Soil Mechanics/ Geotechnical Engineering I
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Lecture – 36
Shear Strength (Contd.)

Once again I welcome you this lecture and I have mentioned in my last lecture that I have completed the shear strength aspect, but still I want to take one more lecture on it highlighting the important aspect because it is very important, shear strength is very important in soil mechanics and geotechnical engineering. So, I want to summarise whatever we have discussed in shear strength highlighting the important points.

So, let me do one by one all important points.

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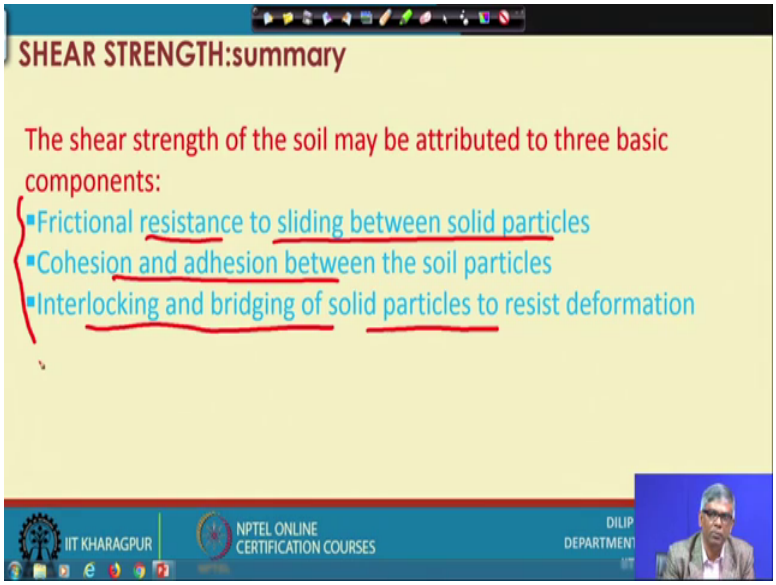

Suppose, I have initially I have discussed about source of shearing strength. We have mentioned you can see that frictional resistance to sliding between the solid particles then cohesion and adhesion, and interlocking and bridging of solid particles. So, sometimes this why I am highlighting this one? Sometime in a competitive exam, where there will be m c q will be there will be certain statements will be will be given and it will be asked find out the statement which is not correct or how many statements are correct how many statements are wrong. So, if you understand or if you keep in mind this point important point then you will be able to do that.

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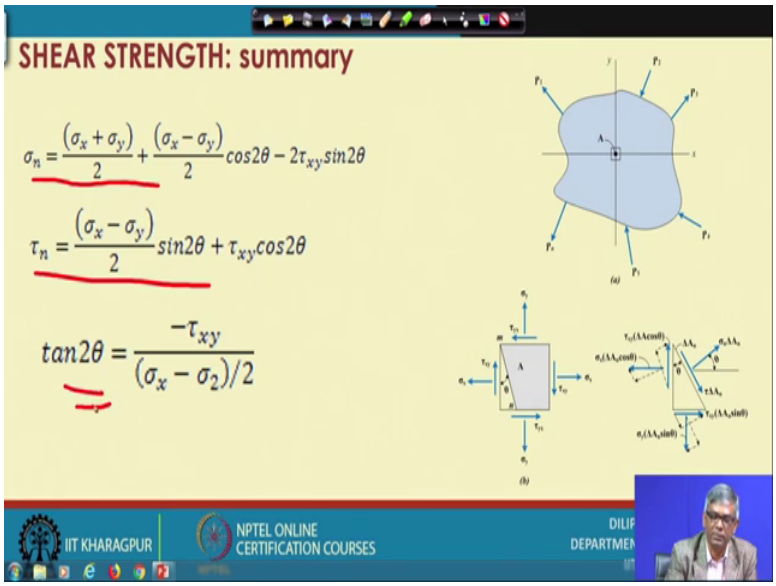

Next one, you can see that as I have mentioned before the initial stage that at any point actually you can soil mass you can find out and they are actually a state of stress you can define in 3 dimensional form. And finally, I have mentioned that for most of the application we can apply we can use a 2D biaxial form and most of the application it does well and if we in biaxial format if you know the state of stress and then we can also can find out the stress at any orientation the plane with any orientation that is what.

And if the plane is oriented with theta this given here then the on that plane sigma and tau and is given here and where actually sigma 1, sigma 2 become maximum that is actually theta also I have given that expression. So, these are the things to be also remember some time many frequently may use here when we will do the problem in shear strength.

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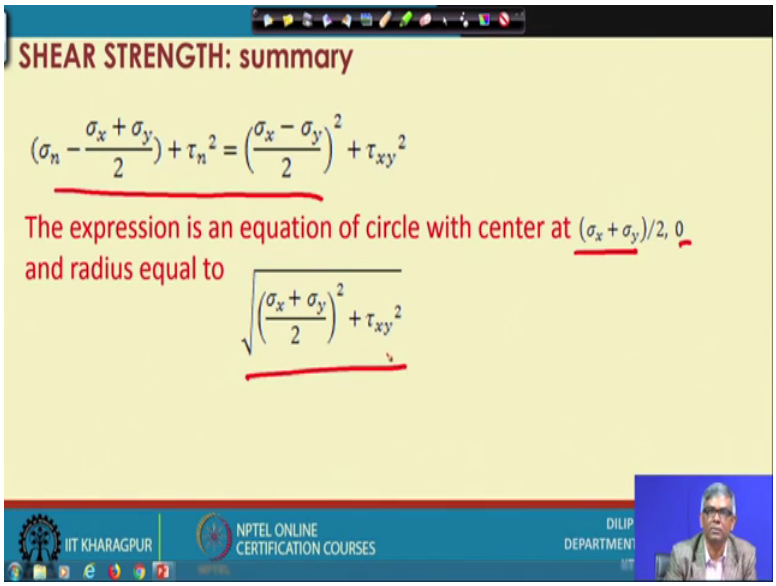

