Soil Mechanics/Geotechnical Engineering I
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Lecture – 32
Shear Strength (Contd.)

Good morning friends, once again, I will come you to this lecture series soil mechanics and the last few lectures I devoted on shear strength and very preliminary information I have given, and also I have discussed about the different test, which we can you carry out in the laboratory to find out the strength parameter of the soil, and they are basically direct shear, triaxial and unconfined compression test. And the way we have discussed, we know that different soil will have different behaviour, and whatever test I have discussed they may be suitable for some case and very routine work we use them.

But actually when we apply additional load to a soil and particularly when it is saturated then pore pressure develops, and that pore pressure sometime it will dissipate over time and some soil dissipation of professional will be quicker like sand, and some soil is distribution is very slow. So, as a result shearing mechanism also will be different when we apply confining pressure and apply additional load to share it, then mechanism also be different. And in fact in the field or in real application those are important; because particularly this suppose loading, it will apply it suddenly and it may not give enough time to dissipate.

So, you have to sometime find out undrained condition, before dissipation of pore pressure we need to know; what is the shear strength. So, that is the way actually there are many other complexities. So, to address those things we generally the triaxial test has I have mentioned before, that is a very universal type of test and we can simulate different types of field condition. So, this triaxial test itself we can classify into 3 different categories, and to address those are the points what I have highlighted just now.

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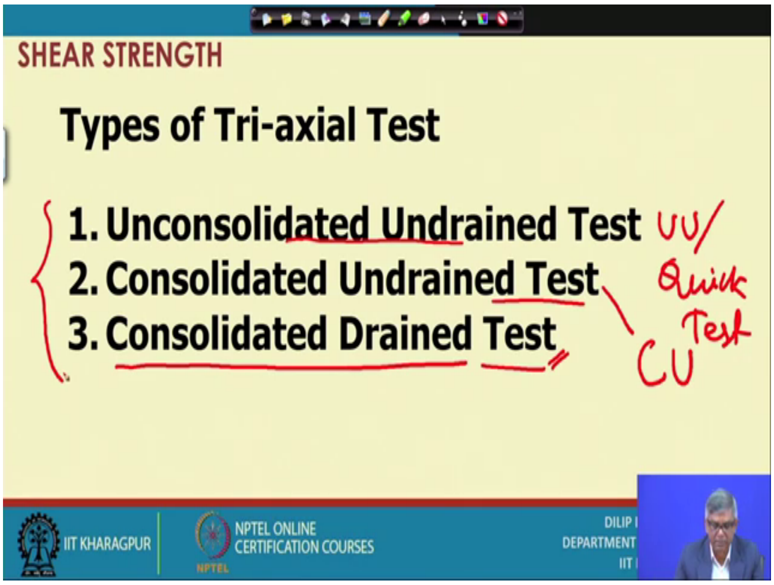

And these 3 categories namely are unconsolidated undrained test, and consolidated undrained test, and consolidated drained test and; what is the meaning of it. This is unconsolidated undrained test; that means, whatever I have already mentioned under triaxial test that we set a sample and then put a cell and then we puts water to enter with some pressure that is we by that we apply a confining pressure and then we apply axial load to shear that.

So, as that test generally takes around 15 minutes, and that is actually is in this process, neither consolidated the sample nor we allow any dissipation of pool water by draining of water so that is called unconsolidated undrained test. UU test universally it is known as UU test unconsolidated undrained test, sometime it is called quick test. And next one is a consolidated undrained test that is another test where, when we apply the confining pressure and soil is saturated, then under that confining pressure that pressure will before transferring to the soil grain, it goes to pore water inside it and that in the form of pore water excess pore water pressure. And if you allow some time and if you allow drainage, that slowly water will come out and this pore pressure will be dissipated and slowly the applied confining pressure; whatever additional load we apply that will be transferred to the soil grain. So, that is the stage that consolidation will do fast, and then after consolidation, the sample we can close the all drainage path, and then we can apply additional axle load then to see at the sample.

