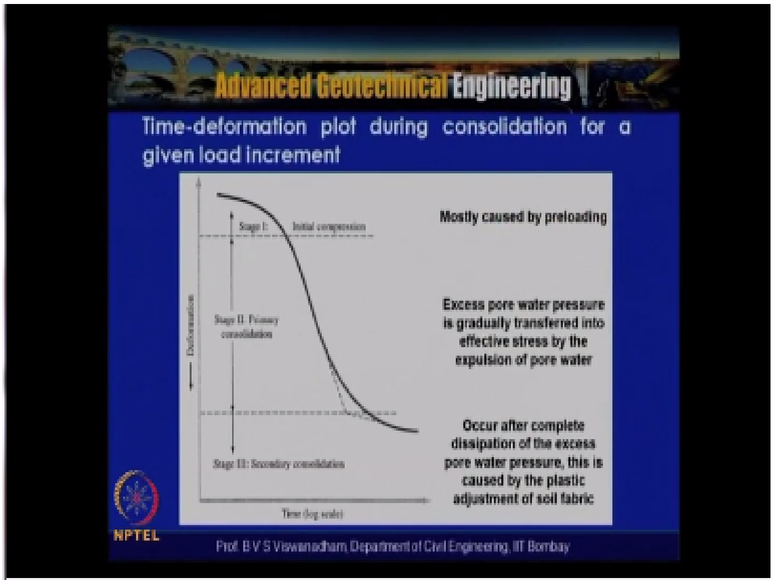

So, in this slide in particular slide time depending plot during the consolidation loading for the given incermentation it can be pressure of safe p1. So, this is deformation initially the sample actually has higher thickness that is a higher wide ration meter under goes compression and then you can see that the straight line portion is actually expending to certain extent you know it tends to have another curvature and then tends to go towards the so we can see that three stages are there depending upon the process of consolidation one is a stage one and the stage two is actually called as which major called primary consolidation.

So, mostly the consolidation phenomenon mean the stage one and stage two is considered and stage three is secondary consolidation for soils very, very prominent like examples like pt which is non like soil means you know the municipal soil waste which under goes very high amount of the stage 1, stage 2 and stage 3, these are the unknown 3 stages of consolidation so initially the unknown occurs because of the readjustment of the particles and some elastic stains are travelling over the particles actually takes place in stage 2 basically in the previous consolidation where the soil undergoes or particles goes irrecoverable you know changes.

And in the secondary consolidation under the constant effective stress the load is not a the unknown void ration continues to fall so this is because of the certain nature of the soils this actually is prevalent so the stage 1 is actually based to the game mostly caused by preloading and stage 2 which is primary consolidation is the excess pore water pressure is gradually transferred to effective stress by the exposition of pore water.

So excess pore water pressure is gradually transferred into the effective stress by the expulsion of pore water and stage 3 basically this commons at the end of you know primary consolidation so this occur after the complete dissipation of excess pore water pressure for a give load and this is caused by the plastic adjustment of the soil fabric that means that the soil fabric is nothing but the soil grade structures so readjustment of the soil fabric actually happens here and because of that this secondary consolidation or stage 3 takes place.

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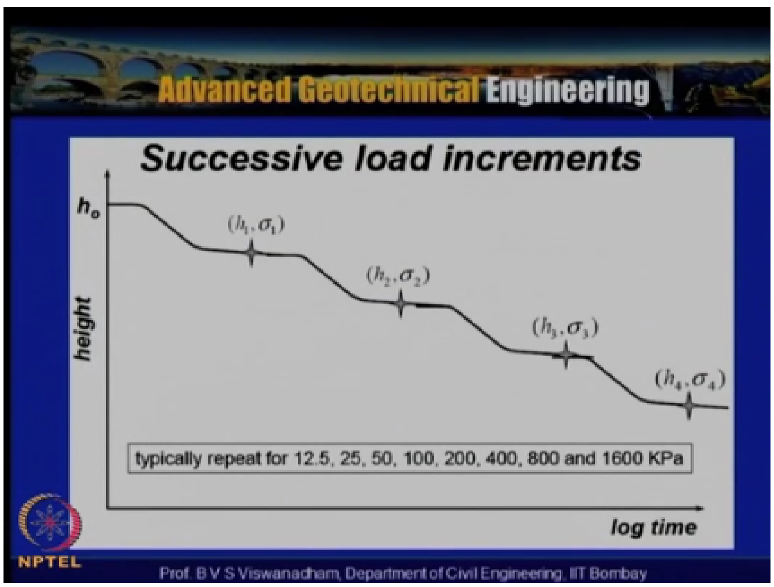

So here in this particular slide the successful loading criminates of high higher lock time are shown so the pressure are typically like we can we can one actually start with the 5k Pascal's and 10 k Pascal's are you can say that 12.5 22, 50 you can see that the load increments are actually always doubled here 50, 100, 200, 400, 800 and 1600 kPa see each time the sample undergoes consolidation and reaches to the new thickness and to the new effective stress like that we can see that the sample undergoes the reduction the thickness.

So this actually happens by the same you know solids will remain same but only thing is that the water which is there in the 3 phase system of the soil will get expelled out.

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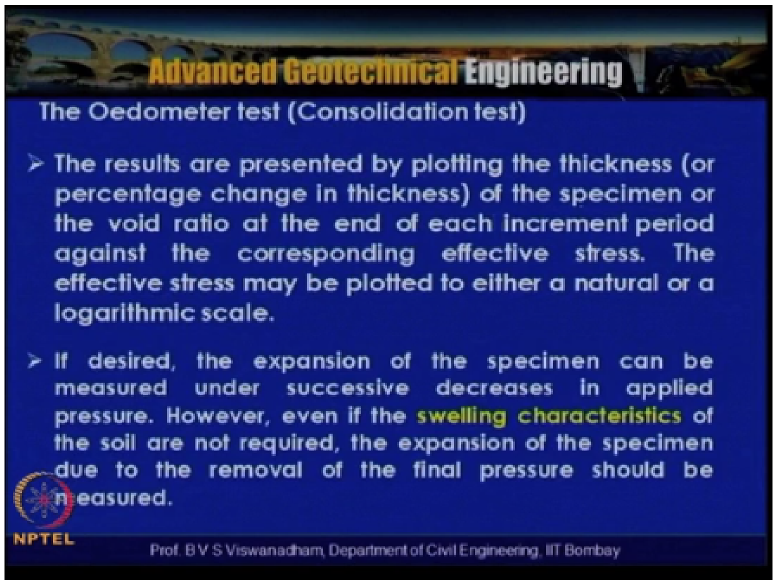

So there are basically the results of this Oedometer are presented by plotting the thickness of the specimen or the percentage change in the thickness like we can say that percentage change in the thickness if it is the thickness is you know let us say Δh is the change Δh/ h are which is nothing but you know the strain actual strain the plotted in the thickness this the results are plotted by plotting the results are presented by plotting the thickness of the specimen or the void ratio at the end each increment.