Next is you can I have also shown that whatever value at a particular plane orientation theta, theta can be anything. So, the variation of theta whatever value we are getting tau and sigma and we have shown that those locus of the points is a circle and that equation of the circle we have shown before that this is like this with centre at sigma x plus sigma y by 2 0 and radius equal to this, this is also I have highlighted.

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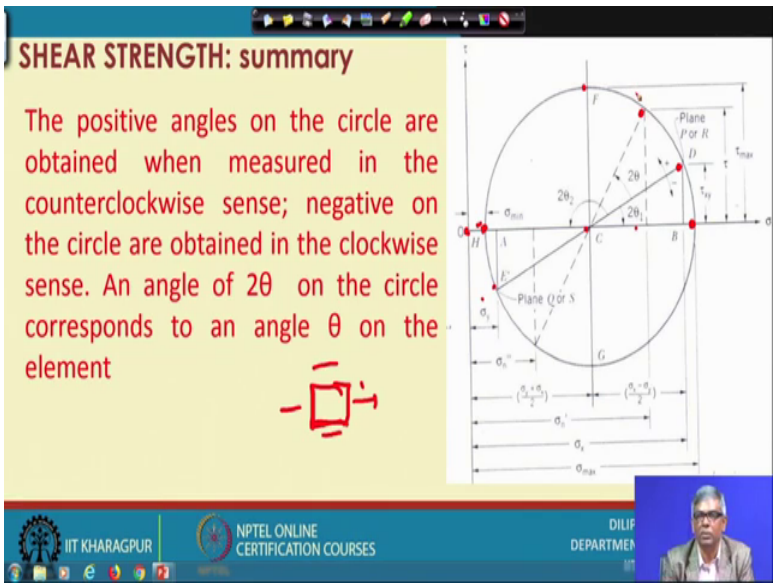

And another important thing I have mentioned that use of Mohr circle if you know the state of stress from there we can draw the Mohr circle and this is the various aspect of

the Mohr circle you can see if the origin is chosen here and if you know the sigma 1, value or sigma 3 then I can get this two terminal point and this will be the diameter. So, half the point take has a centre and draw the Mohr circle and there we can find out many things or if the state of a state of a particular point is given from there that point will be if this is a this is the element and this and this side is given it will be unique point will come here and similar to this and this if you it will come here.

So that means, if you can get this point and this point automatically I again get the diameter or if I know the sigma x sigma y I can find out the radius then I locate the radius centre and locate one point and draw the circle get the Mohr circle. After the drawing the Mohr circle I will get this, this, this, this is maximum shear strength, this is maximum normal strain, this is minimum normal stress and if I want to or find out what is the normal stresses shear stress at any plane which is oriented theta suppose this is the plane. So, I will rotate theta like this then it will intersect at here I will directly read the value here from the circle we will get the normal and shear.

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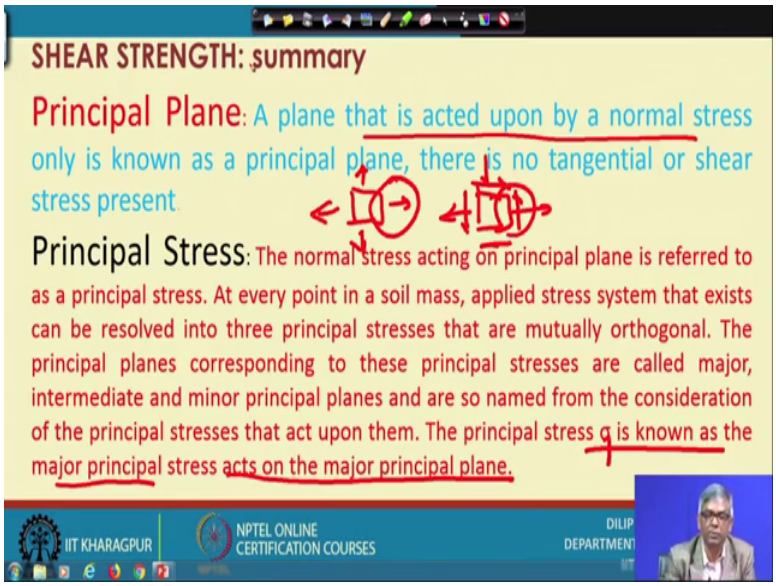

Similarly, principal plane and principal stress I have mentioned you can see the principal plane, plane that is acted upon by normal stress only. That means, one element is here and like this is the, this is there and another element is here and shear is also shear also is acting like that. So, this plane, this plane is not a principal plane whereas, this plane is principal because there only normal stress is acting. And similarly principal stress the

normal stress acting on principal plane is referred to as a principal stress that mean on this plane where there is no shear stress, that plane whatever normal stress is acting that is a normal stress principal stress.

