Geotechnical Engineering - II

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Lecture No. 19

Interpretation of Triaxial Test Results II

In last lecture, I have talked about one class of problem where, just by looking at the pore water pressures which develop in this soil sample. We have tried to speculate the nature of the soil or the type of the soil. So, in continuation to this theme of discussion of the problem, let me take another class of problem till we find a relatively simple and representation of the test results from triaxial testing, and how to develop the Mohr-Coulomb envelope.

So, in a triaxial test, the pore water pressure was measured during undrained testing. Now, this sample happens to be a compacted fill material. So, the first question that you should realize that why this type of tests is being done? So, as I have been emphasizing since last few lectures, triaxial testing is mostly done to catch what has gone wrong; or to prove your point related to some forensic examination which you are doing.

So, I hope this statement itself is clear the pore water pressure was measured during undrained testing on a sample, which is from compacted fill material. Suppose there is some compaction going on; we are trying to create a facility by compacting the soil mass. Until now you have studied compaction of the soil; and what you could derive from this is, you did in-situ density measurements; is it not?

And you follow different techniques that is the balloon method, sand replacement method, core cutter method, nuclear density gauge method or whatever. So, these are the methods which are normally used to check whether the fill has been compacted at the right in-situ density or not, those was four, five, six methods.

So, we got γ_d only from here, $\gamma_{d,insitu}$ and then we obtained moisture content also from here. So, truly speaking this what we are going to discuss today is an extended part of these statement of problem. Having done the compaction of the soil for creating any facility; it could be an embankment, it could earthen dam, it could be a foundation pad, it could be a reclamation, which you are doing. Let us say Navi Mumbai International Airport.

So, having done this part, now I want to link these properties with the shear strength; this is the statement of the problem. Sometimes these types of tests are done to investigate the type of material which has been used, so that you can certify the bills of the contractor; that is where the catch is. So, you allow him or her to continue the progress of the work.

But then I would go and collect maybe several samples 200, 300, 500 depending upon the precision which I want. These samples I will bring to the lab. I will test them, and I know what type of construction work is going on. So, this is the compacted fill material from an earthen dam, something clicks to you. In the Geotechnical Engineering-I course, we have talked about where the compaction should be done.

So, if you remember the best way to link this type of analysis would be if this is the compaction curve. And somewhere here we have the OMC, this side is the dry of optimum, and this is the wet of optimum. And the question was that which side of optimum I should be compacting a material to create an earthen dam, agreed, or, airstrip or a pavement, or a highway.

And this is where I had introduced this concept, if you remember that for a given γ_d, you have two moisture contents. And some of you had asked this question that what is the significance of having two moisture contents, for the say γ_d. Subsequent to this, what we did is we talked about the deformation characteristics of the soil also for stresses, if you remember.

So, we had shown here that how deformation of the soil is going to be a function of σ' on the dry of optimum and wet of optimum. So, this thing shear strength theory is continuing with this story. So, the art of consulting is in the field of geotechnical engineering, you have to start from the particle size distribution.

Go to the compaction curve, go to the compressibility of the system, take out the sample, test it in a triaxial setup and interpret the results; that makes a full story. This is the forensic examination. So, this class of problems normally deals with estimating or evaluating the worthiness of the material; so, the results are as follows.

And just to add to the complexity of the problem, I hope you understand where the economics gets added to the whole system. Because when you are filling something, you are chopping of the mountains; you bring that soil, crush it, make it to a certain particle size, compact it; so, at every stage of the process requires huge amount of money. So, this becomes a game of money.

Now, so these are the results. You have σ_3, two samples were tested 150 and 450. σ_1 is known, 400 and 1000; the pore water pressures are given as 30 and 125. It indicates that the pore water pressures are positive; otherwise, pore water pressures will be written in the negative. This is a straightforward problem; I hope you can solve this. There is nothing much complicated about this. Only thing is once you have got these $\sigma_3{}'$ and $\sigma_1{}'$.

You can obtain it easily. The pore water pressure is known, so $\sigma_1{}'$ will be 370; and this will be 875, this will be 120 and 325. So, the beauty of the testing is we have got the shear stress parameter, shear strength parameters in undrained conditions. What type of testing is this and the effective stress? So, you will be getting for ϕ_{cu},c_{cu} and here you will be getting ϕ', c'.

In the last lecture whatever story, we were discussing about the pore water pressure, pre-consolidation pressure. If I add this information over here, and if I correlate that information with the pore water pressure, I hope you can characterize it, whether it is going to be NC material or OC material; what is the response of the system?

So, if you solve this problem, what you will be getting is, buy some graph papers; or otherwise, do it on your Excel sheet, this is interesting, is it not? So, what you are realizing is that there is a reversal of the parameters; 20 has become 25° in effective stresses, and cohesion has reduced to 24. Why? That is the interpretation part. So, remember when we are doing the undrained testing, what we could have got from here?

We could have got A parameter. But that would become a different class of the problem which I am going to discuss subsequently. Conditions are important, the same material used under different circumstances for different types of stabilities; you have to have effective or untrained parameters. Long-term, short-term, I have discussed this.

So, when you talk about the long-term stability its all the drain tests. And when you are talking about the short-term stability, these are undrained tests. Remember the words that you have to utilize the material either as a cohesive material or a frictional material. On its own, there is no material which would be like x or y.