So, that is called consolidated undrained test why it is called so? And this is universally known as CU why it is so; because we first consolidated the sample and then we see at the sample in undrained condition. So, because of that it is called consolidated undrained test and then third one is the consolidated drained test, this is also the same mechanism as it was in second case that will fast be consolidate the sample under a particular confining pressure, and then during shearing every of application of additional axial load whatever pore pressure developed that has to be dissipated. That means, we have to shear it very slowly so, that when you apply the additional axial load that because, of that if there is any pore pressure developed, that is obviously will develop, and that has to enough time has to be given to dissipate that pore pressure.

So; that means, in each test and will be 0 pore pressure tank so has to be satisfied. So, this way if I first consolidated the sample and again if we apply shear the sample by applying additional axial load, and by slowly but to dissipate the pore pressure every increment and so because of that this test actually take very long time. Particularly for a fine soil consolidation takes 1 or 2 days and then again for shearing the complete sample it will take another, so 2 3 days sometime week. Whereas, this unconsolidated undrained test it takes for consolidation one day and then shearing again if it is undrianed condition then another maximum half an hour. And unconsolidated undrained test, it is just apply the confining pressure and then apply the additional axial pressure as load, and then shear it, so quickly it can be done.

So, these are all the different test some are very lengthy, some are very quick, but we cannot ignore with because of this time taking, but in some situation when you required that is that is a condition is prevailing in the field, then you have to follow that test condition. So, there are 3 boilers this that triaxial test available, so we can now discuss what how we conduct the test, how we get the parameters.

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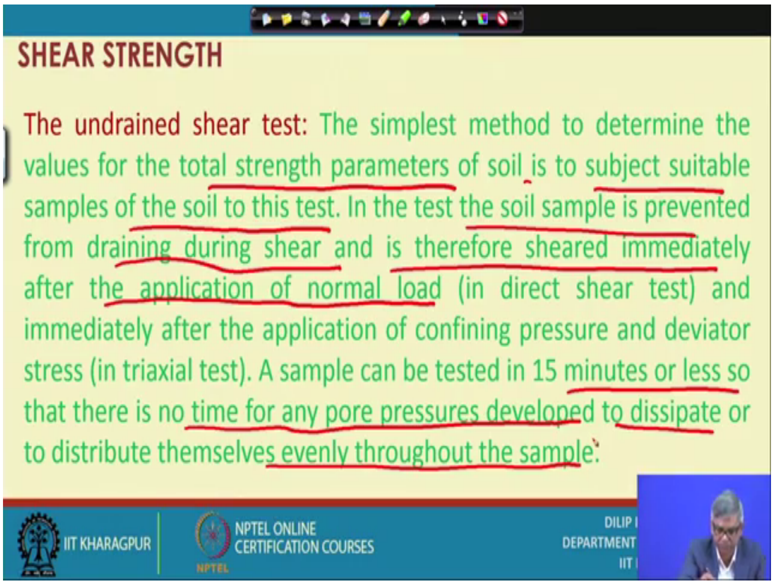

And you can see the first of all undrained test; undrained shear test, as already we have mentioned this I have before. The simplest method to determine the values for the total strength parameter of soil is to subject suitable samples of the soil to this test. That means under this test; shall we can get the total stress parameter, because we are neither consolidating nor dissipating the pore pressure.

In the test the soil samples prevented from draining during shear and is therefore see here immediately after the application of the normal load it directs a test is apply normal load and then shear; it immediately it happens and in triaxial test with after confining pressure (Refer Time: 08:15) that is also immediately fails. Sample can be tested in 15 minutes, and there is no time for any pore pressure develop to dissipate; that means, whatever pore pressure develop in the net there is no time to dissipate that or distribute themselves evenly throughout the sample. So, what about the condition develop that is the condition we generally shear it, we do not bother what is happening inside, and so quickly we get some idea about the strength parameter by this test.

