Foundation Engineering
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Lecture - 03
Shear Strength

In today I will start the third lecture, which is on Shear Strength of soil. So, this shear strength of soil is very important for load carrying capacity calculation of foundation. So, the two major parameters that is cohesion and friction angle of the soil, these will be required for bearing capacity calculation.

So, now in this shear strength, I will discuss that; what are the tests by which we can determine; these two shear strength parameters, cohesion and the friction through laboratory.

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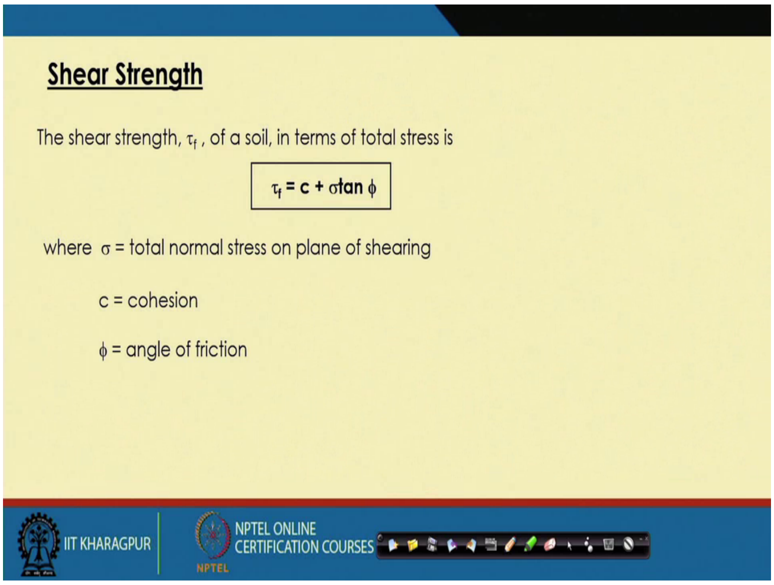

So, first we should know that, what is shear strength of a soil. So, the shear strength of a soil is can be represented by cohesion plus sigma n tan phi. So, this is the is a sigma n, this is sigma n which is the applied normal stress on the soil.

So, here the sigma is the total normal stress on the plane of shearing, c is the cohesion and phi is the angle of friction. Now, this a shear strength expression is in terms of total stress similarly, in terms of effective stress also.

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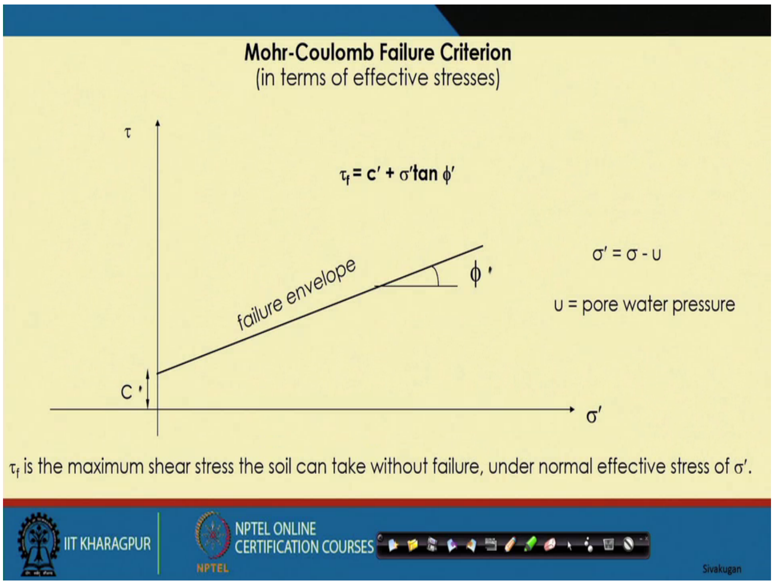

We can write thus similar type of expression, which is c prime plus sigma dash, tan phi dash. Here these is sigma dash or sometimes it is written as sigma bar is the total stress minus pore water pressure.

