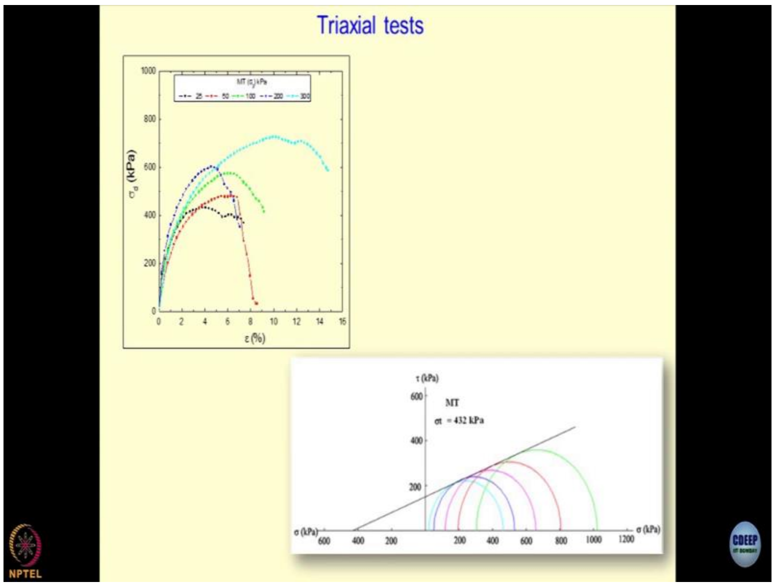
Environmental Geomechanics
Prof. D.N. Singh
Environmental Geotechnology Laboratory
Department of Civil Engineering
Indian Institute of Technology-Bombay

Lecture No. 49
Cracking characteristics of fine-grained soils-II

(Refer Slide Time: 00:15)



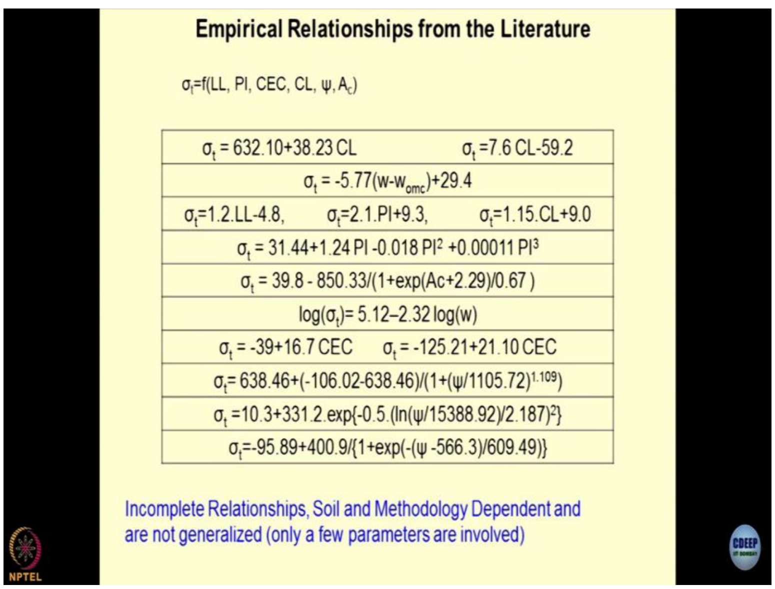
The first in the series to obtain the tensile strength directly would be you perform the triaxial test, and I hope you can recognize this situation very easily if I perform the test, where I do stress-strain relationship, for different types of samples and if I test them and what I have to do is I have to develop the mohr envelopes All right. So, this line which you have drawn is mohr-coulomb envelope and if I extend it up to the back and if I find out the intersection of the mohr-coulomb envelope on the stress axis, normal stress axis this is nothing but σ_t.

So, it actual respect can be utilized to obtain the tensile strength of the soils provided, you have done the test very very precisely. For your quick review, the intercept on the y-axis we have defined as apparent cohesion. So, apparent cohesion is the one where we do not have any normal stress acting on the soil, but even then, the soil exhibit some shear resistance. So, this could be because of the interparticle cohesion, which is because of maybe carbonates or sulfates which are present in the soils.

It could be because of the angularity of the grains of the sands and because of the angularity, there could be a sort of a normally what we call it as a gear assembly sort of effect these are the two gear assemblies. So, in the case of the sands if the sands are very irregular, and if they are highly compacted what happens this is a sort of a gear assembly which gets formed this itself might give you apparent cohesion in sands.

