Geology and Soil Mechanics
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Lecture – 40
Shear Strength of Soil - C

Welcome back. So, in the last lecture we started discussion on shear strength of soil and there we have seen that how you can get the formulation for Mohr-Coulomb failure criteria and all those things we have derived all those expressions rather and then basically we started the laboratory experiment on the determination of shear strength. The first thing we took over that is direct shear strength and there basically we talked about 2 different types of say test one is stress control test another one is the strain control test.

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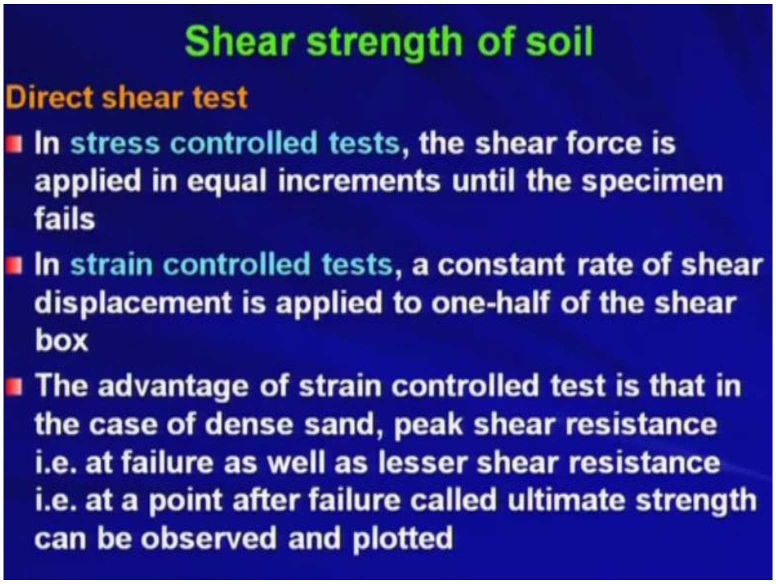

So, in the stress control test the shear force is applied in equal increments until the specimen fails whereas in strain control test a constant rate of shear displacement is applied to one-half of the shear box. So, those things we have discussed and basically there is some advantage of stress control test. The advantage of stress control test is that in the case of dense sand each shear resistance that is at failure as well as lesser shear resistance that is at a point after failure called ultimate strength can be observed and plotted right.

So, we have seen that because in case of dense sand you will be getting the shear stress versus shear displacement I mean that plot if you plot that curve basically you will be getting initial increment then it will reach to the peak and then it will fall down and it will be becoming constant at higher stress I mean shear displacement right.

So, basically in case of strain control test you can capture the whole say stress strain behaviour for the dense sand whereas if you go for stress control test after reaching the peak when the stress will be falling down that part you will not be able to capture because in stress control test you control the I mean shear I mean shear stress right you control the stress and basically and you go to the progressive failure of the material right. So, these things we have seen in the last lecture.

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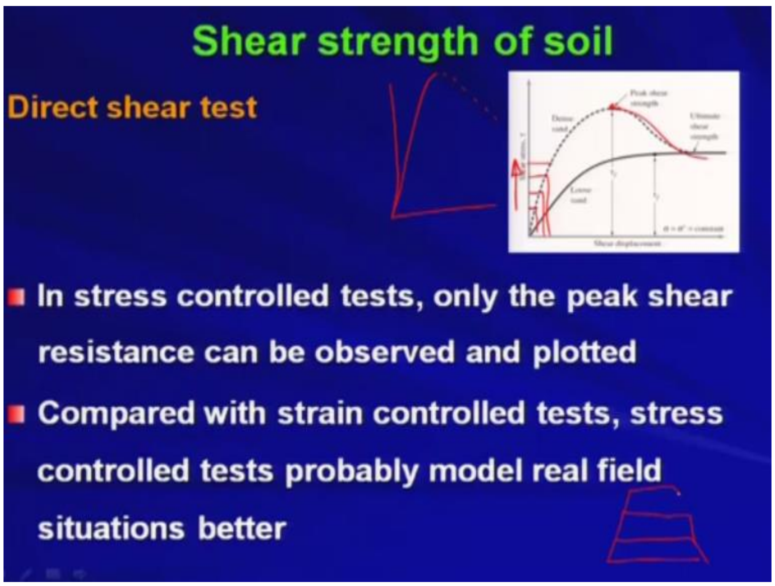

So, basically in I mean if you look at this figure so in stress control test only the peak shear resistance can be observed and plotted. So, in case of stress controlled test basically what you do you control the stress that means some equal increment of stress you are giving and you are observing the strain right. So, in this process basically you will be able because I mean you are continuously increasing the stress so in this process you can maximum reach the peak right after peak that means post peak part you will not able to capture because you have the control to increase the stress incrementally right.

