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ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 37

Module – 4

Lecture – 8 on Stress – strain relationship and Shear strength of soils

welcome to lecture series on advanced geotechnical engineering and we are discussing module 4 shear strength of soils see in the previous lecture we introduced ourselves to methods for determining shear strength of the soils in the laboratory and then we said that you know we have discussed about the direct shear test and what are the you know the stress strains in direct shear test and merits and demerits of the direct shear test.

The we said that you know the other type of very popular testing which is a triaxial compression test and which is the physical model test which actually simulates the stress conditions and drainage conditions as in the soil and it actually as versatile applications so in this particular module 4 and lecture 8 we are going to discuss about you know the different types of triaxial test and pertinent stress paths.

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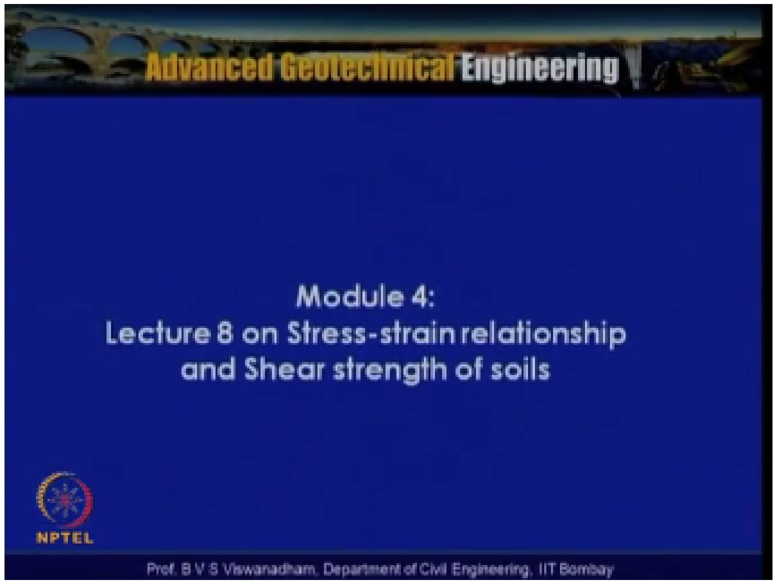

So this is the module 4 in the lecture 8 on the stress strain relationship and shear strength of soils and we are as informed we are going to concentrate on the triaxial behavior particularly with the reference to you know unconsolidated.

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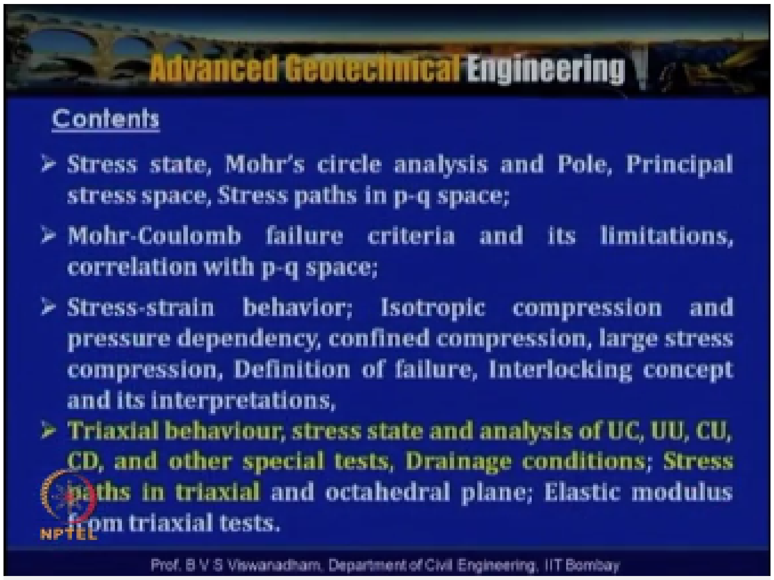

Unconfined unconsolidated untrained test unconfined compress test consolidated undrained and consolidated drained triaxial test and these stress paths for the, you know in the triaxial test.

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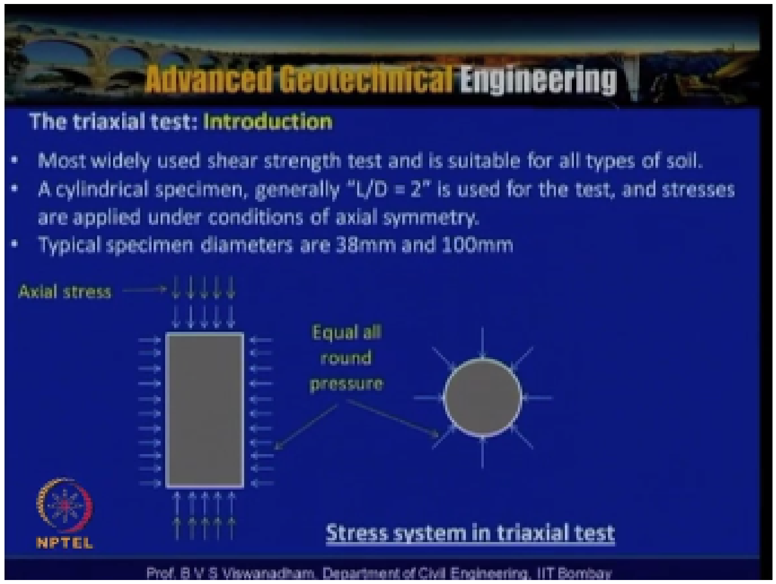

So this as said most widely used shear strength test and is suitable for all types of soil and a cylindrical specimen generally having L/D = 2 this is required to maintain you know the principle planes you know remain plane remain as principle planes during all stage of the triaxial text so one with the failure plane you know passes through the upper and bottom portions then you know there can be possibility of the shear stress generated.

And that in such situations those planes cannot be called as you know principle planes so in triaxial test we this radial plane which is vertical plane as well as this horizontal planes these panes actually remain principle planes throughout the test and the typical specimen diameters as been mentioned 38mm 100mm widely use otherwise we also possibilities of 300mm diameter and you know even the larger sizes triaxial test are actually becoming in work now.

So in order to simulate the you know the confining stress it is actually done through you know by filling the chamber with the water and the water is actually pressurizes by all round pressure and which is actually called as you know the chamber pressure or cell pressure.

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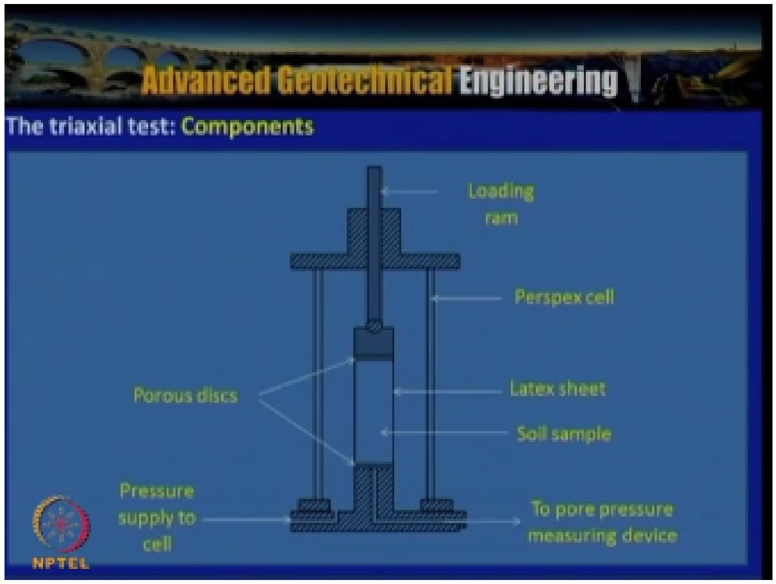

So this is the typical triaxial cell which is actually shown and the sample which is having L/D = 2 that is 38 mm diameter or100 mm diameter and 200mm height or 75mm diameter or 150mm height is actually place and in order to you know prevent you know in a interaction of sample with the water there is a membrane which is actually placed which is placed and so that membrane ensures that water tightness.

And there different ports will be there one port is to you know the supple water into the soil sample and one port is to you know supply to take the to measure the volume changes and another port is to measure any changes in the pressure within the sample and the loading is actually applied from the top that is actually called as deviation load so when we have the sample which is you know confined with all round pressures.

Then you know the pressures all-round for the samples are σ3 and then when in order to you know induce the loading let us example that we consider an example that we have got a soil strata and we have got a sample at certain depth let us say about 5 m depth and above that suppose we are constructing a foundation and the building loading is actually increasing gradually.

So that is actually increase in the incremental load is actually given you know applied by this you know these York under this loading ram and this loading ram induces that σ1 so σ1 = σ3 + P/ A so σ1 – σ3 is actually called the derivate load.

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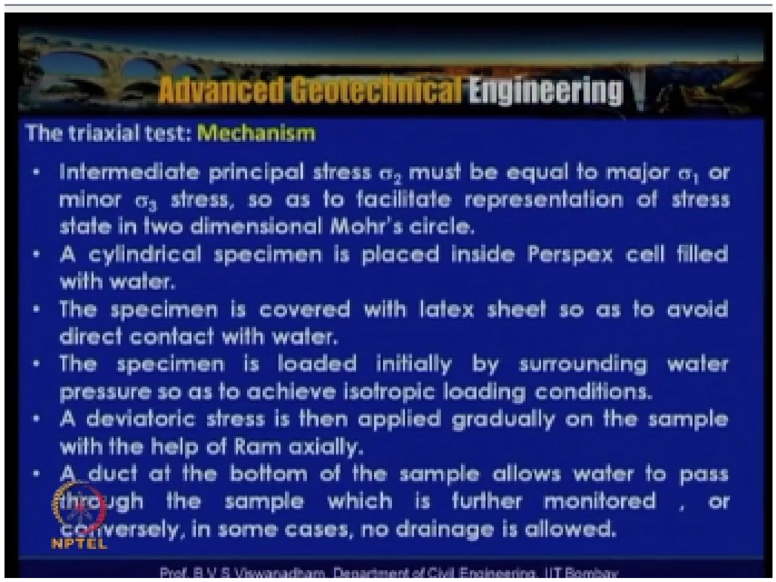

So in the mechanism basically is that intermediate principle stress σ2 must be equal to major σ1 or minor σ3 stress so is to facilitate representation of the stress state in 2 dimensional Mohr's circle and the cylindrical specimen is placed inside Perspex cell filled with water so that the acrylic you know cell will be filled with water the specimen is covered with latex sheet, so as to avoid the direct contact with water, and the specimen is initially loaded by the cell pressure.

And then basically during that stage if the consolidation as to Happen then the consolidation will be allowed and then there after once the consolidation is completed a deviator stress is then applied gradually on the sample with the help of ram axially a duct at the bottom of the sample allows the water to pass through the sample which is further monitored and which actually can have a volume increase or you know which can actually measure the volume changes and the pore water pressure trans user actually measure positive or negative.

Pore water pressure is depending up on the stress tarry of the soil being tested so fine grained soil can stand the mould without.

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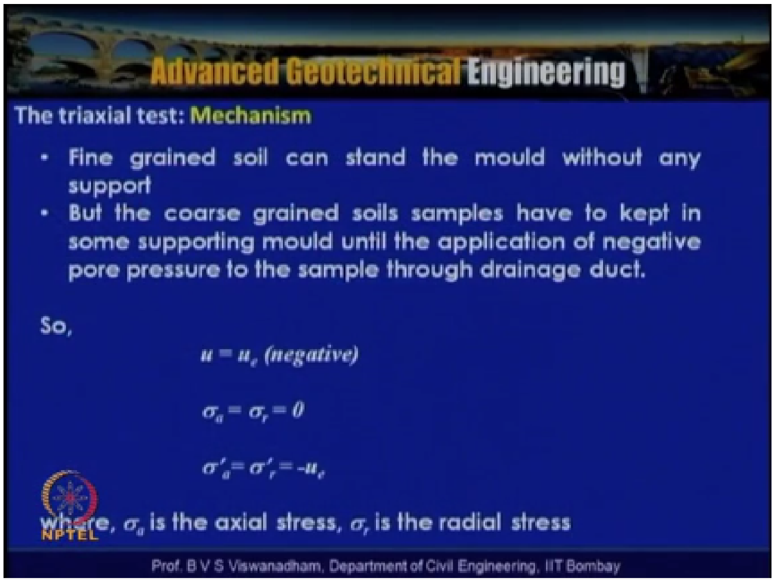

Any support but the coarse grained soil samples have to kept in some supporting mould until the application of negative pore water pressure to the sample through drainage duct so the fine grained soil samples are actually prepared you know on the without any fine grained soil can actually support but in a coarse grained soils or sandy soil samples have to be kept with some section and because of that you then after words the section is actually realized gradually.

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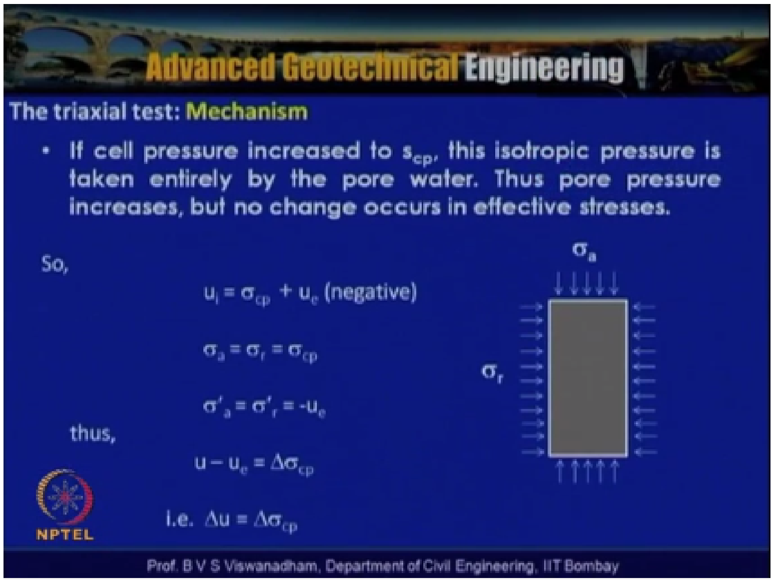

If the cell pressure is increased to say σcp then the isotopic pressure is taken entirely by the pore water and the pore water you know pressure increases but no change occurs in the effective stress because if there is no volume change then the pore water pressure will you know change in the volume there are no change the volume no change effective stress.