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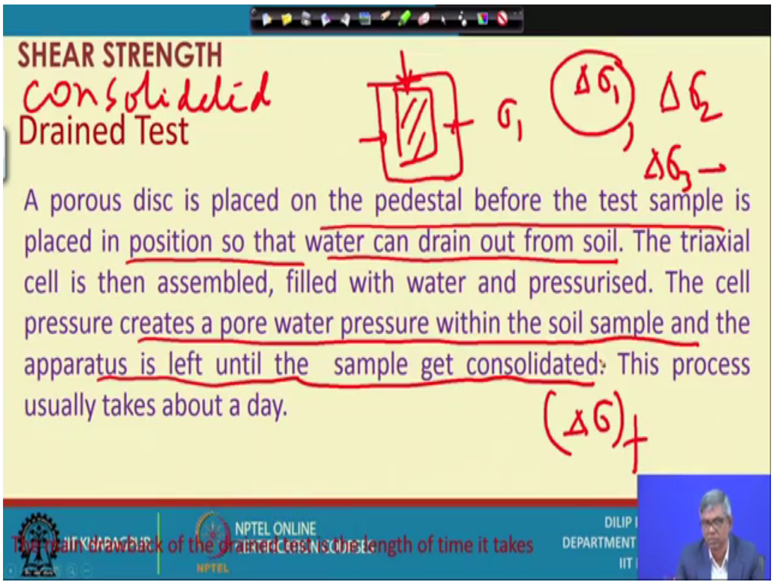

Next is a drained test before drain actually I could have done undrained test, also either way it is the same way drain test is this is not only drain test it is actually consolidated drain test. That means, first is the soil has to be consolidated, and second stage while shearing one has to allow draining of water; that means, a particular soil is sample is there and by inside the chamber, it is applied confining pressure and suppose the confining pressure is sigma 1 under that this soil is first consolidated and then axial load are applied.

Suppose delta sigma 1 is applied, under that whatever pore pressure will be applied pore pressure will develop that has to dissipated. So, you have to give some time you have to see immediately after applying this additional axial load, what is the pore pressure developed and you have to observe when the pore pressure becoming 0, then only you have to take the reading. So that is the way we do this test. So, like that after this 1 is done then delta sigma 2, we do delta sigma 3 like that we have go on increasing and finally, delta sigma f; that means, at failure when how much delta additional axial load is required for the reaching to the failure, so that to be noted.

So, this way actually we are getting totally draining condition and we get a very useful socia strength parameter, porous disc is placed on the pedestal before the test sample is placed in position, so that water can drain out from soil. So, that is confining pressure when we will and then because of the pore pressure inside; so it will try to get dissipated.

So, through porous stone, it will come out the self pressure creates a pore water pressure within the soil sample, and the apparatus is left until the sample get consolidated; that means, until the you have to monitor that because, of this confining pressure whatever pore pressure develop it has to be come close to 0, there are number of checks of course, pore pressure check. So, that I am not going right now and this process usually takes about a day.

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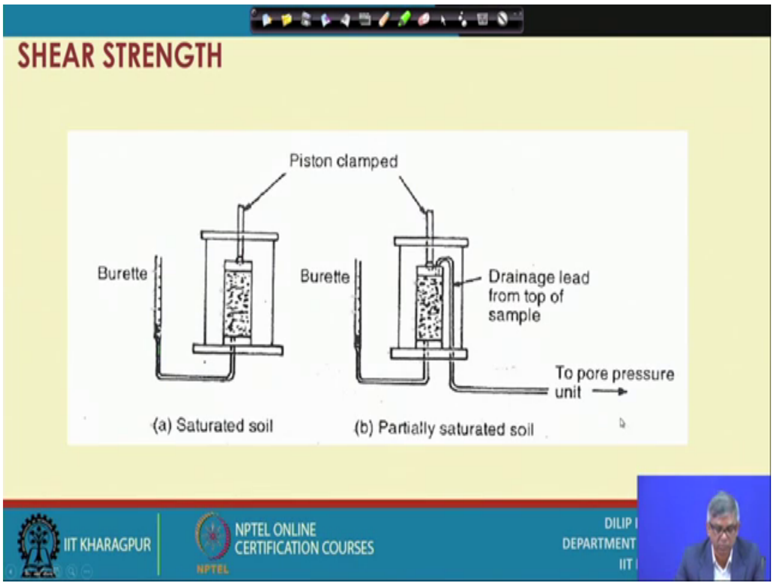