So, in that process you will not be able to capture the post peak part and that is basically the disadvantage of the stress control test. So, in stress control test only the peak resistance can be observed and plotted. So, you will be getting so in case of stress control test you will be getting the plot something like that so you will be getting up to peak okay. So, the post peak part is not possible from the stress control test right.

So, compared with strain controlled test stress controlled tests probably model real field situation better. So, though in case of stress controlled test we are not getting the post peak behaviour or the post peak say response however the stress control test is I mean more towards the actual field condition. That means say in case of what actually you do in any geotechnical structure I mean you generally say if you are placing the structure say suppose I mean if you consider a building construction.

So, what you do, you place the foundation and on top of the foundation you place the first ground floor first floor second floor and so on right. So, what you are doing? You are just increasing the load and that increment of the load eventually will cause the increment of the stress. So, basically in the real life I mean or you can consider some dam construction or embankment construction you do not consider the dam overnight right.

So, basically what you do you go for the first lift then you go for the second lift then you go for the third lift and so on. So, in this process of incremental stress basically you are increasing the or you are controlling the stress right in the soil. So, that stress control test is more I mean associated with the actual field condition rather the strain control test. Whereas strain control test basically what you do? You control the displacement so that I mean displacement control is not really happening in the field in the actual life.

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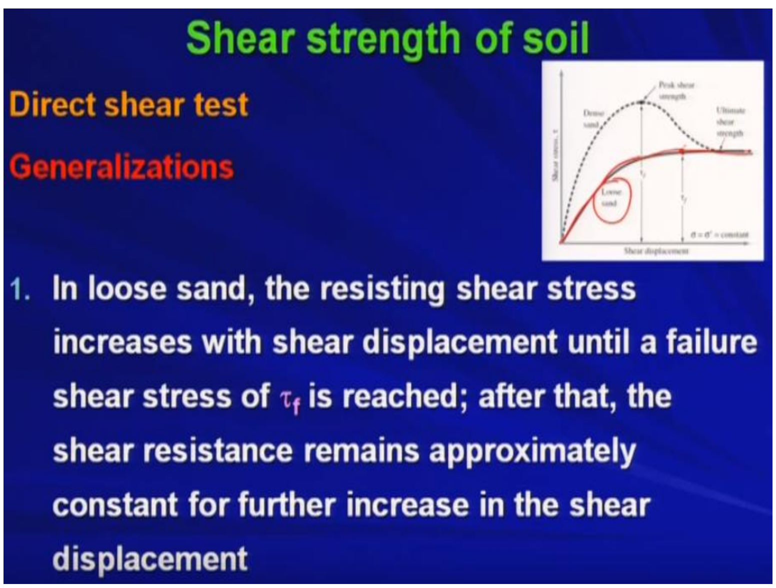

Now in loose sand so now we are going to discuss this stress strain behaviour for loose sand as well as the dense sand. So, in loose sand the resisting shear stress increases with shear displacement until a failure shear stress of tau f is reached okay. After that the shear resistance remains approximately constant for further increase in the shear displacement. So, that means in case of loose sand so this is your loose sand behaviour.

So, in case of loose sand as you go on increase the shear displacement you will be getting the increment in the shear stress so something like that and then you will be reaching here so this will give you the peak shear resistance that is tau f and beyond that this will be becoming almost constant right. So, this is the typical behaviour for the loose sand.