Against the corresponding effective stress so the effective stress may be plotted either natural are logarithmic scale so preferable these curves which are when you plot with e and the effective stress is generally plotted with e log σ or they are also leave the e log σ' or e log P curves so decider the expansion of this specimen can be measured under the successive decreases in applied pressure.

So once the sample as been subjected to loading and unloading the same one the during the process of unloading the sample goes expansion so if descried the expansion of the specimen can be measured under successive decrease in decreases in applied pressure however even if the swelling characteristics of soil are not required the expansion of the specimen due to the removal of the final pressure should be measured so even if the swelling characteristics of soil are not required the expansion of the specimen due to the removal of the final pressure should be measured.

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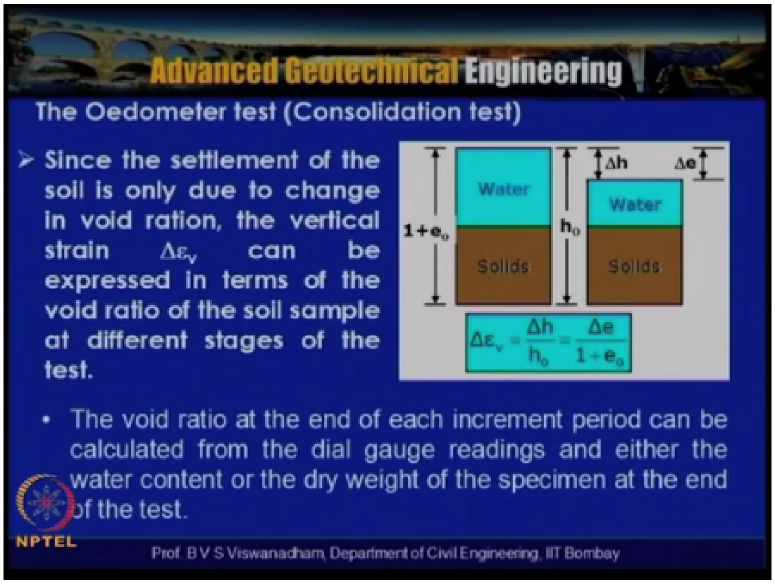

So here in this particular slide how the you know the analysis can be done you know so for example here in 3 phase system 2 phase system where water and solids and with this the volume is $1+e_0$ and so initially so high is Eh_0 and this actually changes to because the volume this thickness reduces to h0 – Δh so Δεv the change in volumetric strain is nothing but $\Delta h/ \Delta h_0$ which is nothing but $\Delta e/ 1+ e_0$ so which is nothing but $\Delta e/ 1+ e_0$ since the specimen of the soil is only due to the change In void ratio.

The vertical strain Δεv can be expressed in terms of the void ratio of the soil specimen at different stages of the test and the void ratio at the end of each increment period can be calculated from the dial gauge readings and either the water content of the dry weight of the specimen at the end of the test.

So since the settlement of the soil is only due to change in the void ratio the vertical strain Δε v can be expressed in terms of void ratio of the soil sample at different stage of the test so we can actually say that Δh/ h0 where h0 is initial thickness = Δe/ 1+ e_0 e_0 is the original or initial void ratio so here the procedure is actually given water content measured the end of test w1.

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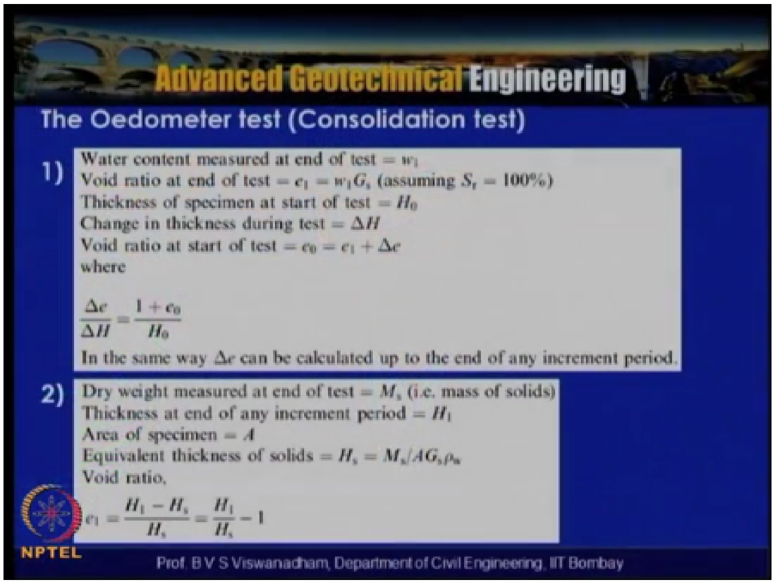

Water content void ratio at the end of the test because it is under completely saturation so e is e1 = w1gs movement once we know the water content at the end of test by knowing the specific gravity of the solids we can actually calculate what is the void ratio at the end of test and the thickness of the sample at their specimen at the start of the test is h0 and the change in thickness is Δh so void ratio at the start of test is e0 and which actually changes to e1 + Δe.

So Δ e= 1+ e0 = Δ H / H0 we can write like Δe / ΔH = 1+ e0 / H0, so in the same way Δe can be calculated up to the end of any increment period then in the 2^{nd} step the derivate measured at the end of test that is mass of the solids and thickness at the end of nay increment period is H1 so area of this specimen is A so equivalent of thickness of this solids we can actually get as Hs = Ms/AGs ρW so with that what we get is that once by the know the equivalent thickness of the solids e1= H1 which is the thickness at end of any increment period – Hs / Hs. So H1 / Hs = 1 H1/ Hs – 1 so e1 is nothing but H1/Hs – 1.