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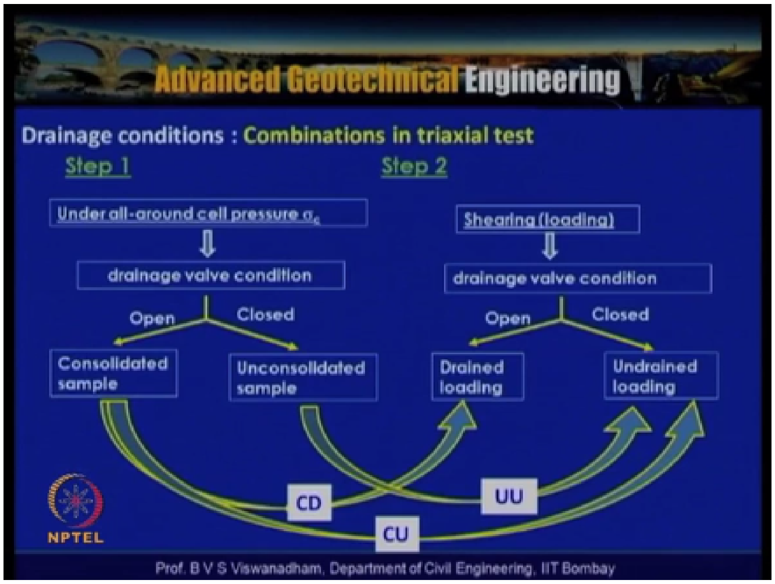

Now we have different drainage conditions like as if they mentioned that actually makes you know the combinations in triaxial test are different types of triaxial test one is that you know we have 2 steps one step 1 is that you know during that consolidation of the sample and then shearing stress the so in this basically there are 2 stages are there you know stage 1 where the consolidation can happen and the stage 2 is the shearing can happen.

Under all around pressures σc drainage volve condition will be open if you are having if we are allowing consolidation so the sample the water in the sample drains out once the consolidation is actually completed then you know it is actually the shear loading in this also the shear loading actually it actually has got the drainage volve condition can be open and closed it can be open if you are having a consolidated drained triaxial test and it can be closed if you are having thinking of so consolidated undrained triaxial test.

And it can be closed in both consolidation and you know drainage shearing stages and that is actually unconsolidated undrained triaxial test so unconsolidated undrained triaxial test is basically a quick test where the sample is as prepared will be tested without any consolidated by applying 3 different cell pressures and if the cell pressure is actually is if the if the sample is actually saturated.

And the even at different cell pressures the demerit load you know will be same so with that what will happen is that we get the undrained shear strength of a soil and the failure you know failure plane or the failure analog will be horizontal so we have certain practical considerations in which we will be actually doing this consolidate drain and consolidated undrained.

And unconsolidated undrained triaxial test for example for unconsolidated undrained triaxial where actually we when you are constructing you know an amazements on the soft soil without any you know waiting period that means that we do not allow the consolidation to take place and you do not allow the even the consolidation during the shear then you know a rapid construction on a particular soil deposit on is let us say and softly deposit actually it simulates the unconsolidated undrained constitution are you know.

Let us say the rapid loading of a founding on a foundation on a unsaturated on a saturated undrained clay is also an indication of you know the example of unconsolidated undrained test or let us assume that a catastrophic you know failure of a in a vertical cut under of a saturated soil under undrained condition is also at some extend indicates an example of unconsolidated undrained test in such situations one need to you know do the unconsolidated undrained triaxial test.

But we have some practical examples in which we can actually say that you know the different types of you know test can be done depending upon the practical situation. The one what we have here is.

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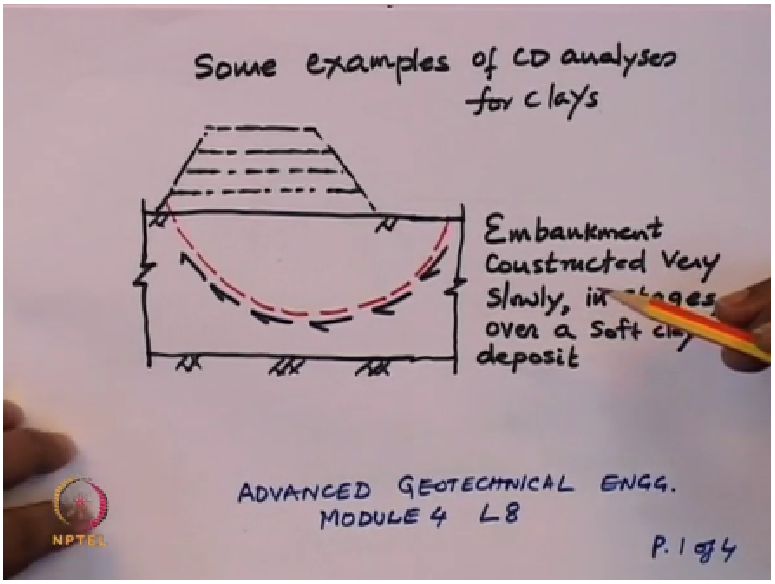

Some examples for the CD analysis for clays this is after wholes and coxes 1981 and consider an embankment constructed very slowly in the sense that embankment constructed in stages and each stage the consolidation has been you as been allowed and between each stage there is an adequate waiting period then embracement was actually constructed very slowly in stages over a soft clay deposit.

So in this example in the suppose if you are having a situation like embankment construction you know very slowly in stages over a soft clay deposit then you know one has to do the consolidated drained triaxial test and this also indicates this also called the drained parameters and where the pore water pressure dissipation actually completely occurs so with that what we can we call is that this effective shear strength parameters like effective position and effective friction angle can be obtained and these are actually also indicate.

For example when we were doing slopes to build analysis particularly under effective stress conditions we have to use for the long term satiability of a particular you know slope or embankment we have to use the we need the effective shear strength parameters like C' and ϕ'.

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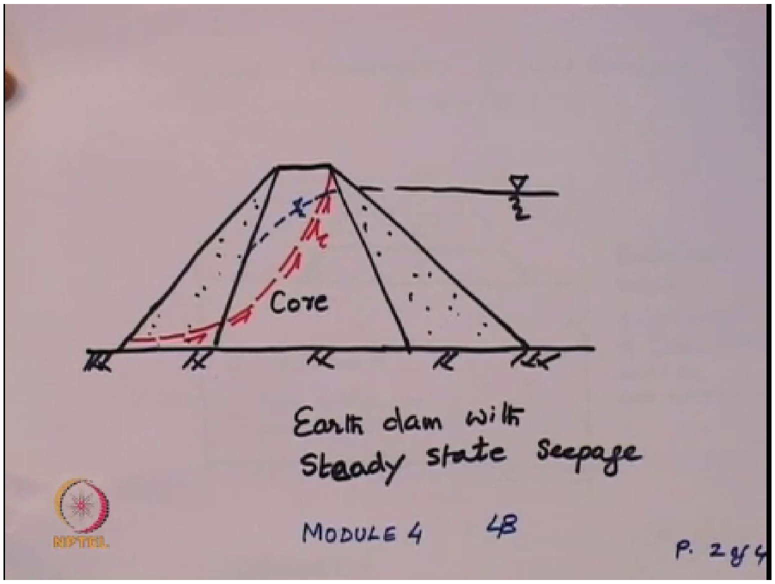

We are actually discussing about the examples for you know some field examples for the you know where we actually adopt 3 consolidated drained triaxial test parameters the other example what we are discussing in this for the C_D test particularly where we can actually get the drained parameters is the earth dam with steady state seepage conditions where in we actually have an earth and embankment or earth and dam constructed with a core and a case.

The casing is actually having a you know material which is a medium the low having low class density materials fine grain soil but with low facility materials and this is the upstream water level and this is the periodic surface and the water flows and then through a drain it actually wants out now this is the failure surface typical failure surface so under steady state seepage conditions under long term conditions and you know then when we wanted to evaluate the stability of an earth and dam subjected to steady state seepage condition.

One need to adopt the effective shear strength parameters that is C' and ϕ; especially obtained form by allowing the consolidation that is the consolidation drainage during the consolidation as well as you know during shearing stages so both the stages actually happen very slow so in a way they give you know the in both the stages what will actually happen is that the particularly in the drainage stage the dissipation of pore water pressure is also most close to 0 because you know the raise of the pore water pressure will not be there at all because the drainage is actually happening continuously the another set of example like.

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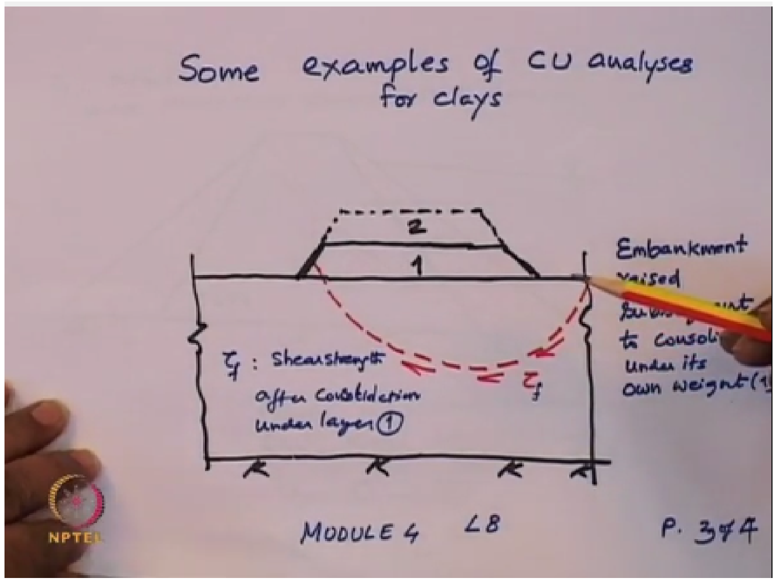

For examples similar situation we having an embankment on soft clay but what we have done is that you know embankment is constructed after you know waiting for a period of you know for consolidation for 1 that is stage 1 an the stage 2 was enablement is raised subsequent to consolidation of a soil under the stage 1 loading of an embracement so in this case what actually happen is that you actually allowed the consolidation to happen and during that stage actually drains allowed.

Then the volume changes in these soil for actually recorded but when stage 2 happen and the no drainage actually happened all of a sudden there is a you know the failure which actually could have raised so this actually situation you know raise and for this type of satiation that you know we can actually say that consolidated undrained parameters are very useful.

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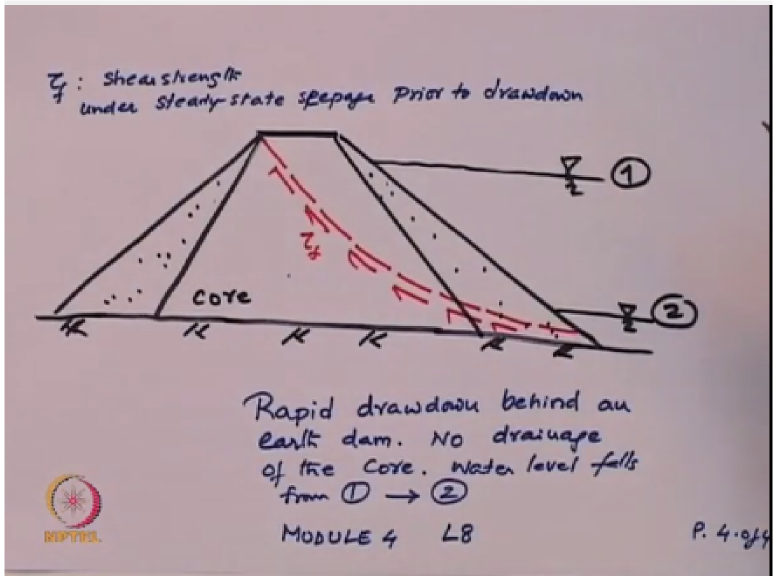

And the other example like the earth and dam example when take we have a core and we have the casing and this is the water level 1 and water level 2 assume that the water level 1 to 2 drops you know suddenly that is called rapid draw down case and in this case rapid round rapid drawdown for across behind an earth and dam and no drainage of the core when it is take place that is the during steady sates seepage conditions the consolidation and all those things as actually happened.

Got the shear τf is nothing but the shear strength and a steady state seepage conditions prior to drawdown but what is actually happened is that the drawdown is so sudden there is no drainage actually during the you know the period of the drawdown so in such situations the shearing actually happens you know under undrained conditions so this is an example for consolidated you know undrained triaxial test parameters.

So here when we have this consolidated undrained case then in such situations what we can use that we use these you know depending upon the typical situations we actually select the type of the test and then we use this parameters for conducting the different special cases of the you know the triaxial test so we have you know.

