Geotechnical Engineering II / Foundation Engineering
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Lecture – 04
Quick Review of Soil Mechanics (Contd.)

Let me once again continue with Quick Review of Soil Mechanics that is part 4 now. And, under this I will try to highlight certain points on shear strength aspect of the soil, again we as I have told you that these are the things will be used again and again in the foundation engineering computation.

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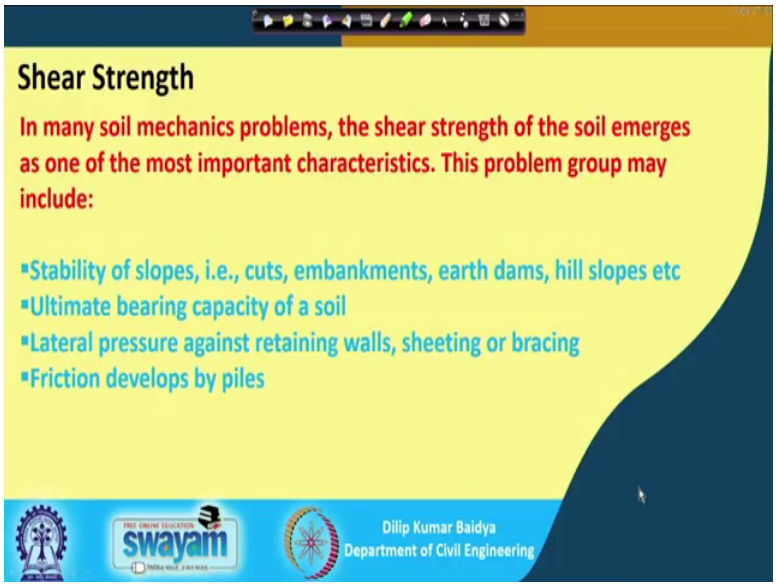

And so, let me take a few slides and what is a shear strength actually why it is important actually in many soil mechanics problem. The shear strength of the soil emerges as one of the most important characteristics.

And, those problems can be grouped like this you can see number of them, when you will study stability of slopes, or cuts, embankments, earth dams, hill slopes, or any other similar structure there be observe structure when will try to do stability analysis the shear strength become a very important. Then ultimate bearing capacity of soil; that means, when you put a foundation on the soil; then the soil will a foundation will give some pressure to the soil and soil will have a capacity, and beyond that if you put then foundation will going is going to fail.

So, that computation of ultimate bearing capacity also you need shear strength concept, then lateral pressure against retaining wall there also we need sheeting or bracing, friction develops by piles. So, you I have mentioned that there are 2 types of foundation; one is shallow foundation and deep foundation. So, pile is a one of the deep foundation type and there while calculating there are capacity and other thing there also we need very much this shear strength concept.

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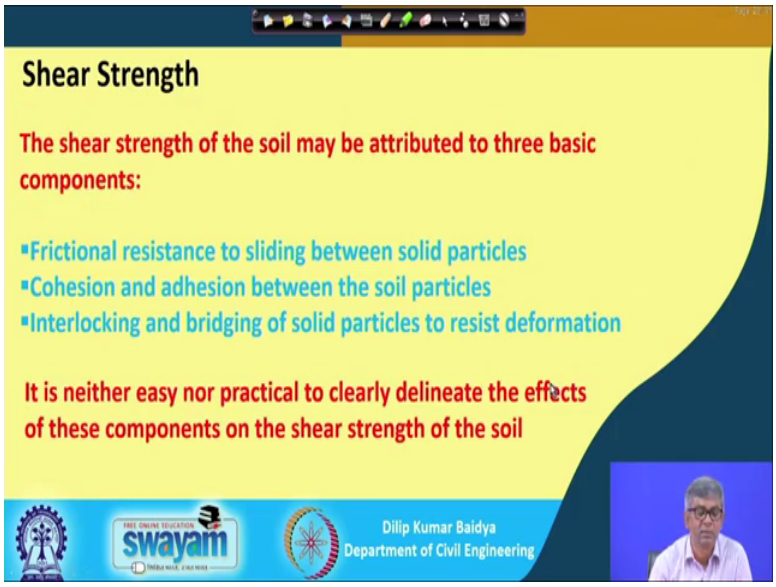