So, consolidation process itself take 1 day and then next is will be your; this is the way actually we do we keep porous stone here, and through this water will be coming out when confining pressure will be there, and we will keep a burette and see the water mark will be changing and after sometime, we will see there is no change that indicates that pore pressure totally dissipated. And sometime other way can be done, pore pressure dissipation can be from the top, it can be taken out and this is kept sometime if the soil is not properly saturated sometime, water also can go through this and you can saturated. So, that is the way also one can do the pore pressure check; that means, when it is going to saturated and pore pressure is totally dissipated that is the way one can do.

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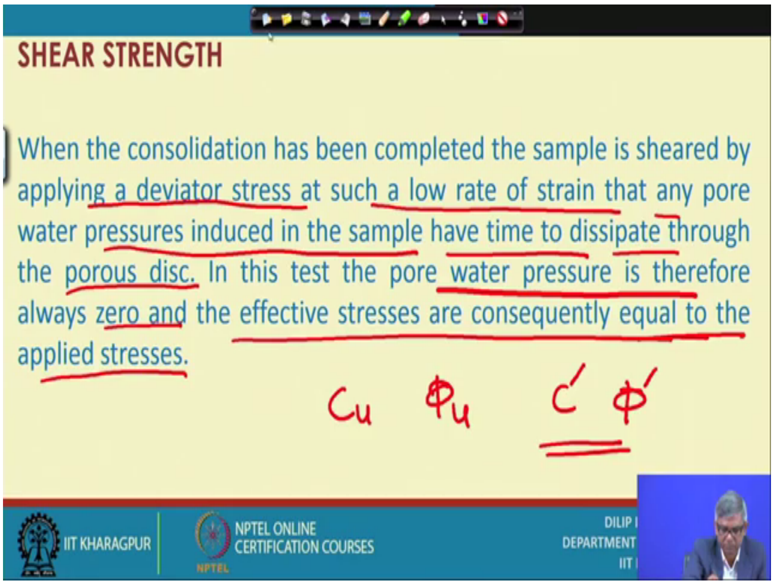

And when the consolidation when a consolidation is completed sample is sheared by applying deviator stress that is what I have already mentioned. At such a low rate the strain that any pore water pressure induced in the sample have time to dissipate through the porous disc. That means, that bottom whatever porous disc is there, so we have enough time so, that that water goes out and pore pressure totally dissipate. And in this test the pore water pressure is therefore always 0, and effective stress are consequently equal to the applied stress.

So that means, it is effective stress whatever finally, we are getting it is effective stress and from this test whatever far parameter we get that is called effective stress parameter, and effective stress parameter when it is total stress parameter it is C u and phi u, an when it is effective stress that is c dash and phi dash and when it is a consolidated undrained so, that is c dash or sometimes c d also it called so that is the way, so drain test c dash and phi dash.

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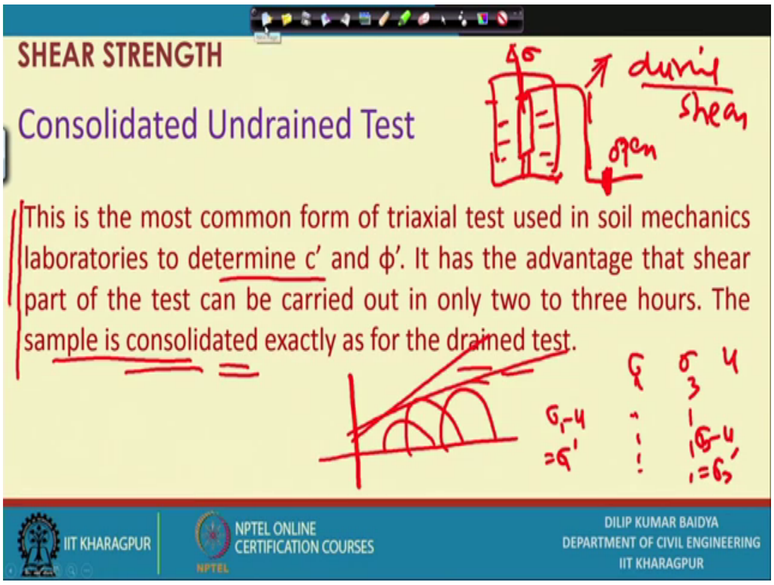

