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NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

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IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 36

Module-4

Lecture-7 on Stress –Strain Relationship and Shear Strength of soils

So welcome to lecture series on advanced with geotechnical engineering and we are in module four and discussing about the shear strength of the soils.

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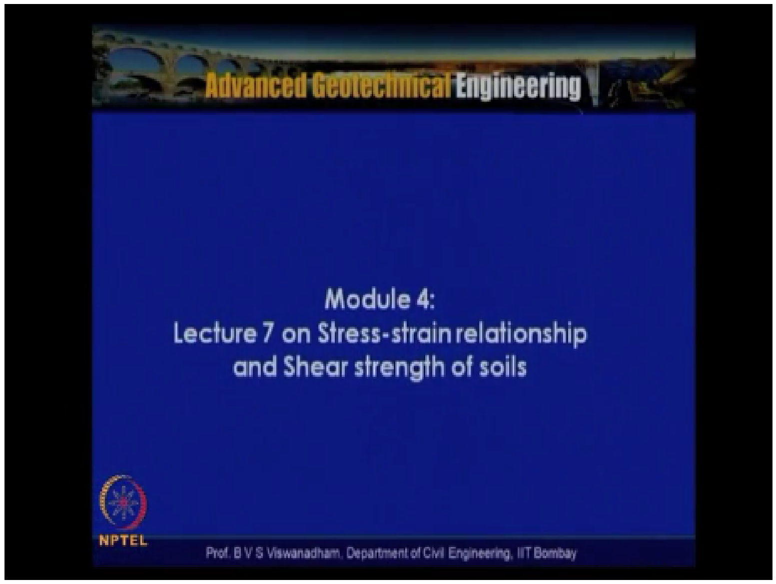

So this is module four lecture seven on stress strain relationship and shear strength of soils so in the previous lecture we introduced our ulcers about the PQ space and discussed about the more Coulomb criterion in depth then in this particular lecture we will introduce ourselves two methods for determining shear strength especially in the laboratory by two predominant methods that is a direct shear test and Tracheal compression method and thereafter will introduce ourselves to stress paths relevant to the tri-axial compression test. And the drainage conditions so after having covered.

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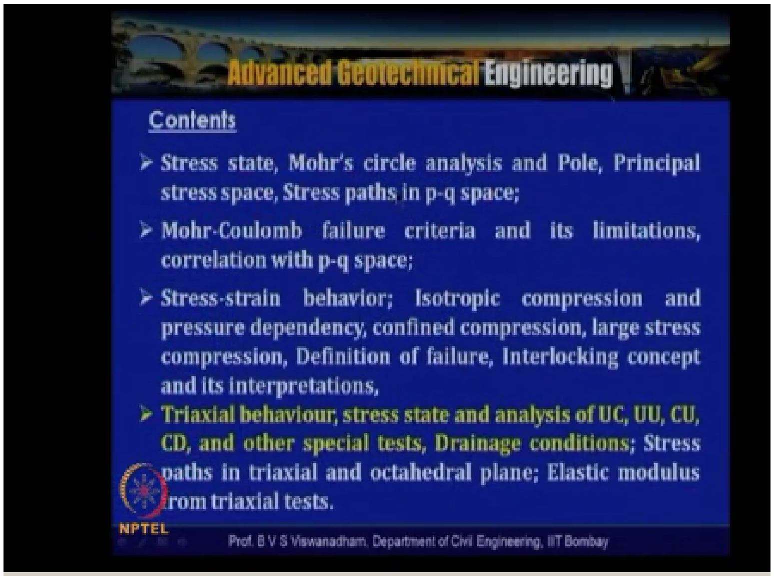

These contents will be looking into the tri-axial behavior and stress state and analysis of unconfined compression on consolidating and consolidated untrained and consolidated drain and other special tests and drainage conditions so we have several methods for determining you know shear strength in the laboratory predominantly they are like direct shear test and two axial compression test and then there are some simple shear test.

And plane strain tri-axial test like that we have you know several classes of tests which are actually can be done in the laboratory for determining the you know the shear strength the behavior system parameters of the soils under considerations both and in disturbed or undisturbed conditions are for the or for the remolded conditions, and then we also have some methods for determining director indirect methods for you know arriving.

At the strength parameters based on the some parameters which are actually measured in the field.

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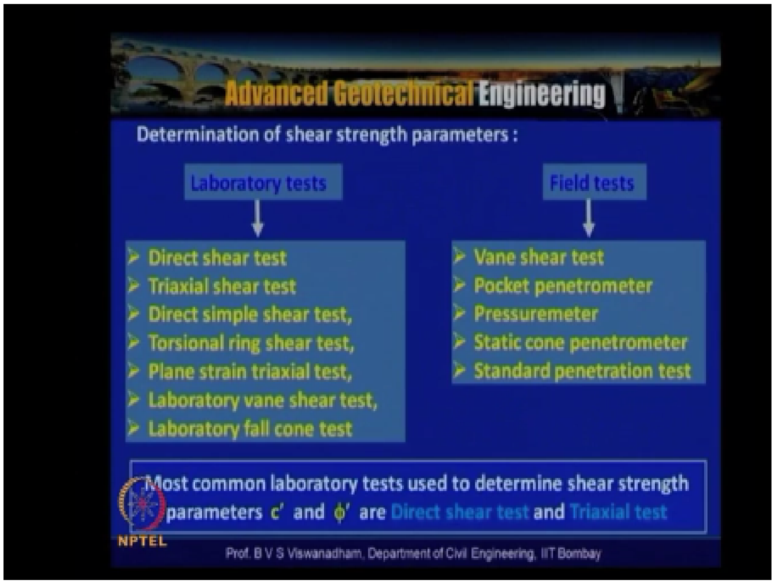

So the different determination of the shear strength parameters can be achieved through laboratory or to field this and the laboratory predominantly the direct shear test and trashy tests are performed you know traditionally and there are also some other classes of tests like direct simple shear test and tensional ring shear test, and plane strain to axial test and for very soft soils we wanted to determine whether the sample making is difficult that in that case.

We have laboratory wind shear test and if we also have a fall contest where it also indicate the penetration of the cone indicates an interpretation of you know the shear strain measurement in the field when we are having a soft soil when the sample pickup is very difficult then you know when shear test at different depths is also popular and then we also have some you know pocket penetrometer tests and the pressure meter test.

We will give the institute properties or institute elastic modulus of soil and as we discussed you know the static conepenetrometer test which actually gives the cone resistance and frictional resistance or shaft resistance and with the by interpreting the shaft resistance and the frictional resistance we will be able to get a you know an idea about this shear strength parameters similarly the standard penetration test.

Which is you know the resistance of the soil is measured by the SPT n value so we have number of correlations which can actually can give you know for different and values you know by their untrained cohesion or you know the friction angle of a soil so most common laboratory tests used to determine the shear strength parameters cr5 in case of total stress parameters and C Dash and π dash in case of effective you know stress parameters so total strength parameters are called as C and π and effective strength parameters are called as C Dash and π dash. And they are basically the direction test and Tracheal shear test.

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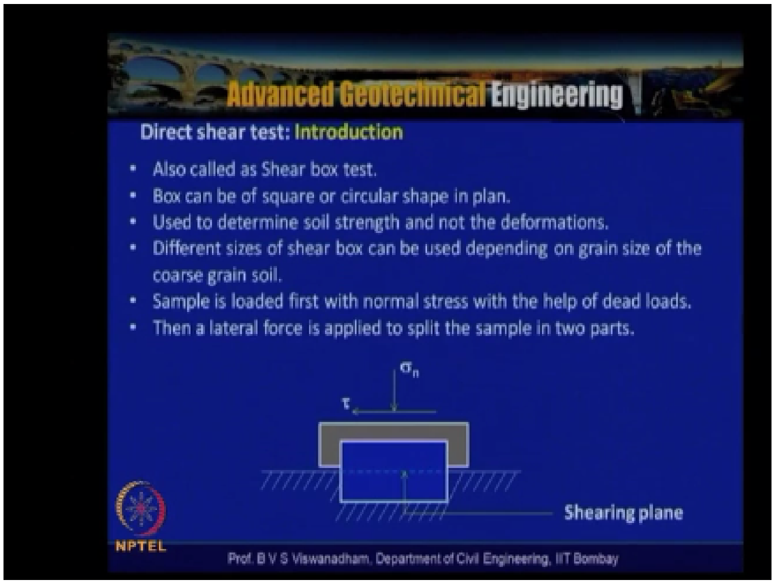

So let us look into the first the direct shear test and it is also called as a shear box test and this box can be square or circular in shape and this box sizes are predominantly 60 mm x 60mm or we have 100 mm /100mm or 300 mm/ 300mmso depending upon the size of the particles which are actually involved and to prevent the scale effects the sizes of the you know the direction boxes need to be adopted and is also used to determine.

The soils distance and not the you know determination and deformations and the different sizes of the shear box can be used depending upon the grain size of the coarse-grained soil or the grain size of the soil under consideration or soil lake material under consideration and the sample is loaded first and with normal stress and then you know subjected to a shear force so that the shear can be applied on a predetermined shear plane which is actually news to the shear is actually reduced along the predetermined failure plan.

