Geotechnical Engineering – II

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Lecture 07

Direct shear box test II

So, this describes the direct shear test which we are going to talk about the direct shear test or the shear box test.

Sometimes this is also known as box shear test. As the name suggests, we take a box and we try to keep the sample inside and shear it. So, this is the setup this is how it looks like. There are some modern avatars of this setup also. But this is a classical setup where you have a box which I was talking about. This box can be connected to a shaft with the load cell through which the shearing is done.

There is a hanger assembly which you are seeing on which the normal stresses or the loading is applied which transmits the normal stress on the sample. This box can be utilized for doing drained and undrained test, both. Now, see what happens is, because of this motor assembly, if I keep the sample inside this box, there will be a relative slip of one portion of the sample on the bottom portion of the sample.

How much strains I have applied to the sample of can be measured with the help of horizontal gauge and vertical strain gauges.

This shows how the sample preparation is done. You take some soil sample most of the videos on the YouTube are incorrect, so please do not follow them much. So, this is the box you must have seen that there are two halves of this box. See it again. You can weigh the soil and look at this the way this guy has mounted the upper half on the lower half of the box. Dimension of this box are usually 6x6 centimetre and sample thickness is about 3 or 3.5 centimetre. There are advanced testing setups which are available in the market where the box size would be 10x10 centimetre but the thickness of the sample is kept as 25 mm or 35 mm, depending upon your requirements.

So, this is the cleavage through which the shearing takes place. Because this is one half and the this is the upper half of this sample. So, this is the sample preparation. Normally direct shear box test setup is used for granular material, not for cohesive soils. Yeah, this is what I would like to explain to you. We have a top plate and bottom plate and if you look at the grooves these grooves remain perpendicular to the direction of movement of the direct shear box assembly for a better grip. If you keep them like this there will be a slippage.

So, this is the top plate on which I can keep a load plate. This ball helps in transmitting the load which is coming from the vertical loading assembly onto the system.

This is how the box is placed and what you have seen is that the box is free to slip on the wheels. So, when you will do this test, I am sure you will understand it better. Now this is how the lateral stresses which are going to come on the sample which is the shear stress can be determined. This is the vertical strain gauge, which is fixed on the top of the sample to understand during shearing how much volume reduction the system is going to undergo. Now, what this guy is doing is trying to set the rate of strain for the sample so that you can simulate either a slow test or a fast test.

This is the application of the normal stress on the sample and now the test is running, and you get response of the sample. I will discuss about the typical test results and the philosophy behind this and how to decipher the information which is used. So, this is the normal loading.

And of course, the analysis of the results, fine?

So, in short this is the container you can say or the box in which depending upon the type of test we are doing I can place a drainage layer. So, this is what is known as a porous stone or a perforated steel plate. And this is for the drained test. In most of the problems in this course, you have to understand what type of conditions are being simulated because answer cannot be unique. So, you have to assume a situation and you have to justify what is that you are trying to do as a designer. So, when we talk about geotechnical engineering-II applications, these are the philosophies or the quantification of the material properties. Now, how I am going to derive this parameter itself is a philosophy. So, this is where actually I am trying to emphasize on.

And if I replace it by a solid steel plate, I am not allowing any drainage to occur, this becomes the undrained test. So, this is how the boundary conditions can be changed. This is the, you can say, one half of the sample. This is the cleavage plane along which the shearing is going to take place. This is another half of the sample, we call this as the plane of shearing. On the top of this also I can put a porous stone or a perforated plate. This is sandwiched between a steel plate, so this is the steel plate to give the rigidity. And then on the top of this is kept the loading cap and this is how the normal stress, σ, is applied. The whole assembly as per my testing conditions can go into a water bath.

So, I can fill up the water in this system, so this becomes the water bath. As I said the typical dimensions are 6x6 centimetre or 10x10 centimetre. So, the size of the sample is going to be 10x10 or 6x6 and usually the thickness is approximately 25 to 35 mm depending upon your requirements. Now, if I take an element somewhere here. Alright? and if I zoom it, what I am interested in is I am interested in finding out what is the state of stress here. So, this is a plane at which σ is acting and then there is a shear stress which might act once I have mounted it on the direct shear box assembly and if I shear it.

So, normally top portion of the sample shears with respect to the bottom portion. Clear? the top portion moves. So, this is where the shear stress comes in picture. Now what I want to do is I want to measure the vertical deformation by putting a dial gauge or this is the era of electronics. So, you can put some LVDTs or you can put some sensors to find out how much the deflection is and I would also like to know what is the horizontal deformation undergone by the sample. So, this is the δ_{h}. So, this is the vertical dial gauge and this is the horizontal dial gauge.

So, essentially, we try to measure vertical strains, vertical deformations, axial deformations, or axial strains by keeping a certain value of normal stress and changing the value of shear stress. And how this is changed? As you have seen in the video, τ is changed by constant rate of shearing. And that is why these types of tests are known as strain-controlled test. So, this is the whole thing which is as strain-controlled tests.