And consolidated undrained test this is a test actually the first stage; that means, your consolidation part after immediately after confining pressure, the soil has to be consolidated and that after consolidation, the soil while shearing by additional axial load or pressure or deviator stress that time actually drainage will be closed. Suppose in the previous case each additional each increment of axial load, we are keeping we are observing that immediately after the application of axial load, when there is a pore pressure developed and that they have to give enough time to dissipate that pore pressure. And when it become 0 then we will be go for next increment, like that we will be continuously applying deviator stress and each a deviator stress under each deviator stress we will see the pore pressure is 0, like that we will go up to failure, and at failure what is the deviators stress that has to be observed or noted. So, that will give you to that will help you to calculate the parameter.

Whereas, in this consolidated undrained test in these basically consolidation part is same and then while draining. So, the suppose this is the sample sorry suppose this is the sample and this is the chamber and this is resting on it, and whatever pore pressure arrangement was there; suppose here going out pore water pressure through it, and so consolidate when it is a consolidation taking place, under application of confining pressure drain is open. And during shear because, of additional because of application of the deviator stress. During shear by applying additional axial stress or deviator stress during shear this drain valve will be closed.

So, that is why it is called consolidated undrained, that mean first stage we consolidate the sample and in the second stage what to do we do not allow drain, but what we do some time. So, if this way actually what way it is helpful? If I can conduct test the this way then it takes one day for for consolidation and for shearing maybe another half an hour maximum.

So, we can save the time, but what way it is useful? It is useful in the sense sometime during the shearing when we apply additional axial load immediately there will be pore pressure development. So, we can keep some operators or some monitoring so, that we can measure the pore pressure at each load increment and so, finally, what we can do, this test from this test undrained condition will get another one set of data, and then subtracting pore pressure you can plot again another set of data and that will give you another shear strength parameter and this way actually by conducting of this consolidating undrained test we can get both undrained parameter and also drained parameter.

How to get drained parameter? Whatever confining pressure or deviator stress or all we have applied that you have to whatever and then pore pressure measured that as to observe pore pressure has to be subtracted to get effective stress. So, when you plot the more circle in terms of effective stress parameter, that way when that gives you the effective stress parameter. Suppose how it will be suppose based on total stress we have got some circle like this and we have got a tangent and this gives you suppose based on total stress and without subtracting the pore pressure, and when you subtract from sigma 1, sigma 3, sigma 1, sigma 3 like that 1 2 3. 1 2 3 and 3 or 4 circle you have drawn and you have drawn a common tangent from there you get a c n we get value of phi. So, that gives you total stress.

And suppose now there is a u, now if you subtract from sigma 1; sigma 1 minus u gives you sigma 1 dash similarly sigma 3 minus u gives u sigma 3 dash. So, like that another set in terms of effective stress we can plot and that gives you some another set of circle and if you draw the tangent and that tangent may become something like this. So, with.

So, that with the application I will show we would later on so; that means, by using though the consolidated drained test is the most suitable test perhaps, mainly because we are actually giving enough time to dissipate the pore pressure and; that means, total effective stress condition we are satisfying where as is in drain test the consolidated undrained test we are consolidating same as the consolidated drain test, but during shear we are not allowing the drainage, but the result final outcome can be almost similar if you can observe or measure the pore pressure. And that pore pressure if I subtract from the total pressure, then we will get the effective stress set of effective stress if you wants to get then we get another set of more circle and from that we can draw the tangent, and by drawing the tangent we can get the value of c dash phi dash. So, this is a very useful; that means, if I have the pore pressure measurement the c u test can be almost come out as a c d test and so, what way it is beneficial, because it is taking only very little time for shearing. So, most of the time people actually adopt this test instead of doing c d test though we are not able to allow draining and pore pressure making to 0, but still it is by this combination this test is very very useful.