So this you know method of testing also makes possible for Renault determining interface parameters like when you have got you know let us say that two different materials let us say that pile interacting with the soil or when we have what a you know retaining wall interacting with the soil and if you would like to have the interface friction angle you know then you know the particular material can be kept at the bottom and a dummy block can be placed and then the required the interface surface actually can be put.

And then the required soil which is to be interacted with you know the particular surface can be placed so with that you know we can actually determine the interface parameters and when we do when we try to determine the interface parameters then it is actually called as modified direct shear test and with that you know we get CA in case if you are having a gecko is you soil then aeration is actually measured and then interface friction angle.

So you know this direction test actually has got you know you know a pre the appliqué the method of you know using failure plane failure along a particular plane is used to actually is a way for Renault determining the interface parameters or if you wanted to determine you know interface friction angle between let us say a rock and you know surrounding the soil outcrop then they knew that can also be achieved through this particular method of testing.

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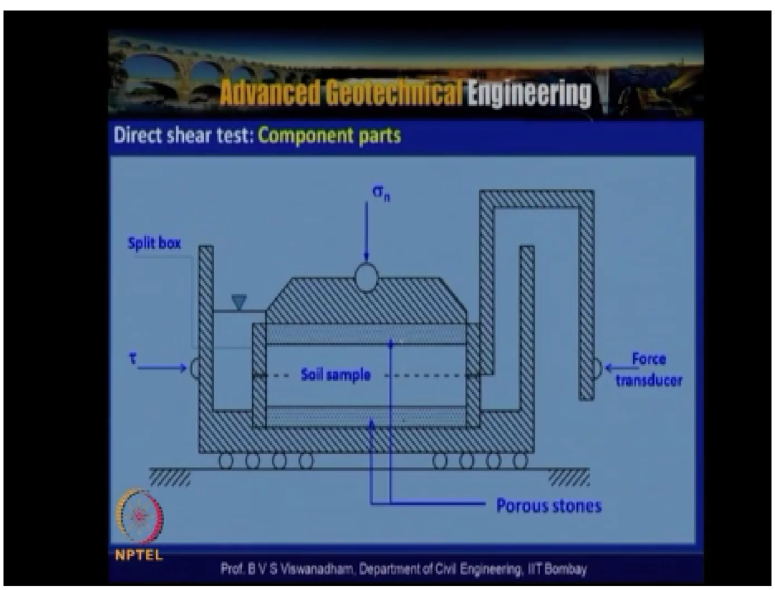

So this typical you know direct shear test configuration is actually shown here it actually has got shear box and it you know in order to this the sum of the to some extent you know test can be performed with some drained conditions but they are actually regarded as you know you can actually do but not possible for us to measure any pore water pressure and other aspects and here you know the configuration is that you have got a per-share box and lower shear box.

And in order to use you know to keep the failure plane at the you know the predetermined surface the serrated plates are actually used at the base and then these selected the inner sessions actually have to be perpendicular to the direction of the sheer so that you know the failure is actually used along that failure predetermined failure plane and in order to allow the drainage you actually have the porous stones and then you know we have the loading plate and through this loading this loading plate can go down or go up.

So it is a you know which is slotted here and this actually with the labor of an arrangement we actually apply the normal stresses maybe can the range of 25 kilo Pascal's to you know300 kilo Pascal's to 400 kilo Pascal's normal stresses can be a you know applying and then what it is done is that you know the shear force is actually applied you know as shown here and with that you know the shear the resistance offered by the you know interacting soil or soil surface is actually measured so with that you will be able to get the shear stress versus shear displacement.

So what when we apply when we apply the shear force if this is the direction of force and you know then there is you know shear force is actually generated and the shear displacement is generated so the when we do at different normal stresses we actually get a set of curves for each normal stress which is actually performed and then you know the depending upon the type of the soil whether it is a dense soil or whether it is a loose soil.

We have you know the variations in the types of the pattern of the stress curves changes similarly if you are having a you know undistributed sample let us say a war consolidated soil or a normally consult side and the pattern of the stress distribution the shear stress versus shear strain variation is subjected to change.

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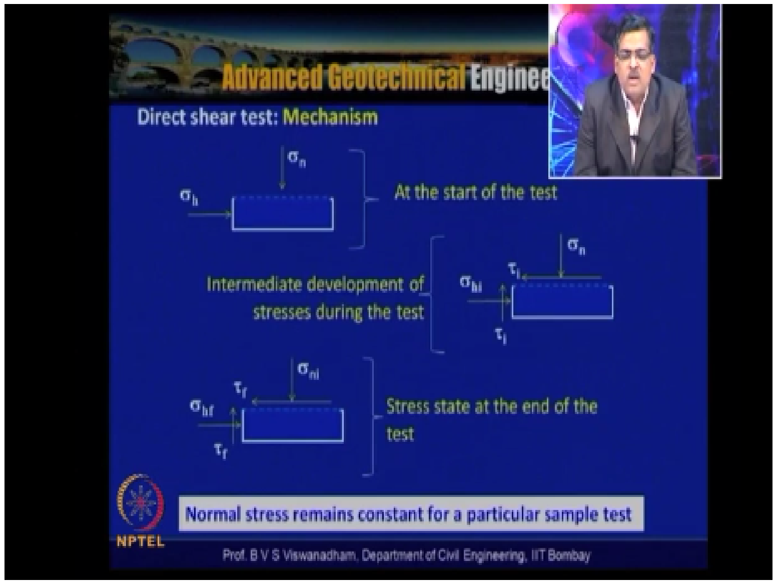

So here the mechanism is that at the start of the test what actually happens is that you have σ, N and σ, H so these are the major principle plane is actually here major principle plane is here and minor principle plane is perpendicular to this and at the beginning of the test but before the commencement of the test you know on the failure plane the major principle plane and the minor principle plane they do exist but when you know the test commences are during the test because of the mobilization of the shear and then those that particular failure plane can no longer be called as a you know the pier in a predetermined plane or which the failure is being introduced it can no longer be called as you know the principal planes so in that principle playing in that case you know then we have to see that you know there is a chance that in the day in the direction.

In the direction test the rotation of the principal planes can actually occur and here in this case the stress state at the end of the test is shown here so you have got a normal stress and then there is a shear stress which is actually mobilized so you know this makes it actually not able to be called as a you know the principal plane during the test and this is the normal stress remains constant for a particular sample of a sample of the test.

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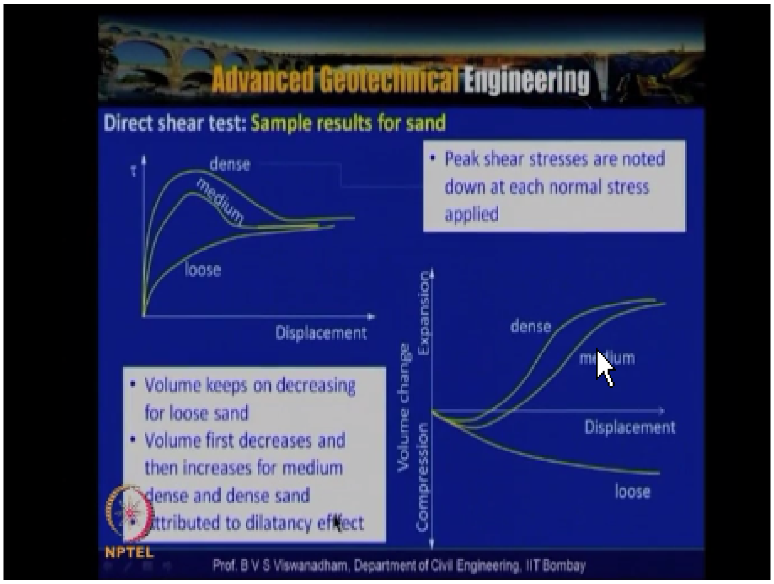

So in this particular figure the typical you know shear stress versus shear displacement for loose sand and mediums and dense and actual are given so as can be seen that you know loose and actually has got you know the continuously the hardening effect can be seen but in case of a you know the medium sand and then sand and particularly for dense and there is a predominantly a peak is actually observed and then once the peak stress is actually.

Observed and there is a decrease in the you know picture stress with increase in the shear displacement of shear strain so peak shear stresses are noted down at each normal stresses and then you know when we plot these peak shear stresses for each normal stress what has been done then what we get is that the τ σ you know type τ; σ space we actually get the you know the more column failure and although the slope of that more cool failure analog joining all these tau 1tau peak one you know σ 1 and σ N 1 σ n 2 σ n 3 and that actually give.

The you know the slope of line actually gives the you know the internal friction angle and if it is actually intercepting it the τ; axis then you know that intercept is actually taken as the cohesion of a soil so when we plot in the direction test as we can see that here the vertical strain can be measured by putting a dial gauge and the lateral movement can be measured by putting a you know the incase dial gauge or a potentiometer or a activity.

So with that what will happen is that you will get shear displacement or shear strain versus you know vertical strain so this vertical strain can be you know can lead to expansion or it can be lead to compression so what actually happens is that in case if you are having a loose and as can be seen here it continues to harden so spread out the inline with whatever we are actually observe for τ σ you can actually see that this undergoes a continuous compression so in this case the contraction actually takes place.