At every point in a soil mass applied stress system, that exist can be resolved into 3 principal stresses that are mutually on the orthogonal the principal planes corresponding to this principal stresses are called major intermediate and minor principal planes are so name from the consideration of the principal stresses that act upon them. The principal stresses sigma is known as the major principal stress act on the major principal plane. So, this suppose sigma 1 major principal this is sigma 1 this is our sigma 3.

So, this is already I have elaborately I have elaborated before. So, once again what is principal plane what is principal stress once again I am summarising here.

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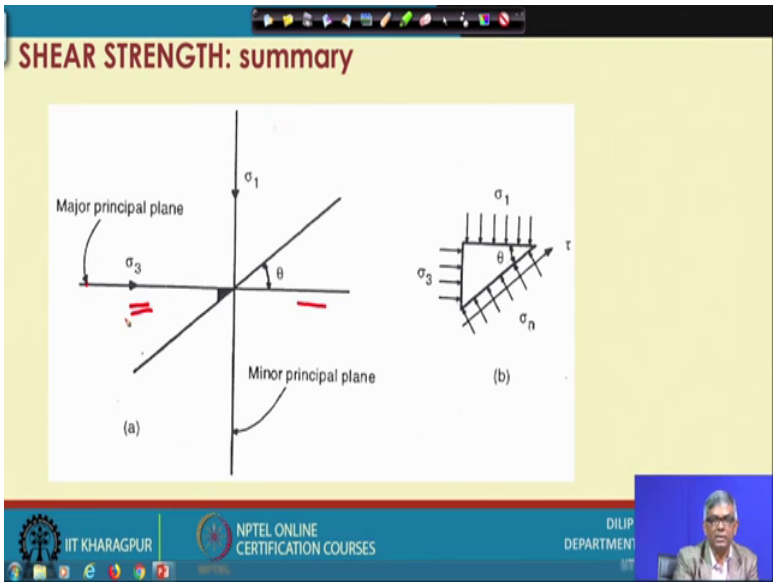

And this is the thing suppose this is the, this is the major principal stress direction. So, major principal plane will be this one.

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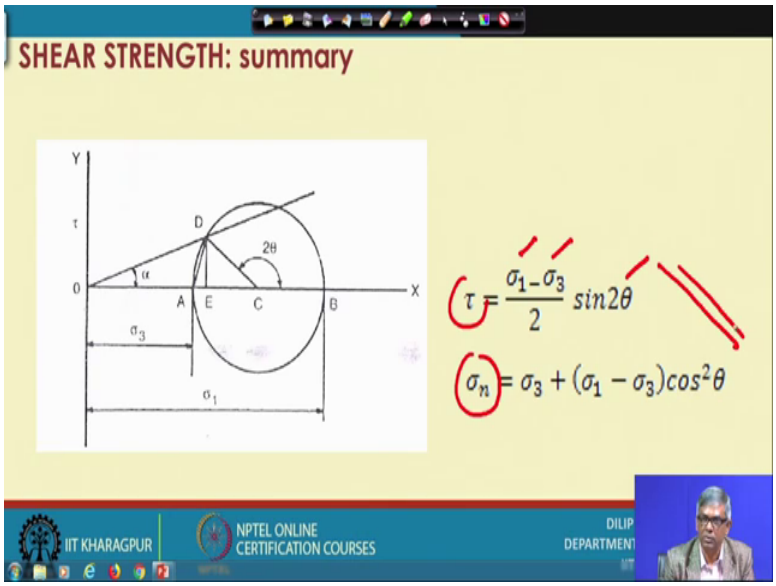

Similarly if this is the, if this is the minor principal plane, so this is the minor principal stress and if this is the one then theoretically we can express what is the value of tau and sigma, in terms of sigma 1 sorry in terms of in terms of sigma 1 sigma 3 and theta if the plane are orient if I know sigma 1 and sigma 3 and if I know the value of failure plane then on that plane what is the tau what is the sigma n I can; you I can find out by using this expression. I have we have also a little different form of equation also that they are same. If it is trigonometrically if you simplify it will get another form so that is also I have shown before.

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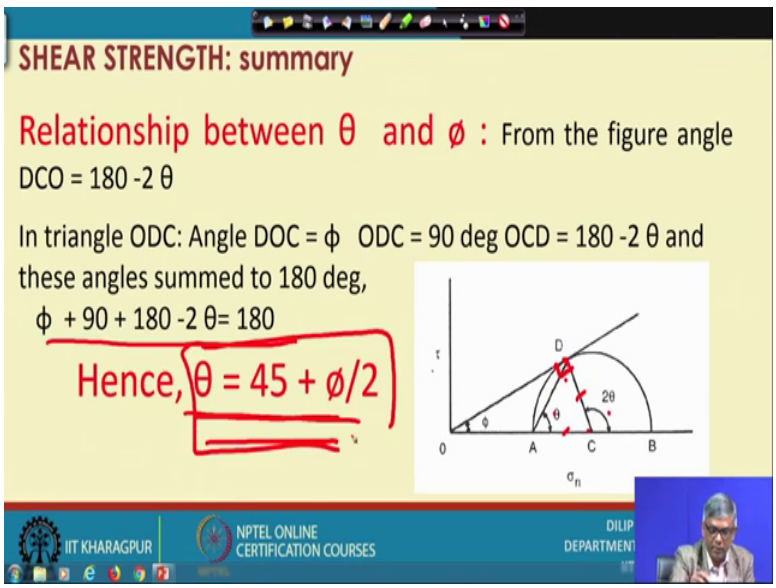

And you can see the relationship between theta; that means, failure plane and the phi that is also important. So, if I know the phi value I can automatically find out the value of theta that inclination of the plane with the major or minor plane. So, 45 degrees plus phi by 2 how it is done? This is the envelop and this is the Mohr circle then if I join from here to here, this is a right angle and this is if this is 2 theta if this is right angle and this will be your symmetric triangle because this, this are same and this also same. So, this, this will be theta and from there actually if I consider a triangle this triangle from that triangle the ODC, ODC triangle 3 angle summation will be 180 degrees from there we get theta equal to 45 degrees plus phi by 2 this is also another important things to be remembered.