So, now this way I will just keep a 1 or 2 application, whatever shear strength I have discussed and let me take first application.

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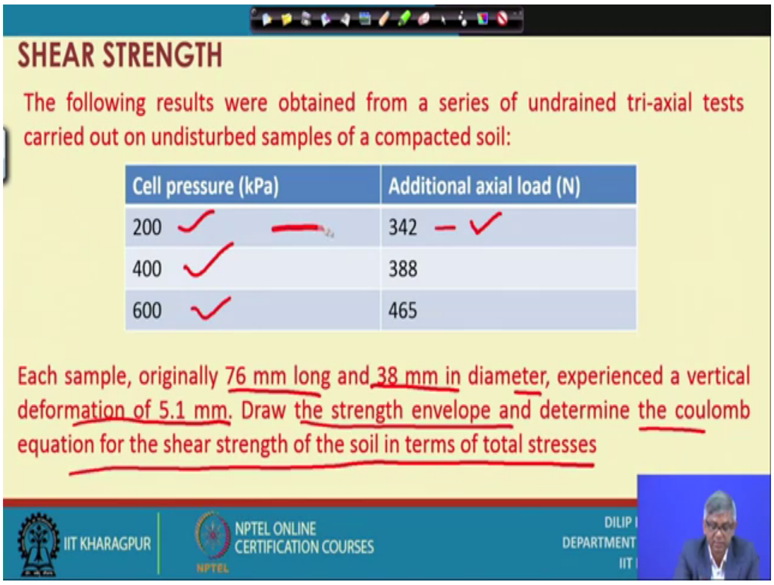

The first application is like this, you can see the following results where obtained from a series of undrained triaxial test carried out on undisturbed samples of compacted soil and we have applied different self pressures about 200 and 400 and 600 one 400 say pressure is applied additional axial load was 342 Newton. So, generally we apply we measure load and from the load we can calculate what is the stress, that actually load by area that

I will show you again during the test the because of the change of cross section the area also will be changing, and that how much area is changing there is a the formula already we have discussed, and by that actually we have to correct it area you have to find out and then find out the actual cross sectional area, and based on that we can find out the additional axial stress and this is nothing, but it is delta f actually force actually and each sample originally 76 millimetre long and 30 millimetre in diameter, experienced a vertical deformation of 5.1 millimetre.

Draw the strength envelope and determine the coulomb equation for the shear strength of soil in terms of total stress. So, this is the problem; that means, we have 3 test so; that means, we can get 3 more circles, and we can draw the finally, common tangent to all 3 circles and which will be the more failure envelop and that one you can find out the equation by knowing the value of c and phi.

So, let me see that how to do it. So, this is the soil sample size is given diameter is 38 millimetre and length is 76 millimetre. So, volume is pi d square by pi d square into l.

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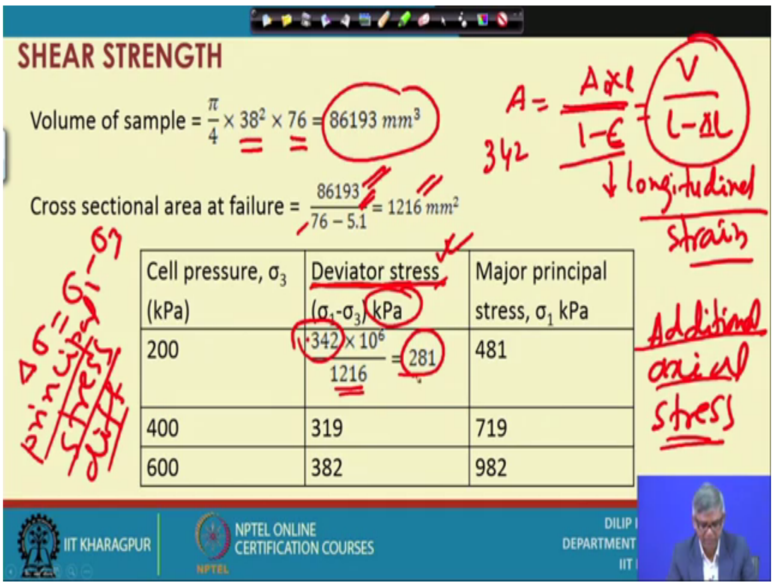

So, this is the 86193 millimetre cube and cross sectional area at failure will be suppose we have given area cross sectional area at any time will be A naught 1 minus epsilon. So, this is the, this epsilon is nothing, but longitudinal strain.