You need not have any shear strength sorry any normal stress, which is applied to get this shear strength. So, we use this σ_t obtained from the triaxial response of the clays as the benchmark of the value tensile strength. And I am sure you must have done the triaxial test. So, you have to apply these membrane corrections and all to eliminate the values which are coming because of the confinement.

(Refer Slide Time: 02:36)



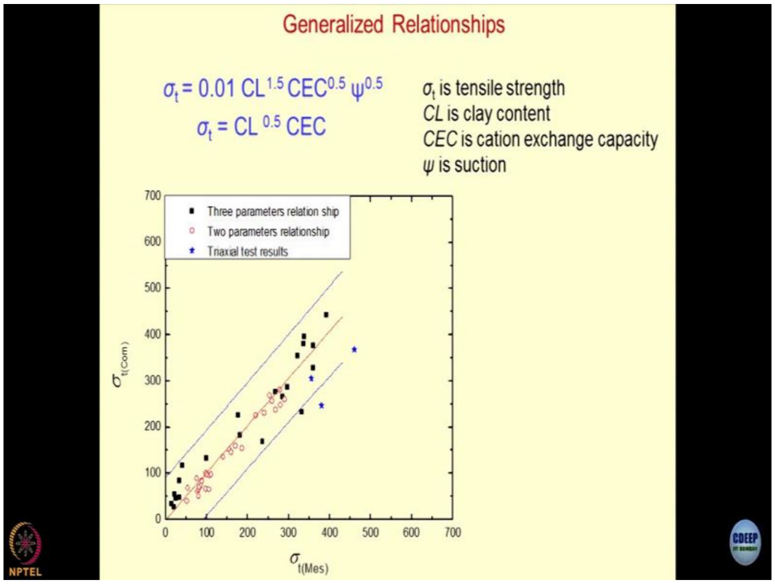
What we did is, we did some literature review, and we realized that tensile strength had been attributed to the liquid limit of the soils. Why because indirectly liquid limit connotes to mineralogy. Tensile strength has also been related with the plasticity index. Again, the reason is simple, because PI is Indirect form of understanding or maybe the reflection of the mineralogy present in the soils.

Then σ_t is also a function of cation exchange capacity again the same reason because of the mineralogy. The clay content, the clay content is the percentage fraction which is finer than certain sized 2μm. So, as the size decreases, cation exchange capacity increases, the surface area increases liquid limit increases, PI increases, all that series is still valid and the suction, so ψ corresponds to the suction value.

And one interesting thing here to see is that the suction includes in it the state of moisture content of the soil. So, higher the moisture content, lower the suction. Correct and AC is the activity of the soil. So, there are several types of relationships which are available in the literature. You will notice that tensile strength is a function of clay content. More the clay content more the tensile strength. Some people have correlated tensile strength with the OMC. The moisture content at OMC and the moisture content at a given point in the soil mass.

Liquid limited, Plasticity index, clay content, the activity of the soil, moisture content of the soil, suction of the soil, and so on. I would say that this is a sort of journey in terms of the evolution of the subject. So, suction came quite recently in the picture before that section was not included in defining the tensile strength, but people have realized that suction is the one which includes all of the parameters into it because the suction of the soil is a parameter which talks about its physicochemical mineralogical response. So, if I measure the suction or if I measure the cation exchange capacity, I can get σ_t values. This work was done by my two master students. Both of them are incidentally in Dhar group, now. And they are doing extremely well. One was the Mr Shinde, and another one is Ramana these guys have done fundamental studies related to tensile strength determination and what we realized is that the relationships which are only single parameter relationships cannot be much encouraged, because you cannot link directly clay content with the σ_t and so on. So, this is a commentary which we created on the subject.

(Refer Slide Time: 05:31)



So, generalized relationships of this type were developed σ_t is some function multiplied by clay content, CEC, and ψ and I hope you are conversant with the symbols by this time and this is how we validated this equation. Number one and number 2 equation does not consist of suction in it, and it deals with only clay content and Cation Exchange Capacity. What we have done is by using these equations, we have obtained the σ_t computed, and this σ_t measured is from the triaxial test.

And we have shown that there is a good relationship between the experimentally obtained results from the triaxial testing and both the equations yield good results. I am sure you will realize that these equations require the determination of two parameters which cannot be obtained in every geotechnical in a laboratory. Is it not except for the clay content. Cation exchange capacity requires some basic paraphernalia in the laboratory.