But in case of dense and medium sand for a given normal stress what will actually happen is that you know initially there will be a compression then thereafter what will actually happen is that has been discussed this was actually discussed in the previous lecture that the soil particles right on each other and then in news and make the you know the loading plate to move upward because there is no other way you know the particles are actually can you know accord accommodate the disturbances are actually created because of the shear.

So in a way what will actually happen is that there is a dilation or in the sense that expansion in volume takes place and this actually get suppressed with the decrease in particle size and similarly when we are actually having increase in the normal stress the tendency of the dilation actually keeps on changing so volume keeps on decreasing for looses and but in case of dense sand and medium sand what will actually happen is that initially there will be a compression and thereafter you know there is an increase in expansion of the soil takes place upon shear so this actually you know phenomenon is actually attributed to the dilatancy effect or it is also called the slope of that particular line is also called a dilatancy angle.

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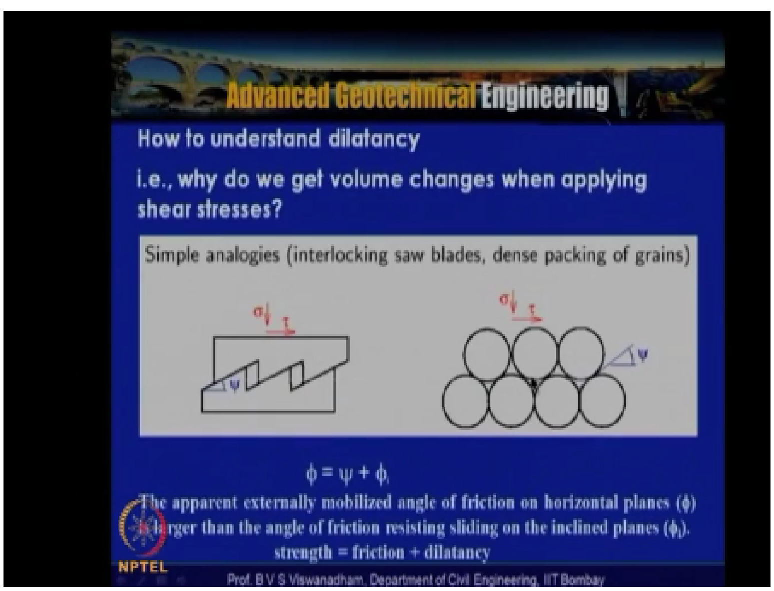

So as we said and we can actually we can analyze our now look into this as a you know saw blade you know analogy so it can be seen that when a shear is actually applied along the sub blade actually we have the movement actually can take place so the apparent you know external immobilizer angle of friction on horizontal planes π is actually larger than the angle of friction resisting the sliding that is π U and π I = friction +dilatancy written C.

So the strength is actually nothing but friction flesh militancy that actually what it actually turns out to be.

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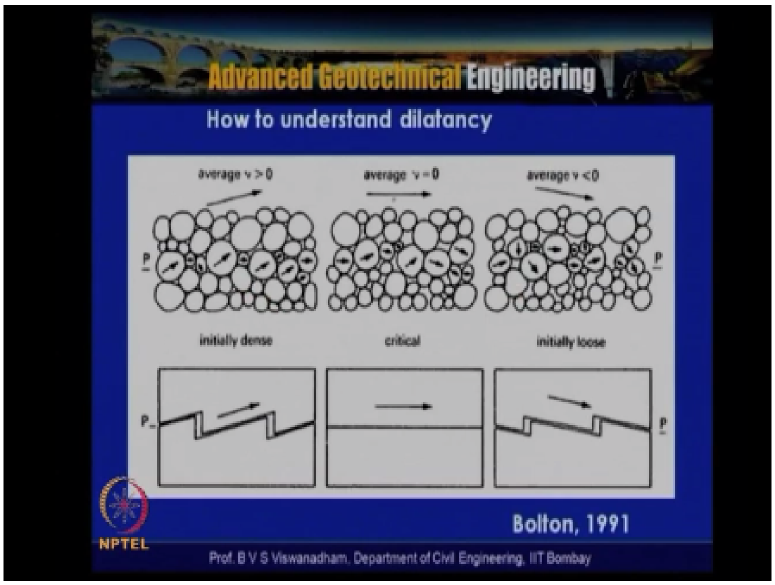

Now as we have seen that it can be possible that the soil can be in very dense state and the soil can so you know at particular situation that you know after you know a certain point actually where the shear we can actually occur at you know constant volume then that is actually called as critical and the when this actually attains at a constant volume the no change in void ratio takes place that is actually the void ratio at which you know no change in volume takes place then it is actually called as a critical void ratio.

And then when you are having initially lose then you know as we have discussed that these all lose pockets which are actually there they can get filled with the soil particles so that the compression actually takes place so the you can see this the orientation of the sublet analogy is actually given in the downward direction and here it is actually done in the upward direction this actually shows that you know the riding effect.

And this is also some depositing effect like you know one particle will get jumbled into other particles in a way what will happen is that there is you know a decrease in the volume takes place.

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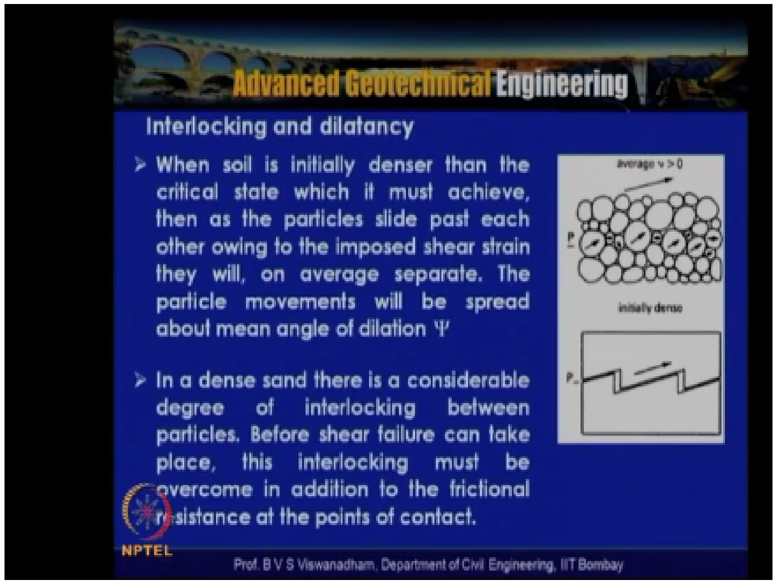

So let us look into this interlocking and you know dilatancy phenomenon's when soil is actually is initially denser than the critical state where critical state is the place where no volume change occurs which it must achieve then as particle slide past each other going to the imposed a shear strain in our way they are an average they actually tend to get a separate and the particle movements will be spread about a mean angle of dilation that miscalled sign and in a dense.

And there is a considerable degree of interlocking between the particles takes place and before shear failure can take place this interlocking must be must be or company mediation to the frictional resistance of the points of contact in factor the peak actually which is attributed in case of a dense and saw samples is actually attributed to the interlocking effect which actually you know results in the mobilization of the peak shear stress.

And thereafter you know the softening actually takes place so in a dense sand there is a considerable degree of interlocking between the particles and before shear failure can take place the inter lacking must be war company in mediation to the in a frictional resistance at all points of the content.

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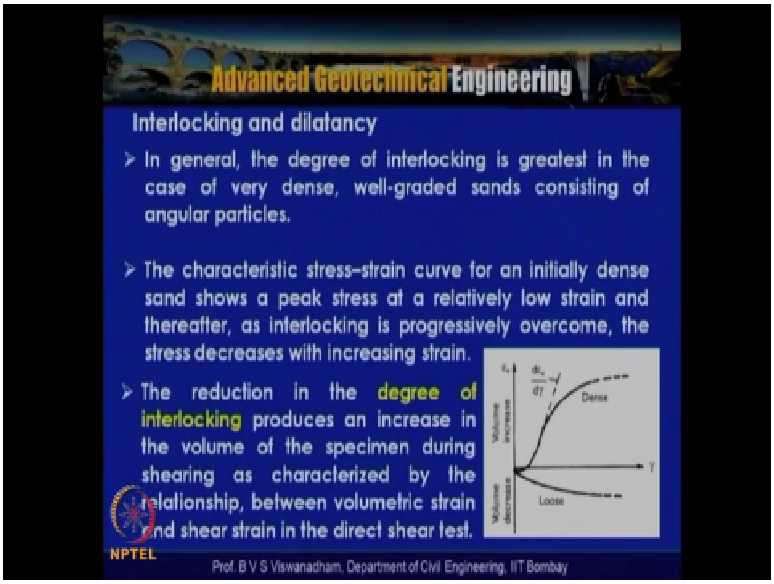

So in this particular slide you know we can see that the variation of the volume increase for a dense sand and loose sand is actually given here in this case of dense and there is a contraction this in the case of a loose sand for a given normal stress we can see that there is an increase in volume takes place so this is you know the slope of this line that is d ε, V that is the change in vertical strain or volumetric strain to this shear strain you know that is actually regarded as that you know the angle of dilatancy.