So, now this longitudinal strain if it is A naught. So, we have got. So, this is nothing, but if we expressed in terms of volume so, it is V by L minus delta L. So, this is another form because area multiplied by L is the volume. So, you can write volume by 1 minus epsilon nothing, but V by L minus delta L. So, we have got volume this much and we have got your length is this and change in length is this. So, we have got cross sectional area 1216 millimetre square.

And then we have got deviator stress; that means, you have to find out deviator stress; that means, you have to find out deviator stress is nothing, but delta sigma is a deviators stress which is nothing, but sigma 1 minus sigma 3. So, this deviator stress some time we denote in different use different names, sometime it is deviator stress, sometimes it is called principals stress difference principal stress difference, sometime it is called additional axial stress. So, this 3 name additional axial stress or deviator stress or principal stress difference principal stress difference why? Because it is sigma 1 minus sigma 3, and additional axial stress because after confining pressure, confining pressure is acting all around same and additionally you are giving axial. So, because of that this called additional axial stress and also it is deviator stress; that means, from this to this. So, it is nothing, but difference. So, that deviator stress. So, 3 name can be used to explain this.

So, deviator stress is can be calculated this way you can see if I go back to the data the it was actually it was 342 Newton. So, 340 Newton this will be this must be point 3 and this is actually metre square. So, this will be point 342. So, Newton. So, it is actually ultimately express in k P a, this is expressed in k P a. So, Newton is expressed in kilo Newton by dividing thousand the point 342 become point 342 and this is millimetre square to make it meter square it is multiplied by 10 to the power 6 should become 286 sorry 281 millimetre square.

Similarly, whatever value was there now 388.

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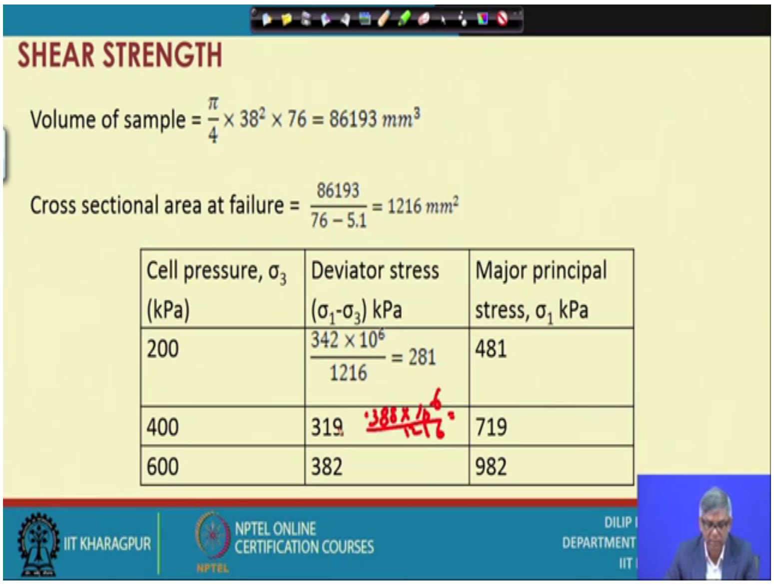

We can write it is point 388 into 10 to the power 6 divided by your 1216 this gives you 319 similarly if I see.