So, here the this shear strain is written in terms of effective stress. So, in my second lecture, I have already discuss what is the effective stress. So, as I mentioned that when we apply the stress a load on a soil. So, these stresses are transmitted through contact between soil particles and through the water.

So, the stresses which is transmitted through the contact between two by between the soil particles or is termed as the effective stress, and the stresses which is transmitted to the water because water is a incompressible material. So, so that is why the if the stress is transferred into the water. So, pressure is developed. So, that is called pore water pressure.

So, the total stress, we can write as a effective stress plus the pore water pressure or effective stress will be the total stress minus the pore water pressure. So, these effective stress in terms of effective stress also, we can write the shear strength parameter and that is the shear strength is c dash here, c dash is the cohesion it is effective cohesion and this phi dash is the effective friction.

So, similarly this is the Mohr coulomb envelop or the failure envelope, where this angle is this envelope phi and these angle c is the cohesion of the soil and this axis is sigma is the normal stress and y axis is the tau is the shear stress. Now in this lecture I will discuss, how this failure envelop is determine; So, by that test.

So, in this part we will discuss the stress and how we are getting these Mohr circle and from this Mohr circle, how we are getting this failure envelop and from this failure envelope, how we are getting the c and phi. So, these things will be discussed in this lecture. Now so, this is similar the failure envelop in terms of effective stress.

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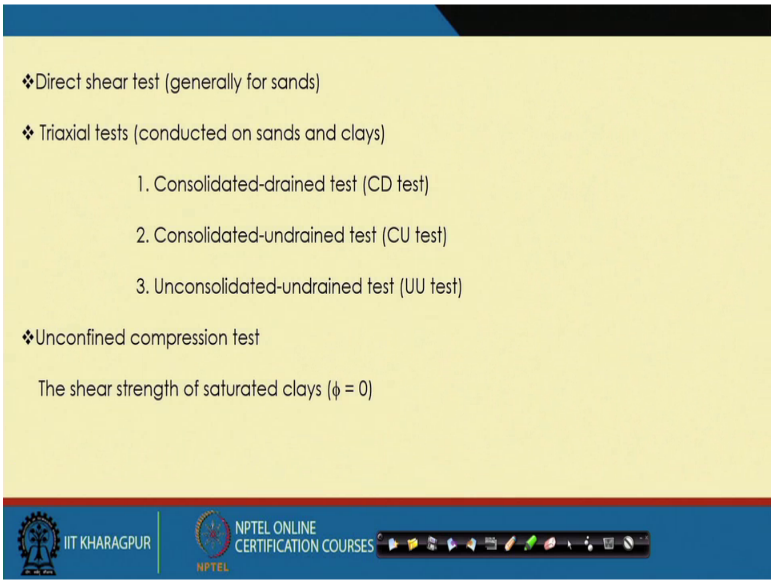

So, now the tests what are the test we can conduct to determine these two parameter c and phi. So, this test are direct shear test, generally is for sands, then triaxial tests conducted on sand and clays both and the unconfined compressive strength, the c is generally conducted for clay soil. So, the strength for the unconfined compressive strength test the shear strength of a saturated clay where we assume that phi value is equal to 0.

So, now in the triaxial test we have 3 triaxial test that is consolidated drained test, consolidated undrained test and consolidated unconsolidated undrained test. So, these are term as CD CU UU because C is for consolidated. So, there is a C means consolidated C and drained d and similarly CU consolidated undrained u similarly u is U unconsolidated and undrained.

Now, when you explain above the triaxial test; so, you will find that there are two stages of loading, one is the consolidation another is the drainage. So, when we apply first initially we apply the all-round pressure or a water pressure around the soil sample, and then we allow this soil to consolidate. And that is whether we it allow the consolidation or not depending upon that, whether it is a consolidated or unconsolidated test so, we can determine based on that. In the next stage we apply the load or deviatoric test where also we control the drainage.

Now, depending on that whether we allow the drainage or not we can say that it is drained or undrained. So, that in this way we can conduct three types of tests and in the next one is the unconfined compressive strength test. So, where we do not apply any well down pressure ok, here sigma 3 value is 0 we generally the pressure which is we are applying throughout the around the soil by water is term as a sigma 3.