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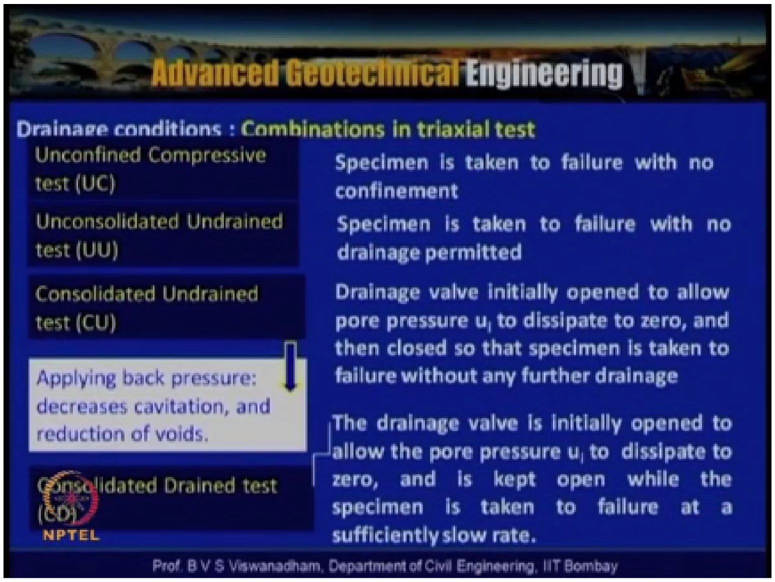

You know in principle consolidated undrained consolidated undrained and consolidated drained triaxial test and there is a special case of you know a triaxial test where unconfined compression test what we call and which is a you know which is without any cell pressure the sample is actually taken to failure so the specimen is actually taken to failure with no confinement that is unconfined compressive strength test and unconsolidated undrained test is actually specimen is taken to failure with no drainage permitted neither in consolidation time nor in you know shearing stages.

And consolidated undrained test actually here at the drainage is actually initially open to allow the consolidation to take place and so that the pore water pressure dissipates to 0 and then it is closed so that the failure can actually happen without any drainage that is a condition where the shearing stage you know the drainage will be close.

So the 3rd type of test is that the consolidated drained triaxial test the drainage volve is initially open to allow the pore water pressure to dissipate to the 0 so that as usual in the previous stage pervious type of test consolidated undrained test the sample is allowed to consolidated and the pore water pressure is you know UI is allowed to dissipate to 0 and is kept open while the specimen is actually taken to the failure at a sufficiently slow rate.

So the strain rate at which the samples are actually are you know test for example unconfined compression test and unconsolidated undrained test they are actually tested at 1.25mm / min and this is the you know the standard rate you know the strain rate at which the sample this particular

1.25mm/ min is actually selected keep in μ that you know the pore water no volume changes actually take place.

And the pore water pressure dissipation also will not actually take places particularly in unconfined compressive strength test actually where because it is not actually having a you know exposure these application on cell pressure the sample is actually not allowed to undergo the changes due to in the temperatures so we have you know in case of consolidated drained an consolidated undrained triaxial test the strain rates are actually calculated based on the permeability of the soil.

Suppose if we are having a marine clay with clay of high compressibility let us say CH then in such satiations what will happen is that the permeability of the soil is so low the even the test ios actually conduced very slow rate suppose if you are having a slity type of soil the stress the test is actually conducted the rate strain rate selected as the permeability of the you know slity soil is actually more than clay soil so the test can actually can be done at a slightly rapid rate compared to you know the rate at which at actually it was done for a clay.

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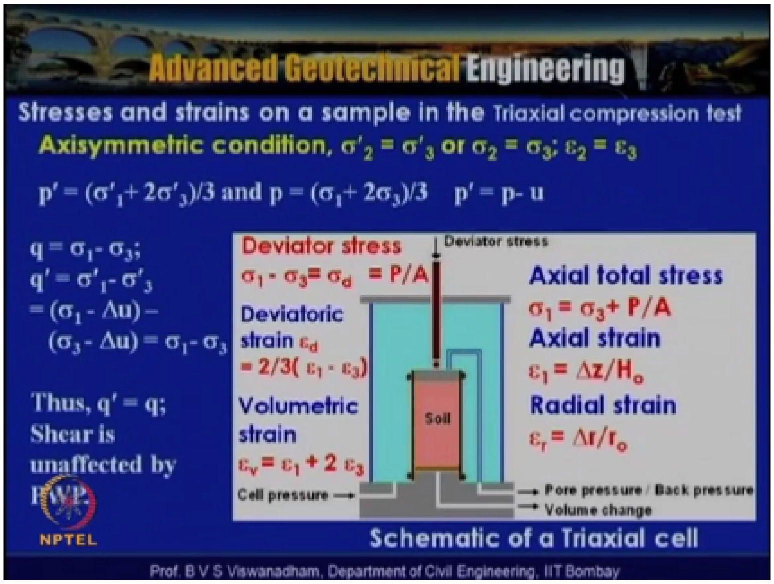

So this particular you know the stress and strains in a sample in the triaxial compression test basically it is an ax symmetric condition where $\sigma 2' = \sigma 3'$ or $\sigma 2 = \sigma 3$ and $\varepsilon 2 = \varepsilon 3$ $\varepsilon 2$ and 3 are nothing but $\varepsilon 2$ in the intermediate direction that is intermediate principle stress direction and so in case of triaxial test because of the cylindrical nurture of the samples $\sigma 2 = \sigma 3$ and $\varepsilon 2 = \varepsilon 3$ so by using $p' = \sigma 1' + 2\sigma 3' / 3$ so that is nothing but $\sigma 3'$ because $\sigma 1 + \sigma 1' + \sigma 2'$, $\sigma 2 + \sigma 3$ so because $\sigma 2 = \sigma 3$ what we have done is that we have return p' as $\sigma 1' + 2\ \sigma 3' / 3$.

In case of total stress it is $p = \sigma 1 + 2\sigma 3/3$ because $p' = p - u$ q that is $\sigma 1 – \sigma 3$ $q' = q$ because $\sigma 1' – \sigma 3' = \sigma 1 – \Delta u –$ of $\sigma 3 – \Delta u$ so because of that $\sigma 1 – \sigma 3 = q = q'$ so thus $q' = q$ shear is actually unaffected by the pore water pressure so here when we were actually having a sample which is confined with you know membrane and then cell pressure $\sigma 3$ and the axial total stress is $\sigma 1 = \sigma 3 + P/A$ $\sigma 3$ will be acting in all directions $\sigma 1$ is actually applied so $\sigma 1 = \sigma 3 + P/A$.

So the deviator stress is nothing but $\sigma 1 – \sigma 3 = P/A$ that is so it is also called as $\sigma 1 – \sigma 3 = \sigma d = P/A$ and the axial strain in the you know major principle stress direction that is $\varepsilon 1 = \Delta z/ H0$. H0 is the original height of the sample and Δz is the vertical compression of the sample verticals strain actually experience with the sample so $\varepsilon 1 = \Delta z/ H0$ and radial strain that is the bulging if it actually happens for example for a loss sand or for a normally consolidated soil then there is $\varepsilon r = \Delta r / r0$ Δr is the change in the you know radios of the sample to the original radios of the sample.

And the deviator strain is actually given by $\varepsilon d = 2/3$ of $\varepsilon 1 - \varepsilon 3$ and volumetric strain is nothing but $\varepsilon v = \varepsilon 1 + 2\ \varepsilon 3$ so with $P' = \sigma 1 + 2\ \sigma\ 3'/\ 3$ and $P = 2\ \sigma 1 + 2\ \sigma 3/\ 3$ and $q' = q = \sigma 1 - \sigma 3$ we will use these deliberations for plotting the stress paths for the different types of triaxial test.

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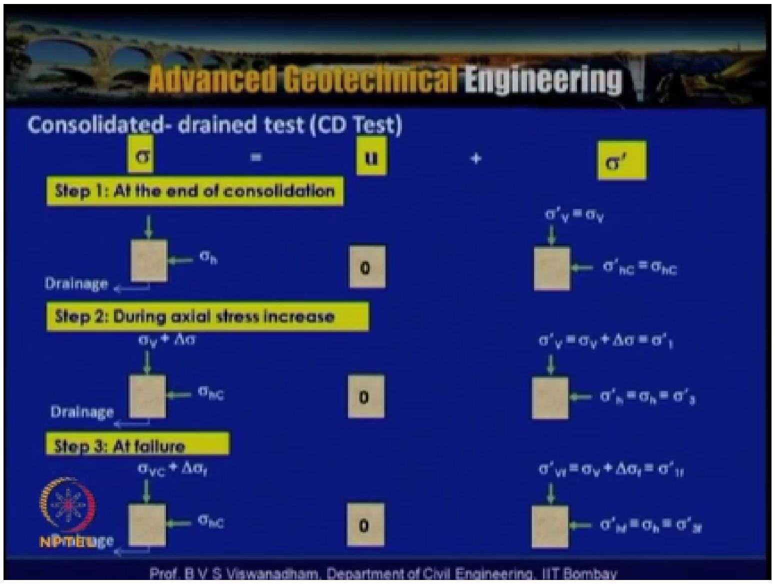

So as we have discussed the you know the types of triaxial test and we said that consolidated and drained triaxial test that is a CD test which is very slow test the if you look into the different stress stages in the during the sample testing in the step 1 is that at the end of consolidation what will happen is that the sample is allowed to consolidate during by allowing that volve to open.

So the pore water pressure dissipation will be 0 so then we actually have $\sigma v' = \sigma v$ and $\sigma H'$ σ' it is $C = \sigma HC$ and during actual stress increases that with the σv and then $\Delta\ \sigma$ increase and here as we have not allowing the pore water pressure the stress stage the shearing is actually done at a such a slow rate that the pore water pressure dissipation will be more or less close to 0 in that situation then we have got $\sigma v' = \sigma v + \Delta\sigma = \sigma 1'$.

So $\sigma'\ H = \sigma' H = \sigma 3'$ at failure then these things turn out to be that is $\Delta\sigma$ tune out to be $\Delta\sigma f$ then the σHc remains constant and the pore water pressure against still remains constant at failure then $\sigma' vf = \sigma v + \Delta\sigma f = \sigma'$ you know 1 $\sigma 1f$ that is the failure and $\sigma'\ Hf = \sigma' H = \sigma'\ 3f$ so this the principle stress in the radial direction at failure and $\sigma 1' f$ is the principle direction the major principle stress direction.

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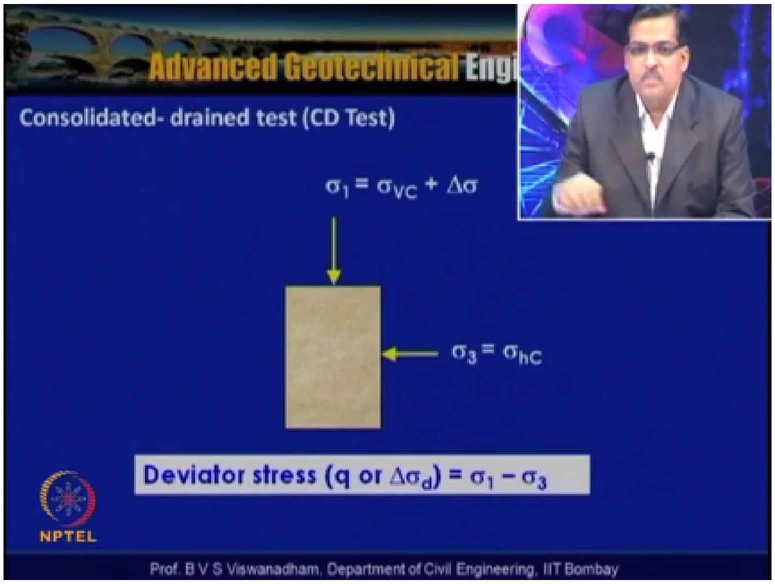

So σ1 = σvc Δ σ and σ3 = σHc that deviated stress are deviator is given by q or Δσd = σ1 – σ3.

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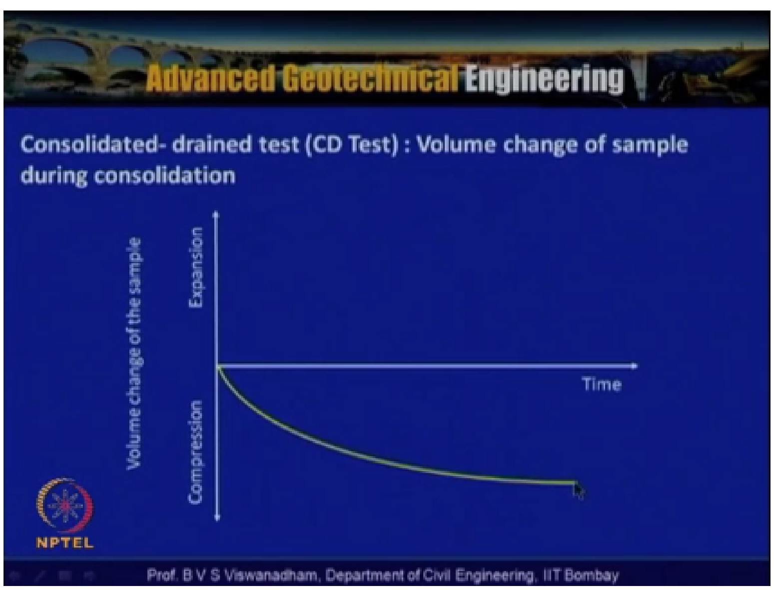

So during the consolidation consolidated drained triaxial test or if you having a CU test the volume change actual takes place so this particular you know volume change of the sample during the consolidation so till the consolidation is completed the you know the sample is actually allowed to consolidate and there after once this consolidation is completed once the consolidation stage is completed.

