Environmental Geomechanics
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Lecture No. 50
Cracking characteristics of fine-grained soils-III

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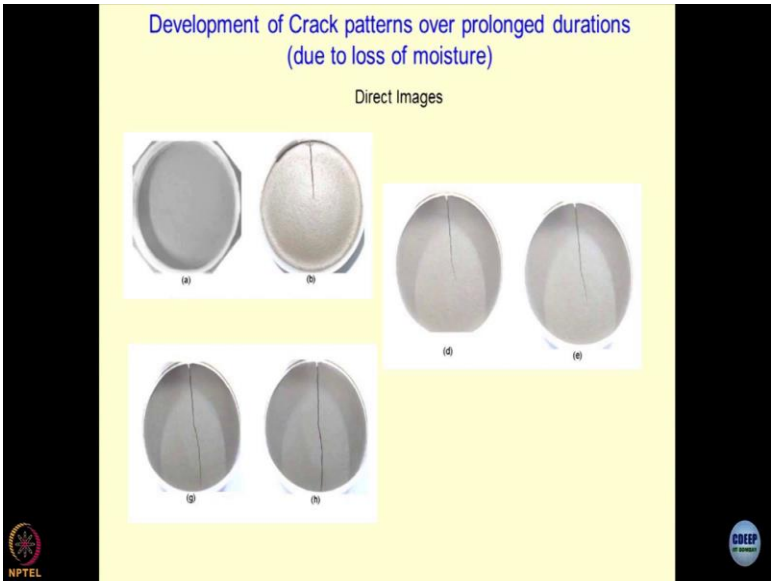

So, the next part of the analysis is the development of the track patterns over prolonged durations due to the loss of moisture. When you do image analysis, this work was done by my PhD scholar, Dr. JV Prathyusha. She is a faculty member at NIT Thadepalligudem. What is that? Thadepalligudem. So, she is working there right now.

So, it is a very interesting concept we wanted to see, when you boil milk, what happens to the milk. And then the whole thought process started from this activity when you boil milk tea how the surface looks like, what changes the material goes undergoes. The problem is when you are boiling any liquid. You cannot put a camera on the top of this why condensation. So we spoiled one camera also very expensive by putting it on the top of boiling fluid, and the whole lens got spoiled.

Any way it happens in R and D, but next time we were successful. So, if you take the initial sample, we call this a specimen of clay in the liquid limit state put in a Petri dish, and then you expose it to the environment, and we wanted to see how this crack propagates in other words, we are trying to see how σ_t develops in the soil mass, this is the crack initiation point. So, over a period of time, this point will keep on moving further.

And this is how the crack propagates. And ultimately the entire thing gets split into two parts. So, for a layman, I think there is nothing much to be discussed over here, but for an environmental geotechnologist. This was a PhD thesis because there is a lot of dynamics associated with a material. Until now, you have never talked about C and pi as a function of time in your system. You always assume C and pi always constant.

But I am sure you must be realizing that here this is a case, where the complete mobilization of σ_t partial mobilization of σ_t, what type of material properties are getting changed in the process of all this happening is a big question mark. So, this one actually we wanted to first of all capture in the image form and then do the image analysis.

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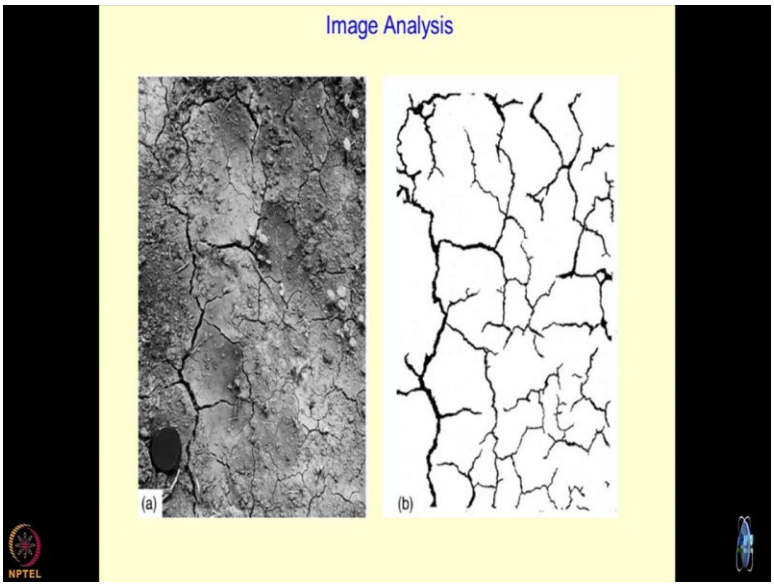

This is what happens in nature. This was a project, which I was doing for a huge reclamation, which was going on in one of the ports. And the question is, if you are not using the right type of the soil, even after the pad is constructed, the entire thing will crack, and your filling will become

defunct. So, one of the ways to analyze the whole thing is you convert this into greyscale results; this is what is known as greyscale results. And then by using software, you can find out what are the features of the tracks which developed.

