Geotechnical Engineering – II

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Lecture 06

Testing for shear strength parameters:

Introduction

We have talked about the state of stress in soil mass and the question still remains that how are you going to solve the real-life situations which I discussed in my lecture number one and two and, in fact in the last lecture also. That is where we have to define the material.

So, this is the genesis of the discussion on shear strength of soils. And when we talk about the shear strength of soils, normally when we quantify this, we use two parameters. So, that is the cohesion and the friction. Normally cohesion is denoted as C, capital C and friction is denoted as phi (ϕ). Sometimes people also call this as phee (ϕ). Now, one thing you will have to realize is that just like human body, you know soils are very moody characters. I am sure in a day, many a times you go through the mood swing many times you go across this process of lean patches and the peak patches.

You feel tired, you feel extra energetic and so on. All right? Same is the case with the soils also. So as a technologist, as an engineer, what I need to do is, I just want to negotiate with this material and I hope you understand what is the meaning of the word negotiation. Negotiation is a sort of a dictation also. So, I am dictating material how you should be behaving, because I am the technologist, I am the engineer I want to just use you like a captain in a cricket team.

Suppose if I ask you to bowl last overs you cannot deny because this is my planning. So, you will notice that when we talk about the shear strength of the soils, we have to basically negotiate with the material which happens to be the soils. And by virtue of being a very complex material which we have been studying since the first course, we have to negotiate it in a very gentle manner.

That means, we have to create circumstances and we have to create situations and under these circumstances and situations we have to let this material respond. So truly speaking the shear strength of the soils is the response of the material. So, this is nothing but the response of the

material which happens to be the soil when it is sheared. I think I already defined the word shearing, is it not? the shear motion where movement is about to take place or is taking place along a plane where there is a detachment from the parent body of certain small body. So that becomes the shearing process. Now this shearing could be caused because of several factors, earthquake is the major factor.

So, when earthquake comes, what happens? The whole ground shakes, there is a relative motion. Now earthquake itself could be because of opening up of the faults. There is a relative motion between the faults. So, there could be a situation where if you have a fault inside the ground this happens to be the ground surface and this is the fault let us say. In geology you must have studied this. The possibility is that this portion slits down and hence what we have done we have created a situation where the relative motion along this plane AA, initially the whole body was like this of the soil mass. And then there is a relative motion of this block with respect to this block along this plane. So, this becomes the plane of shearing.

And what we have been discussing until now is I am interested in finding out what is the state of stress at this point, which is lying on the shearing plane. So, earthquake is the major factor which is responsible for shearing the soil mass. It could be any other human activity also. What type of activity? I mean day-to-day life if you notice that suppose I want to utilize this soil mass and I want to construct let us say a facility over here. After few years we realized that we have already exhausted the capacity of the facility we like to extend it. What has happened? initially there was an equilibrium in the soil mass because the initial condition.

Now the moment you went on to increment the state of stress is changing here this can happen even in the initial stage also, but I could negotiate with the situation. Now if this type of situation occurs the chances are if this happens to be a weak plane, the shearing will take place and the system will collapse. Now weak plane definition in mathematical form would be,

$$\tau > \tau_{cr}$$

Is this alright?

Now, what we are going to do is we are going to simulate all these type of situations in the laboratory first or in the field conditions first. So, when we want to understand the response of the material like soils during shearing, we normally resort to two types of tests either the

laboratory test or the field tests. So, laboratory test would be, the simplest possible test would be let us say a shear box test. Sometimes this is also known as a box test.

A shear box test always simulates a 2D condition. Two dimensional. That means by virtue of being two dimensional this is going to be a plane strain or a plane stress test. If I really want to simulate what happens in the field, truly speaking many times 2D conditions are not prevailing and hence I might have to try a better replication of the state of stress in the soil mass and then I will be conducting a triaxial test. So triaxial test is a three-dimensional depiction of the straits of stress on the material.

Sometimes if the samples are very soft and very sensitive, it is very difficult to make a sample either in the form of the shear box test or a triaxial test. What we do is we take the sample in a container which we collect from the field and then we lower down a vane. This is what is known as a vane shear test. Vane shear test can be done both in the laboratory as well as in the field. Even if you are in the offshore, what you have to do is through the jack up rig or through the boat or ship you can lower down a casing and that casing entraps the sample. And then I can lower down a vane, I will discuss about this whole thing and then I can give some torque and I can find out what is the strength of the material under in situ conditions.

But very soft sensitive clays, soils where the sampling is very difficult, we can reconstitute the sample in the laboratory, and we can obtain the shear strength parameters. Sometimes, we also do Tor-shear test. Shear box test would have some limitation. We cannot shear the sample beyond let us say 10 percent or 12 percent. But if I want to find out the strength of the material at very high shearing, let us say 20 percent 25 percent, then what I have to do is I have to make a tor sample and apply torque in such a manner that I can apply very high magnitudes of the strains on the sample.

Sometimes in the field test we do flat jack, particularly in the field of rock mechanics. When you design the foundations on the rocky strata particularly for the dam let us say or underground caverns you know. If you have seen a hydroelectric power plant hydroelectric plant sorry they have galleries inside through the dam body, have you ever visited a HE power plant dam Koyna dam or anything you have?