So in general the degree of interlocking is greatest in the case where case of very dense well graded sand and soil particles with angular which are angular in nature the texture of the particles if it is an angular and rough and there is a possibility that the degree of interlocking is the greatest and call in the basically in the case of very dense sand or well graded soil mix and then the angular particles and the characteristic stress-strain curve for an infant initially dense.

And shows peak stress at a relatively low strain and thereafter as the interlocking is progressively overcome the stress decreases with increasing strain so that the characteristic stress-strain curve for an initially dense and shows a peak stress that is what we have discussed at relatively low string and thereafter as the interlocking is progressively war come the stress becomes the stress decreases with increase.

In this state so the characteristic stress strain curve for an initially we have discussed at low strain and hereafter as the interlocking is progressively war come thus the strain becomes the stress decreases and increases the strain so the reason for you know having a you know observed peak and then decreasing the stress value with an increase in strain is attributed to the another breaking of that interlocking which actually was provided in that time and then upon shearing then once it is war come that interlocking then what will happen is that there is a decrease in the stress with an increasingly strength so the reduction in the degree of interlocking basically produce.

An increase in the volume of the specimen so the reduction in the degree of interlocking so this particular reduction of or breaking of the interlocking results in the increase in the volume of the soil specimen which is being subjected to shear so as characterized by the relationship between the volumetric strain and the shear strain in the directors so the reduction in the degree of interlocking producers and increase in the volume of the specimen. And during shear as characterized by the relationship between the volumetric strain and the shear strain in the direction test.

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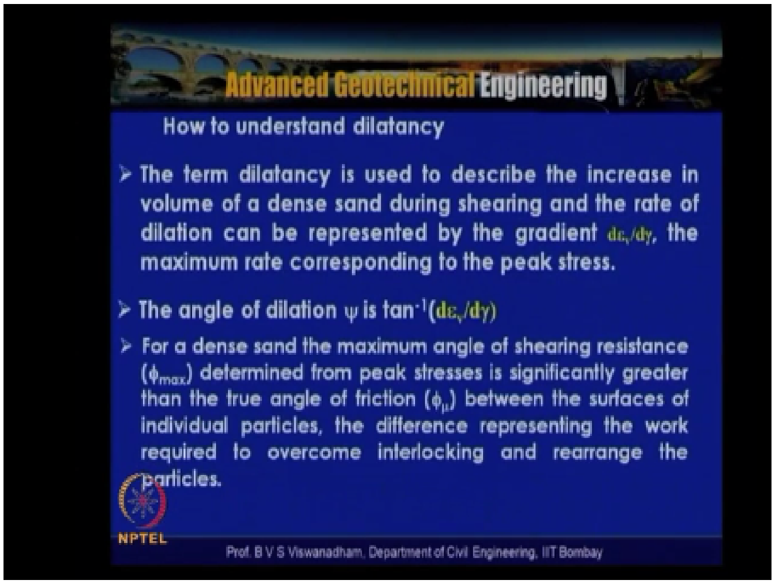

Now the term dilatancy is used to describe the increase in volume of a dense and during shearing and the rate of dilation can be represented by the gradient which is nothing but what we have to said is that d ε, V by D you know ϕ which is the maximum rate of the corresponding to you know peak stress the angle of the dilation IE is nothing but tan inverse D e ε, V by D ϕ and a for a dense and that the maximum angle of shearing resistance π max is determined from the peak stress is significantly greater than the true angle of friction.

So we have a no maximum peak friction angle that is actually determined at the wherever we have the cow peak is there and when you pick up these values and plot the more column and elope with normal in the τ σ space then you know what will actually happen is that the slope of that line with which is actually having a peak shear stresses which is actually called as the π max and there is also true angle of internal friction.

That is actually nothing but you know the frictional resistance offered by the individual particles and for that actually it is π u it is called and that is by view it is called πu indicates for the frictional the sliding friction and the difference representing them you know there is a difference between these two you know between π max and π μ and that is actually because the difference representing the work required to or coming or come the interlocking and rearrangement of the particles.

So π μ is actually more than π max π max is actually more than π μ and this is basically the difference is there is a difference between π max – π μ this is basically the difference is attributed to you know the work done which is actually required to work from the interlocking and the rearrangement of the soil particles.

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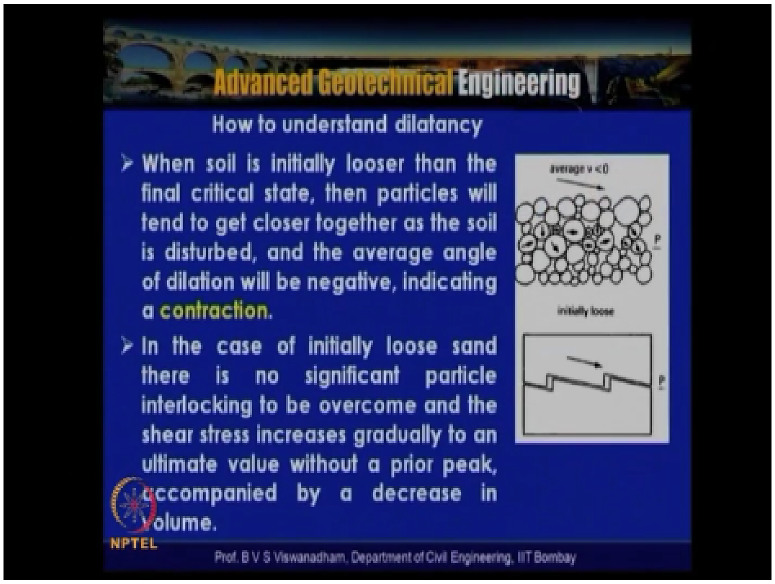

Then we said that when you have got initially loose soil sample there is a no significant you know interlocking takes place and the particles always tend to you know arranged into the new position and you know in the way that the soil undergoes a contraction upon actually shearing and the shear stress increases gradually to an ultimate value without priority component weight decrease in the volume so the in case of initially loose sand there is no significant particle interim interlocking takes place.

So that is the reason why there is no peak is actually observed and the shear stress versus strain variation is actually that and the shear stress continues to increase and after reaching the at-large strange it actually tends to become constant so in the case of initially loose end there is no significant particle interlocking to be or command the shear stress increases gradually to an ultimate value without a prayer priority component by a decrease in volume but when soil is initially loser than the final critical state

Then the particles will tend to get closer as the soil is disturbed and the average angle of you know dilation is negative and indicating a contraction so the angle of dilation is actually negative that is actually indicates a contraction actually takes place.

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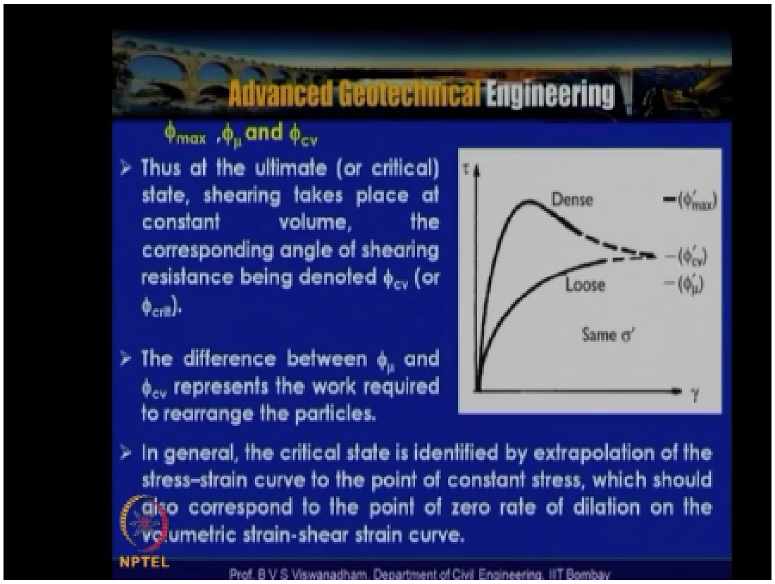

So let us try to you know interpret between π max and π μ and a π cv π CV is the friction A angle at a constant volume and CV indicates at you know at constant volume and so in this particular slide at τ axis you know shear strain is actually shown here and where for dense sand and loose and the shear stress variations are shown here as can be seen that the shear stress is actually maximum here.

And then you know the peak is actually distinct peak is actually shown and then there is a decrease in shear stress with an increase in the shear strain and it tends to become you know enjoying with the curve we are in have what the hardening actually takes place continuously for initially looses and becomes denser by virtue of shearing so this the does that the ultimate or at a critical state the shearing takes place at a constant volume and the corresponding angle of shearing resistance being denoted.

As π cv or π critical it is called π critical friction angle critical friction angle and the difference between π μ and π cv represents the work required so this is actually this gives the π CV and this actually require, this I somewhere here you know somewhere here the this is due to the sliding friction the sliding that is because of the frictional resistance offered by the particles in arranging into the you know, you know the into the denser configuration is actually is you know indicated with the π μ and hear the difference between π μ and π cv represent the work required to rearrange the particles in general the critical state is defined identified by the extrapolation of the stress-strain curve to the point of constant stress and which should be also correspond to the point of zero rate of dilation.