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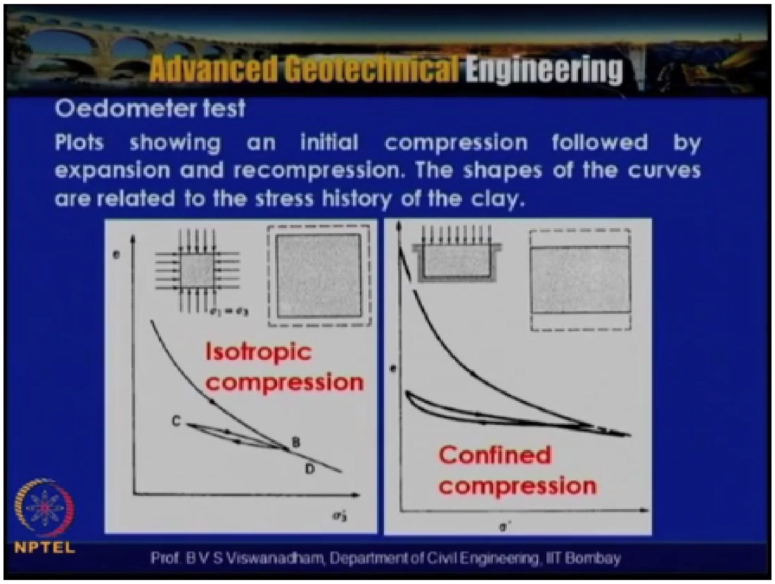

So in the oedemeter test here the first e verse σ' curves are shown on the left hand side of the slide we see isotropic compression curves where σ 1 is = σ3 the sample is actually compressed in all directions identically so this is this state is called isotropic compression and this is confined compression vertically you can see that this is you know the sample is restrain and along laterally and confined in the vertical direction.

So that the deformation actually occurs in the vertical direction so we can see that the distinctly different you known the e σ' plots for the isotropic compression and confined compression can be seen so here there is this here also there is a you know compression takes place and sample unloading is taking place and reloading is taking place and again the sample is undergoing compression.

Here you can see that the sample is undergoing compression and unloading and then reloading so compression unloading and reloading and then it is actually again going to the compression mode so this is this plot actually showing the initial compression followed by the expansion and recompression and the shape of the curves are related to the stress history of the relative to the stress history of the clay.

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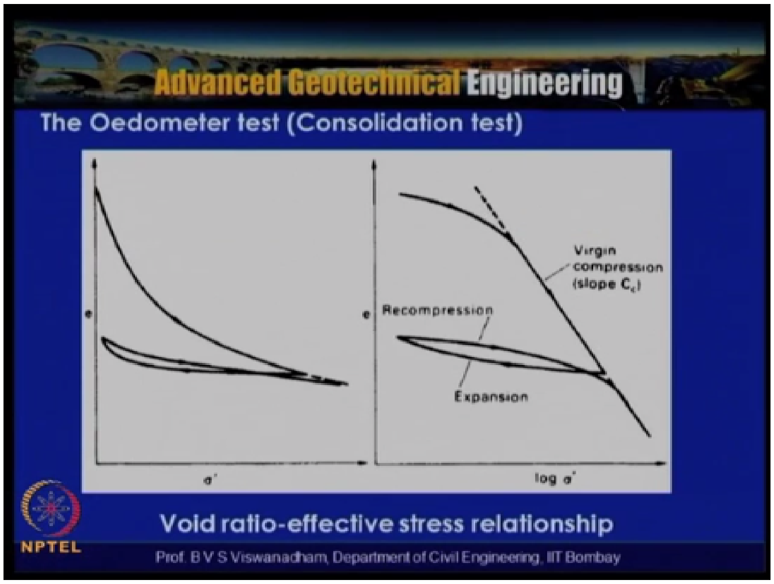

And here is a the result of the odometers test what we get is that we get eσ' and void ratio effective stress relationships on either arithmetic scale on the logarithmic scale so we can see that initial part is flat and then there is a straight potion which actually coherences here and then once we unload here after reaching certain pressure and the sample undergoes expansion and then the sample is subject into recompression and then goes into the compression mode again here.

So this straight line portion this portion is called the virgin compression for a soil and the slope of this virgin compression curve is actually called as compression index the slope of this virgin compression curve is actually called as these you know virgin compression curve is called as the compression index and this is a this is actually this portion is this is called recompression index or this is called as the recompression index and this is actually called the swelling index that is called swelling index when the load is being relieved and you can see that this is the initial void ratio and this is the void ratio.

So this as the process of this application of this load as the soil particles are grain are been subjected to you know the continuous rearrangement of the particles and then irrecoverable changes have been subjected because of that will happen is that the sample cannot actually you know met this particular point in the sense that you know it will it never be you know possible to achieve the same again.

So this is the unique for a given soil for a give type of soil or a clay where we can see that this statement portion and then there is a change in curvature here and then this potion is actually called the you know the compression this gives the virgin compression this is virgin compression curve and the slope of that is actually called as compression index.

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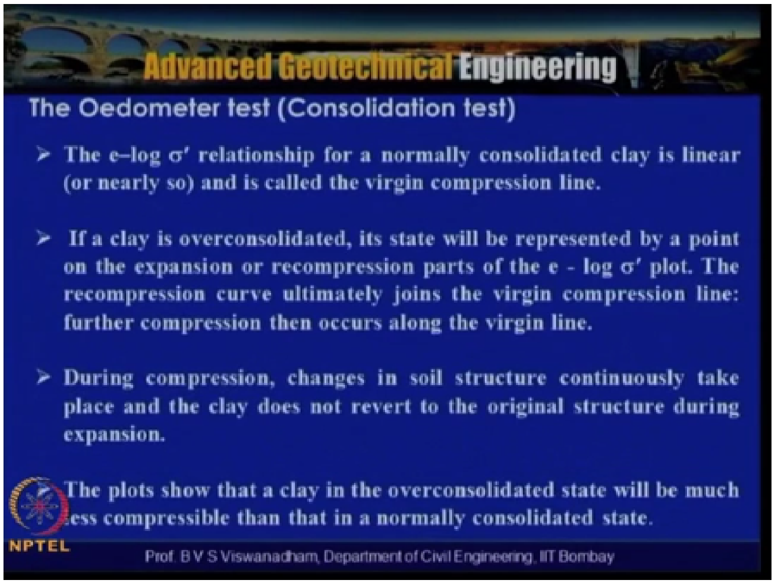

So the e’ σ’ relationship for a normally consolidated clay is linear or nearly so and is actually called as the virgin compression line because the that e log σ’ relationship for a normally consoled clay is linear and it is called as the virgin compression line if the clay is over than solidity it state will be represented by a point on the specimen on the point on the expansion or recompression parts of the e log σ’ plot the recompression curve ultimately joints the virgin compression line.