So, there you will notice that they design lot of systems on the hard rocks. And they create caverns also where the machines and the powerhouse are located. So, for designing all those types of structures, you need to do flat jack test. So, these are the field tests, I can do vane shear

also here I can do flat jack also here. And then there is another class of testing which is known as penetration tests.

I am not going into the details of these tests here because this should be taught in your foundation engineering course. How to establish the worthiness of the substrata where you are going to lay the foundations of the structures. Those of you are interested you can go through this series and what I intend to do in this course is I will be talking about the shear box test, triaxial test, vane shear test a bit on the tor-shear test and penetration test is also a sort of a vane shear test by the way. But then there are different types of cones we call them as CPTU, SPT, SCPT which are conducted in modern day construction of foundations. SCPT is static cone penetration test, CPTU is cone penetration test under undrained conditions, SPT is standard penetration test and all these tests can be utilized to obtain the shear strength properties of the materials.

And as I said this is the response of the soil mass which you are trying to capture by conducting these type of testing conditions, all right? And ultimately what we get is we get cohesion and friction which are the two components to be used for designing any structure. Is this part ok? So now first time today in this course I have introduced the concept of the material. Until now I did not talk about the material at all. We were only talking about the state of stress which could exist in steel, composites, wood, timber anything. But now today for the first time the soils are being quantified by conducting proper tests to obtain the parameters which are responsible to give shear strength.

So, this is another classification scheme which is normally used by international fraternity to classify the soils. In your geotechnical engineering one course what did we do? We classified soils based on their origin, transportation, redeposition, particle size, CU, CC parameters Atterberg limits, compaction curve also we utilized to characterize the soils. Then we utilized consolidation characteristics to characterize the soil. If CC is very close to one highly compressible material which has to be clays. CC extremely less non-compressible material so that was also a definition of classification of the soils.

Now I am sure you must be realizing this type of classification is going to be useful when as an engineer we are more interested in understanding the response of shearing on the soils. So, this type of classification which we do is supposed to be the most versatile way to characterize

the material and to utilize it for any construction project, is this part clear? Rest is all mechanical.

The philosophy part is okay? any questions? So, what you need to understand is how I am going to do a test to obtain a certain parameter which is imbibing the protocols which are required to construct a system. In medical sciences what do they do? When they test your blood, they do pre-parenteral and post-parenteral. Correct? Before breakfast and after lunch. Why? These are two extremes of the blood sugar they are testing.

So, in our case we can utilize this concept very interestingly by putting a condition drained and undrained. So that means, I would put a condition on shearing process in such a manner that I can create two conditions as drained or undrained.

This corresponds to when you are shearing a system and it is a drained condition that means the shearing is extremely slow. You are allowing enough time for material to dissipate its pore water pressures. When you are doing a slow test, you want to drain out even a single drop of water in the form of the pore water pressure to get what dissipated pore water pressure should become zero.

Drained condition, very slow shearing rates and the type of parameters I am going to get would be drained parameters. Opposite to this when I am doing undrained fast shearing. Why? you are not giving any time to the material to realize what is happening, earthquake within two second everything happens. Clear?

So, you want to understand the response of the material when the loading is so fast it cannot realize what is happening that means the pore water of pressure cannot get dissipated, so this becomes another extreme where we say undrained testing/fast shearing and what I am going to get is the undrained parameters.

The practice of geotechnical engineering revolves around these concepts what is the significance of this? Now drainage can be simulated for the soil sample if you remember consolidation theory. I will say that this is the deposit of soil where you have a clay seam like this, so this is the clay seam. And when I load it from the top what is going to happen? the pore water of pressure is going to build up in this now there could be a situation that this is sands, and this is also sands that means clay seam is sandwiched between the layer of sands.

So, the moment you start loading it, this being permeable system what we called is that this is a double drainage system. Drainage is taking place from both the ends. So, what I have to do is if I want to simulate a drained condition I have to simulate the similar situation in my testing over here. Agreed? But suppose if I want to do untrained test, where you do not have sands let us say this is again a clay of different variety this is also a different let us say rock strata, so I have created a perfectly undrained situation by choking of dissipation of pore water pressure. I have to simulate the same situation in my laboratory test, so that I get the undrained response. Is this part clear? any questions?

So, in short what we are doing is, we are trying to understand the response of the soils under different types of loadings. These loadings could be fast, these loadings could be slow, which connote to the dissipation of the pore water pressures or no, clear? By simulating the boundary conditions which exist in the field for a given problem to get c and ϕ components which are nothing but shear strength components. This is what we will be doing now.

And once we have got c and ϕ I can utilize these parameters for designing foundations, for designing retention systems like retaining wall, sheet piles, bulkheads whatever doing the excavations, supporting the excavation bracings and struts. Once I know the c and ϕ also I can do the stability of the slopes. So that means under all circumstances you are going to use the shear strength of the material which is soils. Clear? If this part is clear rest of the things will become very simple to follow.

Now the question could be how I am going to find out what type of subsurface system is do exploration.

So do different types of exploration we call them as geotechnical investigations and by conducting these geotechnical investigations I can estimate what type of subsurface profile is. So, I can go for a bore-log, and I can find out the subsurface profile and this is what is going to tell me what is the thickness of the underneath seams or clays or whatever. Now let us start discussing the first test which is normally done to obtain the shear strength parameters of the soils.