On the volumetric strain stress curve so this also corresponds to so the grade ratio at which this you know this particular phenomenon occurs is actually called as the critical in a wide ratio and this is the critical void ratio so this is the you know you know the critical state is identified by the extrapolation of the stress-strain curve to the point of the constant stress and which should also correspond to the point of zero rate of dilation on the volumetric strain volumetric strains hear strain curve.

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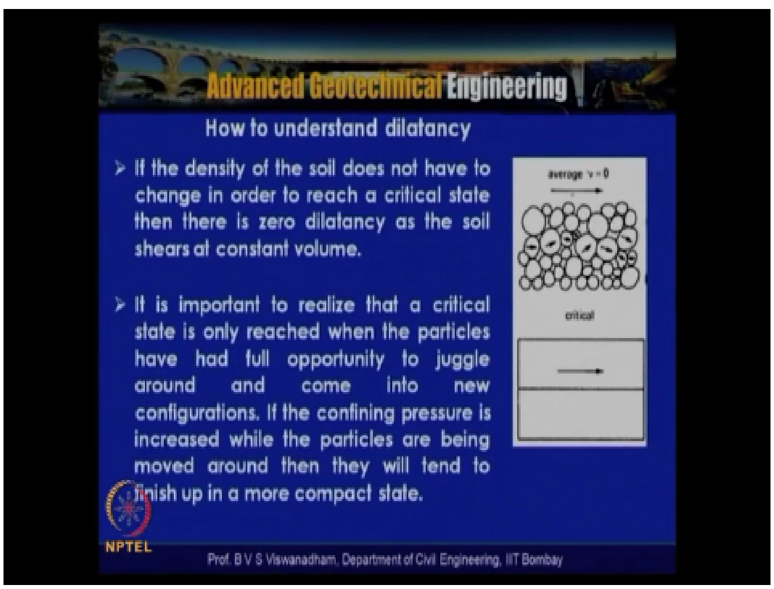

Now you know we all done now we said that at constant volume when the friction angle is interpreted that is also called as critical friction angle or π CV and if the density of the soil does not have to change in order to reach the critical state there is a zeroed written see as the soil shear and shares of the constant volume but it is important to realize that a critical state is only reached when the particles have had full opportunity to juggle around and then coming to new configurations that means that a progressively.

You know this state is actually achieved and if the confining stress is increasing while particles are being moved around then they will tend to finish up in amore compacted state so that arrangement will not actually happen.

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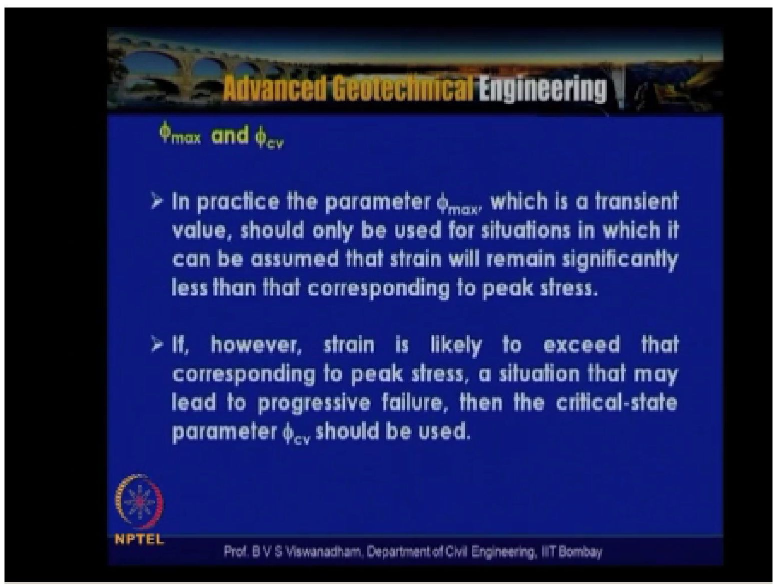

Now among π Max and π CB in practice the parameter π max which is actually is called as a transient value and should only be used for situations in which it can be assumed that the strain will remain significantly less than the corresponding peak stress so if for a given structure when it is actually being designed when the strain is actually less than you know at which the peak stress is actually interpreted then you know, the you know π max is actually can be recommended for use.

So in practice the parameter π max which is a transient value and should only be used for situations in which it can be assumed that the strain will remain significantly less than the corresponding to the peak stress if ever the strain is likely to exceed the corresponding to pick stress if the strain is you know likely to exceed the corresponding pick stress a situation that may lead to progressive failure then it is actually a critical state parameter and π u π series should so when we need to use π CV.

When we need to use π max is actually clarified in this slide if however the strain is likely to exceed they strain in the sense that in use it for a particular structure is exceeded you know that the corresponding to peak stress a situation that may lead to progressive failure then the critical state primarily parameter π CV should be used so here when we look into this.

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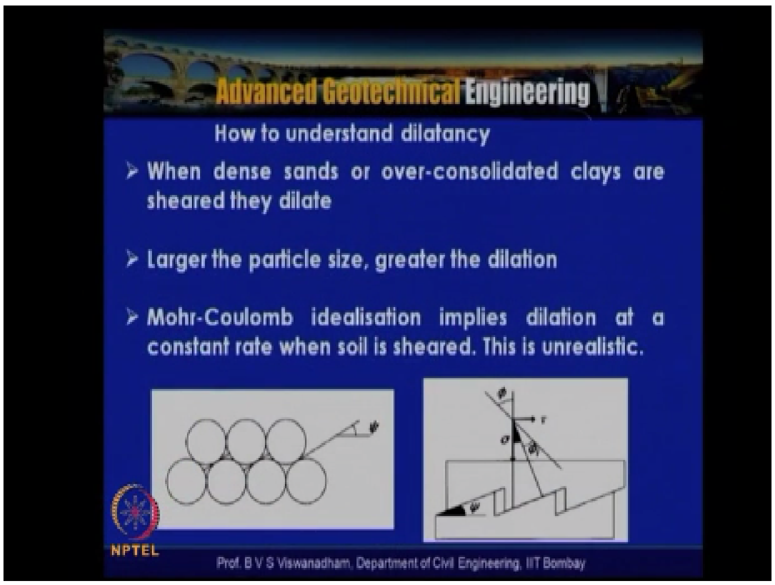

You know for the interpretation of you know the direction test and we actually said that when then sends or work in solid clays are sheared they dilate so when then sands actually our war consolidated clays you know when they are subjected to shear they tend to dilate and larger the particle size greater dilation and the decrease of the particle size actually decreases the tendency of the part aside to dilation Mohr- Coulomb idealization implies dilation.

At a constant rate when a soil is here and this is actually you know appear to be unrealistic so when dense answer were constructed clays are sheared they own they tend to dilate and larger the particle size and greater is the dilation and decrease in the particle size duct suppresses you know the dilation tendency and also increase in the normal stress and increase in the war but then also suppresses the dilation tendency now you know.

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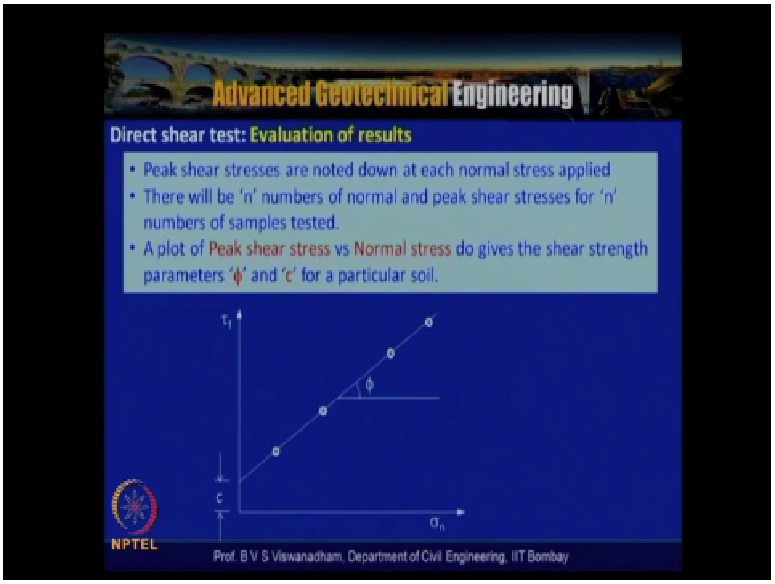

But let us look into the interpretation of the direction your test results and then you know we will try to look into some example and here the peaks shear stresses are noted from the shear stress versus shear displacement or shear strain curve and each normal stress the peak stress is actually when it is picked up and when it is plotted here and the line joining this you know this elope is actually resulted as a Mohr- Coulomb failure elope.

And if it is a purely frictional soil and with the negligible amount of fines there is a possibility that you know the friction angle that the elope can actually pass through origin and the important aspect we should remember is that while plotting this results the τ σ curves out to be on the equal scale so that the proper you know interpretation can be done so there will be you know like one or two or three basically minimum three are required and if you are actually trying to do like say five normal stresses.