Typically for a you know clay it may lost for about more than 4 to 5 days or some time about a week for completion of consolidation and in this practically slide.

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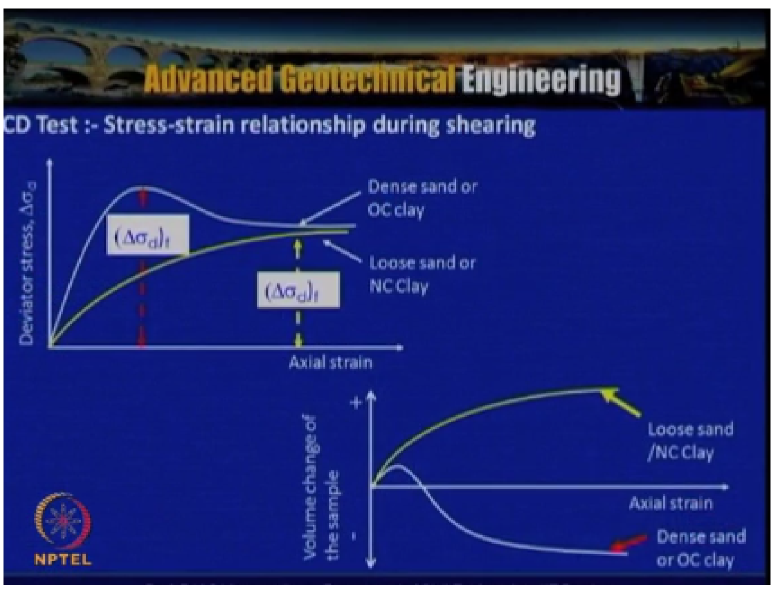

The stress strain relationship during shearing is actually given and this for a case of for the case of consolidated undrained triaxial test where in here we what we have done is that we actually have you know not allowed the drainage to take place during the shear and the you know what you can actually happen is that we have a situation that here the deviator stress actually variation is like this and there a decrease and decrease actually takes place.

So this for valid for dense sand and OC clay and this is for the loss sand or normally concerned clay you can see that dense sand and OC clay there is a hardening takes place and after attaining a peak a distinct peak is actually after excepting the distinct peak weather is a you know a scoffing actually take place so here in this case what will actually happen is that you know here this is actually for CD test that is for consolidated drained test and varying actually here the sample if you can see that loss sand or normally consoled clay there is a compression actually take place.

But in case of dense sand and over consolidated clay initially there will be some compression there after there is an increase in volume that is volume actually increase so this is actually because now we have discussed earlier the behavior of the soil so in case of triaxial test also particularly when you are actually allowing a sample volume to change during the shearing by allowing the drainage to happen that in the case of consolidated drained test.

So what will happen is that you actually have got you know the volume changes actually takes place you know in the way which is actually shown but during all stages the pore water pressure remains to be same the pore water pressure remains to be same and the CD test when you actually have done say it if you wanted to see how actually we can determine it different the parameters the shear strength parameters.

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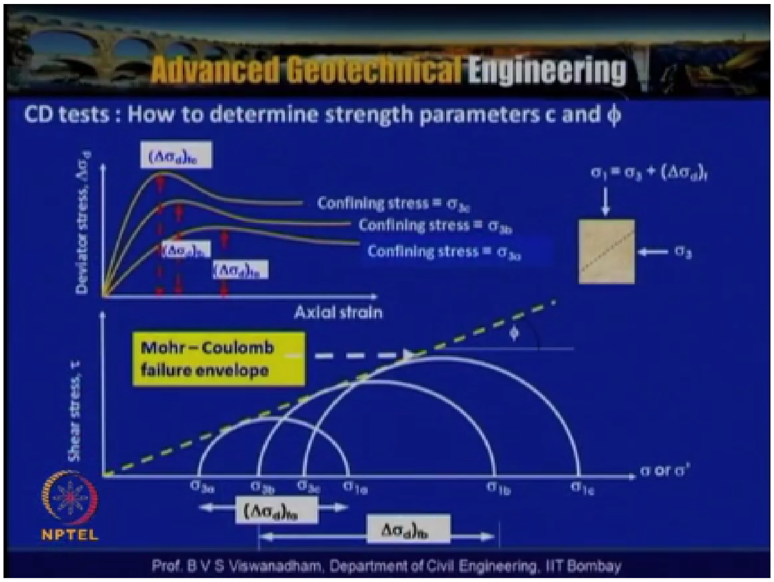

So one what one need to do is that we have to do let us say minimum 3 samples 4 samples and each sample is actually tested for different cell pressures or different confining stress so confining stress one that is σ3 A and confining stress P say σ3 B and confining stress C is σ3c then you we actually have got different types of you know the stress deviator stress verses axial strain curves.

So once you know the maximum or peak values and for those peak value that is this is nothing but the Δσd so we can actually with that as diameter one if you draw the Mohr circle you actually can draw different Mohr circles and depending upon let us say that if it is you know normally consolidated soil and which are loss sand then actually we have a situation like you know C' = 0 the it passes through the horizon and τ σ analog will be like this with where π = π' here which is you know the angle of inclination of the Mohr coulomb failure analog.

See the when this actually interacts with this thing so this is the failure plane whikch is nothing but 45 + 5/ 2 inclination which actually happens and this is angle of inclination of the failure so this is the typical so you need to have this you know the parameters basically to determine different types of sets of Mohr circles can be drawn with the different cell pressures and different deviator loads and so in case of a you know consolidated drain test as the cell pressure is increase the Mohr circle diameter keeps on increasing a deviator load keeps on increasing.

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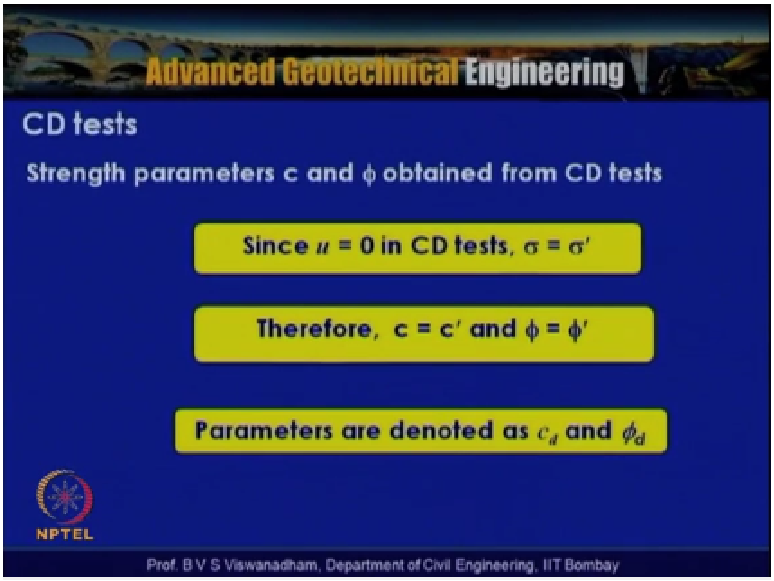

So the strength parameters c and ϕ obtained from CD test since u = 0 in consolidated drain triaxial test σ = σ' and therefore you know this c is = c' and ϕ = ϕ' and what we call these are cd and ϕd this is nothing but drained coefficient and drained angle of internal which is called and these parameters basically represent the long term conditions in a soil where consolidation is actually allowed and then drainage actually taking place during the application of the loading period. So in such satiations the consolidated drain test the parameters are actually.

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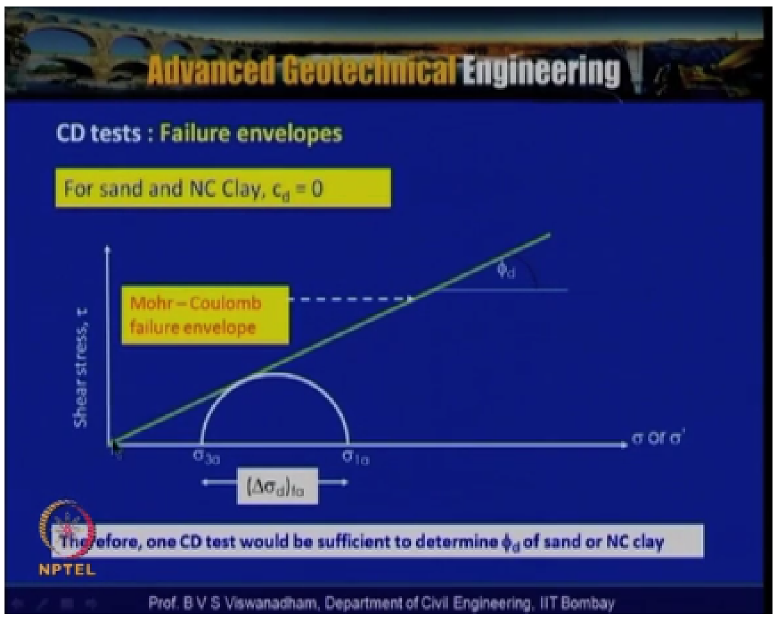

Are weightier for strictly speaking for example if you are having a normally consolidated clay if that is actually identified in the normally consolidated clay and as CD = 0 an Mohr circle is actually passing through the horizon the failure analog actually passing through the horizon therefore one CD test would be sufficient to determine the π of the sand or loss sand or normally consolidated clay.

So one CD test would be sufficient to determine the πD the drained friction angel of a loss sand or normally consolidated clay.

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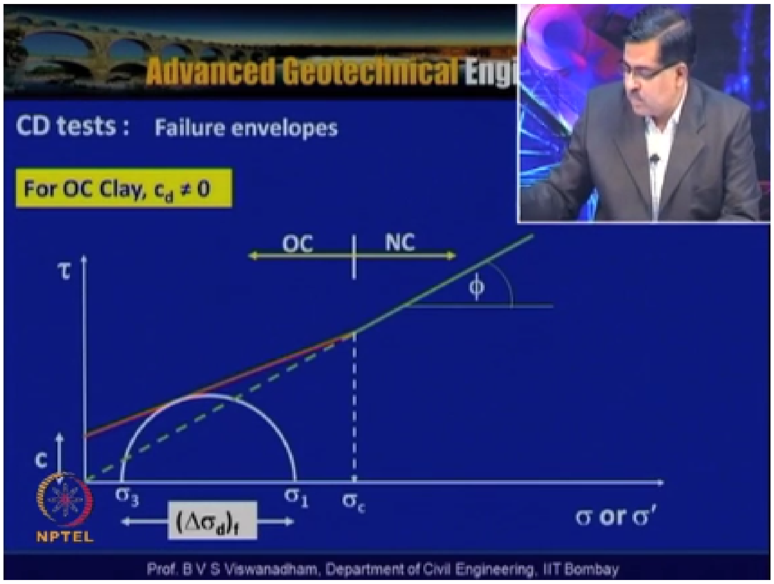

For over consolidated clays for the soils which are actually have been subjected to certain pre consolidated pressure the CD of a over consolidated soil is not equal to 0 or when we are actually having you know a you know very dense sand or dense sand deposits and where in that case also the CD may not equal to 0. So over consolidated clay normally consolidated clay when we look into this here initially up to per consolidation pressure the analog actually the Mohr column failure analog transfer like this that beyond that it actually changes into the normally consolidated this value like it joints with the normally consolidated failure analog.

So the point of transition where it actually changes again the behavior is actually like the pre consolidation pressure that is σc and where in up to that per consolidation pressure stage the sample actually except you know a drained coefficient and then you know there after once see it process σc and there is a possibility that you know it actually merges with the normally consolidated more coulomb failure analog.

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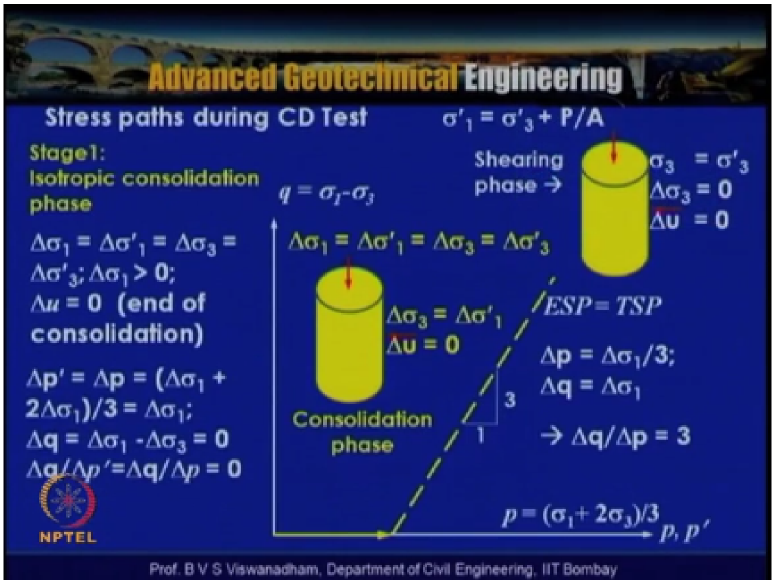

Now let us discuss about the stress paths during the CD test so what we have drawn is that you know we said that there are 2 stages so we have actually represented here q $\sigma 1 - \sigma 3$ and p = σ 1+ 2 σ 3 / 3 or p = σ 1 p' = σ 1' + 2 σ3' / 3 because p and p; are indicated here so during the initial stage that is consolidated phase you know it has been indicated that the stress path actually follows from here to here and thereafter it is subject to shear so this is during the shearing stage.

