Geotechnical Engineering - II

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Lecture No. 18

Interpretation of Triaxial Test Results

Until now, we have discussed about the philosophy of Triaxial test. And I have tried to overemphasize that, why a certain type of tests should be recommended for a given circumstances to simulate the response of the sample or the soil mass in general. So, having covered all these philosophical discussions, I thought will be quite good to take few example problems and then maybe share my ideas about how the interpretation of the test should be done, particularly the test results.

So, what I am trying to emphasize in the subsequent part of the discussion today is that, try to understand the material try to understand why a certain type of test is being done on this and once these two things are in line, you can interpret the test results quite easily. So, the first category of the problem in this series would be straight away test results which you can obtain by conducting the laboratory experiments.

So, suppose if I say specimen of saturated sand, now the moment you see the word saturated sands there should be something, you know, clicking you know, normally we do not talk about the saturated sands as such. So, each word in the problem is just like diagnosing a patient report and doctor has to be extremely careful to understand why the patient is saying something, it might be related directly or indirectly with the with the implications on the patient's health.

So, the moment you see that there is something defined as saturated sands, the first question is that, are we doing traxial tests on sands? This test is under question mark because, as I said some time back, normally, it will be difficult for you to make a sample of sands unless you go for advanced techniques. Under normal circumstances, sand samples are never tested in Triaxial setups, or they should be extremely fine sands.

So, this specimen is 75 mm in length and 37.5 mm in diameter. It’s a typical triaxial sample and this was fully consolidated. Now, particle size also becomes very handy over here because when we are saying saturate sands, this sands basically lie on the border of the silts and fine sands or the person is not very clear that why he or she is trying to conduct this test on this material. So, fully consolidated in a Triaxial cell by applying a cell pressure of 75 kN/m^2.

Now, from this is the first stage of the testing I hope you can understand this is the C part of the testing consolidation part of the testing. Now, from here, the second part starts with the shearing. So, this is the either let us see whether this is a drained test, or it is an undrained test. So, the cell pressure was raised to 550 kN/m^2 and an undrained test was done, and the results are given below.

So, the results are you have Δl decrease in the length of the sample, which you get from the dial gauge which you have attached to the sample if you remember there will be a proving ring so, this is the proving ring reading and proving ring normally are calibrated. So, one division is equal to 1.5 N is the calibration from the proving ring.

The cell pressure remains constant, this is 550 the pore water pressure which you are measuring. It’s a typical straightaway type of a problem everything is clearly defined, you have got the test results try to diagnose the material. So, there is a first category of the problem, there is a mismatch somebody designed a system, and the system fails and now I as a forensic expert go to the site, take the sample, bring it to my lab, analyze the samples and I would like to match this is the sample and this is what it was reported when the design was done.

Excellent example of category one, straight away problem where you are trying to find out some mismatch in reporting or testing. So, this is 18.75, 25.0 proving ring readings are 0, 435, 813, 1020, 1140. The pore pressures are 480, 348 these are corresponding to these values so please ignore my improper tabulation. This is 202, now my question is if you really want to learn the geotechnical engineering, what is your speculation by seeing the numbers which I have written on the board.

Δl (mm)	**Proving ring reading**	**σ_3 (kN/m^2)**	**PWP (kN/m^2)**
0	0	550	480
6.25	435		348
12.50	813		202
18.75	1020		85
25	1140		51

And this is what the diagnosis of the material is. So, the entire story is here itself. Forget about the mathematics part in shear strength theory, we do not talk about the mathematics at all. What is the implication of this whole thing? That is what I said that this is sort of a forensic examination which is going on, what is the speculation?

Do you find something interesting? Very speculating? Yesterday I was talking about the sample being in ICU and you are an expert so, what information you get from here, this is what you have to catch. I may give you a hint, but then it's not going to help you always. Well, I can reverse the whole situation and then you will be in a trap.

So, in this case, as the shearing process goes on, I think some of you are discussing this the other day what essentially is happening is the proving ring reading is nothing but the τ value which is nothing but σ_d value. Is this alright? Shear stress when you are shearing the sample from the bottom and there is a frame and there is a PR attached to this. So, when you are pushing it up, the reaction comes in the proving ring and the readings are this, the load is increasing, and this is your axial strain.