So, this with this then, but shear strength where from it comes, a shear strength actually of the soil maybe attributed 2 3 basic components. You can see their it is listed that frictional resistance to sliding between the solid particles, when the soils are granular particles, it can be fine it can be coarse those granular particle when moves from each other. Then there will be resistance when sliding between soil solid particle one solid particles, sliding over another and there will be resistance. And, cohesion and adhesion between the soil particle that is another source of resistance, a shear resistance. And interlocking and bridging of solid particles to resist deformation.

So, we load apply load then it will try to deform and then to resist deform that type of interlocking and bridging effect also will contribute some of amount of shear strength. But it is very difficult to differentiate that these 2 effects are separate these 2 components, of these components on the shear strength of the soil that will though I have mentioned the 3 components. Grossly this is this can be attributed, but very difficult to

find out that this is the because of these and this is because of these and this is because of that.

But, we have some mechanism which will discuss later on to estimate that oh sorry.

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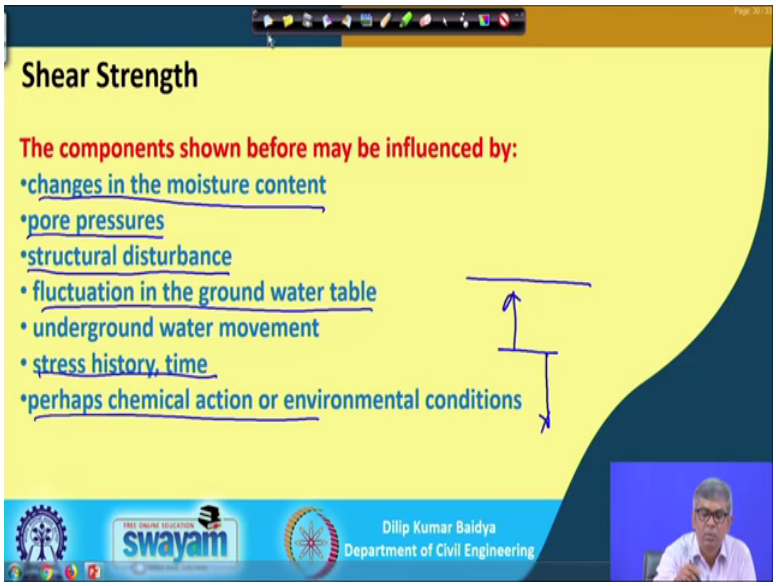

And, you can see that whatever things I have mentioned that frictional, then cohesion adhesion and bridging interlocking affect. They again depends on many or influenced by many things and they are listed here change in moisture content as I have told you the moisture content in the soil is very very important, a dry condition soil will behave something and if it is a totally wet then it will be a differently. So, that is why moisture content is another important and it will influence the shear strength of the pore pressure.

Pore pressure; that means, if we if we consider a soil mass at a great depth and water table is close to surface, the whatever pore pressure is there. And if another side if we consider the water table is quiet depth deep in that case pore pressure will be comparatively less. So, that is also there. So, that pore pressure if the pore pressure is more, than effective stress ultimately will be less and if pore pressure is less then effective stress will be more and that is actually that is the way it influence the shear strength.

The structural disturbance actually the there will be orientation of particles etcetera then fluctuation in the ground water table. So, as I have mentioned that if water table

originally was here if goes up pore pressure will increase and effective pressure will decrease. And, water table goes down that mean pore pressure will decrease and effective stress will increase. And, then the stress history that mean some soil will be stressed before and some soil may be deposited duly. So, because of that their shear resisting capacity will be different, then perhaps chemical action and environmental condition also another important factor which also can change the influence the effective stress.

But, we will not be able to quantify them, but we know they are they all influence the frictional a resistance a shear resistance of the soil.