And further compression then occurs along the virgin line so it joints backs to the original virgin line and during the compression the changes in soil structure continuously take place and the clay does not revert to the original structure during the expansion.

So as during the you know compression you know the during the compression the changes in solid structure continuously take place and the clay does not revert back to the original structure during the expansion and the plot show that the clay in more consolidated state will be much less compressible so one can see that the recompression state the sample will be less compressible that the normally consolidated state.

So basically in the previous slide we have seen that plots show that the clay is more consolidated in the clay in the over consoled state will be much less compressible than that in the normally consolidated state then you will try to look into the defined the different parameters like we have introduced ourselves to while discussing the theory of 1 dimensional consolidation the coefficient of volume compressibility and this can be obtained by using odometers test and this nothing but Mv is nothing but Av / 1+ e_0 where Av is nothing but coefficient of compressibility.

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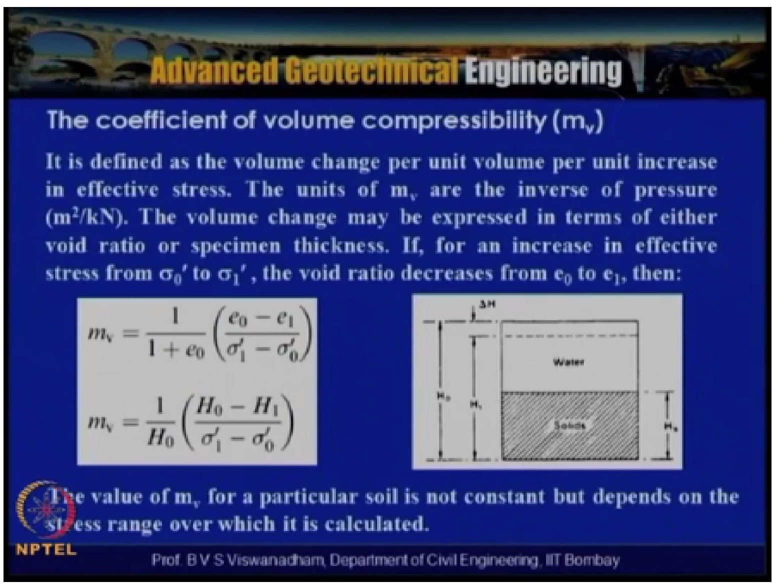

Which is Δe / Δσ' so it is defined as the volume change per unit volume in per unit increase in effective stress so this is a coefficient of volume compressibility is defined as the volume change per unit volume per unit increase in the effective stress and the units are for the m_v are m^2 / kN or m^2mN and the volume change may be expressed in terms of either void ratio or specimen thickness.

If for an increase in effective stress form $\sigma0'$ to σ $1'$ the void ratio decreases from e0 to e1, so we can actually say that here initial void sample thickness is say h0 and the after compression the sample thickness reduced to h1 so h0 – h1 is ΔH and Hs is the height of the solids so m_v is nothing but e_0 – e1/ $\sigma1'$ – $\sigma0'$ that is Δe / you know $\Delta\sigma'$ by you know these 1+ e0 that is the you know these you know 1+ e0 so this is actually given as mv = 1/ H0 x H0 – H1/ $\sigma1'$ – $\sigma0'$

So the volume the value of mv for a particular soil is not constant but depends upon the stress range over which is calculated so the value of mv so this is actually used in settlement calculations also and once we know the mv value we can actually calculate the estimate the settle consolidation settlements so the value of mv of a particular soil is not constant but depends upon stress range over which is this is calculated.

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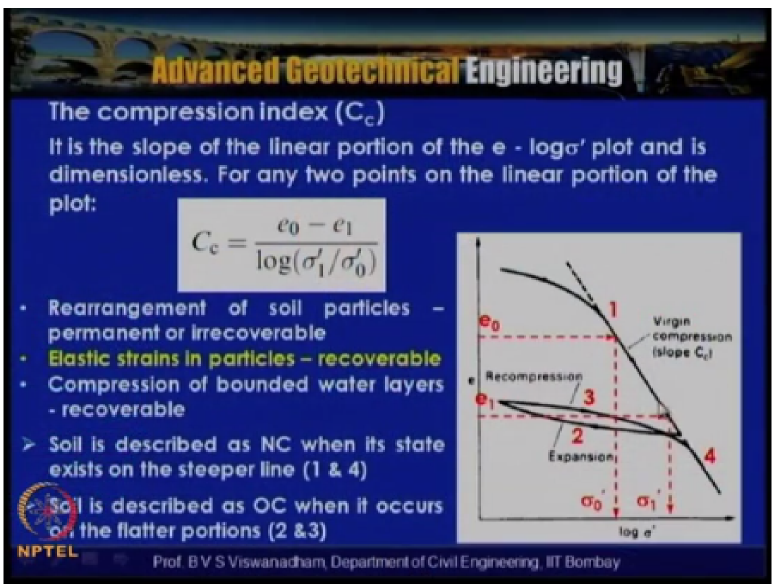

And as we have actually discussed the in the slope of this virgin compression curve is actually called a compression index and here at different positions of the curve is shown here 1, 2, 3 and 4 so here the soil is described as normally consolidated when it is state exists on the steeper line so 1 and 4 so this is actually called as normally consolidated and soil described as over consolidated when it occurs on the falter position there is 2 and 3 here so it can be like after here when the unloading take place again it will be less falter than this one so this process actually continuous.

It undergoes continuously so here the compression index is defined as the slop of the liner position of the e log σ ' plot and is dimensionless and for any 2 points on the linear portion of the plot we can actually find out e_0 and what is σ_0' that is the corresponding σ' e_1 or this corresponding σ_1 so Cc is Nothing but $e_0 - e_1$ /logarithmic of $\sigma_1' - \sigma_0'$ so the rearrangement of the soil particles you know in the in this position the rearrangement of the soil particles take place at per meant or irrecoverable changes take place.