So the shearing stage actually starts from here and the synchronization of this is actually indicated as 3 to 1, 3 vertical 1 horizontal so if you look into the here this Δ σ1 = Δ σ1' because no load is actually applied and Δ σ3 = $\Delta\sigma$3' so Δ σ3 =Δ σ1' and Δu = 0 so the consolidation phase actually is indicated here so Δ σ1 = $\Delta\sigma$1 = Δ σ3 = Δ σ3' and Δ σ1 > 0 Δu0 at the end of consolidation.

So during the consolidation once it is cell pressure is applied the pore water pressure increases to the excess pore water pressure and then you know it dissipates so that is at the end of the consolidation Δu = 0 with that whatever actually happen is that Δp' = Δp = $\Delta\sigma$1 + 2$\Delta\sigma$1/ 3 so if that it gets simplified to Δp = $\Delta\sigma$1 and Δq = $\Delta\sigma$1 – $\Delta\sigma$3 as $\Delta\sigma$1 = $\Delta\sigma$3 Δq = 0 so Δq / P' – ΔQ / ΔP = 0 so because the slope of this actually 0.

It actually passes along the p' line that is q = 0 line it actually passes and subsequently what actually happen is that the sample is actually subjected to you know the subjected to shearing so here during the shearing phase σ3 = σ 3' Δ σ3 = 0and Δu = 0 because no pore water pressure you know changes are actually allowed because the sample is not subjected to subjected very slow shearing rate.

And σ1' = σ3' + p/ A so with this you know this also indicated as the effective shear stress path and total stress path both are actually identical in this case.

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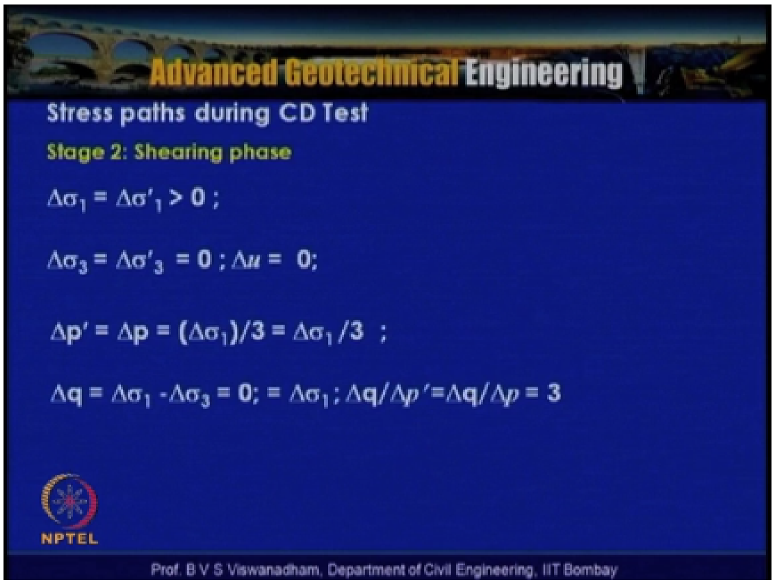

So for case here stage 2 Δσ 1 = Δσ 1'>0 and Δ σ3 =- cells we are no actually changing the cell pressure so Δ σ3' = 0 and Δu = 0 during the shear stage so Δp' = Δp with Δσ 1 and remaining other things are 0 Δσ 2 and Δσ3 is 0 so with that what will actually happen is that Δσ1/3 is the what we get so this is actually Δσ1 Δσ1/3 and Δq = Δσ1 – Δσ3 so = to Δσ3 = 0 what we you have is that we have Δσ1 so Δq/ Δp' because of Δq = Δσ 1 and Δp' = Δσ1/ 3 which is nothing butΔq/ Δp = 3. So because of this reason what you can see is that.

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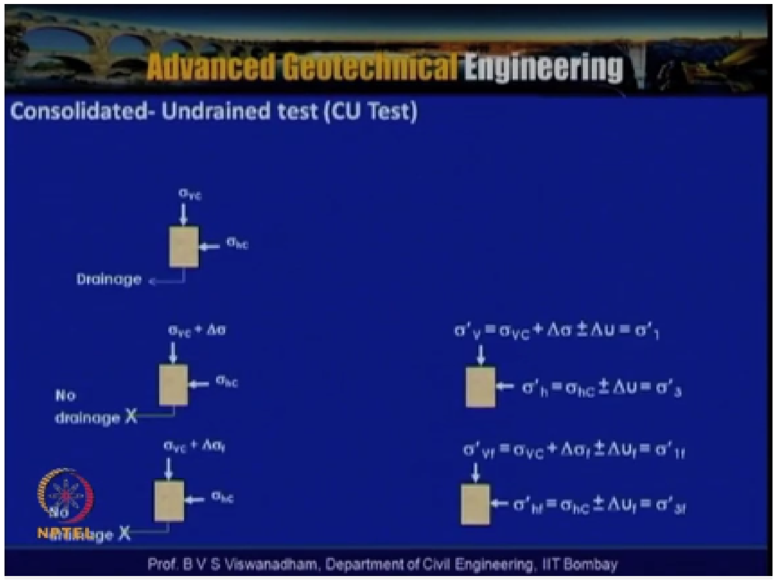

$\Delta p = \Delta \sigma_1/ 3$ or $\Delta q = \Delta \sigma_1$ so $\Delta q / \Delta p =$ is in the is give as 3 here that is the 3 vertical 1 horizontal.

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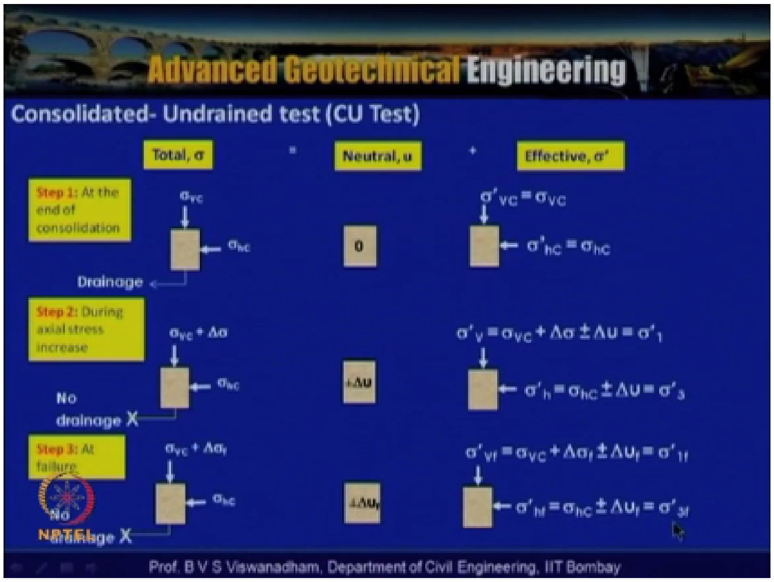

So next you know we introduce our self to the consolidated undrained triaxial test and where in we said that during consolation that drain is actually allowed but during the shearing the you know the drainage volve is actually close so sharing is done to represent a particular clays we where the partial case are examples have been discussed earlier, so this is total and neutral and effective stress.

So here as we are actually not allowing the drainage in the shearing stage so depending on the stress history of the soil the pore water pressure changes occur accordingly suppose if you are having a normally consolidated loss sand sample the pore water pressure will be positive and in case we are having a you know a over consolidated soil are very dense sand sample are dense are very dense sand sample.

The pore water pressure is actually negative after initially positive and the change subsequently changes to negative so at the end of the consolidation the pore water pressure is actually 0 so then the effective stress is σ' vc = σ vc σ' HC = σ HC then during the actual stress increase the pore water pressure is can be + or - Δ u it can be positive or it can be negative depending up on that the changes σ' v = σvc + $\Delta\sigma$+ or - Δ u = $\sigma 1'$ and σ' H = σ HC = + or – u = $\sigma 3'$.

So at the at failure so that can see that during the stress increase that drainage is actually closed here so because of that you know the sample is not allowed to drained then because of that there is a changes in the pore water pressure and at failure again no drainage so wit that you know again the failure shear stress are the pore water pressure changes are + or – Δuf so σ' f = σvc + Δ σf = or – Δuf = σ' 1f and similarly in the horizontal directions σ' HF = σHC + or - Δ uf = σ' 3f.

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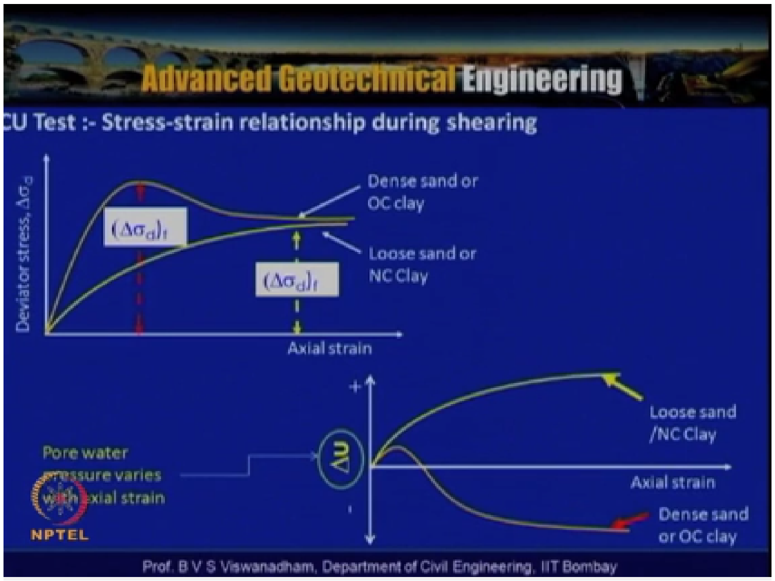

So the volume changes in the sample which is actually same as you know the consolidated undrained triaxial test which is same and in this case Cu test this stress strain relationship during shear which is again you know very similar to that but only thing is that here the pore water pressure is actually take place like this is positive and the pore water pressure is negative if you're having a dense sand and over consolidated clay.

So in this case when you have Cu test basically to determine the shear strength parameters here we can actually get total strength parameters as well as effective strength parameters and for example for the 1st case which is actually shown here the total strength parameters how to obtain is obtain we are having a case where you know two coffining pressure which are actually shown σ3 σ3b and more circles are shown.

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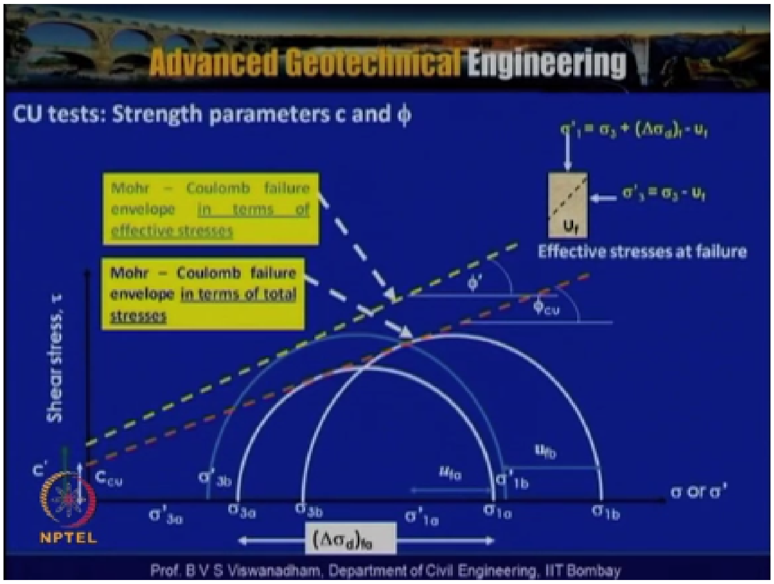

And when the analog is actually is drawn this is the Mohr coulomb analog for the total stress and this is the Mohr circle but depending up on the pore water pressure you know depending up on the you know variation of the pore water pressure we can actually get the Mohr circles accordingly positive or negative so with that what will happen is that we will get the effective strength parameters that is Mohr coulomb failure analog per shifts accordingly and so this is for the strength parameters C and ϕ.

In case of in so with the consolidated undrained triaxial test which we actually we get both drain parameters as well as undrained parameters.

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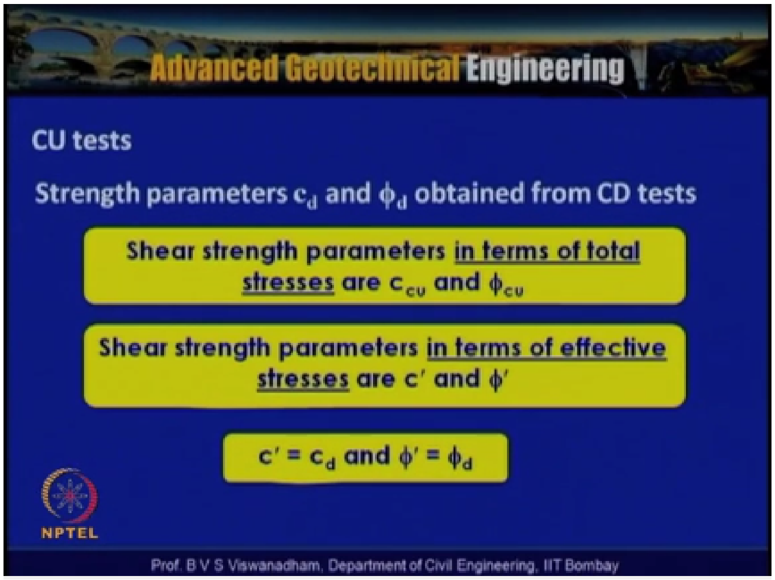

So the shear strength parameters symptoms in terms of total stress are actually called as a C consolidated undrained and ϕ cu in case of shear strength parameters in terms of the effective stress are called as C' and ϕ' so C' = Cd and ϕ' = ϕd they are called the drained friction angle and drained coefficient.