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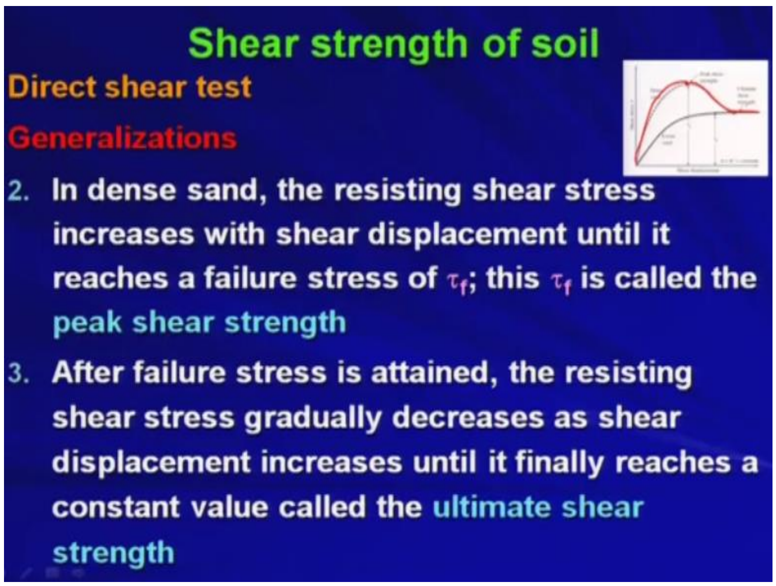

Whereas in case of dense sand the resisting shear stress increases with shear displacement until it reaches a failure stress of tau f. This tau f is called the peak shear resistance. So, as you increase the shear displacement you will be getting the increment in the shear stress okay and you will be reaching the peak that is nothing but your tau f and it is known as peak shear strength. So, you will be reaching the peak and then basically after failure so if I say this is I mean if I when it is reaching the peak at that time I am initiating the failure.

If it is so then after failure stress is attained the resisting shear stress gradually decreases as shear displacement increases until it finally reaches a constant value called the ultimate shear strength. So, post peak region that means after the peak that means after the failure basically you will be getting the reduction in the shear stress however the shear displacement is continuously increasing and ultimately you will be getting the constant say I mean constant shear stress with say increment of the shear displacement and that is known as ultimate shear strength. So, you are getting 2 regions for the dense sand one is your peak shear strength that is happening at the failure and another one is the ultimate shear strength that is happening at a large amount of shear displacement.

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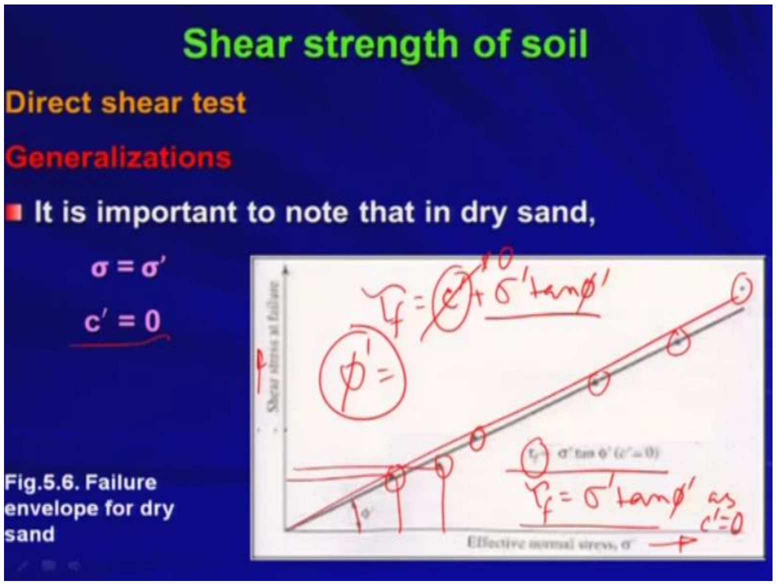

Now it is important to know that in dry sand if you consider the dry sand right completely dry sand there is no water at all so sigma is nothing but the sigma prime that is the total stress is must be equal to the effective stress because only water will cause the difference between the total stress and the effective stress. If water is not there at all then the total stress must be equal to the effective stress and c prime that is the cohesion that is the effective cohesion must be zero.

So, I mean if you can you can see this thing if you take say cohesion nothing but it will try to stick the material okay. So, in case of say dry sand okay you might have seen that all the particles you can I can separate out right all the grains you can separate it out so basically the cohesion is not there only the angle of internal friction is present in the dry sand right. So, basically if you try to plot this behaviour for the dry sand from the obtained from the direct shear test basically the failure envelope for the dry sand will look like this.