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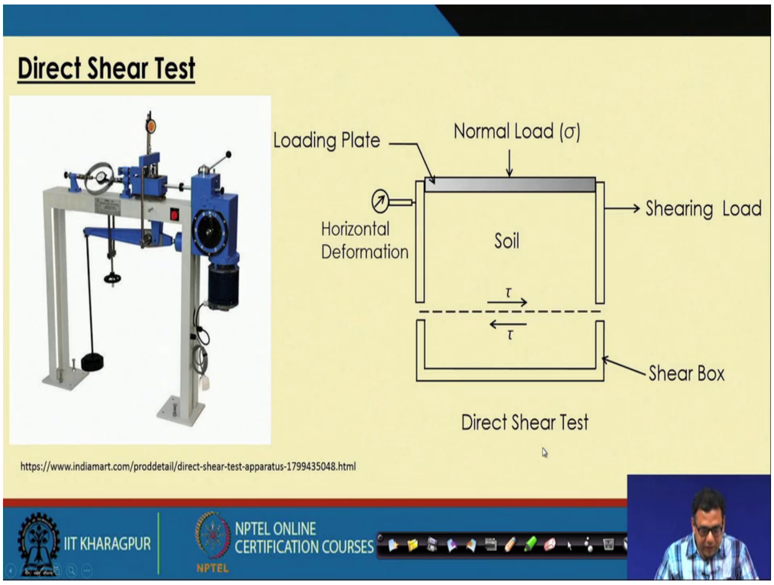

So, now so, this is the first test this is the direct shear test. So, in the direct shear test we have a direct shear test box, where it has two halves. So, it is basically a horizontal load is applied. So, we apply a shearing on in the soil sample.

So, here the this is the failure plane or the shear plane. So, we can say in this test that that failure plane is predetermined. So, this is the failure plane by which the soil will shear. So, we apply the shearing load and we also apply the normal load. So, here under different normal load, we apply the shearing and then we determine the what is the shear stress for different conditions. So, here you can see in this figure. So, this is the normal load we are applying and here this is this is the shears or horizontal stress, we are applying and we are measuring this horizontal stress by this providing and we are applying the dial gauges, which also measure the horizontal deformation as well as the vertical deformation of the sample.

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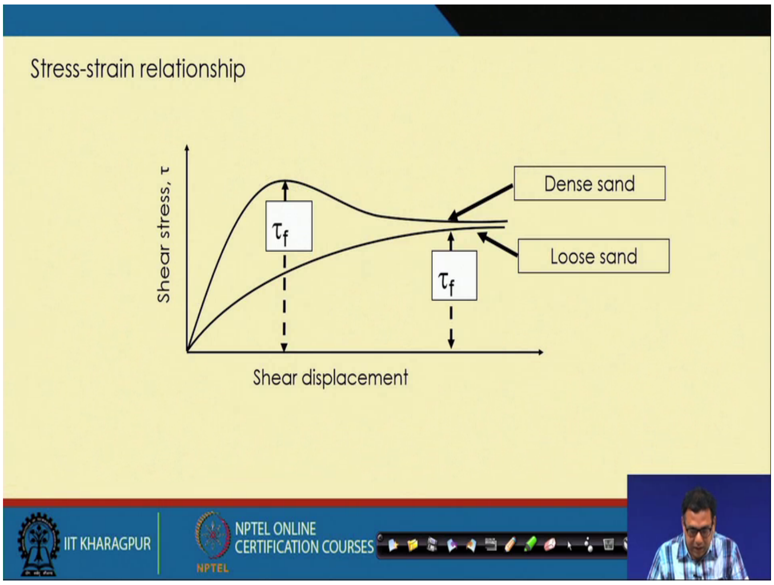

So, that after completion of the test, we will get a shear stress shear displacement relationship. So, this is the shear stress and shear displacement relationship for two different types of soil, one is dense sand another is loose sand. You can see in the dense sand we can get a peak value. So, we will get a failure load or in a peak load and here for the loose sand, we will not get any peak value. So, the stress will increase as we increases the displacement and finally, the both the curve will close to each other after some displacement.

