Geotechnical Engineering - II

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Lecture No. 16

Triaxial Test II

If I do a very slow shearing of the sample what is going to happen? During shearing also, the pore water pressure will be zero, why, drained condition, all my valves are open, correct. So, that means during consolidation pore water pressures are zero, during slow shearing the pore water pressures are zero.

In other words, the total *u* is zero. Fine? That is why this is known as effective stress analysis. Now, if the pore water pressures are zero, what is going to happen?

$$\sigma_3 = \sigma_3' \text{ and } \sigma_1 = \sigma_1'$$

Now, things are simple, if I plot it on a Mohr circle. So, if you have τ vs. σ, what is going to happen? This is the first sample, this is the second sample, this is the third sample σ_3 is increasing. And if I plot on this scale σ' also effective stresses and if I joined this curve and if I depict it as,

$$\tau = c + \sigma . tan\phi$$

Now, this is your Mohr-Coulomb envelope, in the effective form what is going to happen? because the pore water pressures are zero the effective Mohr- Coulomb envelope will superimpose on this Mohr-Coulomb envelope also. That means, τ will remain as same as τ'. Normally we do not write τ' because this is your σ_1 minus σ_3.

So, this will remain same as σ_1' minus σ_3'. So,

$$\tau' = c' + \sigma' . tan\ \phi'$$

But, prime indicates effective, effective is nothing but σ minus u remember the effective stress analysis which we have done. So, because the pore water pressures are zero the parameters which are going to get from this test are going to be effective stress parameters.

Under what circumstances we are going to do this test? the stability of the dam for after 100 years dams are normally constructed not for 20 years or 10 years or 5 years. You want to see whether it is going to be stable after 100 years.

That means in 100 years I am sure the boundary conditions will develop because of the material which you are selecting that the drainage is going to take place completely and consolidation is going to occur. So, ideal candidate test for to be performed on stability, long term stability of dams, earthen dams. Somebody had asked this question we were talking about the heterogeneous and homogeneous dam cross sections and the seepage analysis.

How do you select the slopes of the downstream and upstream sides of the dam, which one is going to be more critical, look at this the moment I have filled the water over here, you have already studied the seepage theory. Now what I am doing I am clubbing the effect of seepage on the stability of the dam which is being governed by the shear strength parameters. So, this becomes a natural complicated problem.

So, truly speaking, if I say that this is the critical section about which the failure at the downstream damage going to take place, all the seepage force is going to act on this slip surface. And this process is going to be dependent upon the way the pore water pressure is developing and the way the pore water pressure is getting dissipated.

So, when you are talking about the stability of a downstream side, which is very critical as compared to the upstream side, because upstream side what is happening? Water column gives a stability to the side of the dam upstream. So, that means for analyzing the downstream slopes, we have to do CD test. Is this part clear?

Now, let us take the second case the second type of testing is CU test. Now, as the name suggests the first one is consolidated and U corresponds to undrained. So, you are doing a triaxial testing in a 50-50 margins you are allowing the sample first to consolidate at a certain σ_c, but you are shearing it in a very, very fast rate of shearing, earthquake, there is no time for the material to understand how it has to behave. So, the fast testing is allowed to study the response of the systems which are not going to consolidate during their lifetime.

So, when the buildings are being constructed, you should go and see the natural formation and what do we do? We lay the foundation here first and then slowly and slowly the first floor, second floor, third floor keep coming over here.

So, normally the curing time is 27 days, footings are very, very heavy in size and dimensions and the weight because of the self-weight of the footing this soil is going to consolidate a bit but after that what happens the rate of construction is very rapid and you are not allowing soil mass to get consolidated particularly when the boundary conditions are not very conducive both side clays.

So, if I want to simulate this type of situation, the best test would be CU test and then I can measure the pore water pressure and I can make it CU prime that is the beauty. So, in short the first component remains same u_c is 0 under σ_3. Now, one thing which I have not written over here and I would like to correct is when you say shearing, what we have to do is if this is σ_3 I have to apply σ_f and this σ_f is also sometimes depicted as,

$$\sigma_d = \sigma_1 - \sigma_3$$

So, this is shearing process that means, after consolidating it I am shearing it by applying a deviator stress. So, this σ_d is known as a deviator stress and deviation is from σ_3. So, that means, the axial stress you are applying in such a manner that the deviation between the σ_1 minus σ_3 becomes σ_d.