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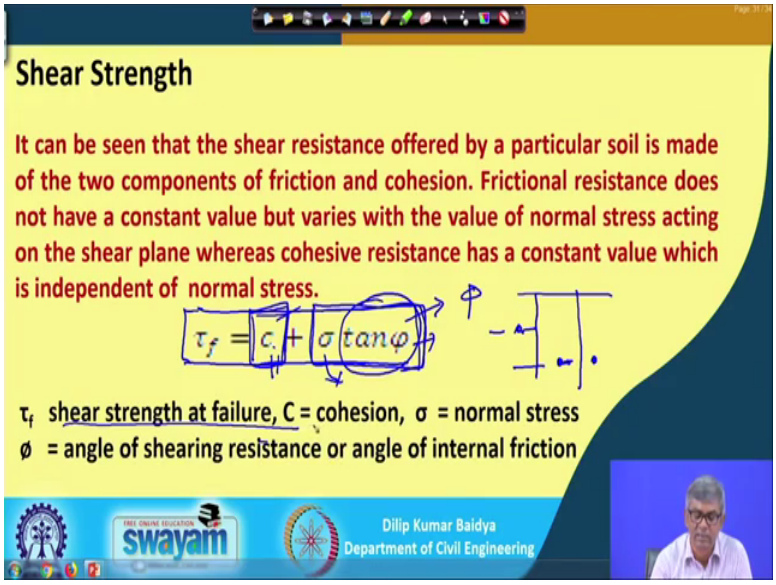

Now, grossly as I have told that we cannot quantify that 3 quantity we have mentioned, but finally, we have to do and there are theory developed and that shear strength of the soil finally, defined or given by an equation by there is a 2 component; one is cohesion component and another one is frictional component.

And, that the cohesion component is constant for the soil, whereas frictional component is variable; that mean it depends on you know how much normal stress acting on it the frictional resistance depend on it. So that means, if I consider a soil at one point here and another point here this point is shallow depth and this point is greater depth, that mean normal stress acting at this point is higher than this point as a result the frictional resistance will be at this point will be more than this point.

So, that is the sigma times tan phi is the frictional resistance; that means, sigma how it is varying because when you go deeper and deeper sigma of the soil is increasing, as a result the frictional resistance when you will go deeper and deeper will be increasing. So, this is the simplified very very simplified shear strength equation shear strength of the soil is C plus sigma tan phi and this is though a cohesion component and this is frictional component, but sigma we can calculate as I have mentioned previously the way we have mentioned and this another component called tan phi.

And, this tan phi and that the phi is actually frictional coefficient of friction internal friction and c is the cohesion of the soil, that mean the c and phi they are the 2 parameter. If, I collect the soil at this point then I have to find out c and phi of that depth. So, that I can use this equation and find out the shear strength at that point. So, tau f is the shear strength at failure that is a this equation is considered as failure condition, c is the cohesion and sigma is a normal stress at that depth considered and phi is the angle of shearing resistance or angle of internal friction.

So, this 2 C and phi, this c and this c and phi actually basically the shear strength parameter of the soil and that to be determine for assessing the shear strength. So, this is actually written in terms of total stress, but as we have mentioned that most of the time in fact, in practical we do always in terms of effective stress.

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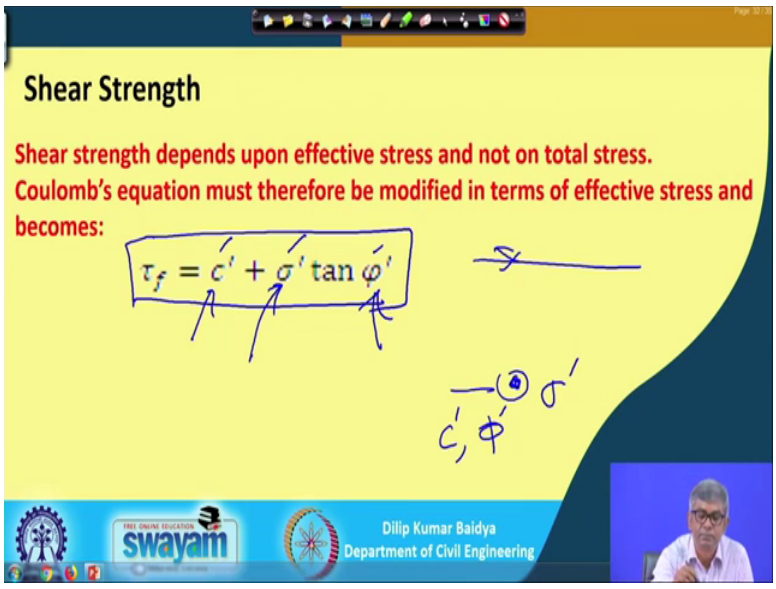