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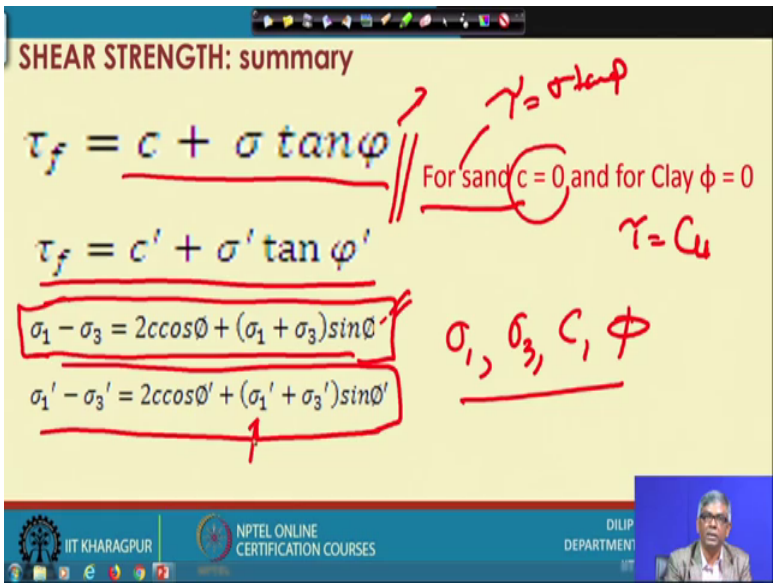

And we have mentioned that shear strength in terms of total strength total stress parameter this is the equation in terms of effective stress parameter this is the shear strength equation. This the Mohr coulomb equation and this is the general form of equation, but when sand then c will be 0, when sand it is c will be 0; that means, for sand the equation tau will be equal to sigma tan phi. Whereas, when it is a clays phi equal to 0 for clay tau will be equal to it is nothing, but c, Cu.

And this is one form of equation shear strength equation with phi and shear parameter and then this is another expression also we have given that is actually sigma 1 sigma 3 and phi of the soil phi c sigma 1 major principal stress minor principal stress and c and

phi they have also relationship this relationship also important now very frequently we use if we do not have graph paper and if you want to do analytically then this is the equation sometime useful for getting the value of c and phi. When you use total stress parameter this is the equation? When you use effective stress parameter this is the equation. So, they are same, only wherever there is a total stress is there it has to be replaced by effective stress. So, sigma 1 replaced by sigma 1 dash sigma 3 will be replaced by sigma 3 dash.

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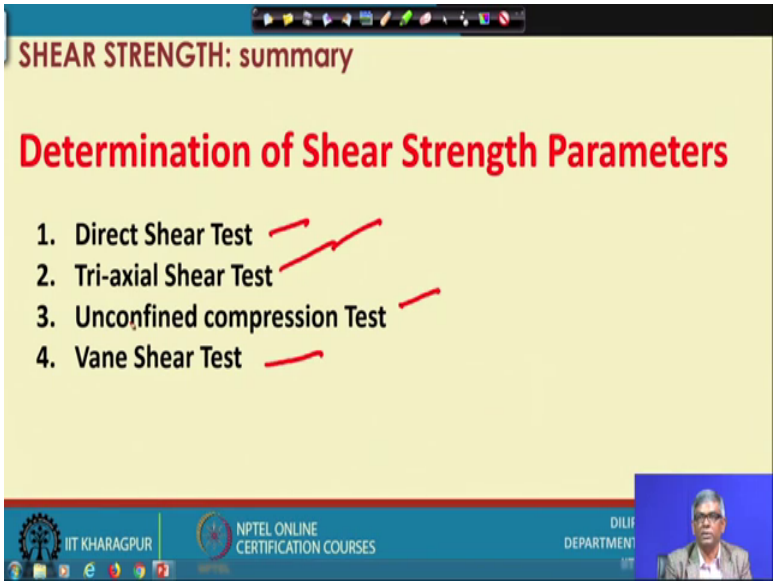

And for determination of shear strength parameters we have mentioned one second I am summarising there are 4 different method there are many other methods also, but it commonly in undergraduate level we cover these are the 4 things direct shear test, the triaxial test, unconfined compression vane shear test. And again triaxial test will have things that I will summarise in the next one and unconfined compression test and triaxial test only difference is that unconfined compression test there is a no self pressure is applied; that means, sample is unconfined.