So, these zone this strength of the soil is called the residual strength and this is the peak value of the ah peak load, that this dense sand is subjected. So, this is the typical loose sand and dense sand curves stress shear stress versus shear displacement curve.

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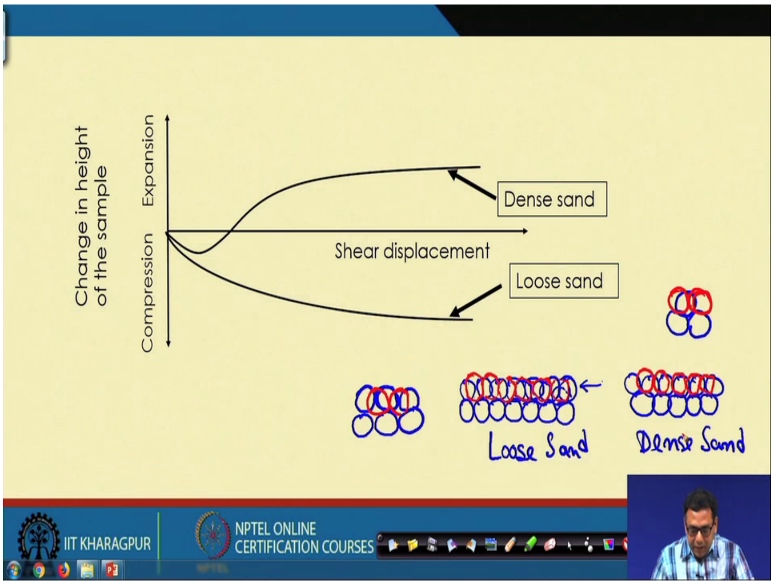

Similarly, if I as I mentioned that in this test also, we can measure the vertical deformation of the soil sample.

So, change in height of the soil sample. So, if it is compression then it is downward and if it is extension it is in the upward. So, here this is also typical change in height of the sample and the shear resistance of the shear deformed displacement of the typical curve for loose sand and dense sand. So, for the dense sand we can see initially there is a compression and then the sample there is a expansion and for the loose sand it is always the compression.

So, which means that, we can say that when we apply the shearing; So, for the dense sand initially the volume of the soil is decreased and after that the volume of the soil increases; and for the loose sand the volume of the soil always decreases as we apply the shearing. So, this is the one of the reasons is that, if it is a supposed loose sand. So, this is the soil particles and for the loose sand. So, this is for the and similarly the particle arrangement for the dense sand similar to this is the dense sand.

Now, when the shearing is applied here; So, what will happen as it is expected for the for the loose sand, the amount of void is more compared to the dense sand. You can see that in the dense sand the argument of the particle uses, that the amount of void within the particles is less. So, when we apply the shearing what will happen? These grain particles now with roll over this particle and it will now move to this position. And this one will move to this position and also this one will move to this position or if I take a different color. So, this rate is the new position of the particles after shearing.

Similarly, for the dense sand the new position of the particles will be like this. So that means, that because of the shearing these dense loosen sand become dense or that is why the because the here amount of void decreases and that is why the always the volume decreases. But for the dense sand initially the this dense sand become further dense and that is why the volume of the soil decreases, but after that it will this volume increases because the orientation changes in such that the voids between the soil also increases.

So, that is why this is the if I typically say that for the for the loose sand. So, this is the initial orientation, and for the dense sand this is the typical orientation. So, after shearing. So, it will be like this and here it will be like this. So, the voids in between the particles will increase due to the shearing in case of dense sand, and it will decrease in case of loose sand due to the shearing.

So, this is a very important thing and these things we will be discussing later on, when you discuss about some SPT correction things.