And, if you write the shear strength equation in terms of effective stress thus equation will be almost same only the c will be by c prime and sigma dash will be sigma will be replaced by sigma dash or sigma prime and phi will be replaced by phi prime; that means, this is the effective friction angle, effective cohesion and if this is the effective stress.

When you will consider effective stress concept, then this is the equation. They are actually effective cohesion you have to use, effective normal stress you have to take and effective friction angle ok. So that means, if I have a ground here and soil water table is here, and if I consider water table is here, then if I want to find out at this point shear strength, then I will find out what is the C value, what is the phi value both in this form and then I will find out at this point what is the sigma dash? Then I will put in this equation to get the effective shear strength.

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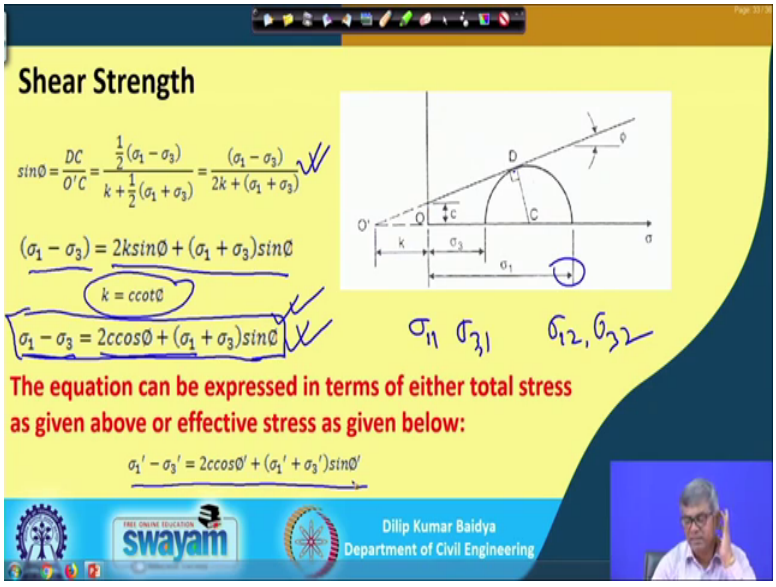

And, this is of course, in soil mechanics is a very basic actually how the failure envelope of the soil looks like; there can be failure envelope generally you will be having an intercept here.

And, there will be tangential to that mean you can draw the Mohr circle and then it will be if you draw a tangent to a Mohr circle then there will be intercept here sorry, and you all um this is the way and Mohr circle actually when you will conduct the test; there will be sigma 1 will be sigma 3 will be applied and sigma 1 will be at failure to you consider

are calculated. And, based on sigma 1 and sigma 3 we can draw them envelope and then like that if I know the failure envelope and then I can draw tangent to that. And, then we have the sigma 1 sigma 3 and C and phi this is the failure envelope; that means, the angle is the phi.

And, this intercept is C and if I consider this triangle and from these actually sin phi can be expressed by D C by O dash C and then simplifying these I can reach this equation. And finally, I can get sigma 1 minus sigma 3 equal to this form and k can be substituted by c cot phi, and then sigma 1 sigma 3 will be will be a equation we can get by this. That mean sigma 1 minus, sigma 3 will be equal to 2 c cos phi plus sigma 1 plus sigma 3 sin phi; that mean this is the relationship between principal stresses and phi and C there will be 2 unknown actually we have C and phi.