So, basically along this y axis you have the shear stress okay at failure and this is along this axis you have the effective normal stress okay so that means basically in the direct shear test what you do you apply some constant normal stress and then you shear it till the failure right. Once you reach the failure you stop the test or if you want to further extend the test to get the idea about the ultimate strength for the dense sand then you can go further but in case of loose sand it will be constant.

So, the once you reach the peak strength that is tau f that is the failure stress failure shear stress that means nothing but your shear resistance or the shear strength so that is your shear stress at failure. So, for a constant magnitude of your normal stress you are getting some shear stress at failure. So, this combination for each combination you will be getting say some individual points right.

So, these points are nothing but I mean at different normal stress you are doing this you are getting you are obtaining this failure shear stress right. So, similarly I mean then basically with these data points if you draw a line and you know this is your linear relation the Mohr-Coulomb failure criteria is considered or is assumed as linear for the soil, most soil mechanics problems.

So, therefore your tau f so tau f is equal to sigma prime tan phi prime as your c prime is zero. Already we have talked that c prime for the dry sand is zero therefore no cohesion so the failure envelope must pass through the origin and therefore the relation I mean you have the relation for I mean the general relation is this is your general relation. So, if this becomes zero then you have the remaining part that is sigma prime tan phi prime and that is written here right.

So, tau f that is the failure shear stress or shear stress rather shear stress at failure is equal to sigma prime that is the normal stress effective normal stress applied on that particular material I mean soil okay dry sand into tan phi prime. So, that means basically what you will get from the direct shear test that means after performing the direct shear test you will be getting this line right. So, this line you can establish after performing the direct shear test.

So, once you get this line you measure this angle so this angle will be you phi prime okay which will give you the shear strength that means the angle of internal friction and that is nothing but the strength parameters right. So, you have 2 shear strength parameters. One is c another one is phi. So, for dry sand c is 0 so you have got phi. So, now you can define the strength and you can you can develop or you can establish the constrictive behaviour for that particular sand.

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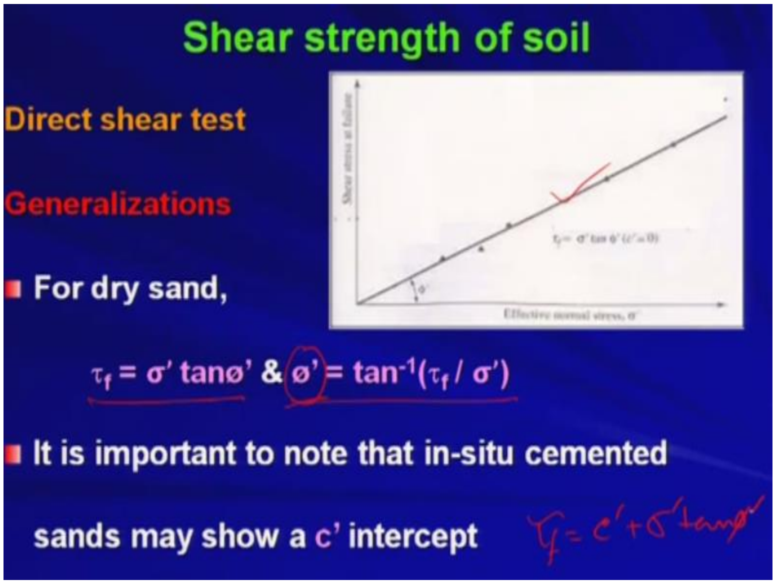

Now for dry sand, so already we have seen so tau f is equal to sigma prime tan phi prime. Therefore, phi prime is nothing but tan inverse tau f by sigma prime. So, after establishing this line you can get the inclination of this line with the sigma axis and which is nothing but phi prime. So, now you can use this phi prime for your design purpose.

Now for example though it is not within the scope of this course however for designing any kind of say if you design some foundation if you design some retaining structure if you design some embankment and if it is made of say dry sand say for example so basically you need this shear strength parameters phi prime to design that. So, if you want to find out the bearing capacity or the carrying capacity of the foundation if you want to find out the stability of the slope or if you want to find out the stability of the retaining structure so all those things basically are the function of this phi prime okay.