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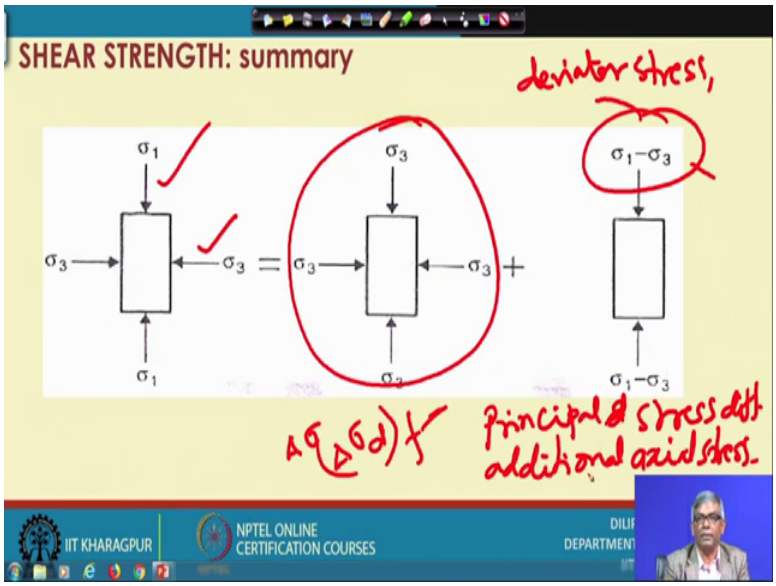

And your during the triaxial test we apply the confining stress and then we apply deviator stress and find out schematically stage wise how we do or finally, what we get some time we have to understand for that I have also brought this one here. You can see during the test this is the condition..

We have sample subjected to sigma 1 this side at failure and samples subjected to sigma 3 this direction this is the final form. But this final form is developed based on this initially we apply sigma 3 all around and then later on we apply sigma that is deviator stress sigma 1 minus sigma 3. So, this is called deviator stress and sometime this is called principal stress difference and that is called principal stress sorry stress difference sometime it is called additional axial stress.

So, any term is used. So, you to understand they are same and they are sometime that will be used as delta sigma sometime it will be delta sigma d like that and at failure of course, sometime it will be additionally f will be given. So, if this is the one schematically or symbolically given you have to understand that the second stage of shearing test in the during shearing whatever we apply this is this, these are all same.

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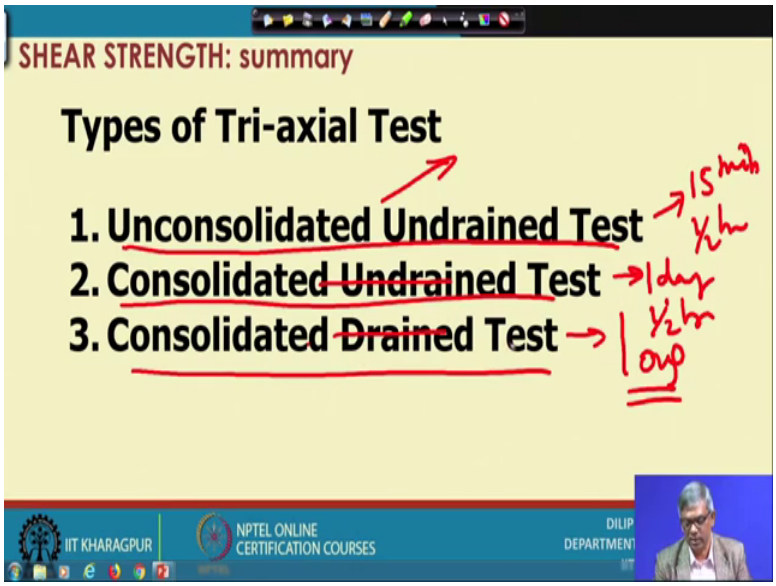

And as I have mentioned that triaxial test is a universal test you can simulate the actual field condition or close to the field condition and to do that we have several mechanism of test, one is unconsolidated undrained test, consolidated undrained test and consolidated drained test the 3 different test are there.

And unconsolidated undrained test actually we apply confining pressure immediately which I applying deviator stress with go to up to the failure and it takes very little time and we get from there only undrained shear strength Cu. Whereas consolidated undrained test initially by applying confining pressure we consolidate that sample and later on we shear by applying the additional axial load, but without draining and whereas, consolidated drain test we consolidate in similar way as it is done in the second one, but I in the second stage while shearing we also allow drainage. So, that in the during the test no never there will be any pore pressure.

So, this test actually it is a very it takes long time may be sometime week long. This test actually one day for consolidation and for shearing may be another half an hour, half an hour. So, all together this may be take this may take 15 minutes to half an hour. So, for routine work we do this, but for some important work we need to do either this or this, but this we do occasionally we do this one with additionally measurement of pore pressure during the shearing and that from there actually we can get the result of this drain test that detail I have shown once again I will show you how to do that.