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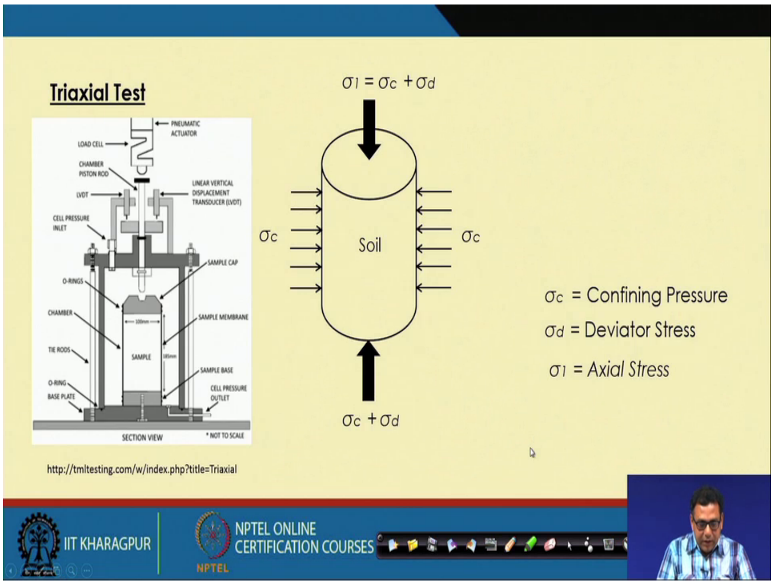

So, next one is the triaxial test, here as I mentioned that here we will apply a sigma 3 or sigma c which is confining pressure. So, here this is a triaxial sample, generally the standard size of the triaxial sample that we use is 76 millimeter height and 38 millimeter diameter. And this is sample this is the sample, where this is a membrane and this is the water where these through these water we applied the sigma 3 value and we allow the soil to consolidated and then a next stage we apply the load and so, that is this is the deviatoric deviatoric stress. So, we applied.

So, deviatoric stress is nothing, but sigma one which is axial stress, minus sigma 3 or sigma c which is the confining pressure.

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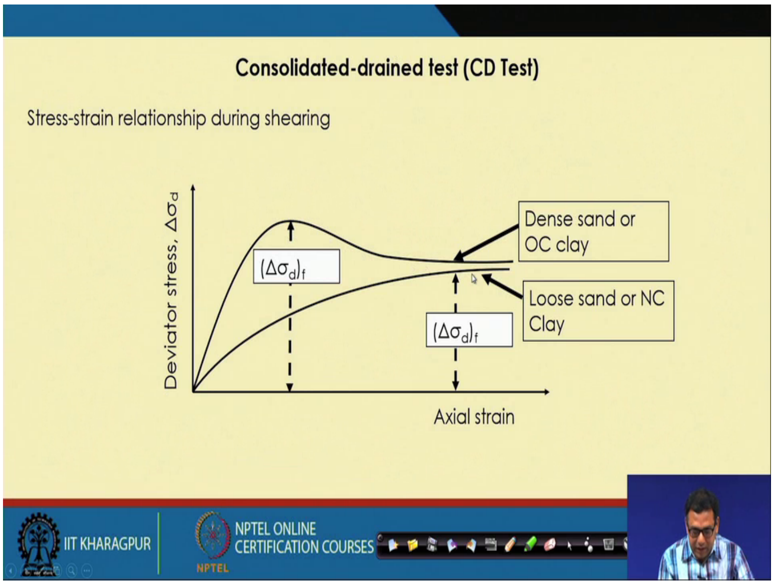

Similarly, for the like dense sand and loose sand in the triaxial test also, we will get the dense sand or over consolidated clay and we have the loose sand and normally consolidated at clay. I have already discuss about the over consolidated clay and the normally consolidated clay, that if the present apply stress on a soil is less than a previously experienced maximum stress of the soil, then the soil is treated as over consolidated soil and if the present apply stress on a soil is equal to or greater than the maximum stress, that soil is experience, then the soil is called as a normally consolidated clay.

So, for the normally consolidated clay, the stress strains behavior is similar to loose sand where for the over consolidated clay the similar to the dense sand that I had already explained. Similar to the volume change, here also in the triaxial sample we can measure the volume change and in the volume change also the work consolidated clay, which is similar to the dense sand a normally consolidated clay which is similar to the loose sand.