So, this is very important parameter which you can find out from your laboratory experiment that is direct shear test for the dry sand. Now it is important to note that in-situ cemented sands may show a c prime intercept. So, it is not true that all the times the sand will show c prime equal to zero. So, if you get some in-situ cemented sand okay some very stiff kind of sand or the cemented sand okay that is not exactly the dry sand or you cannot take out individual or you cannot separate out the individual grains.

So, in that situation sand will may exhibit some c intercept. That means in that situation your tau f is equal to c prime plus sigma prime tan phi prime and the failure envelope will not pass through the origin rather it will have some intercept which is nothing but the cohesion on the y axis that is along the shear stress axis.

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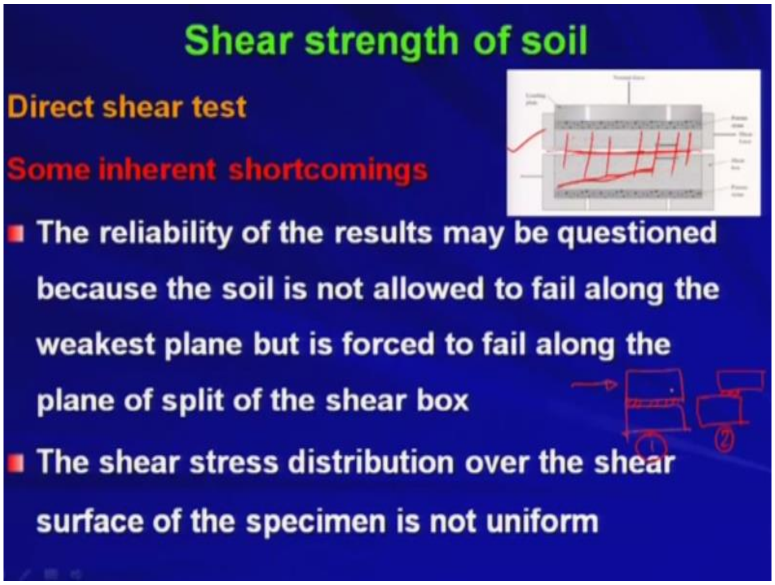

So, some inherent shortcomings, so direct shear test is having some inherent shortcomings and that you must know. So, what are the different shortcomings? So, in case of so this is your direct shear I mean test mould right this is your direct shear test mould. So, basically what you are doing here. First let me let me go through or let me read this statement. The reliability of the results may be questioned because the soil is not allowed to fail along the weakest plane but is forced to fail along the plane of split of the shear box.

Now basically what is happening? So, when you are placing this sand so this is your sand right so this is your sand right or this is the soil sample rather okay. It could be sand it could be clay whatever I do not mind but the thing is this is the soil sample. Now in this soil sample basically you are forcing the soil sample to fail along this surface because along this surface only the boxes 2 halves of the box shear box will move relative to each other right.

So, you are forcing the soil or you are telling the soil you are insisting the soil that you must fail along that plane which may not be true right. You may have the weakest plane where which is lying here. So, basically you are missing that weakest plane because you are forcing you are not identifying the weakest plane and soil will be having the tendency always to fail along the weakest plane because I mean it is obvious right.

So, if you I mean if you carry some load or if you are taking some stress right or anything so whatever I mean organs is weak for your you right so that organ will fail first. So, this is the similar kind of analogy you can draw for the soil. So, if this is this is my weakest plane the soil will try will train to fail along the weakest plane which I am missing in the direct shear test because in direct shear test we are imposing the failure surface or we are forcing the soil to fail along this surface which is predefined right.

So, I am defining the failure surface rather I mean rather soil should tell me that this is my weakest plane so I must fail along that plane so that kind of information I am not getting from the direct shear test. So, that is one of the biggest shortcoming in the direct shear test. I hope you have understood that. Now the shear test distribution over the shear surface of the specimen is not uniform right. So, basically what is happening?

So, suppose in the first instance you have the 2 boxes like that right. When you are pushing okay the one box one half of the of the box with respect to the other half basically what is happening in the next configuration so this is your configuration say 1 that means at the initial stage or the starting of the test. Now in the configuration 2 basically you are getting some relative movement right of the 2 halves right.