So, I wanted to explain you cannot apply σ_1 here. Exactly, so, the best thing is that truly speaking with a σ_d which is getting transmitted from this, which is equal to σ_1 minus σ_3. So, now, you can compute σ_1 from here which will be equal to σ_d plus σ_3.

$$\sigma_1 = \sigma_3 + \sigma_d$$

This is how we read this what in short this indicates is having done the consolidation test if I shear it σ_d is increasing, and the failure occurs. So, this becomes your σ_f. So, once you have done the consolidation, this part remains same. So, that means the σ_d corresponding to σ_f and with the failure is taking place will be the deviation with respect to σ_3 of σ_d which is σ_1 minus σ_3. So, what you have to do is starting from σ_3 you have to apply this deviator stress to compute σ_1.

So, this component remains same. A CU test can also be done to obtain the C_V value. The second part is different from this point onwards we shear it in a fast manner and fastness is in

the form of undrained test. The rate of strain is so high that it does not get time to get drained. So, this becomes an undrained test. The strain is going to cause the failure you remember this?

What is the significance of this at this point, zero strain axial strain, zero shear stress, as you move along this axis, what happens the shear stress picks up. And then ultimately what happens? The more and more axial strain the more and more shear strength is getting mobilized. And then the failure comes at this point that is answer to your question.

So, at this stage, if I say that this is σ_d, which is σ_1 minus σ_3, and σ_3, what will happen to pore water pressures? Because this undrained test, u_d will not be equal to zero? There will be some value. Now, what should I do with this? This is where we define a parameter A. So, the A parameter becomes a pore water pressure parameter.

So, the first time I am introducing a term A parameter, which is a sort of a efficiency parameter, what is the efficiency and of what? The efficiency is how much cause and effect has been created. So, what is the cause? Shearing and what is the effect? The pore water pressure. So, that means how much pore water pressure gets developed for a given σ_3?

These are all efficiency parameters, where I am going to use this term A parameter? Ultimately all classification system I have forgotten now, I do not need any of those fine grained, coarse grained, organic material, non-organic material, specific gravity, density nothing I need, what I need is? How the system is corresponding or is responding.

If I change σ_3, how much pore water pressure will develop, and this becomes an efficiency parameter. And this is nothing but A. So, I can right now, the pore water pressure is equal to A into σ_3, once you have got the pore water pressure, your effective stresses can be obtained.

$$u = A.\sigma_3$$

So, that means a σ_3' will be equal to σ_3 minus u_d and normally we write this as failure because A is at failure the pore water pressure is going to be a function of σ_3 unless you achieve the failure. And then σ_1' will be equal to σ_1 minus u_d at failure. Effective stress envelope also from here also the parameters which are going to get from here like here we had c, c', ϕ, ϕ'.

$$\sigma_1' = \sigma_1 - u_d$$

And they were same because the pore water pressures were zero. In this case, what we are going to get is we are going to get c_{cu} and ϕ_{cu}. There is a special category of the parameters

which we use. C consolidated undrained, phi consolidated undrained and I think you can understand because this was a 100 percent torture to the sample, this is 50 percent.

Third, we have to create a situation where 0 percent torture. So that becomes your UU test. I will talk about this slightly later let me complete this story first. Is this part okay? Triaxial testing is more of a philosophy rather than numerical modelling of something. Engineering when you do with the materials is more of a philosophy it is the mathematics is only a tool which we utilize to represent parameters. What all can be done in this CU test is a very interesting test.

So, I hope you can understand if I am doing a CU test what is going to happen to this shear envelope? All these Mohr circles are going to shift on the left-hand side. That means the first circle will shift on the left-hand side and this is u_d. Once all the circles shift on the left-hand side because of pore water pressure that is one of the situations, there are possibilities that u_d might be negative, and the entire set of Mohr circles will shift on the right-hand side.

So, we will talk about that. Anyway, so under general circumstances, if you have a situation like this, what is going to happen? Your envelope is going to get shifted and this becomes your effective stress envelope. So, by conducting a test, we have got different types of parameters depends upon me. When you do your blood test?

There are several parameters which are listed on the blood test report, which you can make out you go to a doctor. He sees everything and says everything all right, you start taking this dose and this dose and do not eat this and do not drink this finished. Why? Because he must have seen some parameters and based on this, he is recommending a future course of remediation or treatment. Is this part clear? Now, let me introduce the concept of pre-consolidation pressure.