And elastic strains in particles are partially recoverable and compression of bounded water layers is recoverable so in this particular slide what we have seen is that definition of the compression index and in how this can be determined and we also have see that the normally consolidated and over consolidated tubes we have been introduced so we will actually look into that hiw these terms can be defined.

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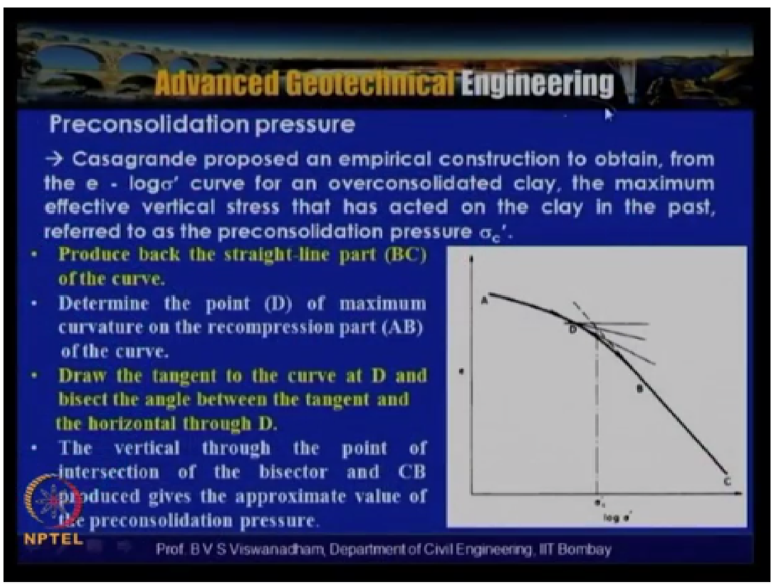

Before that we actually have to look into the another output from the consolidation test or ideation odometers test is per consolidation pressure so casagrande purposed an empirical construction to obtain per consolidation pressure from the e log σ' curve for a over consolidated clay the maximum effective vertical stress that as acted in the clay in the past refereed as the pre consolidation pressure.

So the maximum effective vertical stress that as acted on the clay in the paste referred to as the pre consolidation pressure so pervious so here once we have worked with the data is plotted for the e void ratio and logarithmic of σ' so we actually have got you know the portion AB and the portion BC and this irrelatively a straight portion so we are not we can unloading and reloading a components so here this actually portion is shown here so the in order to determine the per consolidation pressure of a given soli.

Suppose if you are having if you can actually get an under stable sample from the side and then in the test is actually done without much sample disturbance then there is a possibility that will be able to assess what is it is what was the you know the stress the soil as been subjected in the past, so the procedure is like this first what we need to do is that we have to draw a tangent to the straight line portion of the e log σ' curve extend this backward so extend this tangent backward and secondly what we have to do is that we have to look it a point D of the maximum curvature on the recompression part of the AB curve.

So this involves some sort of you know judgment and by proper judgment the determination of the point D of the maximum curvature of the recompression part AB of the curve can be obtained so you know the we have to draw the horizontal which is parallel to the logarithmic of σ' access through point D and draw a tangent passing through D so bisect an angle between this you know this tangent which is actually drawn through these point D which located on the maximum curvature point of the e log σ ' curve.

And this horizontal and one the point where this you know the extended that tangent of the linear motion of this compression curve where it meets this bisected line passing through point D and when you drop the vertical line below and that gives the σc' or Pc is called pre consolidation pressure the vertical through the point of the intersection of the bisector an Cb produces the approximate value of the pre consolidation pressure.

So with this procedure which is actually given by Casagrande we can actually obtain what is the you know the pre consolidation pressure and what was the stress of a soil what was the stress the soil would have been subjected in the past so the pre consolidation press as we just now seen how this can be determine in the laboratory.

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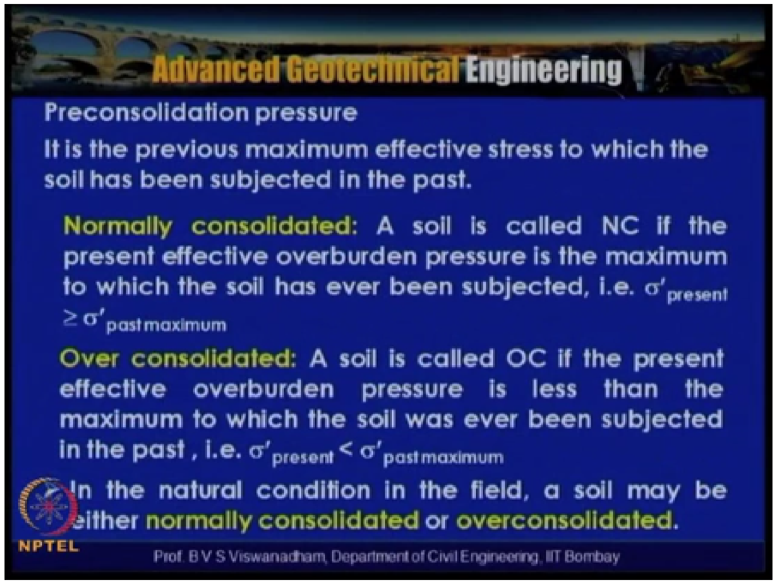

So it the pressure it is the pervious maximum effective stress to which the soil has been subjected in the past so here we actually introduced also to two terms and we have been actually discussing that the normal consolidated and over consolidated soils and a normally consolidated soil is nothing but a soil is called as normal consolidated if the present effective overburden pressure is the maximum to which the soil is ever been subjected so a soil is set to be normally consolidated if the effective present effective over burden pressure is the maximum pressure to which the soil is ever been subjected.

That is σ' present effective stress is less than is greater than or equal to σ' passed maximum σ' present greater than = to σ' past maximum and over consolidated soil is defined like this a soil is a called as over consolidated if the present effective over burden pressure is less than the maximum to which the soil was ever green subjected in the past that means that σ' past maximum is much more than the σ' present that is σ' present is less than the σ' past maximum.

So in the natural condition in the field the soil may be normally consolidated or over consolidated so mostly the you know in India the among the costal you know the our peninsula mostly the soils which are actually there are normally consolidated in nurture and in case of you know Europe and other countries because of the glaciations or other natures you know the soils can actually be more consolidated state so in along the costal line the most of this soils the remain in normally consolidated state in Indian peninsula.