And so you will actually get the five a number of shear stress displacements and a plot of the peak your stress versus normal stress do give the shear strength parameters π and C from the particular soil so we were able to get the C and π for a particular saw a particular soil from this curve.

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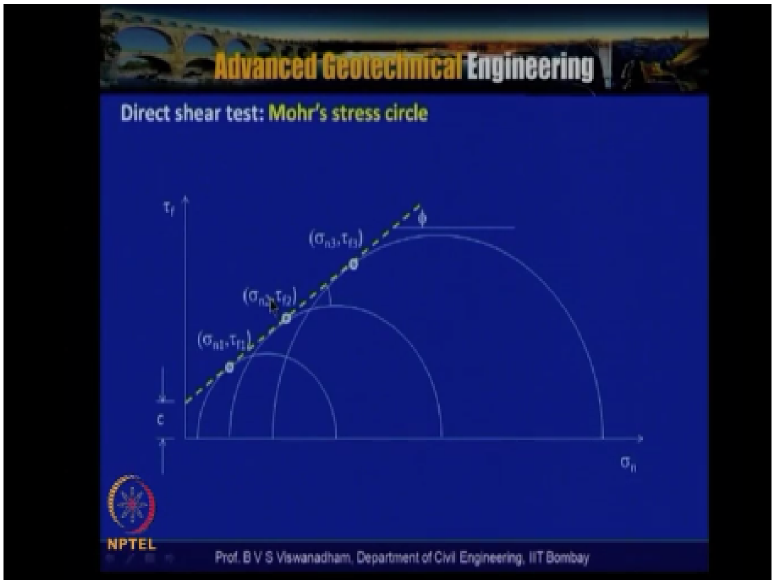

And further you know there is a way very we can actually construct the more circles because here in this case what we are trying to do is that we can actually construct the Mohr-coulomb failure runner up and we know actually this particular point so what we can do is that you know the this point you know more circle more Mohr- Coulomb hypothesis actually states that when more subtle is in contact with the failure analog.

Then you know that is the point where you know the file you stress the τ σ you co-stars actually achieved at a particular normal stress so here for σ N 1 τ F 1 is the failure stress σ n 2 τ F 2 is the failure shear stress σ n 3 τ F 3 is d so this is actually the dotted line which is actually shown is the you know failure envelope and now you know with the with particular you know dropping perpendicular to the σ axis from the failure.

No we can actually look at the center of the Mohr circle and with this as actually a center we can act if you draw a Mohr circle then we will be able to locate you know major principle stress and minor principle stress and from the known stress state and the stress state on the Mohr circle if you draw a line horizontal parallel to the σ axis it actually intersects at a point P and that point is actually regarded as pole and from the pole when we join these points two major principles tress ordinate here and minor principle does ordinate here then actually we can get the inclination of the majorprinciple plane and minor principle plane.

And so when we draw the Mohr circle will be able to get the you know major principle plane and minor principle plane locations and magnitudes of the stresses in the direction of the principle planes and all so as can be noted if you look into that initially when the when you know when you start the you know they prepare the sample and then kept it for you know you know equilibration also at the time and the no normal stresses.

I when they when the normal stress is applied when the no shear stress applied when we have got along the predetermined horizontal plane you actually have you know the principal planes but upon shearing and during shear test actually in a case of direction test the principal planes are subjected to rotate and they rotate in the direction of shear and the degree of angle of rotation of the principal planes is approximately you know regarded as equivalent.

To the friction angle of a soil and so like this when we do you know different normal stresses and when you get reach the top f2 and top f3 the failure stresses you can actually draw these more circles and these more circles from me from here onwards so the line which is actually joining to this parallel to this one that is actually is nothing but the you know the it indicates the failure plane and this indicate you when you when it is actually meets at the point say p1 here and it is joining here then this is called the you know major principle plane inclination.

And when it is joining to this particular point that is called minor principle plane so we actually can determine the angle of the inclinations of major principle planes or minor principle planes and their magnitudes when we know the stress state points at failure for σ n 1 and then τ F 1or σ n 2 and τ F 2 and σ n 3and top f3 so this is the initial condition it has been has it been described here.

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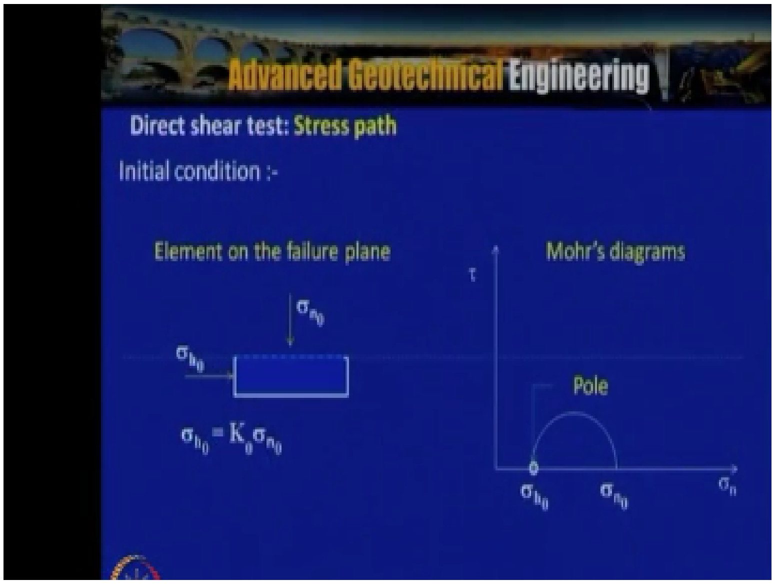

Initially when we actually have you know σ n 0 that is the normal stress let us say a 50 kilo Pascal's or normal stress is applied and for a normally consolidated soil you know when you take a pressure at rest k not as say . 5 then in that case the horizontal stress which is actually there the soil is you know σ H0 = K 0 into σ, σ 0 n not so 50 kilo Pascal's in 2.5 let us say 25 kilo Pascal's will be there so when we draw that when we have the normal stress σ and not and you know the in each this is called initial more circle and this much.

This more circle is actually well below the well below the Mohr-Coulomb failure and elope then we actually have discussed it that the this more circle is regarded as the stable condition then further when with that same normal stress you know when we try to increase induce the shear then what will actually happen is that the more circle actually you know the generates the you know the shear force and with that what will happen is that the more circle.

You know becomes like this so with that what will actually happen is that you know you can actually get a point where you know it you know reaches to the failure so that is actually you know these during the test and before the failure and so from here if you look into this year when you have this point at failure so what we have discussed it is that you know when you draw in order to locate this and this when point is actually drawn so this is the center with this is the center and this is the radius when you draw then this as the radius when you draw the Mohr circle then you can actually get amore circle tangential to the so-called failure and a rope and then passing you know this point and this point and then you know when you draw and locate a pole then when you join it to the major principle stress here then what you get is the major principle plane so the major principle plane is here and minor principle plane which is actually here so these are the you know directions or inclination of the minor principle plane and major principle plane.

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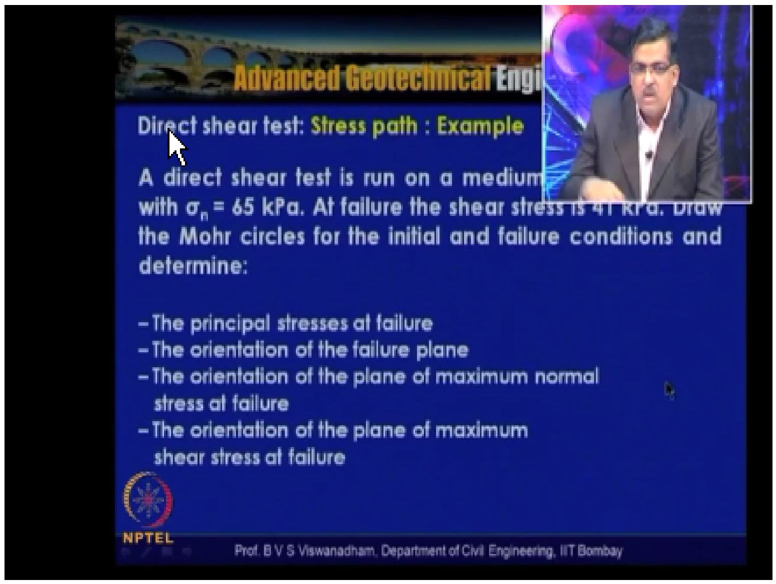

So let us consider an example where in a direct shear test is actually run on a medium dense and dense sandy silt with normal stress of 65 of Pascal's at failure the shear stress is observed as 41 kilo Pascal's and draw the more circles at the initial and failure conditions and determine principle stresses at failure and the orientation of the failure plane and the orientation of the plane of maximum normal stress at video orientation of the plane of maximum shear stress at failure.

So these you know issues can bead dressed you know by the discussions whatever we have we had till now.