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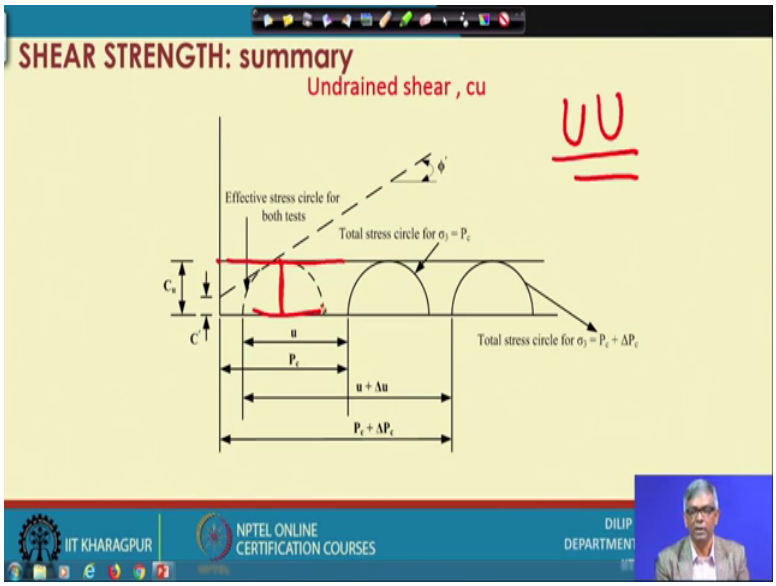

So, as this is also I have summarised that when you do undrained shear during UU test during sorry during UU test, during UU test on saturated sample we get a udrained shear strength independent of confining pressure; that means, if you measure the pore pressure also during shear. And if you finally, convert into convert into a effective stress circle you will get only one circle and the circle size also will be same and that is what it is shown here the shear strength envelop will be tangential to this so that means, this one will be the half the diameter and the diameter is nothing sigma 1 minus sigma 3. So, that can be, so that one can be obtained by this we have given before.

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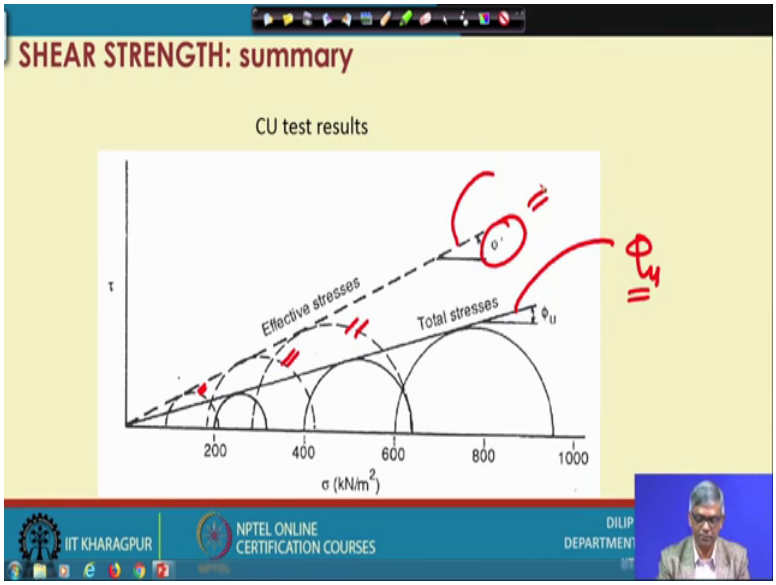

And for c u test if you do CU test consolidated drained test we can draw the circle here this and common tangent if you get you will get a phi u as I have it is mentioned. And I have also mentioned that CU test can be utilised as a CD test by the measurement of pore pressure during the shearing and if you measure the pore pressure additionally and finally, whatever confining pressure you applied and whatever confining pressure principal stress you have got at failure they are subtracted.

If the pore pressure is subtracted from that if that is the effective stress and those effective stress corresponding effect stress circle if you draw and from that circle if you draw a tangent we will get another envelope which will be stiffer than the earlier one and from there whatever angle will get that is actually effective stress friction angle so that means, CU test both total stress friction angle and effective stress friction angle we can get. So, this also we have discussed before once again I have highlighting here this is since it is important.

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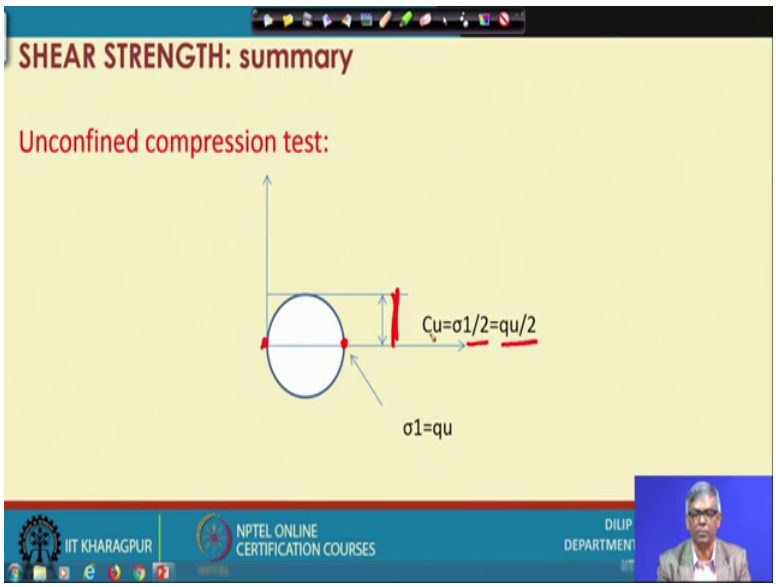

And for unconfined compression test as we have mentioned before that your sigma 3 is 0 and this is the qu and qu nothing, but sigma 1 and then if I want to find a your envelop will be horizontal and then; that means, at a distance of r. So, r is Cu equal to sigma 1 by 2 equal to qu bar. So, unconfined compression test sometime if it is unconfined compressive strength is given then from there we have to find out Cu undrained shear strength is just half of that.