How it is done, we have discussed this. So, and of course, suction measurement. So, suction measurement is still not many people are doing. So, for the sake of convenience of both parties, the suction measurement is being done, and it is not being done, or suction is known and/or not known. You can rely upon these equations, and you can go ahead with the design of the systems.

So, I am sure you must realize these efforts were quite significant in obtaining the σ_t value of the geomaterial just based upon it is, I always read it like this physical and chemical response. So, it is a physical, chemical and mineralogical and mineralogical and physical. So, this is how you read this relationship. So, in short, we have the physics of the material, the chemical state of the material and the mineralogical state of the material.

These type of relationships become much more useful for designing the clay lines, and the top covers for, different types of disposal facilities. I am sure you can realize one more advantage of having these equations, particularly if the soils are contaminated. So, I can always find out what is the level of contamination of the soils and how these parameters get changed and hence how σ_t is going to get change.

So, this is how developmental work goes on. Sir here, by general specifications we have three options to analysts analyze the tensile strength, three parameters, two parameters triaxial test, and in different cases, we get different tensile strength. In these three methods, we get different σ_t values; right now, we are preferring which case we are taking. No, I did not follow your question, can you repeat it. Sir, here we are considering three parameters, two parameter triaxial tests and in every case σ_t is different. No see, three parameter and two parameters are the equations.

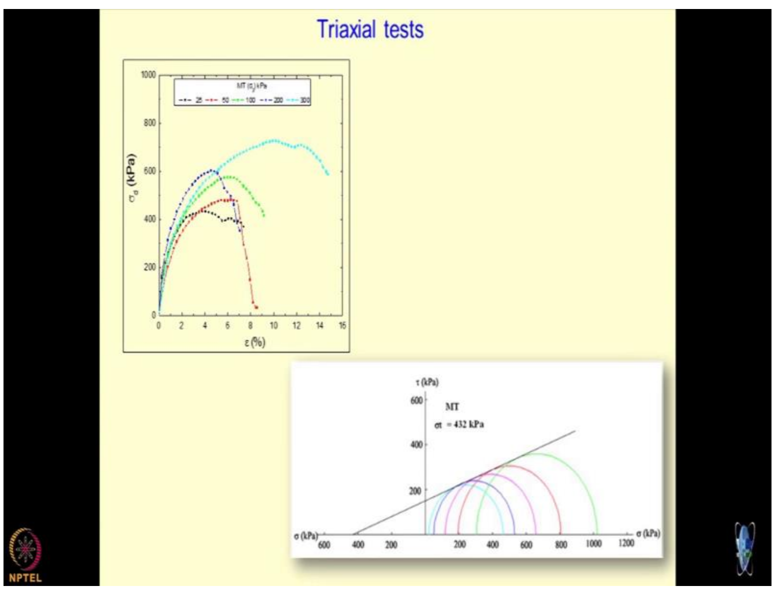
So, what you get is σ_t computed. So, σ_t computed you get from these two equations, and σ_t is the tensile strength test which you get from triaxial testing, if you match these two, then you realize that there is a significant match between the two. So, what in the first case you are considering a suction also and to two parameters, there are no suction values. So, in case of that, you will get something σ_t value something lower. I think you missed the whole story. The whole story was that everybody is not capable of measuring the suction value. Because it requires a lot of gadgets. So, the idea was to give two equations, if you can measure suction that is also good. Unfortunately, you cannot get rid of CEC. So, the cation exchange capacity has to be included. So, the choice is yours if the suction value, you can substitute over there and if you do not have and then you can go ahead that is what the whole idea is. Yes, So, what is the question, but this is if we include the suction value.

So, we get more σ_t value this is the something concluded. It is basically the root of ψ the way the mathematics and it is not so easy to decipher because it is a multi-parameter system, so I am sure you will realize that these powers will take care of something. So, truly speaking, this becomes root of CEC×ψ This is how the mathematical representation is, as I said these empirical relations are ascribed, subscribed, are basically these equations go in the name of the researchers who developed them.

So, you never questioned that Casagrande's equation to find out CEC value from the liquid limit is that not. You always say point not nine multiplied LL minus 20 is this correct? He was a person who obtained this relationship. So, these are empirical relationships which might be useful for designing the systems now your question should be that how based on only 3 triaxial data you are generalizing the thing.

So the answer would be this a philosophy. You are free to conduct your experiments. Then you get σ_t values. And to substantiate these, I think you should realize that if you look at this figure.

