Geotechnical Engineering - II

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Lecture No. 12

Selection of Parameter (Shear Strength, SS) I

See, suppose this is a particle perfect the sphere and we started sharing it under compression. So, what is going to happen? It will tolerate up to certain point, elastic range. Now, there might be a breakage, crashing which might occur the moment crashing occurs what happens the system becomes slightly less rounded, sphericity is changing. The more and more system become flaky, irregular, interlocking effect comes, that you have to take into account which one easy is to compact this or an irregular system or a fine material you have to decide which one is easy to compact.

Yes, so that means here the densities cannot be achieved very high, there is a limitation of this. So, even if it gets converted to a rhomboidal structure, that densities you are going to achieve much, but once we start shearing the whole thing is again back to this discussion. So, in my opinion, more cohesion will get mobilized. So, if you remember in the last lecture, what we discussed is, the more and more the system is irregular, what is going to happen? The better interlocking effect is going to happen and better interlocking is going to give more cohesive nature to the soils. Keeping the density constant.

So, all these graphs are going to be density dependent, please remember. That is what I said, shear strength is increasing the form of the cohesion not the friction. So, you just imagine the strength comes out of the two component and it’s an interplay between the two components, clear?

So, for general soils this could be any situation depending upon the stress and now you cannot say sand will show only friction, clays will only show cohesion that part we will start discussing slowly and slowly. So, in short, what we have done is? We have devised direct shear testing again to characterize their response and this time, what we have done is we have included the state of stress to which they are getting exposed.

So, from this stage, if I want to lift it, let us say because of flooding, I have to lift the embankment. So, what is going to happen? This $\sigma_1{}'$ becomes $\sigma_1{}'$, $\sigma_1{}'$ not in that way let us say $\sigma_A{}'$. So, this $\sigma_A{}'$ is going to be from σ′ to $\sigma_A{}'$. So, c, ϕ is getting converted slowly and slowly to maximum c and less ϕ.

Texture and friction truly speaking for fine grained materials or coarse-grained materials. No, you can't mix it up. So, in fine grained material, when you talk about the texture, this is the pore structure and that is what is going to govern the texture and that is what is going to govern the cohesion. So, write this question. Maybe after third lecture we will discuss about this OC, NC comparison and just write down at the back of your notebook.

I think I asked somebody else also to write to you or somebody else to write a question. So, that time we will discuss about the fine-grained texture thing. In coarse grained material, we do not define texture as such. So, texture is a misnomer for coarse grained material, coarse grained materials are basically particle shape, size, specific gravity, and why specific gravity? So, that the particles should not get crushed. So, if you are dealing with pure quartz, that is not going to get crushed up to 30 MPa. So, this graph is going to be linear.

But suppose if you are working with a soft mineral like sandstone, no sorry, suppose let us say calcium carbonate or Calcite is going to yield very easily. So, for coarse grained material, we normally do not use the word texture.

Time dependent consolidation of the materials. So, at a constant stress time dependent deformation of the soil mass. So, the best possible example is you take a candle put it on a table in a dingy room forget about it and come after 5 years or 10 years what happens? Initially the candle would be like this and then constant stress is gravity, time dependent deformation that is creep. So, normally we do not take into account creep effect much in soils unless you go into the theory of rheology. So, read the papers by Rakshith Shetty and he has worked in the creep of fine-grained materials.

So, for all your practical purposes the settlements are going to be either immediate settlements or majority of them are going to be consolidation settlement provided you are dealing with fine grained materials. So, you must have realized that we stopped somewhere at 90 percent in the test, and we said that this is going to be maximum time factor for 90 percent and beyond which you did not ask a question. So, beyond this consolidation creep takes over and we say that this time tends to infinity.

In concrete, you must have taken a creep coefficient to design your concrete beams and columns, is it not? So, this factor is a function of some multipliers point nought nought something multiplied by delta T. Now, let us switch over from 2D to 3D which is going to be more realistic.

So, let us start this dialogue between the plane strain versus Triaxial state. We know the pros and cons of conducting triaxial box test that means the plane strain idealization and we said there that most of the time when I take out a sample from the ground, this is going to be a 3-dimensional situation.

So, this is more realistic as compared to plane strain. However, it is very difficult and expensive to create a 3D situation in the laboratory and test the parameters and complicated also, but more realistic. So, suppose, if I take an element and if I apply σ_1 over here, and because of σ_1 application the strains are ε_1, σ_3, ε_3 and σ_2, ε_2.

So, plane strain is the condition where the strains in the perpendicular direction of the system are negligible or 0 or they do not change, embankment on which the trains pass by. So, this is the width of the foundation, this is the top width, this is the length tending to infinity, this is the height of the embankment in Geotechnical Engineering-I, we analysed this embankment for seepage analysis, and the sequence of construction you borrow the soil from somewhere compacted and achieve certain density because all the parameters are going to be dependent upon the density.

