Geotechnical Engineering –II

Professor. D. N. Singh

Department of Civil Engineering

Indian Institute of Technology, Bombay

Lecture No. 13

Shear Strength of Cohesive Soils

In last few lectures I have talked about determination of shear strength of soils. And we have emphasized more on the coarse-grained soils, fine-sand and sands. We have not talked much about the cohesive soils.

So, when we talk about the shear strength characteristics of soils, normally we divide them in two parts that is, the shear strength of granular materials or granular soils and shear strength of cohesive soils. So, this we have done enough and this is where we discussed about the direct shear box test and then I took enough time in describing that or building up I would say that this is a two dimensional situation and how to transform from 2D to a 3D situation.

So, this we defined as the plane-strain condition. Remember, all these tests are strain-controlled, we are not doing stress-controlled test. However, when we transform from 2D to 3D, this becomes a triaxial condition. A good example of transforming from a two-dimensional strain-controlled test, now suppose, if I want to do a stress-controlled test so, what I have to do is I have to change the stress and find out the strength of the material or the shear strength of the material. Mostly we find out the pull out capacity.

So, these tests which are stress-controlled are normally performed for finding out the pull out capacity. In your 10 plus two physics, you have studied this type of situations if I have a pully arrangement over here, and if I keep a direct shear box setup over here, the trick is the way you will be making the sample. So, the lower half of the sample would be the soil of your interest, mostly granular material and what we will do is we will create an interface.

So, this interface happens to be let us say a geogrid what is being used for making the reinforced earth structures when you go on the highways you will see re-walls reinforced earth walls. So, this is the interface and then again the top portion of the box or the sample is also filled up with the soil sample. We connect it with a thread or a wire which passes through the pully, and we apply different type of weights W_1, W_2 and so on until the material fails, clear?

So, this is a typical test which is we can utilize the direction shear box test setup to obtain the pull out capacity. We can know what is the friction getting mobilized at the interface of the geogrids or for that matter any type of intrusions it could be a metal plate also. So, depending upon what type of project you are dealing with, you can always simulate this type of situation. So, this becomes a constant stress-controlled test.

Now, coming to the triaxial conditions, a bit of philosophy is to be understood before we plunge into these tests. Mostly these tests are done to understand the response of the soils which are fine grained clays, silts, silty clays, silty sands, but not sands, not fine sands because as you will notice, subsequently, it is very difficult to make a sample if the sample happens to be a sandy sample.

So, when we talk about the cohesive soils, we normally try to simulate the drainage condition. Because the basic difference between the coarse-grained material and the fine-grained material is its permeability. So, the whole intention of performing triaxial testing is to study how the sample or the soil is going to behave for different drainage conditions. And then, as a technologist, you are going to recommend a test and you will be using those parameters to simulate the condition which really occurs in the nature.

So, in short, these tests should not be generalized, they have to be understood and the parameters which you are going to get from them have to be utilized in a very meticulous manner. So, first thing is that drainage condition is being controlled, what it also indicates is the consolidation part is also inbuilt into it. So, until now, in your Geotechnical Engineering-I course, what we did is, we simulated different types of boundary conditions, if you remember.

Let us say both side pervious, you have sands and there is a clay layer which is sandwiched into it. We define this problem as both end draining, you apply the load, the drainage occurs from both the ends, and we want to find out what happens in terms of consolidation to the clays. So, we are talking about the permeability of the system because if you remember the consolidation is a function of hydraulic conductivity, k.

Then, the drainage condition can also be simulated in the form of the rate of strain. The same thing we did for the direct shear box test also. We went for extremely slow testing, and we went for the fast testing. So, the way we bifurcated these tests is slow and fast test depending upon the rate of strain.

So, rate of strain can be obtained by if I know how much deformation I have to give to the sample, in how much time. So, suppose if I say a certain amount of deformation is to be achieved during shearing for a given time. So, the question is how I am going to obtain the time.