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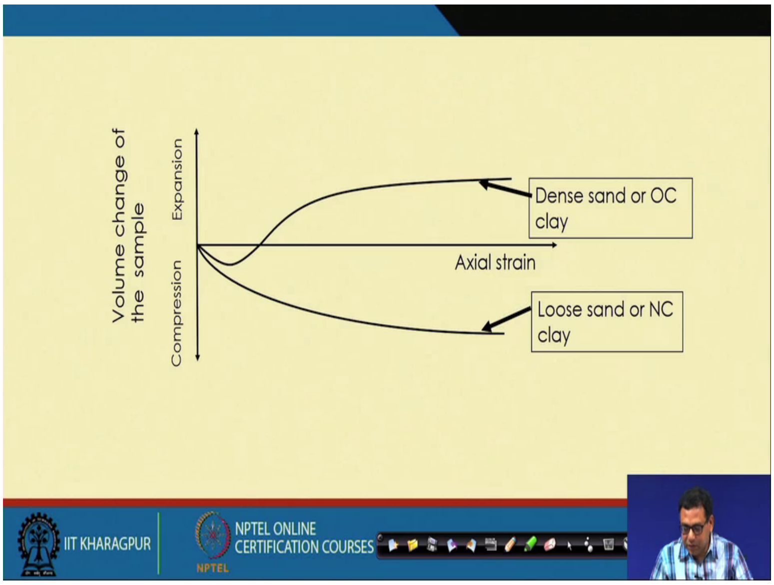

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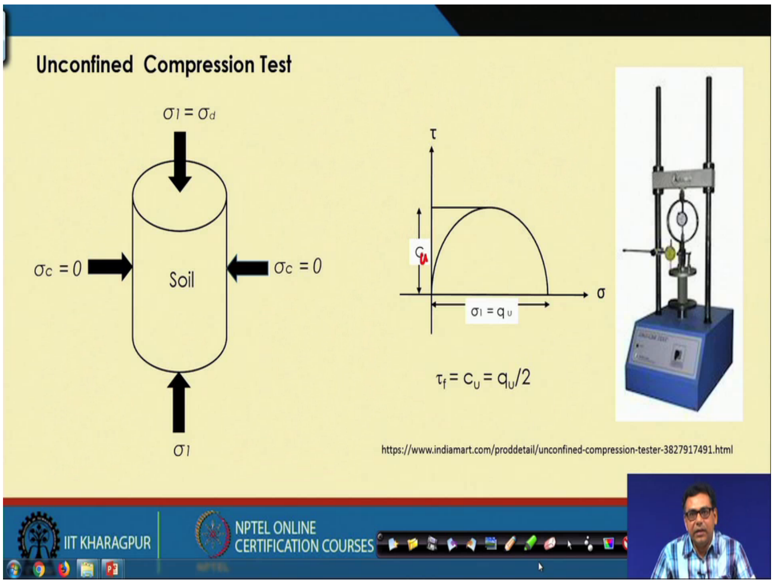

The next one that we are talking about is the unconfined compressive compression test. The major difference between the unconfined compression test and the triaxial test, that in the triaxial test we are applying a sigma 3 or sigma c that mean the all down pressure around the soil through the water. But here sigma 3 or sigma c value is 0, we are not applying if you look at this sample here we are not applying any stress around the soil we are not applying any pressure.

So, here only sample we are applying the load, all and that that load is measured by the proving ring and deformation is measured by the this dial gauges. So, now, the that is why in a sigma c value is 0, if the sigma c value is 0. So, the deviatoric stress will be equal to the sigma 1 or the axial stress. So, now, if I draw the Mohr circle; So, this is the sigma and the sigma axis x axis is the sigma axis and the y axis is the trowel axis.

So, as the sigma 3 value is 0. So, the Mohr circle will start with 0 0 and this value is sigma 1. So, that is why we can write the undrained cohesion of the soil is equal to the unconfined compressive strength of the soil divided by 2. Because this is the C or Cu Cu and sigma 1 is equal to q u. So, this is q u is the unconfined compressive strength. So, the value the strength that will get we have to divide it by 2 to get the undrained cohesion of the soil.

So, with this I am finishing this lecture 3 and in the next lecture 4, I will start the soil exploration part.

Thank you.