(Refer Slide Time: 11:07)



As σ_t decreases, what is going to happen? Strength of the material is going to increase. Su value is going to increase. So, simulating these type of things in the laboratory might be having limitations. So you require different types of setups in particular, where extremely low values of the stress and strains can be measured number one and you require very sensitive setups. Then only you can get extremely fewer values of σ_t and then this portion of the graph can be completed.

So it is a hypothesis which is proven by some data points. 95% confidence band is not a very poor band to convey the message that these relationships are working. Understand how the graphs are plotted. The graph is plotted by getting the computational values of σ_t by using these equations, which are derived earlier, **"Professor - student conversation starts"** we got a particular value for σ_t from triaxial, then for that how do you get y value. For the same soil, that means, I am sure you will realize that CL, CEC is associated with the soil.

So, that means for the same soil if I plot σ_t computed and σ_t, which is from the triaxial testing. This is how they sit. Must be like for every triaxial test there will be a particular computed value right. No, that will be very difficult because you cannot mould the soil sample with variable moisture contents. So, when you are doing triaxial testing, your sample is fixed, that means the soil is fixed and the moisture content is fixed. In other words, the suction is also fixed. So, suppose if I say number one soil for which suction is known, that when the moisture content is known, CEC is known and CL is known.

If I substitute the values over here, and if I do a triaxial test, the 2 data points wherever they sit, this is the trend which emerges. So, the quick answer to your question would be that σ_t values are for the same soils. No, sir. I did not understand for a particular σ_t with respect to the y-axis you got value. Forget about σ_t. That is what I am saying is for the given soil, I have two values of σ_t 1, which I get from computation and which I get from triaxial.

I am plotting column number 2 and 3 for the same soil. That is it. Sir, yeah, then this charge won't be there right. Which one? I thought for each triaxial test we will be like for a particular sample we will be computing the value numerically and then plotting. No, so that is what I said this is all soil specific because for a given soil the CL is known, CEC is known and suction is known provided W is constant.

So, if you are interpreting this graph in such a manner that is moisture content changes whether I can use this relationship or not then this becomes an interesting question because ψ itself is a function of moisture content that means, for the same soil with same CL, same CEC, you might have to conduct several experiments by changing the moisture content and measuring the suction then you will be getting several circles, and then you will be getting several σ_t values that are possible. **"Professor - student conversation ends."**

Otherwise, the simple way to look at this would be fixed column number one and compute σ_t by substituting these values and by conducting triaxial test might be computed why in Y-axis, so why triaxial test that star mark result is coming that because for that σ_t computed will not be there if I plot x y z together on a scale this is a three dimensional part, which I will be getting.

If I want to convert a three-dimensional plot to a 2-dimensional plot, what I will be doing, I will be keeping one column constant that is it. As simple as that, so I am keeping the first column constant and plotting for that value. Y versus Z? So, your σ_t measured is z, σ_t computed is one of the two values Y and for a given x I am plotting these two rather than saying for a given σ_t. It is not that like that. For a given soil you have two σ_t values are three σ_t values which you were plotting. So, you have to look it like this for a given soil, if I use equation one if I use equation two and if I do a triaxial test where the results would be and if you plot them this is what the picture would be. You said that as undrained shear strength is increasing that tensile strength of the soil is decreasing, undrained shear strength of the soil is increasing tensile strength might be decreasing correct.

So, what we observe in the field is su σ v prime is point 2 constant as a function of letting us say PI, yes. So, we can say that that soil which is below the certain depth will have lower tensile strength and soil above the means. So, all these are the limitations of the Casagrande's methods; please remember they are not talked about the tensile strength as such, they are blind of these parameters.

I hope before you interpret all those relationships, you should realize that the relationships are blind of these parameters, they cannot be employed here their domain is totally different. There you are using one term OCR value also so that OCR is not coming into the picture unless you relate OCR with the suction value. Your analogy is good, but try to understand the limitations of the existing relationships. Now, beyond imagination would be a fact that linking the tensile strength which appears to be a mechanical property with the mineralogical, chemical and physical properties is a very interesting philosophy. So, do not go by the terms only CL, CEC and ψ this is a hunch of a researcher that he or she has used these parameters to obtain something which has a very wider application, Fine. Read the papers which have been written by Sudarshan Shinde and KV Ramana, Hanumantha Rao. These relationships were derived by these three guys. There is a lot of philosophy which we have discussed in the paper.