You will find it slightly intriguing. The data obtained from a CU test on a soft clay, what comes to your mind? No, before you enter into all that game of numerals. The first question is how soft it is; and second question is why triaxial is being done on this. And third thing is how it was done; the concept of back pressure which I will be talking about today.

Because, soft samples are they cannot stand on their own. They are so soft that they may get distorted, soft sensitive clays. So, specifically it is written that there is a soft clay is not sensitive it seems; had it been sensitive, triaxial would have been tough to conduct on it. So, I would have done a UU test by using a vane shear, either in-situ or a laboratory.

So, in the casings, you bring the sample from the offshore environment by using a boat or a ship. Bring it to the lab, mount it on your setup, and do vane shear test; and this gives you a very good answer, UU test; vane shear is always UU, clear, unconsolidated undrained test. Now, with this preface, you have to determine shear strength parameters; so, you were asking this question and philosophical answer would be.

So that means they are ruling out few things from the algorithm, which they do not want to tell you. So, all these things will discuss subsequently. So, shear strength parameters in terms of effective stress. So, CU test if you are performing this on a on a soft clay, you are going to get c', ϕ', pore water pressures are measured. Now, from this point onwards, I am adding something extra to this; so, this part is okay.

Now, the second part is a different specimen of this sample, a different specimen of this soil is tested in undrained conditions under a σ_3 of 150 kN/m^2. And it fails when the deviator stress is equal to 75 kN/m^2. Calculate the pore water pressures in the specimen at failure, interesting problem. Have you understood the three parts of the problem?

The first one is the statement, defines the purpose of doing it on the material. Now, what goes in your mind the moment it says that the soft clay? I do not know what type of response this soft clay is going to exhibit. But, in the last lecture what have discussed if you remember, we talked about NC, OC states and the pore water pressures. And whether the NC material will be exhibiting ϕ value or C value; or OC material will be exhibiting C value or why ϕ value.

So, those things will eliminate the doubts from your mind; and you can achieve the exact situation. What is your impression about this material? Now, what I want you to understand is that whatever material we are working with NC or OC, that you should be aware of knowing; at least that should be aware of. So, for a given σ_3, if you see the value of pore water pressure, the moment you keep on increasing the pore water pressure, what happens?

The pore water pressure keeps on increasing. For what type of material is going to happen? That is to be understood. It is left to the technologist to use this material the way they wanted to. Now, suppose if I want to extrapolate something on both the sides. And if I really try to see 455 to 227, 110; and by the time I bring it to 100 kPa, who knows what the pore water pressure was over here.

And from 100, if I take it to let us say 50; the chances are that either this is going to be zero or might be negative. So, you have all the rights to see what has happened in the lower stress ranges; and what is going to happen in the higher stress ranges. Some of you were confused. Now, this at failure thing is everything is at failure now. So, first of all, you should understand that we have three Mohr circles for three specimens.

Is this part clear? And we are going to have a unique Mohr-Coulomb envelope. Now, go back to the statement of problem, try to understand whether C is going to 0 or ϕ is going to 0, or c' is going to 0, or ϕ' is going to 0. Soft clays, you are working in the range beyond reconsolidation pressure; so, I do not know whether you are guessing or not.

So, somewhere over here, you will be getting $\sigma_c{}'$; are you getting this point? So, everything is being done in the NC range; and for NC material what is going to be 0? So, I hope you must have realized that you might be understanding problem totally in a different manner, though the problem could be totally different.

The rest is mathematics and geometry; so, this part is very important. This is a typical NC material; two ways to prove this positive pore water pressures, correct, soft clays. Pre-consolidation pressure happens to be extremely small value, no issues. So, I will say $\phi \neq 0, c' = 0$; and now I can solve this problem. So, first part of the problem has been given to you to understand the material; second will fall over easily.

So, once you have established the failure envelop what is the interpretation of this? You have $(\sigma_1 - \sigma_3)$ is known, σ_3 is 150. That means what is the value of shear stress associated to this? σ_d is known, because ds by 2 or this is nothing but $\frac{\sigma_1 - \sigma_3}{2}$. So, we have decoded everything now, things have become simple.

So, based on this assumption, what this assumption helps me in fixing the Mohr-Coulomb envelope. Read the statement of the problem, a different specimen of this soil is tested in undrained conditions with σ_3 is equal to this. Where is σ_3 following line in our results nowhere; this part is missing over here. So, I am testing it somewhere very close to pre-consolidation pressure.

And it fails when DS is 75; so, I got τ value as 37.5. Now, what I should do further? Everything is known; and what you are supposed to find out? Compute the pore water pressure at failure in the specimen. So, if ϕ' is known, state of stress is known or not. What is failure? The Mohr-Coulomb envelope is known, Mohr-Coulomb envelope is known.

Now, this is the point where the failure is taking place. Can you construct the Mohr circle? So, this becomes your radius, and this is the Mohr circle; job done, finished, reverse problem. So, what we did yesterday was a forward problem. And today what we have done? We have reversed the whole situation. First, we identified the material, what is soft clay, NC material.

We know a state of stress, what exists at the failure. And from there now we are computing the pore water pressures, compute it; that should be a unique number. So, this comes out to be about 98.8; ϕ' will be equal to 25°. I repeat friction angles are never written in decimal places and second decimal places. They are always absolute numbers. Thank you.