Because the way you are straining the sample is in your control. So, a known amount of rate of shearing is given to the sample and normally this is depending upon the gearbox assembly. I can go for 0.125 mm/ min or 0.000125 mm/min. It depends upon what is that you are trying to do.

So, this is going to be a fast test, this is going to be a slow test. When you do these experiments in the lab you will realize it better. Now I am more interested in analysing the results.

The first type of result which we get from this analysis or this type of testing would be stress in kPa versus normal stress in kPa. Sorry let us not go to the normal stress right now. Let us talk about only the axial strain. The δ_{h} which I have shown over here. If l is the length of the sample. The strain would be, axial strain would be $\left(\frac{\delta_{\mathrm{h}}}{l}\right)$. The second type of response which I will be interested in is, how during shearing ε_a is your axial strain. So, if I say that this is compression which I am getting from δ_{v}. So, this is a δ_{v} axis. If δ_{v} is positive its compression. However, if δ_{v} is negative this is what is known as dilation.

Now, what happens is starting from this point, static condition. There is no shearing going on the sample. What you have done is you prepared the sample kept it in the direct shear box setup, applied the σ value, no shearing. Fine? There might be some compression particularly if the soil is dry. If soil is saturated, there will be less compression and if compression occurs the densities are going to change. Now, we are going to plot the response of the material once the shearing starts, not before that. But if you are very eager to observe the vertical deformations or the strains in the sample you can compute. So, the moment shearing starts, as you strain the sample what happens is, this is how the response would look like.

This is one state of the sands. Normally this is the typical response for dense sands. There is a hump followed by a residual portion. So, if you keep on shearing it, it will become or it will attain an asymptote. So, this is the dense sand's response. We call this as the residual shear strength. This is the peak shear strength. On the same plot if I superimpose the loose sands, this is how the loose sands would look like. I hope you remember the denseness and the looseness of the material would depend upon RD. The relative density of the sands. And relative density is a function of e_{max}, e_{min} and the void ratio at which the sample has been prepared.

In case of the loose sands, shearing does not result into a hump. We don't get a peak. But when we deal with the sands which are dense, the typical response is you get a peak followed by a residual. What is the philosophy of this relationship? Why do you want to study this? I hope you can easily understand that ε_{a} is nothing but the amount of strain the system undergoes when it comes under shearing loading. Correct? earthquake. Somewhere here in between what you are observing is that the response of the loose sand and the dense sand almost becomes unique. This is what is known as a critical volume condition. Sometimes people also define this as a constant volume.

If you plot the deformation versus strain relationships, what you will observe is the loose sands when you shear them are going to get compressed. However, what is going to happen to the dense sands? Dense sands will dilate and they would show like this, the response. So, this is for the dense sands, this is for the loose sands. Hope you can understand dilation occurs when the void ratio is minimum. That is the dense state of the material. Compression will occur when the material starts from $e_{\max}$. When you are shearing the material starting from a very high void ratio, the material gets compressed, compression takes over, ultimately a state of constant volume comes. When you shear a material from a very dense state, what it does? it defies the confining stress and it dilates.

Now, this is what is known as on a scale of e if I plot because e is related to the compression and dilation this becomes e_{cr}. This value becomes e_{cr}. Sometimes we also define this as e_{cv}, void ratio corresponding to constant volume. This is a typical response. Now, the question is why did we do all these things? what we are going to get out of it? Now comes the job of the designer. So, if I ask you a question which response out of the two you are going to consider for designing a system? this one or this one? you are getting a peak strength you are not getting a peak strength over here. So, this type of questions designers has to answer. Particularly when you are designing systems for earthquake resistant structures.

I will never go for a material which shows very high strength. I want the underperformer. I use the word underperformer. Correct? But then at least it is certain that it will perform under expectations, no doubts. But it is not very unrealistic and not very dubious. And ultimately it is going to give me some value of the strength which is constant for further straining. Not like this material where it shows peak very early but then later on it shows a great drop in the strength. So, the whole idea of designing the systems is how much shear strength I can mobilize? I have used this word today first-time mobilization please remember this word.

How much shear strength I could mobilize out of this material under shearing process corresponding to its dense and loose states. Seeing the response like this, where most of the structures which are going to be sitting on these types of deposits when the earthquake comes you can realize what is going to happen. The whole system will get densified, compression or if the material happens to be an extremely dense state the dilation will occur both the situations are going to be dangerous for you. That means what I should be doing is, I should be defining the range in which I should be compacting the material for more stable conditions and that happens to be approximately 10 percent plus minus of e critical value, e_{cv}, value.

So, this is the range in which I should be doing most of the constructions. Why? Because this is a very stable state the deformations are not going to be extreme which are going to cause detrimental effect to the structures which are sitting on the top of them. So, this much information output I could decode by doing simple tests. Fine? So, this is the peak shear strength. I will define it as τ_{peak} and this is the residual τ_{r}.