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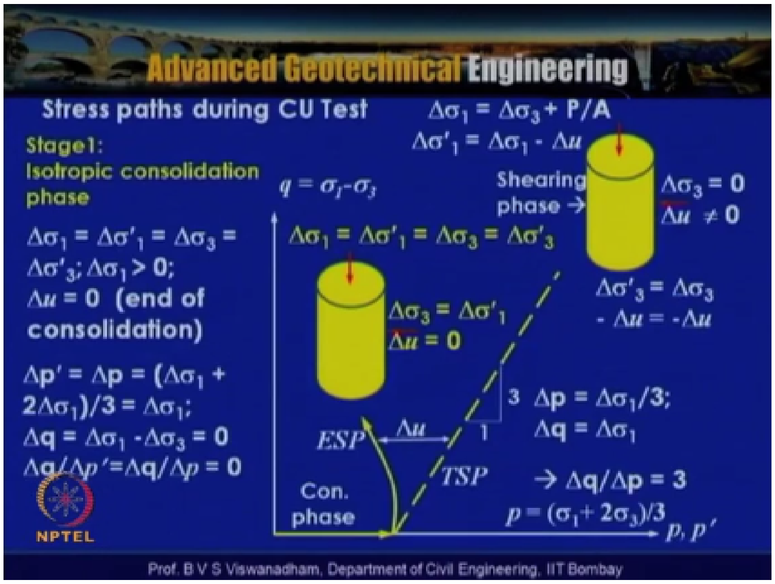

So the stress paths for the consolidated drained triaxial test so we have seen consolidated drained triaxial test and in the case of consolidated drained triaxial test we notice that the stress paths for the you know effective stress path and total stress path in the total both look alike but in case but in case of you know the consolidated undrained test where the shearing changes actually happens so because of that you know during the shearing the pore water pressure changes actually happens.

So the effective stress path actually runs like this is semantically which shown here so we have isotropic consolidation phase $\Delta u = 0$ an $\Delta p' = \Delta p = \Delta\sigma 1 + 2\Delta\sigma 1 / 3$ which is nothing but $\Delta\sigma 1$so $\Delta q = \Delta\sigma 1 - \Delta\sigma 3$ with $\Delta\sigma 3 = 0$ and $\Delta\sigma 1$ is $= 0$ here $\Delta q/\Delta p' = 0$ so with that what will actually happen is that $\Delta q = \Delta\sigma 1$ and so with this actually what will happen $\Delta q = 0$ and $\Delta p = \Delta\sigma 1$ $\Delta q/\Delta p' = \Delta q / p = 0$ so the in this case also during the consolidation phase the stress path actually runs like this then depending up on effective stress path means it runs like this.

Total stress path means it runs like this so here in this again $\Delta p = \Delta\sigma 1/3$ and $\Delta q = \sigma 1$ so $\Delta q/\Delta p = 3$ so this is actually runs like this so this is for shearing stage which are shown and this is for the shearing stages which are shown and this is for the you know for the initial consolidation phases which are actually shown.

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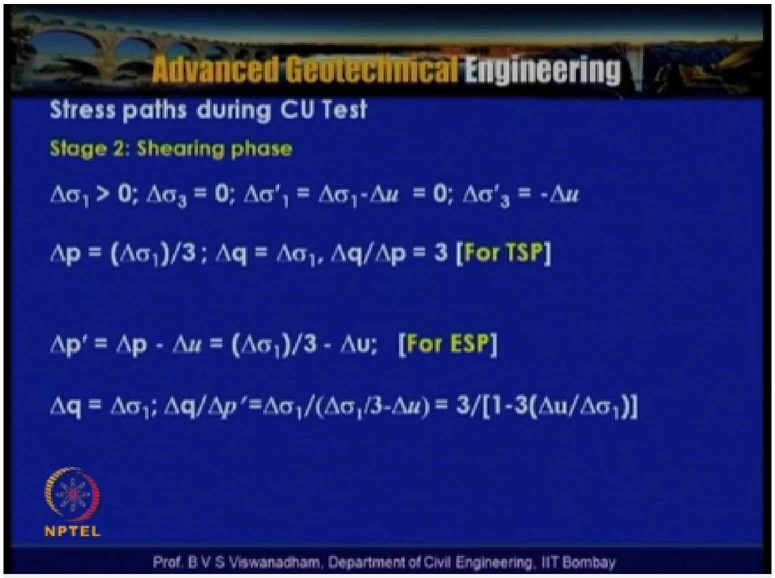

So for the effective stress parameters and test for effective stress paths and total stress path the shearing phases is actually indicated here $\Delta\sigma 1 > 0$ where in $\Delta\sigma 3 = 0$ so $\Delta\sigma 1' = \Delta\sigma 1 - \Delta u$ which is = 0 and $\Delta\sigma 3' =$ Δu and $\Delta p = \Delta\sigma 1/ 3 = \Delta\sigma$ 1 so $\Delta p = \Delta\sigma 1/3$ and $\Delta q = \Delta$ σ1 so Δ q/ Δ p = which is nothing but Δ σ1/ 3 Δ σ1 / Δ σ1/ 3 becomes 3 that is for total stress path but in this case you know Δ p' = $\Delta p - \Delta u$ which is nothing but Δ σ1 / 3 – u that is you know what we have done is that Δu the pore water pressure change actually as been subtracted.

And $\Delta q =\Delta$ σ1 where Δ pΔ q/ Δ p' = Δ σ1 / Δ σ1 / 3 - Δ u so that is when you simplify that one because this is you know different so we have 3 / 1 – 3 to the ratio of Δ u / Δ σ1 so we because of this particular variation.

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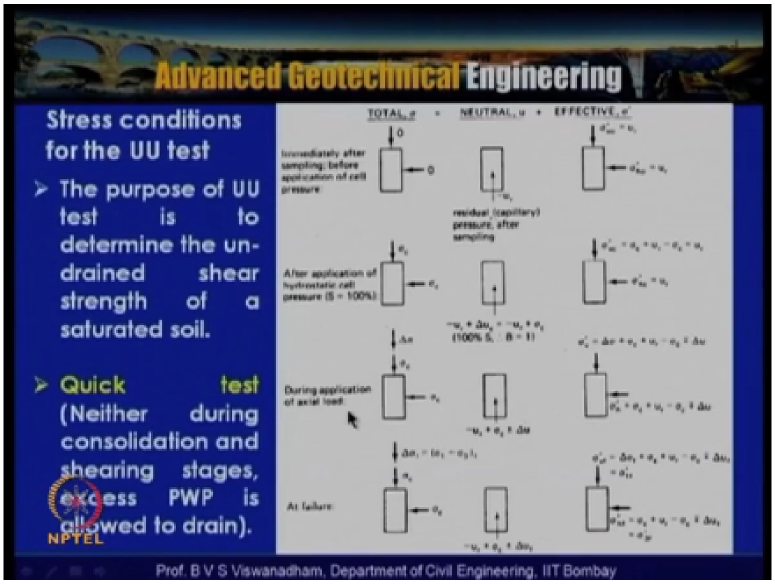

The effective stress path actually run like this the now as we said that we have another class of you know the triaxial test which is a quick test which is actually called unconsolidated undrained triaxial test the purpose of the unconsolidated undrained triaxial test is to determined the undrained shear strength of a soil of a saturated soil where predominantly if it is saturated then we actually have you know the undrained coefficient of a undrained shear strength of a soil.

So this is quick test neither during consolidation nor shearing stage excess pore water pressure is allowed to drain but there is a possibility that the pore water pressure develops but is not allowed to drain so this indicates you know these are you know sometimes we actually get for catastrophic loading or shear loading the shear strength parameter this parameter which are actually obtained from this can be used for the design so this is basically for short term considerations this can be applied.

So different stress states are conditions are actually shown here so this is actually the sample as prepared 0 the effective total stress on the sample on outside 0 the pore water pressure inside the sample is actually negative and then because of that you know σ' v = positive Uf will be there so because of that negative pore water pressure the sample actually stands vertical so the effective stress is that σ' v0 = uf σ' H0 = uf so all round actually motioned an effective stress of equivalent to the negative pore water pressure which actually there in the soil.

The after application of the you know hydrostatic sun pressure then you know what we have done is that we applied σc the total stress on the sample changes to σc and σc here now the pore water pressure here is nothing but – uf that is negative + Δ u c because we applied σc because of that there is an increase in soil sample pressure.

And 100% saturation means the water actually attracts the load and then you know σ' v c = σ c + uf – uc so this another you know set if this will come and σ' HC = uf will be there during the application of the axial load these are the stress states which is nothing but you know because of the shear there is an increase in the pore water pressure that gets added here so the stress state is actually different stage actually the stages are given 1 is just application of the just placement of the sample.

Before application of the just placement of the sample before application of cell pressure then other one is actually after the application of cell pressure and then during the application of the shear load and then at failure.

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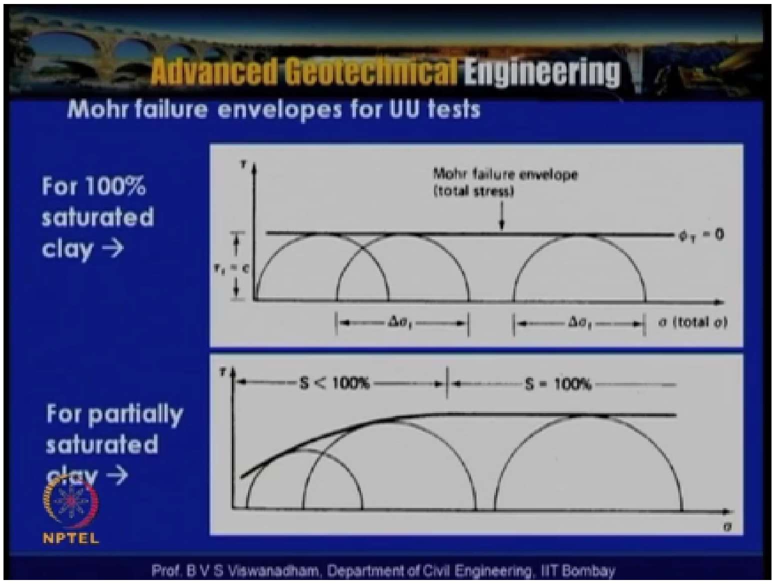

So the Mohr circles are you know for the 100% saturated clay are indicated like this so you can see that this is independent of the you know what ever the cell pressure we applied for example you know this is a case where you know 0 cell pressure but when you actually have a cell pressure of say 50kPa 100 kPa and 200kPa and the soil is completely saturated and unconsolidated undrained test is per long performed.

Then we actually have a case where you know you get the horizontal failure analog that is Mohr coulomb failure analog the $\phi t = 0$ or $\phi u – 0$ and so that the τf = shear strength = cu and that is the more coulomb failure analog will be horizontal only so this indicates that you know stress is actually independent of the that stress so whatever may be the confining pressure we apply that much you David load generate in such a way.

The diameter of the Mohr circle remains constant say for example then you are having a partially saturated clay and initially when we do unconsolidated undrained test using a with partially saturated samples then actually we you have got you know when degree of saturation is less than 100% so with high cell pressures and when you have high confining pressures and because of the cavitations actually what happens is that the water is actually of the air which is within the sample is sanded out with water.

So what will happen is that 100% saturation is actually unsowed so and at very high confining pressures the Mohr coulomb failure analog tent to become horizontal so then the sample actually becomes you know 100% saturated so in that case again it maintains the you know horizontal plate 2 for the Mohr coulomb failure analog otherwise initially for partially saturated samples actually have got curve linear more coulomb failure analogs can actually happen.

And you know sometimes people mis lead for using this value for cu and ϕu as strength parameters and undrained conditions.

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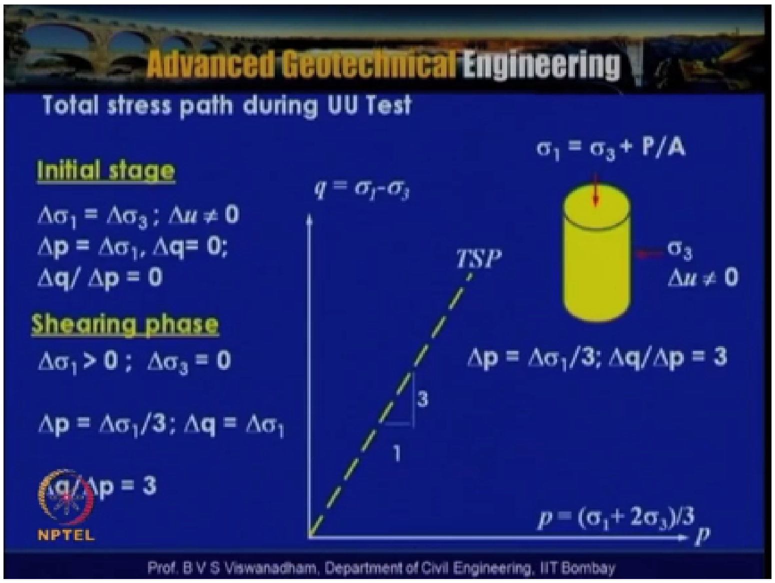

So the total stress path during unconsolidated undrained triaxial test are actually given here so in this case because neither unconsolidated nor shearing the stage there is a drainage so what is actually happening is that the stress path actually starts directly here this is the total stress path only and where you have σ1 this is the σ1 = σ3 + p/ A and σ3 and Δu not equal to 0 so intail phases initial stage is that Δ σ1 with Δ σ3 and Δu is not equal to 0 so Δp = Δ σ1 Δq = 0.