And, then if you carry out test with 2 values of sigma 1 and sigma 3 and then I can form 2 equation. Suppose I conducted a test with sigma 1 and sigma 3, sigma 1 and sigma 3 1, and sigma similarly sigma 1 2 and sigma 3 2; then based on these I can set 2 equation in terms of unknown C and phi. Then finally, by solving them I can find out the c and phi. This is the equation well known equation relationship between phi and cohesion and a major and minor principal stresses. And this will be frequently used for finding out C and phi if you know the normal principal stresses.

And, this is actually in terms of total stress, but if you same thing if you write in terms of effective stress the equation will be same only sigma 1 will be replaced by sigma 1 dash sigma 3 will be replaced by sigma 3 dash and like that and phi will be replaced by phi dash.

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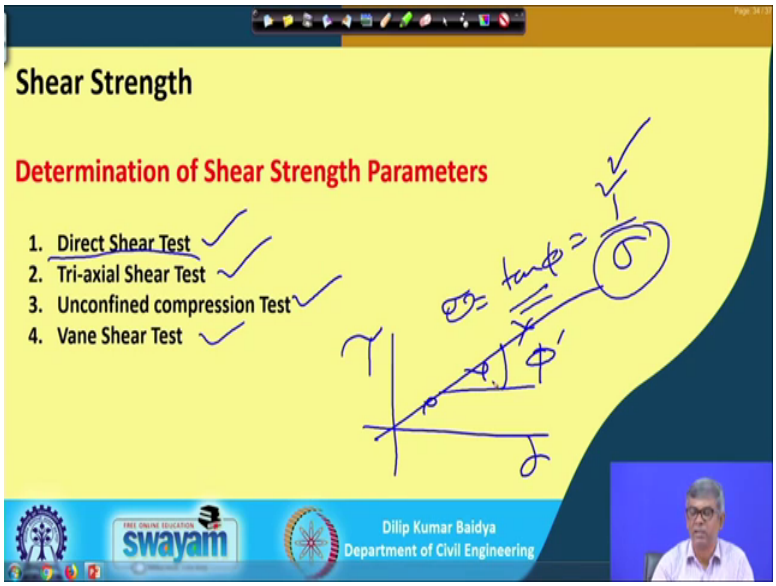

Now, this as I have mentioned that C and phi are the shear strength parameter and this you have to find out and there are number of methods to find out there is a direct shear test, there is a tri axial test, there is a unconfined compression test. And there is a vane shear test and direct shear test actually we make in a box actually it can be divided into 2 halves in between inside that you will make a soil sample and the 2 parts of the box we try to slight by force.

So; that means, in a predefined failure plane we try to fill the soil and based on that we particular normal stress we apply and then horizontal stress. And we find out what is the failure load and from there we can find out what is the shear stress and what is the normal stress and your sigma equal to or tan phi equal to tau by sigma. So that means, I will apply horizontal force and that horizontal force from the horizontal force are failure divide by the cross sectional area give you the shear stress.

And, whatever load you have applied that load divided by cross sectional area of the sample will give you sigma and then tau phi will be nothing, but tau by sigma. So, that is the direct shear test apparatus we used and that is the way we calculate by of course, we can do by one test we can find out phi, but since the test may not be that accurate and there maybe some experimental problem we try to do 3 4 test. And finally, if we plot tau versus sigma like these points are coming like this. And finally, you join them and then after joining this find out the slope of this suppose this is phi that is the friction angle of

the soil. And, most of the time shear strength direct shear test is carried out for a dry sand and so, dry sand will have only phi and that can be easily obtained by this way.

Similarly, there is a tri axial test tri axial test means actually here all 3 dimension actually pressure will be applied and this is actually actual field emission can be simulated in the test. And so, there is a apparatus where we can put the sample first and then you can apply a confining pressure, and then applying a normal pressure or we can increase the normal pressure till the sample fails. And, based on that we can find out 2 2 normal 2 principal stresses at failure and number of test we can carry out. And finally, we can draw number of Mohr circle based on that and draw drawing the common tangent to those Mohr envelope we can find out the soil parameter of the soil.