So in a natural condition in the field the soil can be either normally consolidated or over consolidated and normally consolidated we say that when the σ' present is ≥ σ' past maximum and over consolidated we will say that σ' present is < σ' past maximum.

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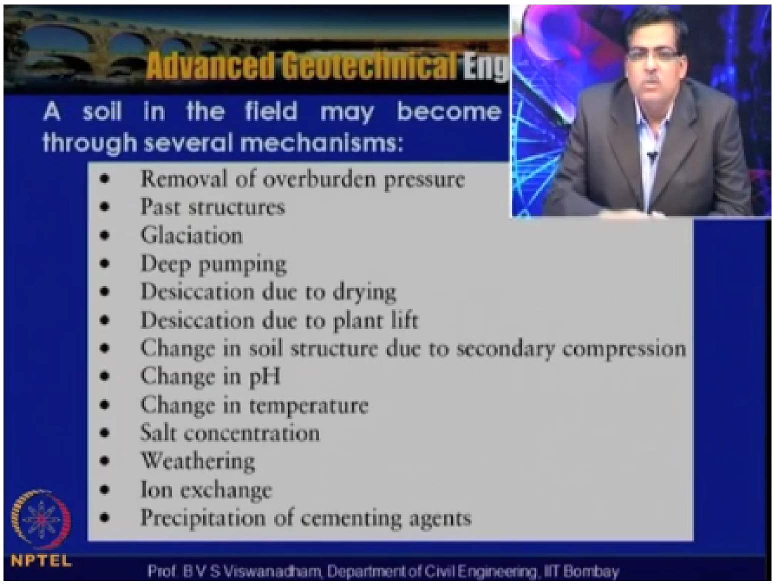

So a soil in the field may be become over consolidated with the soil variable in the continuous depots is actually take place it can actually become over consolidated through several mechanisms 1st is that you know a structure may might have been existing till today but may not be there so the past structures and removal of our overburden pressure removal pf the overburden pressure or glaciations.

And deep pumping that deep pumping of a and a desiccation due to drive mostly in the water zone and the upper portion of the soil the soil is actually said as set to be in the over consolidated state and that is because of the desiccation due to drive and then desiccation due to plant lift the lift of water in the water zone and this can also cause you know the over consolidated state to the soil.

And the change in soil structure due to secondary compression and the change in the pH value and the salt concentration and change in temperatures weathering ion exchange precipitation of cementing agents suppose if the cementing agents are getting predicated into the soil deposit and it also lead to the formation of over consolidated soils so particularly you know what we can say the glaciations and the past structures are removal of the over burden pressure are the major causes for the soil deposits to change into over consolidated state.

For the particularly the deep soil status and the other thing what we call what we come across in normally is that in hard crust what is this is basically because of the desiccation due to dry this will be in the over consolidated state naturally. So whenever possible the per consolidation pressure for an over consolidation should not exceed in the construction.

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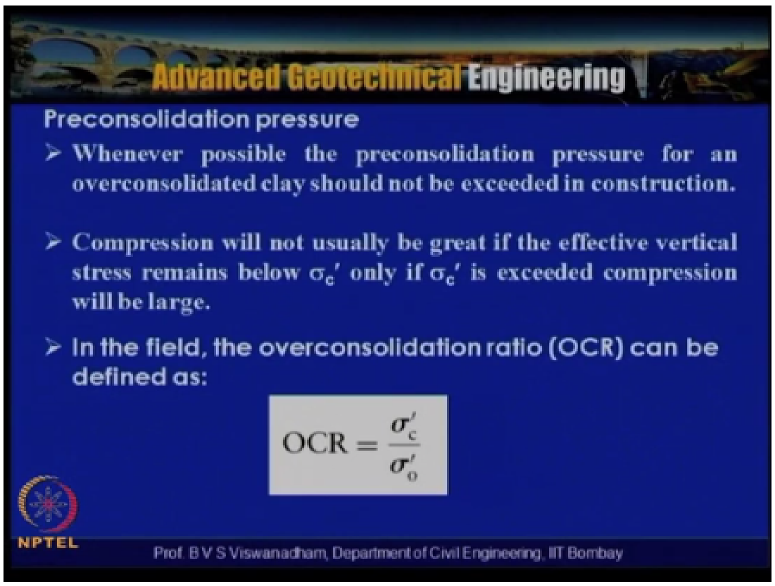

Whenever possible the pre consolidated pressure for an over consolidated clay should not exceed in construction if that is the case then it will undergo settlements again it will go into you know the compression again and the soils will be subjected to irrecoverable changes again the compression will not usually be great if the effective vertical stress remains below σ’ c and only σ’ c is exceed compression will be large if σ’ c is exceed then only compression will be large.

So if the given for example if we having a certain soil and if your actually trying to construct say 1 or 2 flow building and they compression may not actually you know will be will be there and if the so if this does not cause you know series problem with the design life of the structure they may not be issue so compression will not usually be great if the effective vertical stress remains below the σ’ σc’ and if σ if only if σc’ is exceeded the compression will be large then we are actually try to determine one more term which is called as OCR.

OCR is the thing but ratio of σ σ'c the pre consolidation pressure to the present effective over burden pressure so normally for normally consolidated soils so OCR will be in the range of 1, 2 you can say 2 and the any value of OCR greater than 2 or is called likely over consolidated soils and there can be some soils because of the past existence of the structures and some glaciations activity much might have taken place in that particular site because of the history there is a possibility that the OCR can have value up to 9 to 15 or so.

So highly over consolidated soils they actually have they would have undergone the consolidation and the water content in those soils is very less in case of normally consolidated soils they are soft in nature and have very high water content and compressible in nurture.