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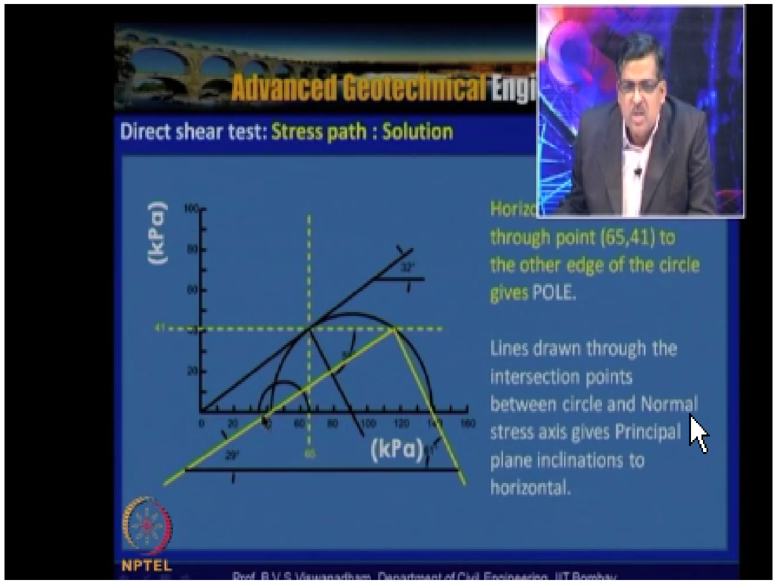

So initially when normal stress is actually applied starting at the test then the 65kilo Pascal's is actually located here and when we when we locate with us is a being a salty sand and friction angle is actually given as 32 degrees so when you take using Jackie's formula k 0 = one_ sine π and with that one - sine 32 degrees is equal to then you know it comes out to be around 35 Pascal's and with that you know 65_35 30 kilo Pascal's as the diameter when you draw the Mohr circle you will get initial Mohr circle for the initial condition.

Then you know it has been given as you know the failure shear stress is actually located at a 65 kilo Pascal's normal stress at a the normal stress is actually somewhere around 41in kilo Pascal's so what actually happens is that you know when you locate that point and because it is given as silty sand and the coefficient is actually assumed to be 0 and then it actually passes to the horizon so with that what we can actually get is that you actually have got τ σ and elope this is the τ σ and elope actually here passing through this is, this is the point which is actually a65 and 4.

So when the so the angle of internal friction is equal to 30 degrees the slope of the line passing through the origin and point that is 65and 41 and then you know in order to find the center of the circle you know with the you know by dropping a you know perpendicular from here then you know we can actually locate a point where it actually you know intersects the center then with this as the center and this as the radius we can actually draw a Mohr circle and that particular Mohr-circle you know represents you know the Mohr circle actually becomes like this and then because we have taken this as the radius so it becomes tangentially here and this particular point where it actually intersect σ and that is actually regarded as the minor principle stress.

So in this case about 40 odd kilo Pascal's is actually is the minor principle stress and here σ one is actually here about 145 1 40 kilo Pascal's is the major principle stress so we actually have located you know the Mohr circle and drawn the Mohr circle and the θ which is actually 45+5 by 2 that is actually for 45 + 32x 2 which 61 degrees angle between horizontal.

In the line joining the center of the circle and point 6541is 180 - 2 θ which is about 58degrees so that is actually here is indicated here now you know horizontal line is extended through point 6541 to the point to the other edge of the circle which actually gives pole and the line drawn through the intersection points between the circle and normal stress axis gives the principle plane inclinations to the horizontal.

So as we have discussed that when we draw this line for the point to this point and this point will actually get the inclination of the principle planes we you know with reference to the more circle diagrams with that we will be able to get the we can locate we can see that you know initially when the sample is actually just prepared then we actually have what 65 degrees and about30 30 yard kilo Pascal's as the minor principle stress but now the principle stresses magnitude has increased as well. As the direction also changed in the direction test.

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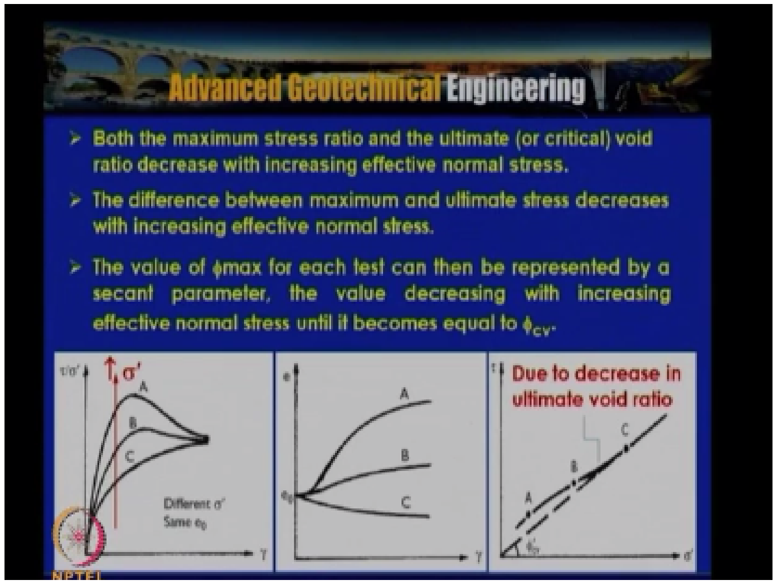

So further in continuation of whatever we have been discussing you know we can actually look into you know the another way of plotting the shear stress versus you know the shear strain data as ratio of τ σ dash for a different σ Dash when you actually take with increase in σ Dash actually in this direction see actually has got lowest be and a then you know there is a you know typical ABC plotted actual are shown different σ Dash and say me not in our initial void ratio.

Is actually same for all the samples which are actually shared at three different normal stresses both maximum stress ratio and ultimate are critical void ratio decreases with increasing effective normal stress then the difference between maximum and ultimate stress decreases with increasing effective normal stress so the value of the π mix for each test can that we are presented by a secant parameter and the value decrease with increasing effective normal stress until it becomes equal to π CV.

So because of this particular phenomenon what actually happens is that at low effective stresses you know you we actually have you know the difference between you know the critical friction angle as well as the you know π max that is a peak friction angle but when it actually has got the normal stresses actually increase then the what actually happens is that the suppression of you know the you know the peaks actually appear and then you know predominantly the hardening actually takes place because of that what will actually happen is that you know they merge to the π C V axis.

So you can see that you know at high normal stresses are I effective stresses there is a the beyond you know point B you can see that there is a you know merging of these angles takes place so this particular phenomena is actually attributed to the decrease in the ultimate void ratio so the both maximum stress ratio and the ultimate or particular decreased ratio should decrease with increasing effective normal stress and the difference between the maximum and ultimate stress decreases the increasing the effectiveness stress and the value of the π max for each test can this be represented by a second parameter and the value decreasing with increasing effect on normal stress until it actually becomes equal to πC.

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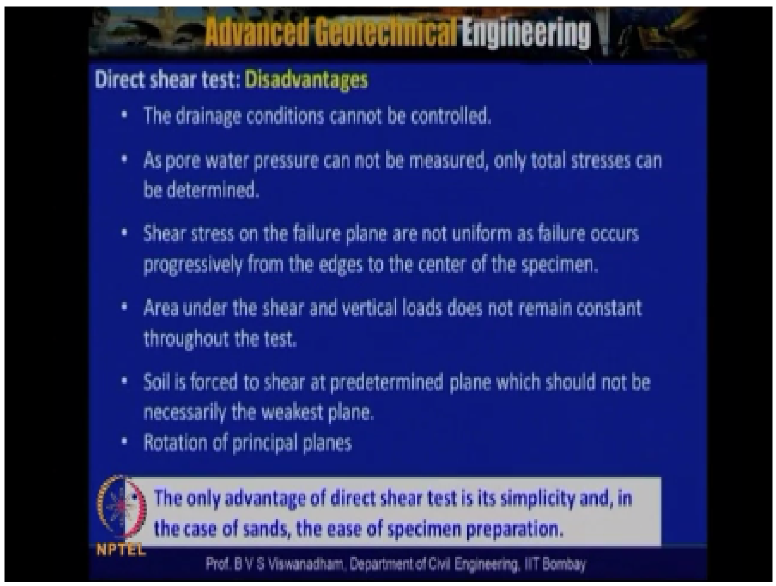

So after having discussed the direct shear test it actually has got you know first of all the ratio test is a simple test and actually allows to determine the strength parameters of soil very easily and the failure plane is actually one to be noticed that the failure plane is actually predetermined and very difficult to you know control the drainage condition but however to some extent what it can be done is that when you have got a shear box and if you wanted to get to some extent you know consolidated and drained parameters what can be done is that the sample can be prepared particularly if you are having some silty sand or silt samples the samples can be prepared either under revolt a conditions are only conditions and they allowed to you know saturate under the particular normal stress over a period of time.

Then you know the shearing can be done in a very low strain rate so that the stress the you know the there is no generation of excess pore-water pressures during the shear so with that you know with this exercise we can actually get drained parameters up to a maximum extent otherwise you know basically the total strain parameters are actually obtained and so in a way the pore water pressure measurement is actually difficult.