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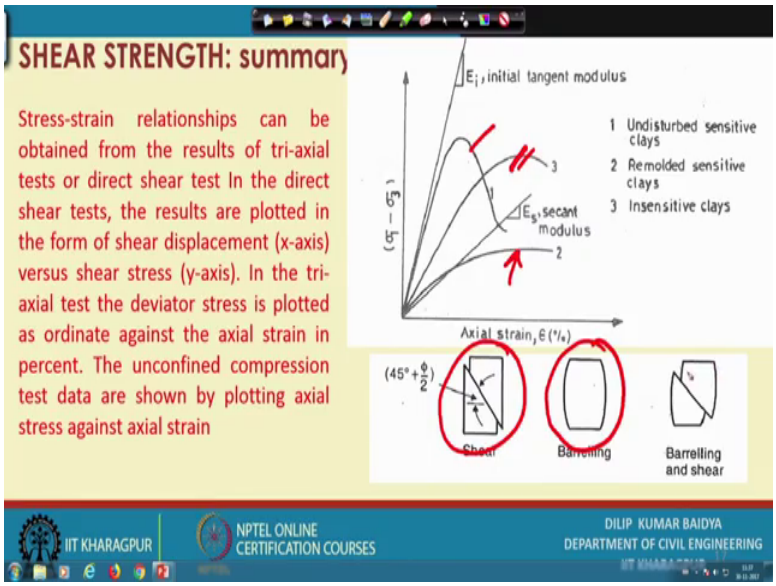

And different stress strain behaviour of different soil this is also we have explain and this one has to know, if sensitive clay sensitive clay without disturbance then this is the one and if it is a remolded same soil if it is remolded then we get a stress strain behaviour like that. And if it is insensitive clays normally that is non sensitive then we get a curve like this and during the shearing the soil can fail in different ways that is one way of failure that is shear prominent.

Shear plane it is so, and some soil without showing any prominent failure angle it will continuously decrease in length and increase in diameter, but to terminate the test generally we stop the test at around 15 to 20 percent strain level and some soil may fail both shearing and barrelling together. So, it will shear it prominent shear plane also will be seen also there will be some volume bulging also will be observed.

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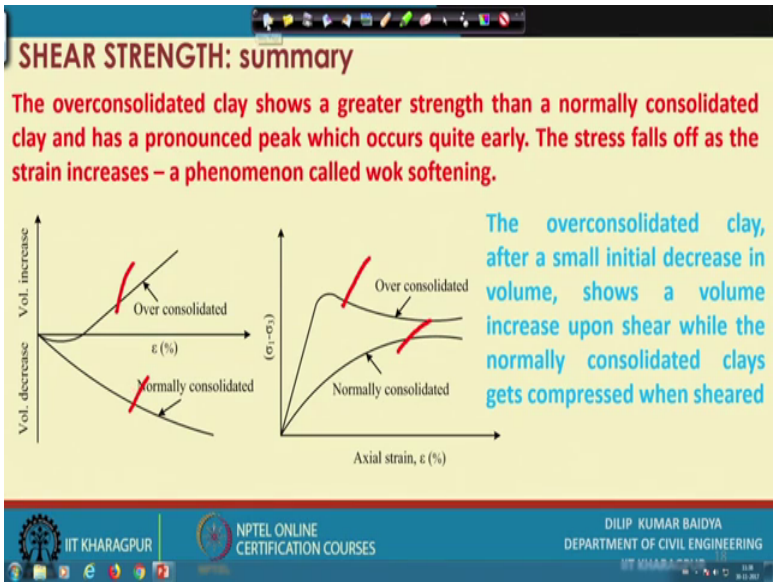

And this is also behaviour of normally consolidated over consolidated this is over consolidated, normally consolidated this is a volume change of over consolidated normally consolidated this is we have explained elaborately before. So, once again I am repeating or summarising this one here.

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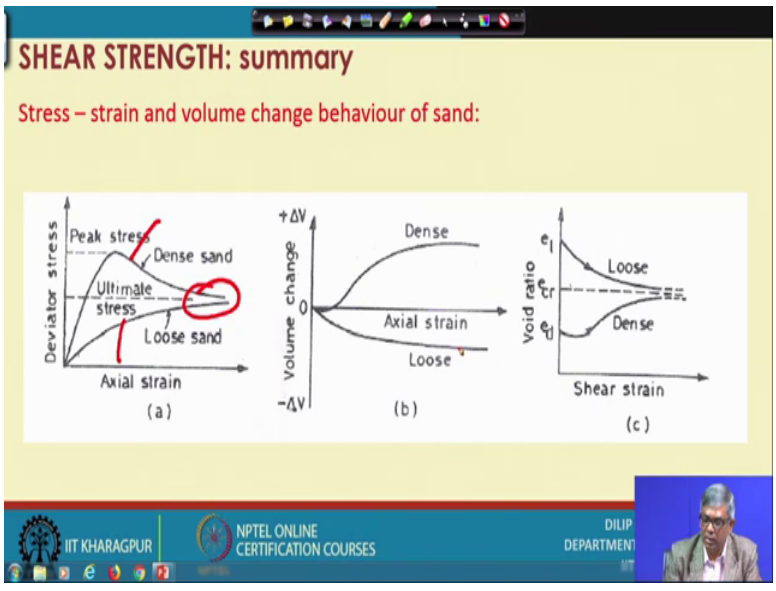

And this is actually again stress strain behaviour of the sand again if it loose or if it is a dense, dense is this, loose is this and this is the value both will reach at large strain value ultimate stress for both looser sand will be nearly equal. And for dense soil actually

generally volume increase will be there at a after certain strain rate whereas, loose sand will be continually decrease in volume and correspondingly we can find out what is the critical void ratio. So, critical void ratio as we have the, we can see if the from this diagram what we can conclude if the soil is having void ratio with greater than critical void ratio; that means, that is the soil is loose and during shear it will have a decrease in volume decrease in volume means sorry if the, so void ratio is large; that means, loose that void is large and then it will be continue volume is decrease means volume void ratio will be decreasing.