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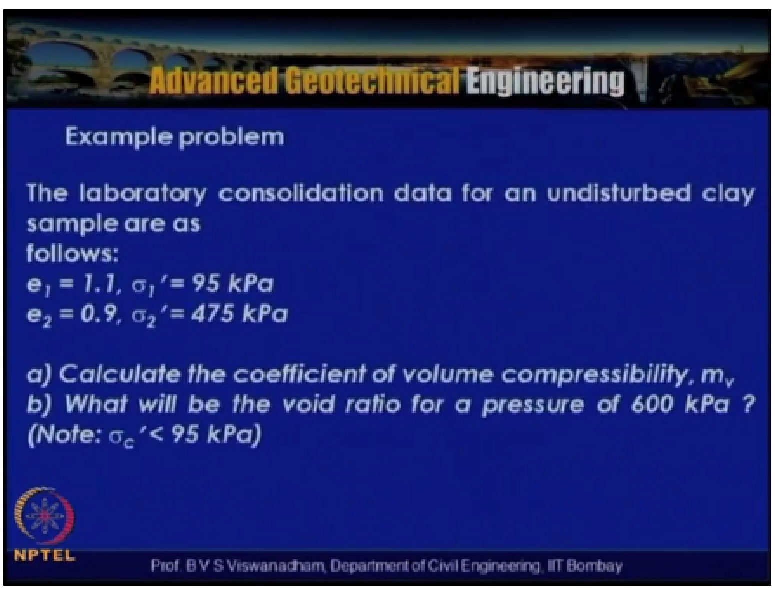

So before looking this example problem which we will discuss let us look into this particular slide where in we have a distributed.

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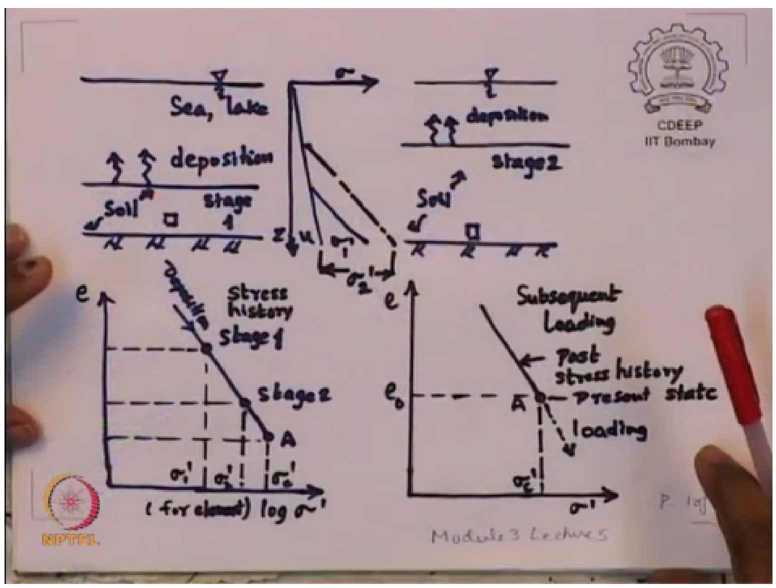

We have got a you know bottom which is actually having an impervious and assume that there is a soil which is actually has got a stage 1 deposition and then the soil is actually disposition getting deposited here and the disposition process is actually happening and this is the water level in the sea, lake or history where history is nothing but where wide portion of the river where it meets the sea so the σ verses z is this is nothing but this is what you know pore water pressure.

And then this effective stress in stage1 so when the disposition actually happens then the when the disposition happening in stage 2 the height of the soil deposited increases with that what will happen is that this element undergoes increase in the effective stress and what will happen is that the effective stress increases from σ_1' to σ_D' so the element is subject into increase in effective stress from σ_1' to σ_2'.

So this is plotted for the element here for this element which is at a certain point which is actually selected in stage 1 and stage 2 where in it actually says that e and verse log σ' so this is the stage 1 point where up to that the stress actually has been subjected in an element A is σ_1' this is because of the disposition of the soil and stage2 because of stress increases from σ_1 to σ_2 that is $\Delta \sigma$ is increase in incremental effect effective stress this is stage 2 and if this actually is point A is σ_c' that is the pre consolidation pressure so this is set to be in the normally consolidated state.

So this is the past stress history and this is for the e σ' which is actually shown here past stress history and the present state and they are loading when it actually happens again it goes into the normally consolidation mode here so this is you know a true NC clay.

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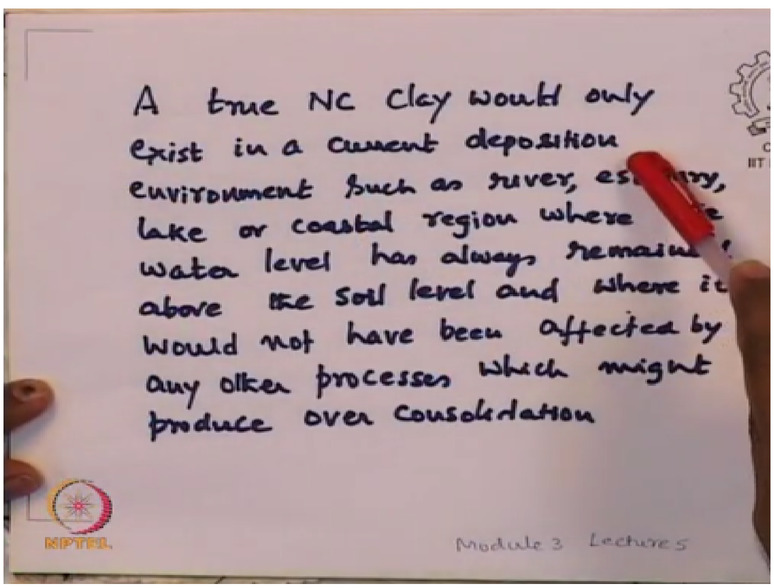

Would only be exists in current deposition environment one more things is that normally consolidated soils the continuous disposition actually take place mostly these are also called as and deposits such as river estuary lake or costal region where the water level has always remained above the soil level where it would not have been affected by any other processes which might produce over consolidation.

Which might produce over consolidation so a true normally considered clay would only exit in current deposition in environment such as river estuary lake costal region where water level is always remained above the sea level above this soil level where it would not have been affected by any other process which might produce over consolidation state and during the deposition what will happen is that the.