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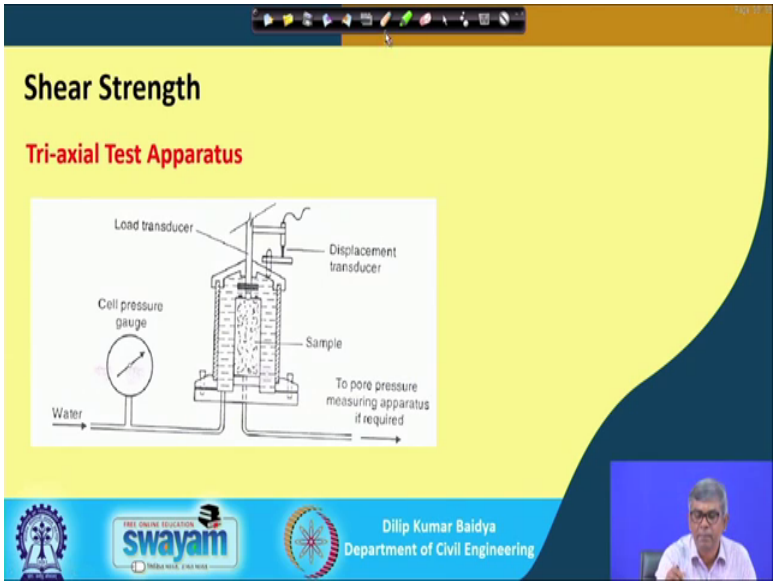

So, typically this is your the tri axial apparatus is like that you can see here, this is the a soil sample and this will be kept in a chamber and this in this chamber. And, then you can apply through water you can put all round pressure here. And, then when water pressure is applied then all valve can be closed and then you can apply normal load through this where by which we can apply some normal stress and we can go up to the failure. And of course, this is a very generalized type of test apparatus or you can different condition we can simulate, undrained condition you can test, drained condition you can test and there can be also consolidated or unconsolidated also you can test.

So, different type of test can be carried out and by enlarge the procedure is you have to fist apply a all round pressure. And then under that pressure you have to apply additional pressure to fill the soil sample. So, that is the by enlarge a brief a schematic of the tri axial apparatus.

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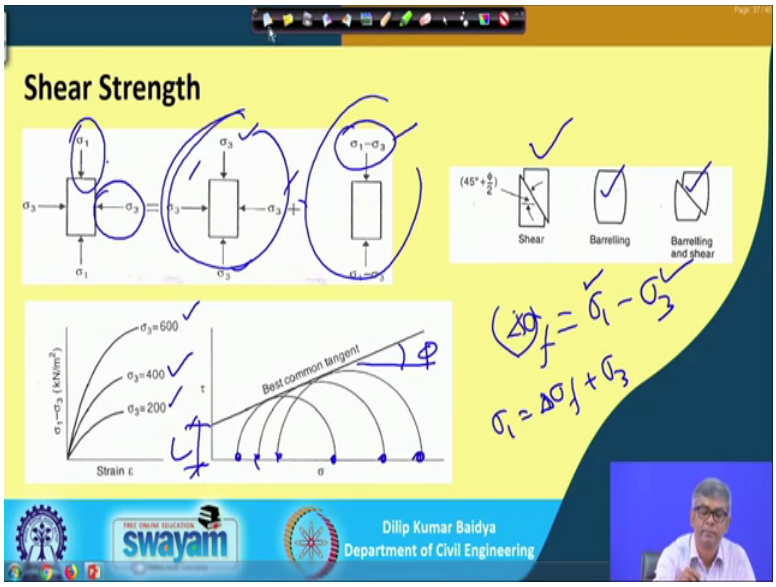

And, this is the as I have mentioned you can see from this procedure you can see during test, when we apply normal stress the at failure suppose this is sigma 1 and sigma 3 you have applied, but this will be actually consist of 2 parts actually initially you have applied sigma 3 all direction. And, then later on you have applied sigma 1 minus sigma 3 this is called deviator stress or principal stress difference.