So, this is these are 2 halves of the box direct shear box. So, basically now so this is your say configuration number 2 that means when the test is progressing so you are getting this kind of situation at every each and every point. So, at the initial stage when you applied the shear test that shear test distribution right over this area right agreed so whatever shear test whatever pushing you are doing or you are applying to the soil so that will be acting on this area.

So, total area will be participating in the resistance of the shear test. However, when the test is progressing that means at that time you will be getting this much of area which will be taking care of the shear resistance or taking care of the externally applied shear force right. So, that means the shear stress distribution so if you consider the shear stress distribution over the area the shear stress distribution over the shear surface so this is your shear surface of the specimen is not uniform right.

So, as you are applying the shear force you are getting some reduction in the shear surface and that shear surface reduction will not I mean guarantee right the shear stress distribution is uniform. So, that is another biggest disadvantage of direct shear test. So, I hope that you have understood the direct shear test concept.

So, this is however with these 2 shortcomings still people use direct shear test and this is a very handy test okay and I mean no matter whatever shortcomings are there but direct shear test results have found have been found that if you design something based on this direct shear test results those things will I mean function properly right. It has been seen from the experience also. Now coming to the next type of say laboratory experiment that is triaxial shear test.

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So, a soil specimen in this physical test what we consider we consider some cylindrical soil specimen. The soil specimen of 38 mm in diameter and 76 mm long generally we consider this kind of soil specimen so we have to I mean we have to do some P test say exercise okay so to prepare the soil. So, basically the sample should be made of some cylindrical sample something like this okay so 38 mm diameter and 76 mm height okay.

So, this kind of cylindrical sample we prepare okay. Some mould is there and you have to take really proper care to find out to obtain this kind of sample. The specimen is subjected to confining pressure by compressing of by compression of fluid. That means this specimen so this specimen whatever you are getting and I will be showing the triaxial test setup in the next slide. So, basically what you do.

You press the soil sample and you apply the confining pressure that means all round some pressure you apply okay some radial pressure you apply radial as well as axial all those things I mean in all directions you will be putting same amount of pressure by compression of fluid. Generally, this fluid is water. So, you put water inside some chamber and in that chamber, you put this say soil sample and because of the soil I mean water pressure that pressure will be exerted on the soil specimen.

To cause shear failure now under this hydrostatic as you know from your mechanics background that under hydrostatic pressure the specimen will not fail right. So, to cause the failure to cause the shear failure in the specimen one must apply some axial stress through a vertical loading ram and that is called as deviatoric stress right. So, we will come to that point. So, basically, we are getting 2 different kind of say pressure, application of pressure. One is the confining pressure another one is the deviatoric pressure okay.

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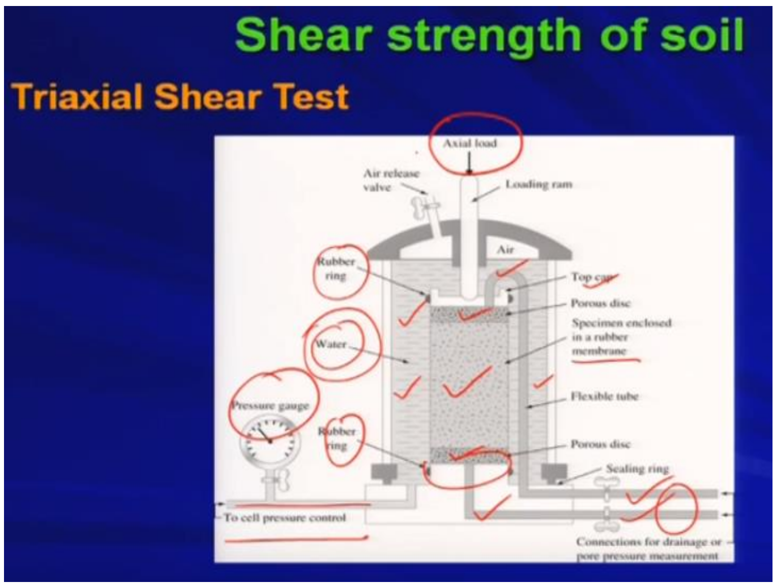

So, basically this is your typical triaxial say test setup where actually this is your soil sample okay, the specimen enclosed in rubber membrane. So, basically the soil sample will be enclosed in a rubber membrane. So, that means you are putting the soil sample inside a rubber tube otherwise the water so because this the whole chamber is filled with water as I told you right and this other I mean if you do not put the rubber gasket right so rubber membrane so basically water will try to wash the soil sample or try to enter the soil sample.