So, if I know the initial length of the sample and if I know the Δl I can always find out $\left(\frac{\Delta l}{l}\right)$. Now this $\left(\frac{\Delta l}{l}\right)$ is nothing but ε_a, so you shear starting from point 00, what is happening? You are straining the sample, the proving ring is increasing or in terms of the σ_d value σ_3 remains constant after the consolidation process is over. So, consolidation was done at 75 kN/m^2.

What is so peculiar here are you observing something? This is what you have to catch, the consolidation is done. It is an undrained test, what undrained test tells me is that initial volume is going to be final volume of the sample.

$$V_i = V_f$$

So, what is changing? If had been a drained test, alright. So, this is for a typical undrained test had it been a drained test, what difference it would have made? It would have become V_f plus minus volume of water. I have used very trickily plus minus V_w, why?

$$V_i = V_f \pm \Delta V_w$$

That is what we discussed yesterday in the lecture, the positive pore water pressures and the negative pore water pressures. So, the moment you are seeing the final volume is getting changed and the volume of the moisture or the water, which is coming in a sample, or within the sample is controlled.

Now this becomes a typical condition which I am imposing on this, it is my wish. Now, the hint is, if you look at these numbers, what do you realize? So, the more and more you shear a sample, what is happening? The pore water pressures are decreasing, that is the crux of the problem. That is the material you have to capture this. So, there is a decrease in the pore water pressure, under what circumstances this is going to happen? It is a drained test, the more you shear, the more water goes out, but this is a undrained test, that is the problem.

So anyway, what we will do is let us decode this further. So initial V_i is length of the sample, multiplied by area of cross section, this we maintain constant in the Triaxial test, we do not allow, normally area cross section to chamber is going to change. And then what is going to happen? l_i the final l will be l_i minus Δl into A_{final}, let us write it as A_1 because *f* will be used for failure.

$$l_i . A = (l_i - \Delta l) . A_1$$

So, from here I am getting the area correction factor. So, A_1 will be equal to if I can write this as l_i into A upon l_i minus Δl.

$$A_1 = \left(\frac{l_i}{l_i - \Delta l}\right) . A$$

So, this in other words becomes A_1 will be equal to A upon *1* minus ε_a.

$$A_1 = \left(\frac{A}{1 - \varepsilon_a}\right)$$

So, we have obtained the corrected area of cross section this correction has to be applied otherwise, your test will be wrong. Now, I know the value of the proving ring.

So, the proving ring stresses are nothing but σ_d value. So, that will be equal to proving ring divided by A_1. So, I can compute the value of σ_1 minus σ_3 which is essentially equal to σ_1' minus σ_3' rest is all mechanical exercise. So, these are first class of the problem where what you have done is by getting this hint of undrained test on a material which is supposedly to be known, saturated sands, we are trying to interpret the pore water pressures and then we are trying to understand the material.

Now, in this question, what you are supposed to do is you plot (σ_1'-σ_3') and (σ_1'/σ_3') as a function of ε_a. That you can do now. Why are we doing this? We are trying to do this because if I know the τ versus ε_a response or if it is like this, I can classify the soil. So, this becomes a NC material NC response, and this becomes an OC response.

So, what I have done? I have established the material by doing the Triaxial test very simple example. And the hint is here most of the time geotechnical engineering analysis and experimentation and experimental investigations are directed towards cross questioning, cross examining something. The second part of the problem would be plotting the Mohr circle at failure having done all these things you plot the Mohr circle at failure.

So, what is the check whether testing has been done properly or not, whether the guy says that you find it out at failure I do not know whether I have achieved the failure or not. Now, what you should be doing is you should plot the results over here and see whether the peak has been achieved or not. Otherwise, this test is incomplete. So, in the practice of geotechnical engineering most of the time these types of investigations are done which are sub judice.

I do not know you have to plot and you have to see. So that is what I am saying. The whole idea is with all this story depicted over here, look at the trend if there the hump OC there is no hump NC, check whether the failure has been achieved or not wright a line, test was incomplete. If you are still on this part of the curve you cannot say anything, are you getting this point?