Sigma 1 minus whatever we are applied applying that is actually sigma 1 minus sigma 3. So, these 2 together actually you apply first this and then this and these 2 together result this and this under this condition we achieve the failure. And, like that different sigma value we can sigma 3 value we can apply. So, somehow sigma 3 is 200, then stress strain curve you can stress versus deviator stress we can strain versus deviator stress we can plot. Similarly, applying sigma 3 400 another graph you can plot sigma 3 actually 600 another plot we can get.

And, from here we can find out the sigma 1 and sigma 3 at failure that the principal that is that is called delta sigma at failure. We can find out and from there since delta sigma f is known that is nothing, but sigma one minus sigma 3 and sigma 3 is known. So, sigma

1 can be calculated sigma 1 would be delta sigma f plus sigma 3. So; that means, sigma 1 sigma 3 at the beginning known and then you have you have got sigma 1 at failure. So, that mean sigma 1 and sigma 3 you get suppose first set of test sigma 1 and this is sigma 3, second set of test sigma 1 and this is sigma 3.

Third set of test this is sigma 1 and sigma 3, we get all 3 circle and then you know the that the same soil that mean failure will made up will be same so; that means, their envelope will be tangential to the all the 3 circle, but during test you hardly get this similar this circle that it will be tangibly commoner it will be common tangent will be and will be there. So, what will do by approximately you have to draw the common tangent, it may not be tangent ideally, but to get a best fit result you have to draw a common tangent by eye estimation and after doing that from this slope we can get the phi and from this intercept we can get the value of C.

So, this is the tri axial test procedure by which we can get the soil parameters C and phi and again the different condition as I have mentioned that drained condition, undrained conditions. Of course, a drained condition parameter is a more effective and, but it takes long time sometime undrained condition with pore pressure measurement we can do also.

So, those are the things actually the part of soil mechanics in details we have discussed, but as just I have given you that some highlight about the tri axial test are not go beyond that. And, during the test actually soil may fail like this that is called shear failure, the soil may continuously, shorten that is and then this is called bulging, and it will shorting, and in elongating in the lateral direction that is called bulging.

And, sometimes simultaneously bulging and shear may take place and that is the another type of failure.

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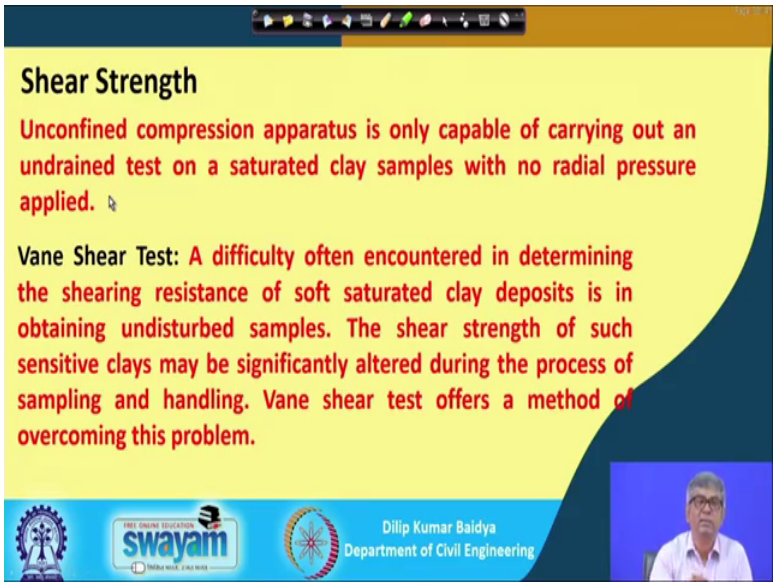

And, then there is another test actually unconfined compression test. Unconfined compression test also almost similar only difference is that sample will be prepared the same dimensions are same only thing is there will be all round pressure will not be there. Only after fixing the sample we will put directly normal stress and based on that normal stress soil will fail. And, this type of test will be carried out for only carrying out the undrained undrained test of saturated soil.