So, a typical triaxial sample would look like a cylindrical sample where this is the radius of the triaxial sample, and this is the length. So, there are some empirical relationships which are available and what is normally used is that,

$$t_{100} = \frac{\pi l^2}{C_v}$$

This is what is known as Bishop's equation. What it indicates is that triaxial testing is the best way to find out the coefficient of consolidation also.

So, very precise determination of coefficient of consolidation by conducting triaxial test. And remember, in one-dimensional consolidation when you got C_v value, there were a lot of limitations. Limitations 1, number 1, that the sample was unidirectionally loaded, alright, so this is your one-dimensional consolidation sample. And the sides were constrained, we did not allow the sample to deform in the lateral direction and the drainage took place from top and bottom.

So, these are the two draining conditions, one-dimensional situation. Here this is going to be 3-dimensional situation what is more realistic. So, when you take a sample from the field under triaxial attraction conditions, and when you do a triaxial test, the C_v which you obtain from a triaxial test is always going to be the best possible representation of the sample characteristics. Fine, because I can control everything, I can control the drainage conditions, I can control the consolidation process, I can control the rate of shearing.

Now this rate of strain is again going to make it a slow or a fast test. One of the limitations of the direct shear box test was that we could not control the pore water pressures which are going to develop in the sample. And that limitation we can overcome by adopting to the triaxial testing. That means most of the time, when we do the slow test, the type of parameters which I am going to get, so the first time I am using the term type of parameters, emphasize. So, type of parameter is just like a pathological examination of a patient.

So, there is no way you can generalize the findings of a blood test report or a serum report or a stool test or whatever, urine test. So, the first time I am utilizing this term, that type of parameter, which I will get. So, a slow test is by philosophy when you are shearing the sample, you are allowing enough time for the sample to dissipate the pore water pressure, is this part clear?

So, when you are doing a slow shearing material understands that there is enough time to realize what type of disturbance is going on. It is not an earthquake loading. It is a slow shearing 0.00125 mm/min. Very slow test. Why do I want to do this type of test because this type of situation prevails in the nature. And we will discuss about this. So, when we do a slow test, this happens to be a drained test.

However, when you perform a fast test, you do not allow any time for material to understand what is happening. It is just like extreme torture. And you just want to see how much resilient the material is to the external disturbance and the loading. So, in that case, when we do a fast test, what we get is undrained parameters. So, these are the bifurcation, I hope you realize that now we are trying to enter too much into the intricacies of the testing process.

So, what we have done very intelligently, we have first of all, defined the boundary conditions, drainage conditions, type of consolidation, no consolidation, full consolidation, rate of strain I brought into the picture. And from here I am trying to simulate the type of shearing which a material experiences and from here, I have related to drained and undrained situations.

In real life, what is the significance of this? Understand this concept slightly properly, most of the consultants do this problem and they do not choose the parameters correctly. And that is the reason we mark their reports with red colour. They have to very careful when we do wetting of your designs, we try to find out the mistakes related to the type of parameters you are selecting and whether they are proper or not.

Now suppose, if I, for the sake of discussion now this happens to be a Marine clay and I am designing let us say pile. And this pile is going to take care of a pile rake or an oil platform. What type of loadings are going to come on the system, the first is wave loads, the waves keep on coming and hitting the structure. Wind loads in offshore environment winds are with a very high velocity, what is happening because of these types of dynamic loading? the system starts sawing depends upon the amplitude frequency of the waves, depends upon the type of forces the wind is going to cause.

Ultimately, the system deflects the question is what parameters I should be utilizing for the Marine clays to design this type of a system. One situation. The second situation is suppose I have a stiff clay and on the top of this I am constructing a facility, an embankment. The third situation is the embankment itself. So, what normally is done you go layer by layer compact the soil and you achieve a certain height.

So, I have talked about three situations the first situation is an offshore environment. The second situation is embankment on the stiff clay and the third situation is raising the height of the embankment. Now try to understand how as a doctor or a technologist you are going to prescribe a test to a pathological department, your laboratory and how would you use the parameters.