Vibhav. See, the question is that there is nothing like having a unique solution to a problem, it is all your interpretation I hope you are getting this point. So, I am just trying to create several situations which would help you in maybe interpreting and becoming a top-class legal adviser to a company.

τ is coming from here proving ring. This was the frame, what we did is we connected proving ring over here and this was connected to the sample in the form of a plunger, good that you have asked this question, and this is resting on that load plate and below that you have the porous stone, and this is resting on the pedestal. So, when you shear it from the base, the reaction comes in the proving ring because the frame is rigid axial strain is causing the shear stress to develop. Look at this graph the more and more you shear, what happens? The more and more shear stress gets developed.

So, the first reading corresponds to 00, next is this, next is this, next is this, next is this, so on, so on, so on, and failure occurs over here post failure, residual. So, in other words, the proving ring value gives you the deviator stress. The proving ring gives you the σ_d, that is it. Why? Because the moment you shear it, when you are applying a strain from bottom is getting sheared and that is what you are measuring over here the dial gauge reading is this, I hope you are not getting confused.

So, dial gauge gives me Δl and this ($\Delta l/l$) gives me ε_a and this ε_a has given me A_1. So, proving rings are a steel ring this is connected to the rigid frame somewhere here because of the rigidity of the ring, you know we have utilized the hoop stress and when I deform it by applying the axial stress, this also gets deflected, and this is the proving ring constant. That means one division which is observed in the proving ring corresponds to the load which is getting transmitted on the system equal to whatever 1.5 Newton or whatever.

So, this is the system on which works. So, the best way is you apply the load and see how much the deformation the system is undergoing. So, when you go to the lab, please get this thing done because the rings are the ones which are standard materials which are used ellipse cannot be used. The idea is you are taking the help of the hoop stresses, that is it.

How this area will be changing. Very good question. So, when you are compressing a soil sample, what happens? Initially the sample would be like this, no issues discuss. Now what is going to happen? Because of the shortening of the sample, this is how the bell-shaped failure would be, did it happen or not? And at failure this is a failure plane and what you are finding out is σ and τ, that is it, under application of σ_d and σ_3, that is it.

A cylinder cannot be rigid, because this depends upon the type of soil. So, if I am working on a rock sample, what is going to happen? Rock will not tolerate so much of deformation and if you keep on compressing them, which is known as UCS on rocks, there will be a brittle failure. So, what will happen is there will be a vertical split, and this is how like the concrete cube rock sample or the rock core we call it will break. This test is normally done to obtain elastic modulus and Poisson's ratio of the rock and under undrained conditions mostly.

Sometimes you will find very distinct failures. So, depending upon again the condition of the soil sample, it's good that you have asked this question, the shear plane develops and what is going to happen now? Remember the first lecture of the course, with respect to the parent rock mass, soil mass, the tendency of this rock block would be to slide, that is what the shearing process is. So, shearing plane is AA which gets developed because of the Triaxial testing and on this plane, you are trying to find out the state of stress.

So, this point what he will also asking about is the failure point. So, that means, if I know this point, I can complete Mohr circle provided what? that becomes the second type of problem material is not known, only state of stress is known, that we will go into. The state of stress I think I can give you the Mohr circle would look like be very careful about the effective state of stress or normal or total state of stress because your answers will be wrong if you plot the results on opposite scales.

And that is why yesterday lecture was dedicated on the type of parameters which you get from this test. So, you should remember that all these results are you know filtered out by applying membrane correction. That is it and area correction. So, what I will do is I will make a wax sample I will test it in UCS I will be getting some result then what I will do is I will encase it in a rubber membrane, and I will redo the test. So, I will be getting now response like this.

And then I know at failure how much axial strain is coming because of the membrane and how much shear stress is getting imposed on the sample because of the rubber membrane. All round pressure σ_3 consolidation stage is if you remember this is σ_3, this is σ_3, all round pressure. So, you cannot share the sample because no shearing is being done.

So average stress is this point and what about the deviator stress? 0 that is it. From this point onwards you are shearing the sample keeping σ_3 constant. So, all this is happening under application of σ_3, and what is $\Delta\sigma_3$? This minus 75 and what 75 corresponds to consolidation test, all the pore water pressure has been removed.