So, quickly if I want to find out undrained test of undrained strength of the saturated soil, we can carry out by unconfined compression test. And, there is a another test that I have listed that is vane shear test, that is actually some of the soil as I have mentioned that whatever direct shear test, or tri axial test, or unconfined compression test, there actually you have to collect the sample prepare the sample and get the test done in the laboratory.

And, some there are some soil where actually if the so, sensitive that we cannot sample it. Or if you sample it during sampling procedure it get disturbed and as a result, during laboratory test whatever result will be getting that results will not be truly representative.

So, as a result those type of soil sometime we carry out some in situ test and that is the one vane shear test one such in situ test there is a there are a 2 vanes put perpendicular to each other rectangular vanes perpendicular to each other, and they connected to a rod and that vane will be puts inside the soil, and then the vane will be rotated by a torque. And, vane actually the initially because of the resistance of the soil that it will take some

amount of torque, but at when the resistance when the applied torque will be becoming more than the resisting torque of the soil then soil will indicate the failure.

And, based on that we can find out the shear strength parameter of the soil; so, that is the one I can show you in the next slide you can see this.

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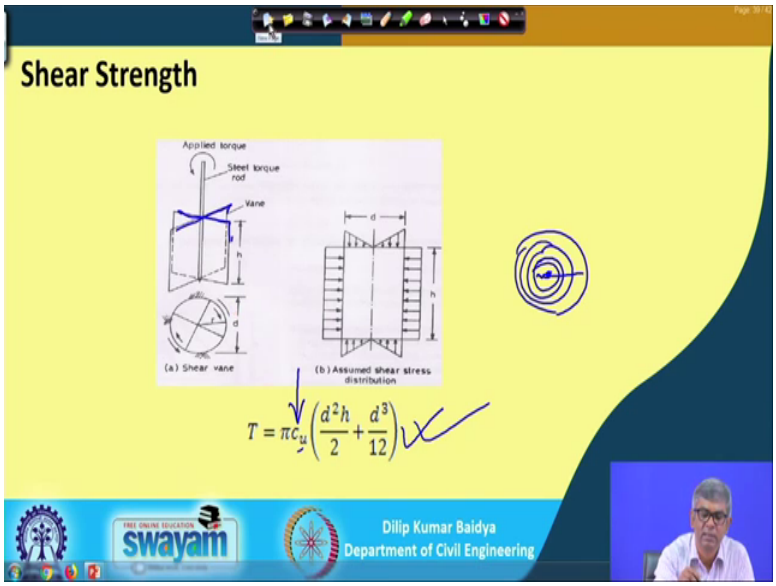

The vane actually looks like this there are 2 rectangular part you can see this is one rectangular part, this one and this is another rectangular part, and they have definite dimension with this rod and with this rod torque will be applied. And, then when you do this the shear resistance will be from the base and at the vertical cylindrical surface 2 places and also at the top. Sometime, if it is not deep enough resistance at a top will be ignored and if suppose the resistance from here, and whatever resistance is there like this like this different resisting stress is there, if I take moment at this point that will get the resisting torque around the torque from the soil.

And, then again and the full of vertical surface there will be some stress is acting resisting stress, that if you again take the moment with respect to stress that is another resisting torque. This 2 resisting torque if you compared with the resisting torque applied through this and then simplified then you will get this equation, that T equal to pi c u d square h by 2 plus d cube by 12. There actually c u is the undrained shear strength of the soil of the soft soil, and d and h actually dimension of the vane.

So, by this way quickly also you can find out the shear strength of the soil for sensitive soil. That is actually very very important sometime you ask question that where the vane shear test is suitable and etcetera and sometime how to find actually then that mechanism also you have to explain. So, this is again we have is a part of soil mechanics, but determination of shear strength. So, on say because of that I have again put it together quickly.

With this by and large I have completed shear strength aspect; next aspect will be compressibility. I will take one more session on this quick review of soil mechanics. That is all today.

Thank you.