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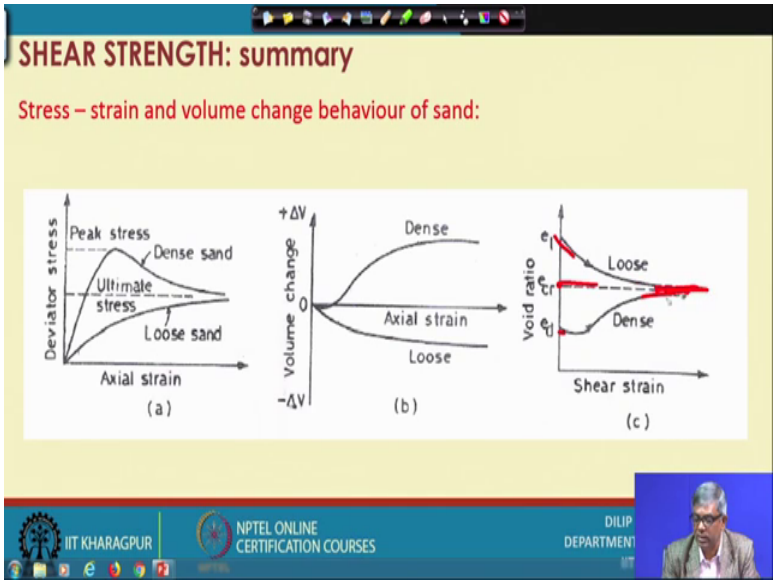

Whereas if the void ratio is lower than the critical void ratio; that means, void ratio it is less means it is dense, and when shearing its void ratio will be the volume change will take place the volume will increase and then that because of that your void ratio volume will decrease and because of that your void ratio will be increasing. So, finally, that it will reach to a constant value whether it is loose more than loose sorry more than critical or less than critical and if you increase the strain level both will come to a common value that is equal to critical void ratio.

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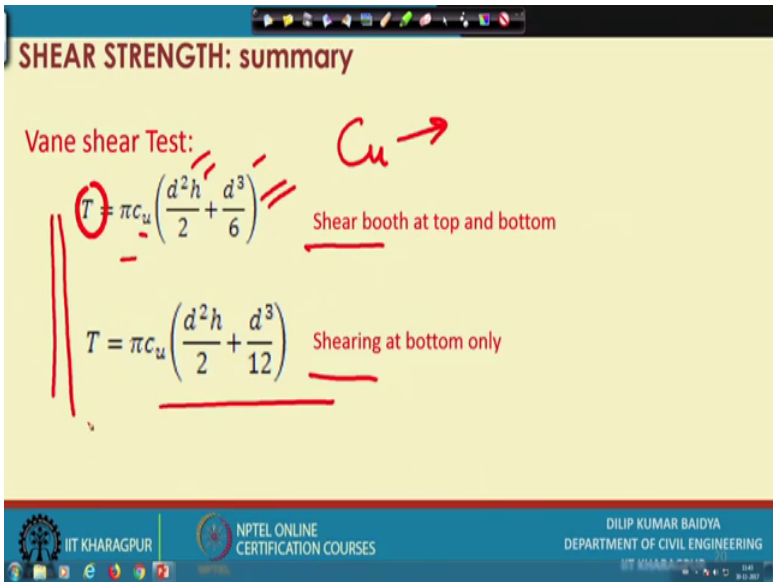

And finally, as I have mentioned that either normally consolidated or over consolidated or loose sand or dense sand we can do different test. For example, direct shear test is suitable for sand and for saturated sand and all can be done by either direct shear either triaxial or different triaxial test we can apply for both (Refer Time: 22:49) and cohesive soil. And unconfined compression test can be done for only saturated cohesive soil and we have also mentioned that in some soft sensitive soil sampling is difficult or maybe sampling can be done, but during this process and sampling process its effect it properties changes change significantly and those soil instead of doing sampling directly institute test can be done.

And one such institute test is a vane shear test and vane shear test that details I have shown before and there will be a four blades welded to the rod and then each between the two vanes there will be angle will be 90 degrees and that vane will be pushed inside the soil vertically and rotated by apply a torque. When the resisting torque of the soil will be same as the or applied torque is greater than the resisting torque of the soil is show the indicate the failure and show that from that condition we can actually find out the value of Cu. So, applied torque is this and in terms of Cu and the blade dimension we can express this from here I can find out Cu.

And similarly when we do vane shear test the resistance maybe they are from both top and bottom some time it may be only from bottom. So, if you consider only from top

only both from top and bottom than this expression can be used and if there is no resistance from the top only resistance at the bottom than this equation can be used. So, this is the vane shear test directly we can get the value of undrained shear strength of the soil.

So, by and large this that is all about shear strength. I think I will go to next topic maybe from the next lecture with this I conclude shear strength topics.

Thank you.