Marine clays are under consolidated material. Correct? Fine. So, what I have done I have defined a statement under consolidated young materials. Everything is inbuilt into it, I need not to define anything else. The message is conveyed in the fraternity. System always remains saturated beneath the water, water is somewhere here, consolidation is never going to occur, drainage is never going to occur.

This becomes a typical case of unconsolidated undrained test. That means depending upon the patient, I am treating what I have done, I have diagnosed the entire situation what is him or her and now I am recommending a test and I will be obtaining the parameters. Now, what is involved in this? In these few parameters involved number one the material itself marine clays, here their formation deposition is known what type of soils they are is known, what type of structure is going to come on them is known.

I am not allowing any type of consolidation to occur in the system and there is no drainage which is going to take place we will be discussing about these types of tests. These are known as UU test. Hold on, we will come to that, you have to listen first the entire story rest of things become very simple. So, this becomes an unconsolidated undrained test, UU test.

Now look at this situation, you have stiff clays, now stiff clays are the ones which have something to do with OCR value and we have discussed about OCR, the way they were formed. So, I knew not to use any other term except for defining the OCR parameter and saying that there is a soil deposit made up of this type of OCR. And I am trying to construct a foundation system on the top of this stiff clay.

Now what are the characteristics of the stiff clay? Permeability is extremely low. And we will study subsequently that these are the materials which I am going to show you mostly the stiff clays are going to show you mostly the cohesion value. The marine clays will show you only the friction value because we call them as NC material, normally consolidated material. These are over consolidated materials.

So, now I am realizing I am now bombarding with the concepts. So, the moment I write these terms everything is clear I do not define anything, what type of soil is there, what is the particle size nothing because what I am doing is, I am just dealing with NC, OC and the situation.

Now, if I start constructing on the top of this, when you are putting an embankment as for the stability of the stiff clay is concerned, OC material consolidation is not going to occur. Correct? So, this classifies as unconsolidated test, U part comes in the picture. Look at the formation of the embankment, you normally do the entire thing and 300 mm thick layers, and the embankment takes you almost few months to years to construct the entire thing. 40 meter high, 50 meter high, 60 meter high embankment which you are doing they cannot be done over a 24 hours they take time.

So, when I am compacting this type of material, unconsolidated behaviour is correct. Chances are that there could be some consolidation, so we do not write it as a CU test, we write this as a UC test sorry, we write it as a consolidated-undrained test, and we define this as CU test. So, UC is not correct. The better way to define this is consolidation has occurred in the process of compacting the layers on the stiff clay and the chances are that the drainage might not take place.

The third situation is when we talk about the long-term stability and long-term stability always indicates to the situation where the drainage has completely occurred from the system. So, this becomes a consolidated-drained test. So, most of the earthen embankments and dams are made by using the information which you get from a CD test. Please do not goof up between these parameters at all because it is just like x patient and y's report. I hope you understand this point.

Inbuilt is the information which you have studied until now how to characterize the material. So, once the characterization has been done, now the question is I am trying to capture the response of the material when I am shearing it under the drainage conditions by applying shearing loads. General concepts.

Now one concept which I have not still talked about is in all these cases, I am talking about the samples which can withstand the effect of gravity. That means once you draw it from the ground, you bring it, it is stiff enough and you can, or it can maintain its integrity. However, there could be a situation where the soils are very sensitive, very soft, take out a sample from marine clays, chances are that when you take out a sample from here, that sample will not be able to withstand its own weight. It may collapse. These types of soils are known as sensitive soils.

So marine clays, these are soft clays and not only soft we call them as sensitive. So, the question is if you have such type of deposits, what type of testing you will be doing to obtain the shear strength parameters. So, this becomes a different class of the problem altogether. Soils which cannot sustain even their weight, they lose their integrity they are so sensitive. If I say something to you, you feel very dull and tired or maybe something excited, or sometimes very down.

So, this type of external loading has caused a sort of a distress in your body. So, even if I take all these samples and if I touch them by hand, the chances are there that I am going to disturb them, I have generated some pore water pressure. Marine clays permeabilities are extremely low. The moment you touch them is good enough pressure to cause pore water pressures in the system, undrained condition.