So Δq/ Δp = 0 that is that this pointn and the shearing phase Δσ1 > 0 and Δσ3 = 0 so Δp = Δσ1 /3 Δq = Δσ1 so with this again the inclination of this is Δσ1 Δσ1/ you know is again 3 so Δp = Δσ1/3 Δq / Δp = 3.

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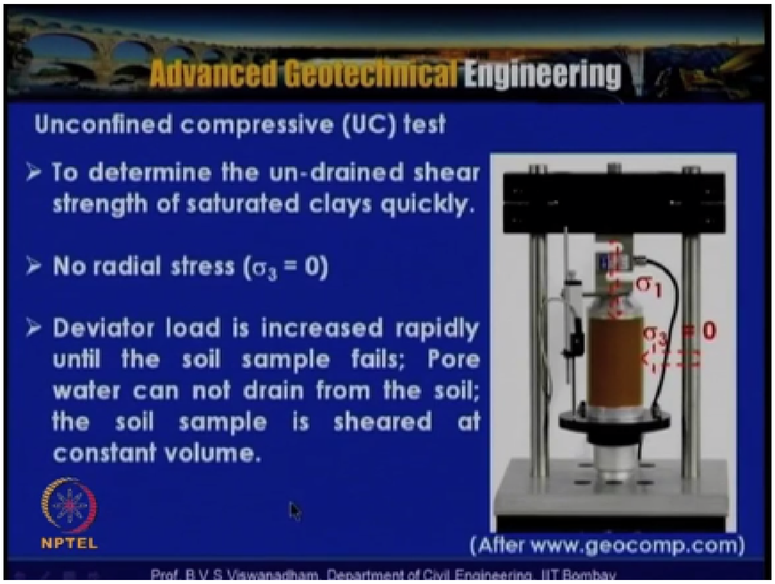

So as a we have be discussing that there is also unconfined compressive strength test this is one thing basically to determine undrained shear strength of a saturated clays very quickly and in this case is a special case of triaxial test which is called with σ3 = 0 the cell pressure is actually 0 so in this particular slide where a sample is actually loaded which is actually shown with σ1 that is the deviated load because σ3 = 0 and the sample is actually in not confined with you know the chamber pressure.

So in this case basically this is a quick test where it can actually give undrained shear strength of a started sample sometimes it is also used for partially saturated soils basically to get the you know unconfined compressive strength of a sample and then there afterward we can actually get the undrained coefficient the sample need not be completely you know saturated but truly speaking it should be it determine to determine the undrained shear serge of a saturated clay quickly.

And deviated load is actually increased rapidly until the soil sample fails pore water cannot drain from the soil so the sample is shear of at the constant volume the sample is actually sheared at constant volume without any change in the you know volumes and the without changes in the pore water pressure.

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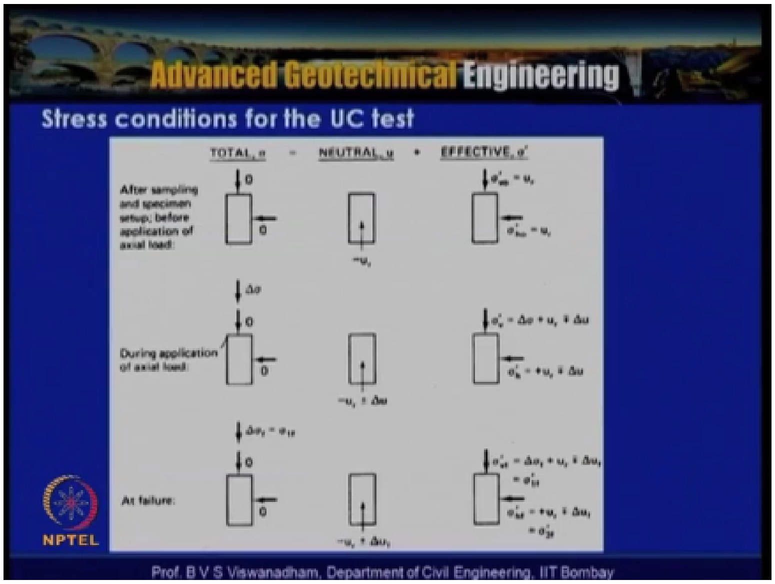

So the stress states are actually given here every the sample is prepared this is same as the unconsolidated undrained triaxial compression test and this is neutral stress or pore water pressure is – uf so initial effective stress is that σ’ v0 = uf similarly during the application of load you can see that there is a pore water pressure change occurs but not allow to drain so the test is actually done such a way that no dissipation of pore water pressure take place no volume under no volume change conditions.

So σ’ f σ’ v = the Δu + uf that is the uc that is during the initial conditions so this at failure conditions.

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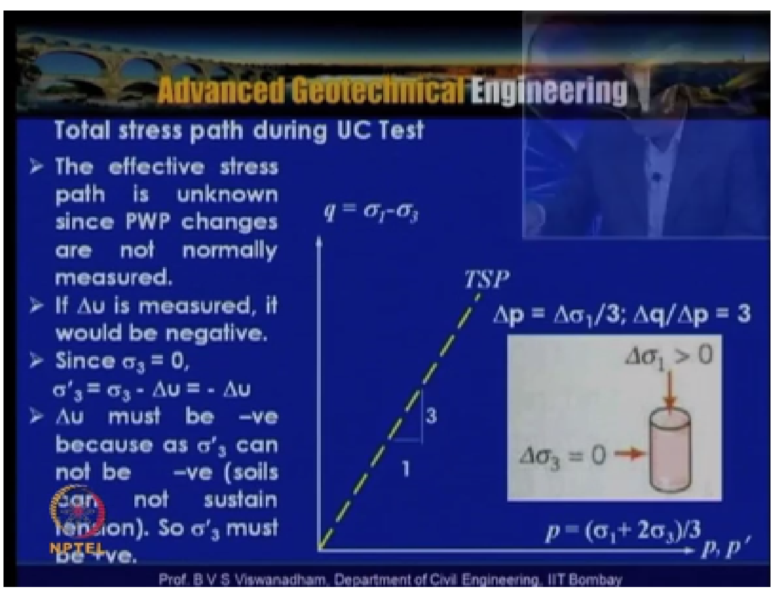

So the total stress path during confined compression test again it actually resembles to this it actually passes through you know the horizon and the in as Δ u measured it would have been negative since it would be negative since σ3 = 0 σ' 3 = σ3 – Δu is = - Δu so Δu must be negative because as σ' σ'3 cannot be negative so soils cannot actually sustain tension so σ3 must be positive.

So then effective stress for these unknown in case of un test because the pore water pressure changes are not normally not normally measured they are not measured normally if Δu is measured it will be negative since σ3 = 0 and this Δu must be negative because as σ-3 can be negative the soils cannot sustain the tension so the σ-3 must be actually positive, so her the Δu if it all you measure during un kind front test the pore water pressure will be negative.

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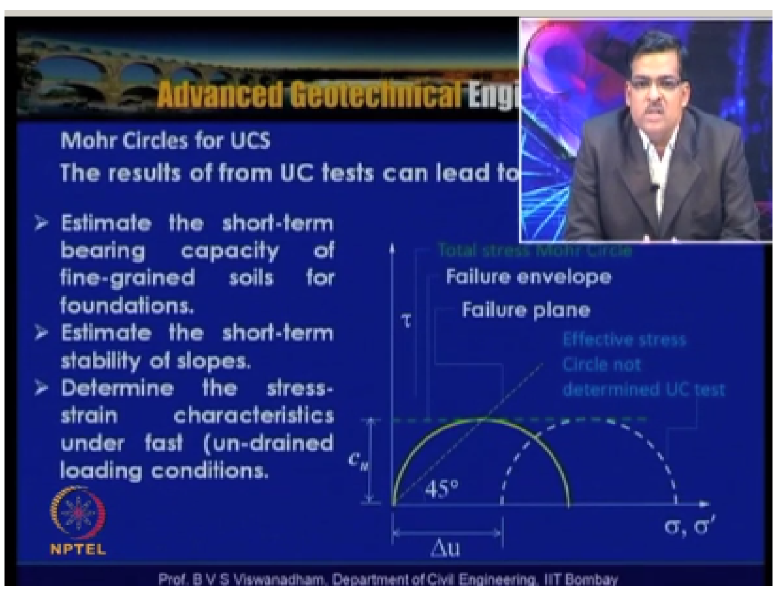

And resultant mohr circles for the you know the un kind front compressive test actually gone here, so this is you know the total test circles because this starts from horizon because σ3= 0 and this is the mohr cooler failure analog sand this is the total stress more circle and if it all means the effective stress will be like this the effective mohr circle towards the right side because Δu is negative and if it is positive it comes this side, so the effective stress circle cannot be determined in the uc test.

This is only just indicated here and this is you know the as the ϕu = 0 the failure look line is actually only 45+5/2 it is only 450^0 so the failure plane is actually indicated here and this point where it actually intersects that is actually the horizontal analog of a more cool and mohr circle vary analog , so the cu is actually shown here so basically the results from the uc test are actually you can lead to usage of the estimate of the short and paring capacity of a find grain soils foundations.

And basically for un considered drain test also we can use this classic and estimate this short stability of the slopes are written dams and determine this sustain characteristics under fast under loading conditions, so founded to see this sustain characteristics of a material under fast loading conditions and this actually particular test is actually use.

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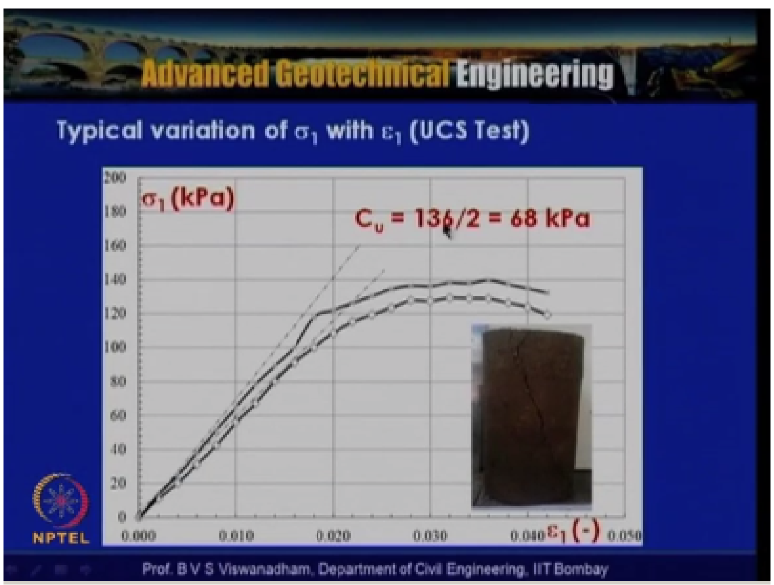

So this is a typical variation of σ1 that uc1 so we you can see that the sample where the failure surface is actually is about you know is inclined like this and so you can see that this is σ1 and this is ε1 and so the average of these two values is actually gives this is the deviate in lower σ1/2 gives the you know 136/2 which is actually gives un drain position of a soils and so this in this case this is a partially soil saturated soil which is actually having you can say CT clay type of sample where you know you can say that you know the drained quotient is about 69PK.

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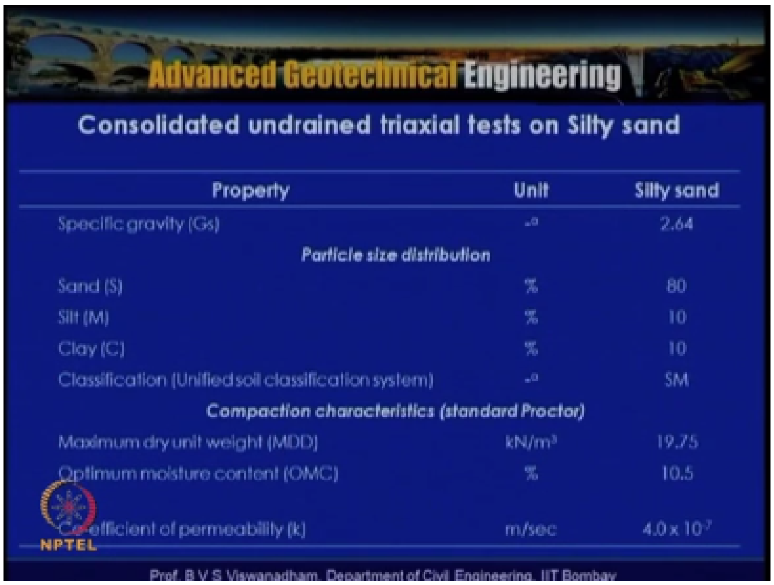

So we also have some you know results which actually typical results of consolidated undrained triaxial test on silty sand samples are actually shown here.