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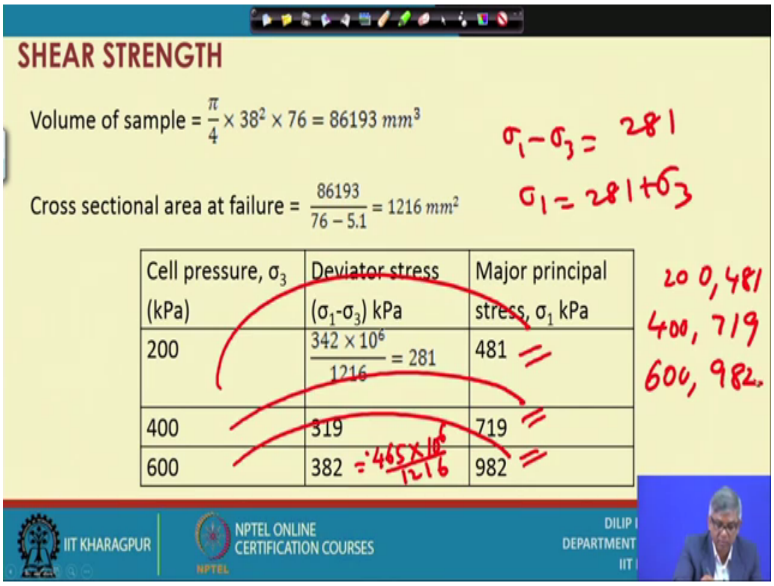

This one 465 this is actually 0.465 into 10 to the power 6 divided by 1216, this calculation gives you this 382 so; that means, we have got now self pressure and you have got deviator stress and deviator stress once you know sigma 1 minus sigma 3 equal to something about 281 then sigma 1 will be 281 plus sigma 3 that gives you 481. So, 281 plus 481 similarly 31 and 400 and 719, 600 and 300 and 982.

So, like that we get this verses this, this verses this, and this verses this; that means, we are getting 200, 481 one data 400 and 7 1 9 and 600, 982. So, we can draw 3 circle now you can see.

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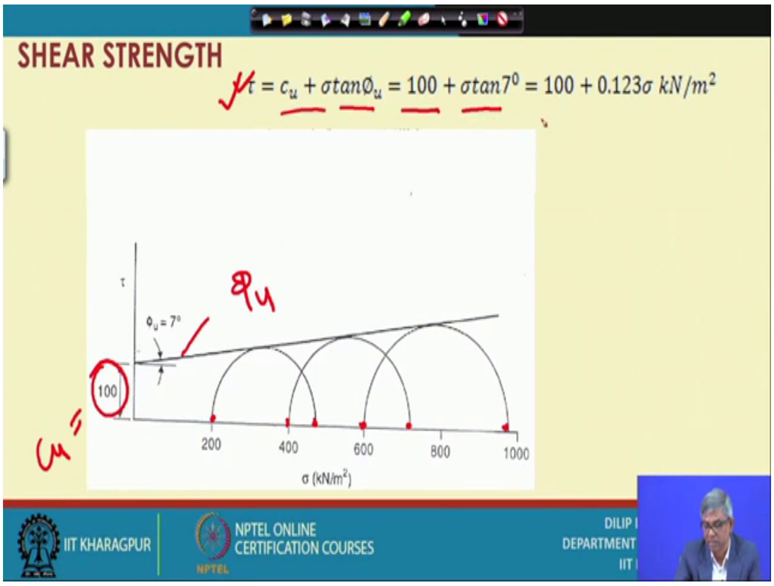

In the next slide, we have we could do 3 circle first one 200 sigma 3, and this is the 381 or 481 something then 400 and something the corresponding value, 600 sigma 3 corresponding your sigma 3 value sigma 1 value.

So, sigma 1 sigma 3 1 set, sigma 1 sigma 3 second set, sigma 1 sigma 3 third set and if you draw a tangent to this you can see it is you are getting a intercept that is nothing, but C u and your getting this phi, that is phi u since there is a no it is a undrained test. So, we are getting use. So, then shear strength equation if I write more column equation (Refer Time: 29:37) to C u sigma tan 5 u. So, hundred plus sigma tan 7 degrees, then that equation become 100 plus 0.123 sigma that is kilo Newton per metre square this the equation shear strength equation for this test. So, this is the one of the application I just simple application I have done, I will do few more in the subsequent lecture. So, with this I will stop here.

Thank you.