So, that should be avoided. So, this water is only allowed to apply pressure on the soil specimen. That is the only function of this I mean say cell water right cell fluid okay. Now this rubber membrane okay will be tightened by this rubber ring at the top as well as the bottom okay. Now you apply pressure with some so this is the pressure I mean this is the pressure gauge usually measure the pressure how much pressure is applied inside the cell.

So, to cell pressure control so that means through this line through this pipe actually you control the cell pressure that means you can increase the cell pressure or you can decrease the cell pressure. Cell pressure means the water which is put inside the say I mean cell or inside the chamber right. That chamber that water will be under some pressure.

So, you can increase the pressure or you can decrease the pressure and that is known as cell pressure right and now once you apply the cell pressure the soil sample will be experiencing the cell pressure from all in all the directions right in the radial direction as well as in the top direction bottom direction all directions it will be experiencing the cell pressure.

Now the soil specimen will be having the porous disc at the top as well as the bottom to facilitate the drainage right. So, under this process the soil specimen may consolidate and this consolidation will be facilitated by the drainage of the water drainage of the water from the soil specimen and that drainage will be taken care of by this porous stones okay.

Now this is your top cap this is your say these pipes these 2 pipes basically they will be taking care of the pore pressure determination right so basically when you will be applying the load okay I mean deviatoric load or the deviatoric pressure basically the water will be trying to draining out from the soil specimen and that will be collected through these pipes this pipes and they will be connected to some pore pressure measurement arrangement and that will give you the pore pressure how much pore pressure is getting dissipated something like that.

Now so once you apply the pressure in the water that is cell water right so that cell I mean pressure will be enhanced, cell pressure will be increased. Now under that situation you I mean under that condition basically the soil will not fail because you are having the hydrostatic pressure all round right. So, to fail the soil basically you need to apply some axial load through this piston and through this loading ram and this axial load is known as the deviatoric stress okay and when you apply the deviatoric stress then only soil will be under some shear failure mode okay.

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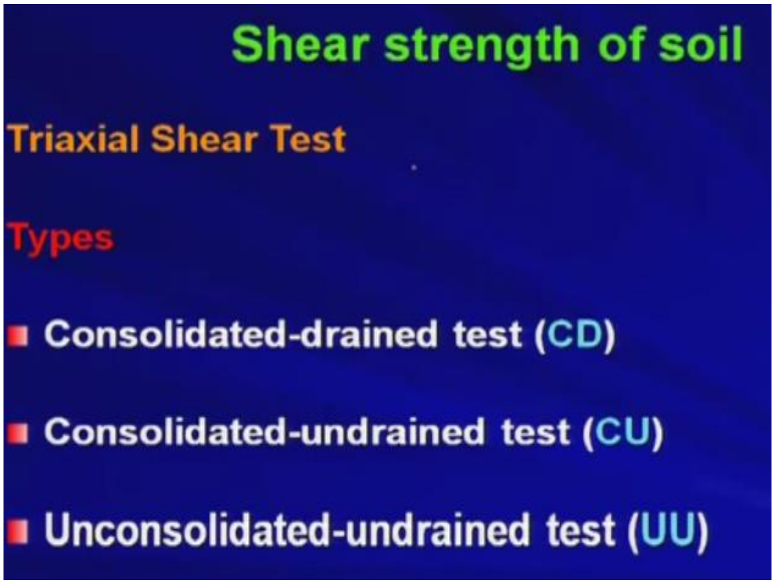

Now what are the different types of triaxial test? The first one is consolidated-drained test okay. We will come to these tests individually and we will discuss the pros and cons of each test and we will see that what are the different procedure you have to follow to obtain these different types of triaxial test. The first one is consolidated-drained test. Generally, it is defined or it is represented as CD test okay in soil mechanics.

Then consolidated-undrained test and that is known as CU test and unconsolidated-undrained test that is UU test okay. So, basically, we will discuss all these tests separately and then we will see that I mean what test should be done at what condition and what test will be giving you better result and I mean under what situation okay. So, these things we will be seeing in the next class. So, I will stop here today. Thank you very much.