And only the total stresses can be determined in this particularcase and shear stress on the failure plane are not uniform as failure occurs progressively from the edge to the center of this basement so one thing we need to notice is that the shear stresses on the failure plane they are actually not uniform as the failure actually occurs progressively from the edges to the center of the specimen and area under the shear and vertical loads does not remain constant throughout the test so one more assumption way you know observation we have to make is that the area.

Under the shear and vertical loads you know does not remain constant throughout the test and the soil is actually you know force to shear along the predetermined plane and we should not actually necessary the weakest plane so if you look into that you know we actually have you know imposing failure along a predetermined plane which may not be the failure plane in the particular sample in such situation is actually you know we are actually regarding as you know the failure to take place along a predetermined failure plane.

And the another disadvantage a demerit which actually comes as far as you know direct shear test is concerned is the rotation of the principle planes as we have seen that during shear the principle planes undergoes rotation in the direction of shear and the angle of rotation of this principle planes is approximately you know estimated as the you know the inclination of the failure envelope with the horizontal that is the friction angle and so these are the some you know disadvantages.

Which are actually listed here and the only advantage with the direction test is simple and in case of sands is easy for the sample filtration so another advantage is that you know the interface parameters and this is actually where you know when you have actually got multiple interface layers nowadays you know when we actually design a landfill lining system when we wanted to have you know the sliding friction values or incase.

Of the reinforced soil walls when you wanted to have a sliding friction between the reinforcement which is actually being even a which is interacting with the surrounding soil in order to get these parameters or interface between a geo-membrane interface and soil under you know different conditions like you know without water or with the you know with the presence of the water in a number of cases actually where you know the interface characteristics can be analyzed and this is actually becoming very handy as far as you know determining the you know these the use of the direction test is actually concerned.

Now as we said that the another way of determining the strength parameters is the tri-axial compression test in fact the tri-axial compression test is the first physical model test which actually very you know we are in the institute conditions are actually attempted to be simulated so here this tri axial sample actually simulates.

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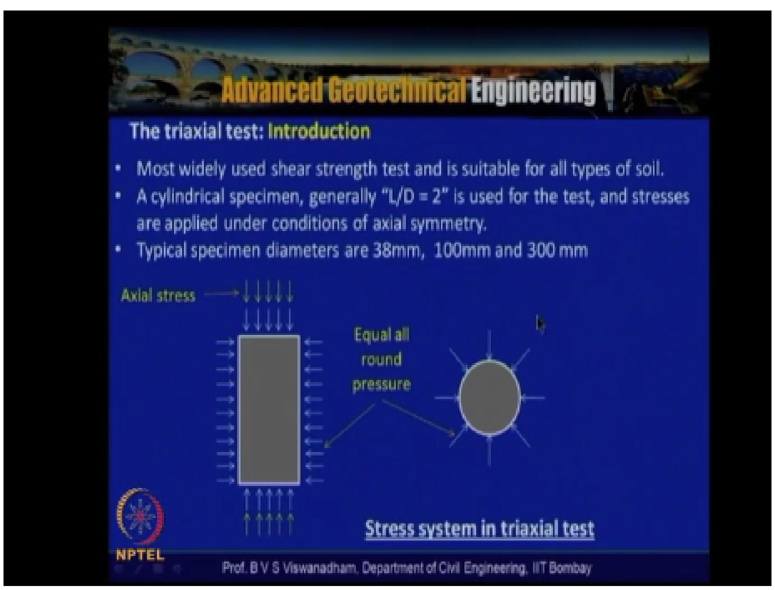

Let us say that if you are having an soil sample collected from a certain you know certain depth let us say at say 5meters depth or ten meters depth and then know the soil sample will be actually having a vertical stress and the lateral stress which is actually equivalent to let us say an equilibrium conditions it is K0 times σ V and with that what will happen is that it is subjected to these conditions now on these conditions.

Let us say that there is an increase in the you know vertical stress which is actually happening and upon that increase in vertical stress if you wanted to see what is the angle of the resistance actually offered by the soil and that can be actually simulated by using this particular type of test which is actually called as a tri-axial compression test so this actually test actually has got you know a you know one of the widely used tests wherein you can actually get you know you know have the parameters which actually can have well control to drainage conditions the soil strength parameters can be estimated very accurately and mostly ways.

It for shear strength tests in suitable for all types of soils and varying you can actually do on very soft soil and very not very soft soil in a way soil sample can be made to stand and then also loose and then science yes different techniques need to be adopted and needs to be considered and one important point we need to actually highlight is the L/ D ratio so in this case the L/D is actually maintained as to that means that length of the sample is always the two times the diameter and this actually you know one particular you know requirement.

Which actually needs to be satisfied is that you know because of the L / D =2 what will happen is that the failure plane will remain within the within the sample length only the otherwise you know if you are noticing whatever we are actually applying on the horizontal surface and along the you know along the vertical plane and these are actually regarded as the minor principle planes and they actually remain as minor principle planes during the test and even the end of the test so that means that you know in the case of tri-axial shear stress whatever the limitation.

Which we actually have said the two major things one is that you know the non-uniformity of the shear along the failure plane and induced failure plane and the rotation of the principal planes those limitations are actually wore come very easily in a shell shear stressed and the typical sample diameters for the you know the sample assessment diameters for tri-axial test of a 38mm 100 mm and300mm and 38 mm is generally used for you know the small samples that 8 mm diameter and 76 mm height on there is also one more intermediate size which is actually 75 mm diameter and 150 mm height or 100 mm diameter and 200 mm height or 300 mm diameter and 6 mm height in some special cases where we are actually having a large size particles then even you know 1000mm diameter or finite among diameter.

And one meter height or 1000 mm diameter and two meter height very large traction test cells are also available nowadays so in this particularly what we do is that the sample is actually prepared under from the disturbed or undisturbed conditions or remote sample is actually prepared or undisturbed sample is actually place and these sample sizes are such as that you know the from the different sampler tubes we can actually can collect the samplers and then you know preserve the you know original soil fabric and original preserve.

The degree of the disturbance and so that in strength parameters you know directly the samples which are actually corrected from the borehole investigations the same thing can be used here and with that when you can when you perform and different types of drainage conditions we are able to maintain then there is a possibility that you will be able to determine the stands parameters shooting to the field conditions depending upon the type of the you know you know the stress test which you are conducting can be adopted.

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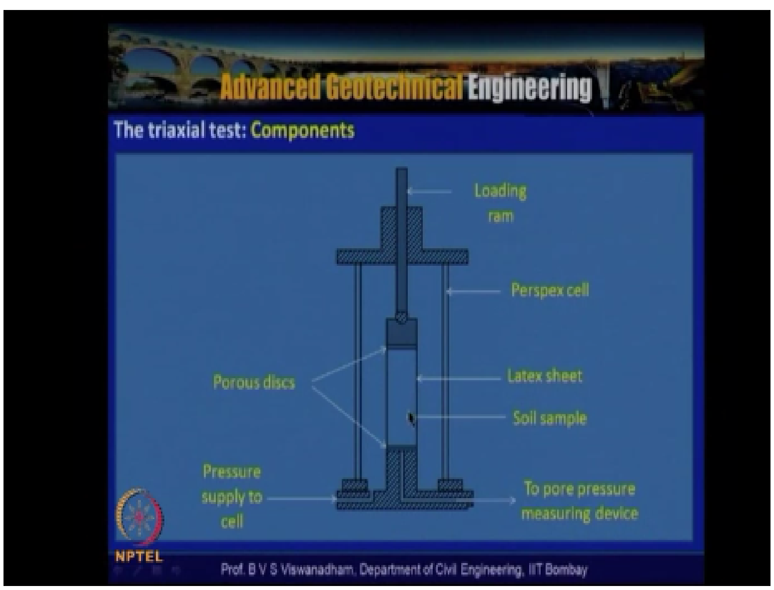

So this is the you know typical component of a tri-axial test where you actually have what a sample and a chamber in which you know what you have is that you know the confinement is actually provided in the form of filling the water so initially when the sample is actually place and to as an interface you know there is a membrane which is actually placed called rubber membrane and then you know the load cell which is actually placed three here this is the pork or loading ramp and inside is actually filled with water and this water is actually pressurized.

It two different pressures and you know when we are actually having you know σ 3 1 σ 3 2 and σ 33 different cell are actually applied so and then four different cell pressures when it is actually applied initially the pressures are actually uniform and then you know to in order to simulate the increase in the load what actually happens is that you apply deviator stress so with σ 1 = σ 3 +you know σ 3 + P by a and you know that is actually you know what we get is that σ 1 = σ 3+P/ a and what we regard as σ 1 - σ 3 as the deviator stress.

The difference between major principles stress σ 1- σ 3 is actually called as the you know the deviator stress so we get deviator stress versus axial strain and that is in case when you are actually doing a compression test so sometimes you know we can actually have controls on the you know you can actually arrest the movement of water so that means that no volume change is actually allowed then in that case we can simulate untrained conditions.

And we can also measure whites the war water pressure upon shear when the drainage is actually not limited in a saturated sample and when suppose if you are trying to you know drain the water and subject it to you know sharing condition then know what will happen is that the you know consolidated drained conditions are drained parameters are okay, so in the next lecture we will try to look into further about the axial tests and further we will try to look into the other aspects of the interpretation of the virtual test results you.

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