Typical plane strain condition, normal stress, confining stress nothing is going to change in the perpendicular direction. That means ε_2 is going to be 0 for plane strain condition 2D strain condition. And if I say that the L is the length, B is the width, H is the height. What is the volume of the system?

$$V = L.B.H$$

You must have done this enough in your 10 plus 2 Physics JEE. Now,

$$\frac{\Delta V}{V} = \frac{\Delta L}{L} + \frac{\Delta B}{B} + \frac{\Delta H}{H}$$

These are nothing but the strains. Now, this becomes the volumetric strain. I will be using it quite a lot.

So, there is a volumetric strain which is being experienced by the sample under Triaxial condition σ_1, σ_2, σ_3 and depiction of the triaxial condition is for a quick reference, what did we do? We plotted σ_1, σ_3 where is σ_2? In between and we have ignored it. So, this is σ_2 this is the intermediate principle stress σ_1 is maximum or sorry not maximum major principle is stress, σ_3 is minor principle is stress and σ_2 is intermediate principles stress.

So, this is the volumetric deformation which I am talking about. Volumetric deformation happens in 2D case also plane strain case, direct box what did we do? We measured ΔV separately and we measured ΔH separately, what remains constant is area of cross section. But, in assignment number 2 I have written find out the changes which happened because of the change in the area of cross section sample. So, if I assume that the area remains constant over here, which is the gross negligence you should normally apply the area correction. In triaxial case imagine σ_1, σ_2, σ_3 are acting we have ε_1, ε_2, ε_3.

Now, what is going to happen? This will be equal to,

$$\varepsilon_V = \varepsilon_1 + \varepsilon_2 + \varepsilon_3$$

What is the relationship between ε_2 and ε_3 3? What we are assuming is we are assuming that the σ_1 is the cause remember, which is causing the deformations under applications of σ_2 and σ_3 otherwise life will become very complicated and what we are trying to study is because of application of σ_1, σ_2, and σ_3 how much ε_1, ε_2, ε_3 get generated in the system that is the typical triaxial condition.

The simplification of this would be when I put,

$$\varepsilon_2 = 0$$

that means, when I say,

$$\varepsilon_T = \varepsilon_1(1 - 2\nu_1)$$

Is this okay? Typical 3-dimensional condition what about the ε_V under plane strain condition, why? So, when you did a consolidation test and your oedometer ring was the steel ring to put the sample there and compress it from the top, you assumed that ε_2 and ε_3 are 0, understand this concept. Typical uni-dimensional loading that is why we call it as one-dimensional consolidation loading. So, in a consolidation setup you apply σ_1 and what you measured is ε_1 the steel ring is giving a confinement and there are no strains because sample is not free to deform in the ε_2, ε_3 way.

So, this is a typical one-dimensional loading which we have used under consolidation loading concept. Two dimensional is the direct shear box, 3 dimensional is triaxial test. So, we are graduating now from one dimensional to two dimensional to three dimensional. For the equal volume changes, if I say that these two are equal ultimately the soil does not know whether you are assuming these as a two-dimensional system or a three-dimensional system. So, what are the relationships we are going to get you are going to get this will be equal to 2 times triaxial. What is the meaning of this? Plane strain always gives you a higher Poisson's ratio as compared to the triaxial condition.

What is going to happen to the friction angle? So, if I plot let us say ν versus confinement can you help me in plotting this, suppose if I said this is one graph and there is another graph which is one is going to be plane strain, the top one. So, this is the plane strain, and this is the triaxial. The more and more you confine the sample the deformation the lateral directions are going to be extremely less that is the logic. So, what ground does? What nature does? When you take out a sample from let us say an infinite soil mass homogeneous isotropic semi-infinite.

So, if you take out a sample from here the neighbouring soil is confining it, the moment you have taken out the sample to the laboratory what has happened, the effect of confinement is lost. So, you have to recreate this effect of confinement to get the parameters which are realistic parameters and hence, you have to expose the sample after bringing out from the field to the third dimensional loading and you have to go for triaxial loading, it is a typical triaxial condition. So, normally, what we do is σ you are basically talking about ε_2, ε_3, it is a cylindrical sample which we are taking out. So, this is axial symmetry case there is a symmetry about this axis.

So, whether this is σ_3 and σ_2 does not matter, which one, because your ε_2 and ε_3 for triaxial samples, we are talking about the triaxial sample are going to be same because this is a cylindrical sample, triaxial sample is always a cylindrical sample. And concrete technologies what do they do? They do not break cylindrical cubes, cylindrical sample sorry, they believe in cubes because they are more interested only in the ultimate strength and the crushing strength. But for us there is a lot of stories before the ultimate or the crushing state is achieved.

So, our philosophy of designing the systems is different. Now, there are few relationships which you can write,

$$[\phi_{PS} - \phi_T] = 0.8°$$

$$\phi_{PS} = \left[1.1 - \frac{B}{L} \times \frac{1}{10}\right] . \phi_T$$