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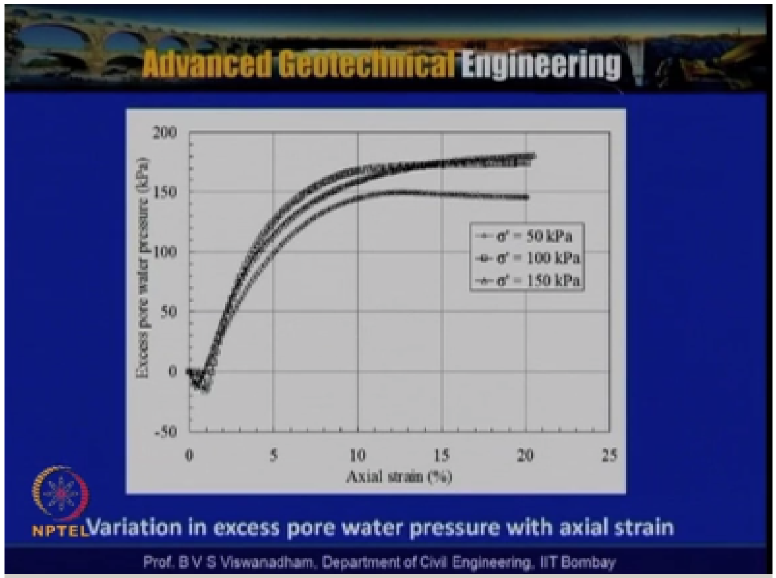

So you can see that the sample is actually tested with 3 in different some pressures 50KP and 100KP and 150PK so this is actually 50KP some pressure within tested σ1 – σ3 and this at 50KP 100KP and 150KP and this is the excess pore water pressure measured because this is you know mostly you can actually see that the pore water pressure is positive because this is you know a close to normally consolidate sample straight.

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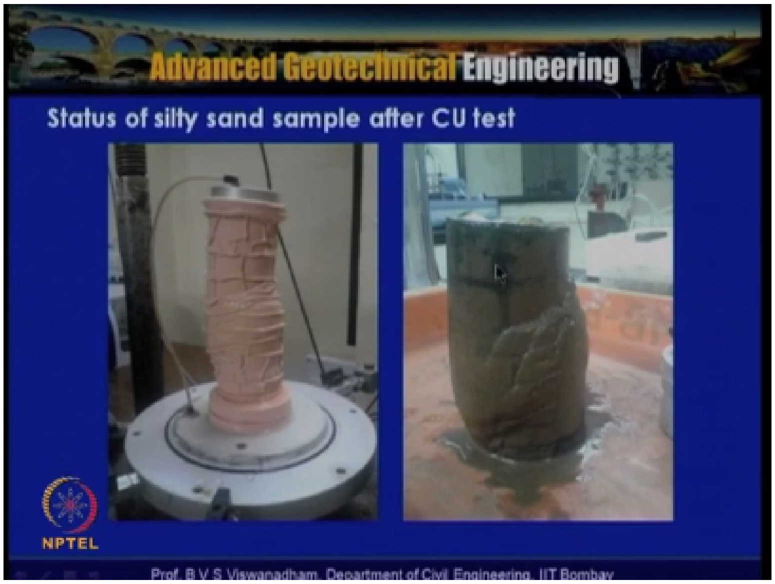

So the sample at the end of the shear you can see that the sample actually has undergone measured portion of bulging and you know then the subsequent shear failure actually happen this is actually happen within the membrane and once the membrane is actually take out this is the case.

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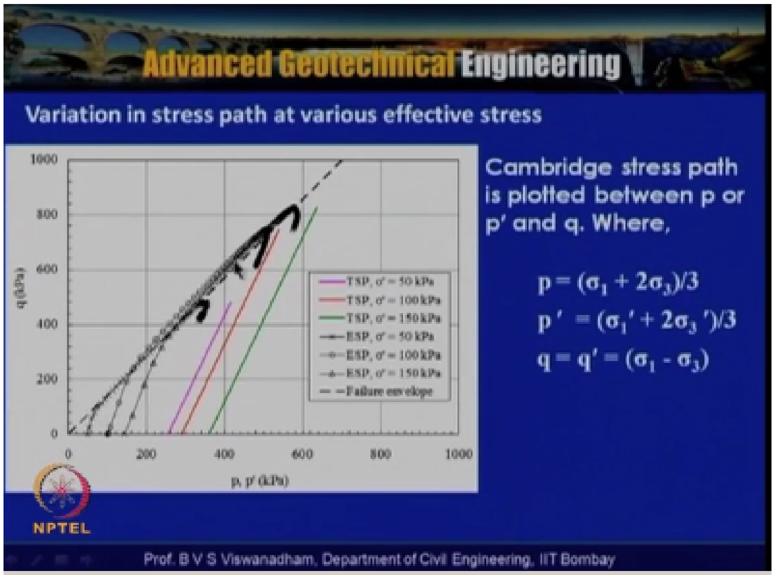

And then the stress path is actually are drawn here with P = σ1 + 2 σ 3/3 from the test data which is actually obtained so these are the total stress parts and that is 50KP and pressure 100KP and 150KP and then these are you know the stress paths for you know the effective stress for 50 100 and 150.

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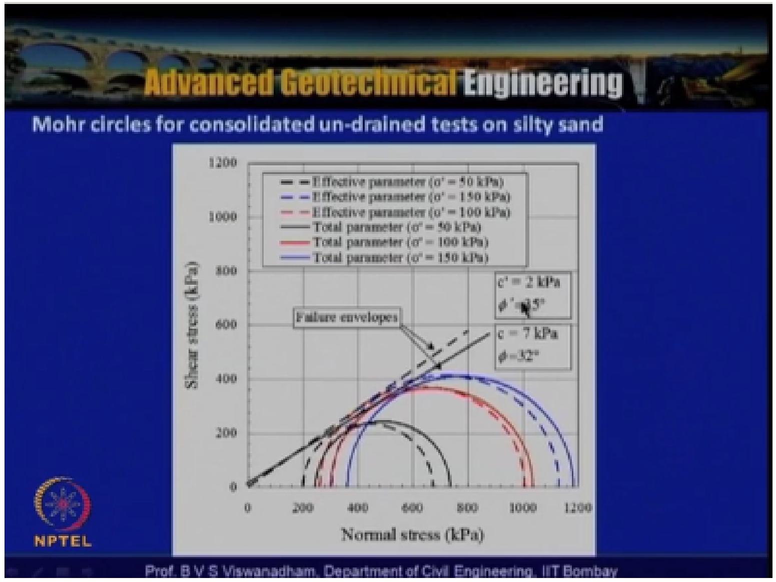

And these are Mohr circles for the Silty sand samples which is actually tested so the sample found to have the undrained parameters of the undrained parameters are C7Kp and 532^0 and the drained parameters which is you know 2KP and 35^0 so this is the drained parameters.

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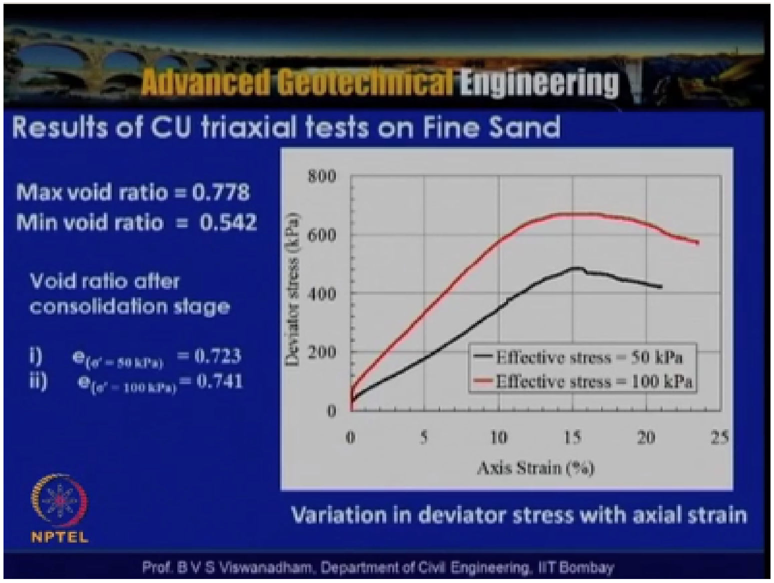

And this is for example of a consolidate undrained triaxial test on fine sand having the maximum void ratio 0.778 and 0.542 minimum void ratio and this void ratio after the consolidations stage is very dense nature and deviate stress versus action strain is shown for two different sul pressures 50 and 100Kp.

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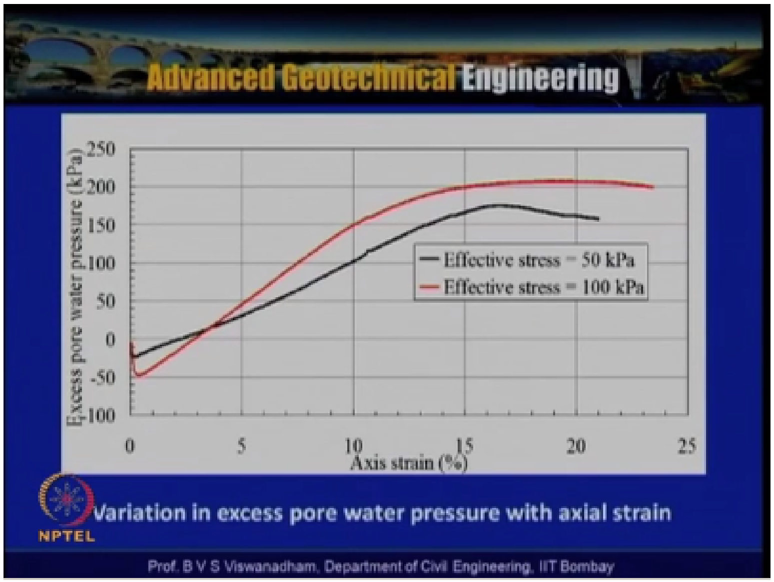

And this is the pore water pressure you can here you can see that because of the damn sand the pore water pressure variation is actually negative.

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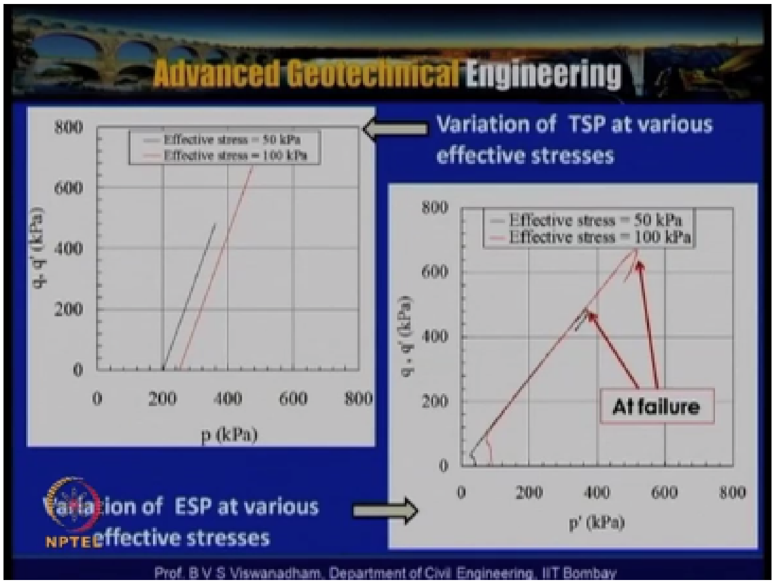

Then these are the typical stress paths in this particular slide you know we have seeing a status sample particularly.

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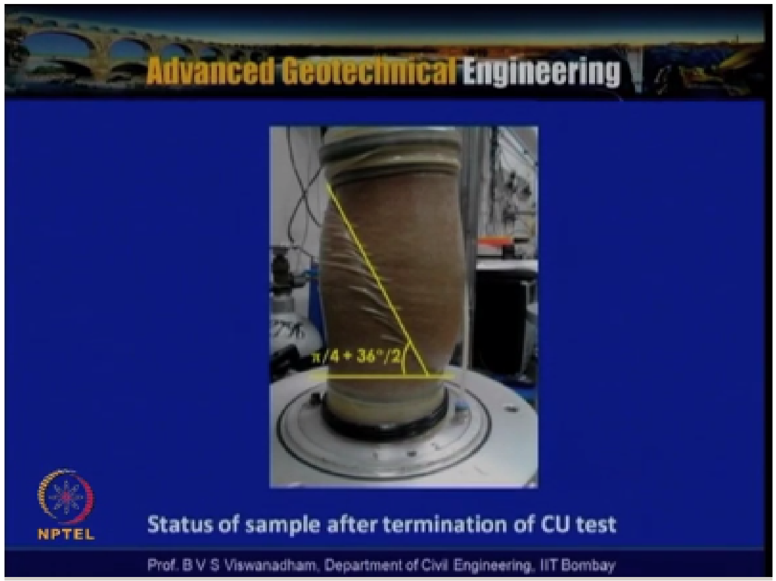

Very dense sand sample after termination of consolidate undrained triaxial test so you can see that the sample bulging as well as you know the shearing actually which has taking place with π/4 + 36/2 45 + you know 45 + 36/2 that is the angle of inclination of the weight is bring about 630 is the failure of clay and where in you can see that you know the den sand sample actually exhibits you know the failure plane which is distinct failure plane and when you actually have louse sand and normally consolidated soils.

We have you know predominantly bulging actually takes place so in this particular lecture what we have done is that you know we try to understand about the different types of triaxial test particularly un consolidate drained triaxial test and consolidated undrained and the consolidated drain triaxial test and un kind find compression test is special case of solve these test which actually w have done for as a for a compression case and we know that you know by maintaining different combinations of cell pressure and action pressures we can also do extension test by using the triaxial compression test.

But in this particular case mostly we are covered about the un kind compression test or UU and Cu and CD triaxial compression test pretend in details and then you also discussed about the these stress paths pretend to that with q and p and p- and then we also have discussed about how we can actually determine the drain parameters and undrained parameters dependent upon the situation like for example undrained baring a past t or you know when you are actually have you know short term stability of a slope.

Then we can actually think of using undrained parameters undrained 10 parameters when you want to be have a long tends stability of a slop or long term stability of an embankment then long term baring capacity then we actually have to use and the effective strength parameters like drained parameters c- and ϕ-.

NATIONAL PROGRAMME ON
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