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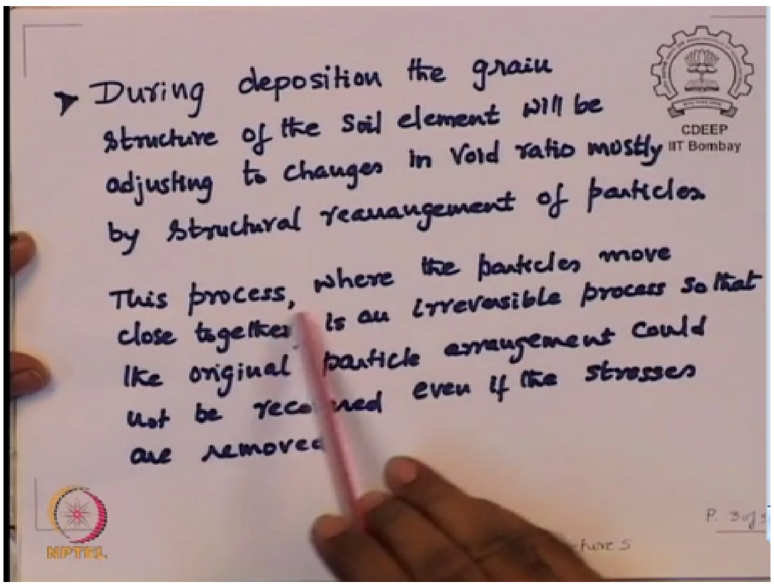

The grain structure of the soil element will be adjusting to changes in void ratio mostly structural rearrangement of soil particle takes place so that is why the along the compression line there is a you know the constant you know compression undergoes and then the as the because of the deposition the stress keeps on and the effective stress keeps on increasing and this process where the particles move closer is an irreversible process so that the original particle arrangement could not be recovered even if the stresses are removed.

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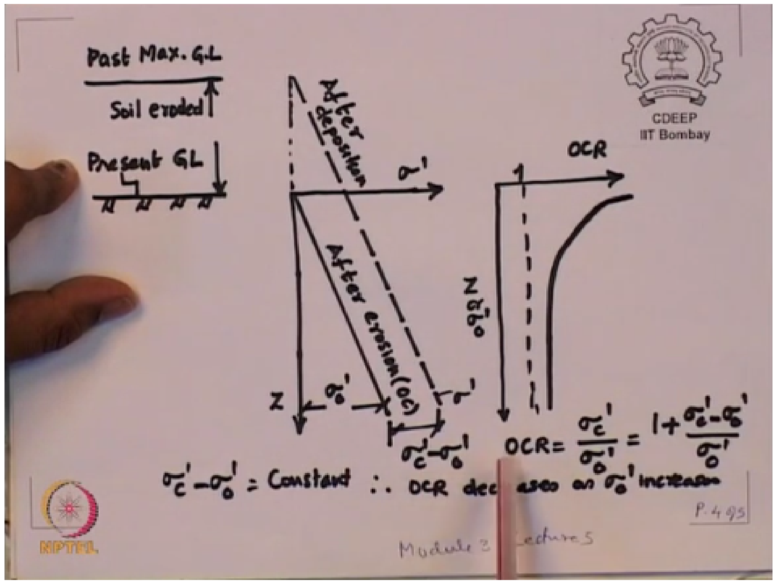

Where as in case of over consolidated clay what we said is that this is the present ground level but the past maximum ground level was here this can be with the ice or with the soil where either it would have eroded it will be in subjected erosion or this ice which was actually there was subjected to say glaciations so in that case now the over burden which was there as the soil where which the soil strata was subjected will not be existing now

But the past you it was actually subjected so in this case what will happen is that with the present over burden this is σ0’ and the after deposition you know this is the path so what will happen is that we can see that the OCR actually decreases with as this σ0’ increases or with the z or σ0’ the OCR variation will be there with increase which increases which decreases with an increasing σ0’ so here OCR is actually defined as σc’/ σ0’ which is nothing but we can write 1+ σc’ – σ0’ / σ0’.

So in this σc’ – σ0’ which is actually constant and this is actually for the over consolidated portion in the case of OC clay basically this is the clay that has been subjected.

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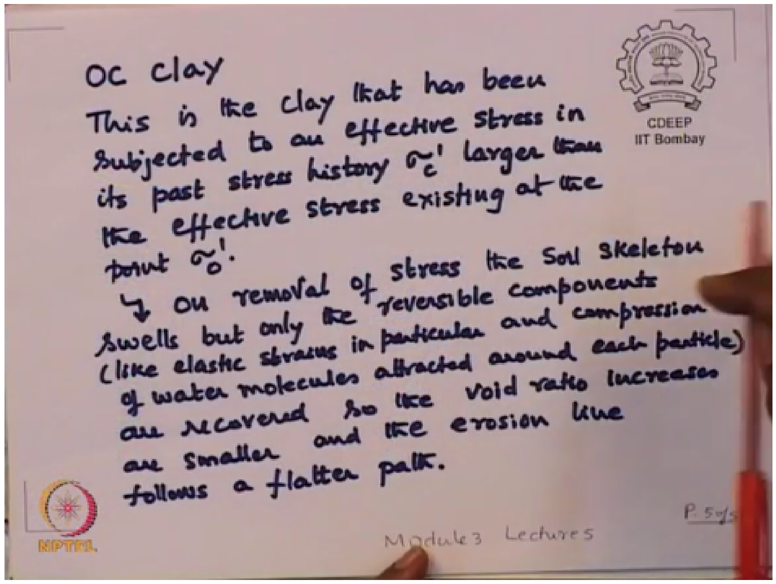

To effective stress in the past stress history and σc' larger than the effective stress existing at the point σ0' so removal of the stress the soils skeleton swells but only the revisable components like elastic strains in particular and compression of water molecules attracted around each particles they are recovered and so that the void ratio increases are smaller and the erosion line follow say falter path.

So what w3e have understood is that the normally consolidated and the over consolidated soils are distinctive different and normal consolidated soils undergo you know the large compression and they have very high water constants and by knowing liquid limits we can also determined what is the compression index from the order of the compression index value we can actually determine in case of over consolidated soils the soils would have been already subjected to consolidation.

So you here in this constant in this contest we can actually say that that the soil terminally fine grains spoiler clays very sensitive to the stress strain so then in this particular lecture what we try to introduce our selves to the you know the so called you know how we can actually do the odometers test for determine in the consolidation characteristics of soils.

So from the odometer test what we can actually get is that compression index and coefficient volume compressibility and then also we can actually get by we have popular two methods are there for determining the coefficient of consolidation with those methods we can actually get the variation of the coefficient of consolidation with time and as we have discussed with that coefficient of consolidation and coefficient of permeability or related so by using that relation we can also obtain what is the change in coefficient of permeability when actually happens within increase in the effective stress.

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