So, I would be more interested in finding out what is the length, what is the width. What is the depth of these cracks, what is the intersection angle, what is the area which is getting included in one of the tracks? So, for me, this thing becomes a sector. So, if I want to correlate the area, the thickness of the crack, the length of the crack and the time it takes to complete pattern to get formed, this would yield a lot of interesting results. This is a game of patience.

I hope you realize somebody has to really sit down and do all these types of micromechanics modelling over months and years.

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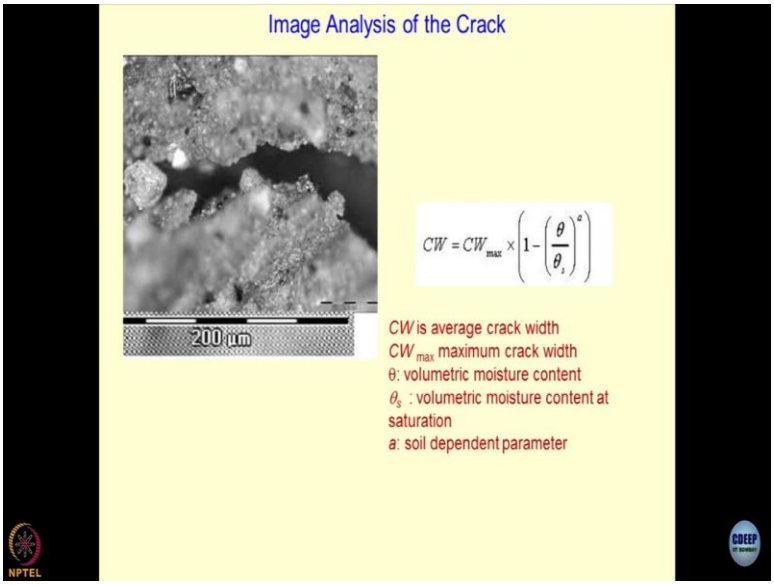

This Show the beautiful third dimension of the crack I hope you can realize that this much scale is 200µm. So, what is that we have done is we have if you go back to this image and if you if I want to see what are the features of these cracks in the third dimension perpendicular to the plane and what is the width of this crack at a given point of time, then this type of analysis is done, it looks like a canal separating the two islands. But, truly speaking these are two splits of the soil samples because of the desiccation cracks. So, I am more interested in finding out the area of the crack, width, and depth over a period of time because this can be linked with the tensile strength.

So, from this type of analysis, we came out with this function that is the crack width equal to maximum crack width, which can be attained by a soil mass and this is the ratio of the moisture contents corresponding to the cracking time and the saturation moisture content volumetric and a is some coefficient.

Why is these analysis being done, when user agencies like sports, they approach you their objective is that the pitches should not crack in the very beginning of the match commentators say no some second day onwards third day onwards, the pitch will start taking turn and spin and whatever. So, you can design the pitches like this you can design the turfs like this you can design your geostructures like this, where depending upon the time how much strength should be mobilized in the form of tensile strength.

So, suppose a landfill cover, where a lot of methane gas is going to get generated inside, and I want to make sure that the methane pressure is not going to be high enough to, first of all, crack the top covers. For that what I can do is I can provide some methane collection points. From there, I can suck out the methane which gets developed in the system, because the landfills are huge in area, so, every point you cannot cover by installing a gas collection points, it might be possible where the internal pressures are building up so high in the landfills, that they might influence the stability of the top covers.

So, I can do a reverse analysis, a material which has a tendency to show this much of the maximum crack width at a given moisture content, if it happens, how to retrofit the system and that is what my Ph D student Prathyusha did, we devised micro materials which can be injected into the soil mass to stop cracking of the soils. I hope you understand how the philosophies can be developed out of simple research ideas, and you can give a solution to the industry.

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This is where we did a very advanced study which is known as three-dimensional laser microscopy, extremely expensive equipment, we had this in our laboratory, and we could utilize this type of a system, a laser beam can be utilized to fathom the third dimension of the crack. So, it depends upon the concepts of the physics where the light scattering is minimum in case of laser beams. And as the name suggests that this is microscopy which is done up to the third dimension. So, the cross-section of the crack that is the length and the width and you can obtain the depth also the third dimension also.

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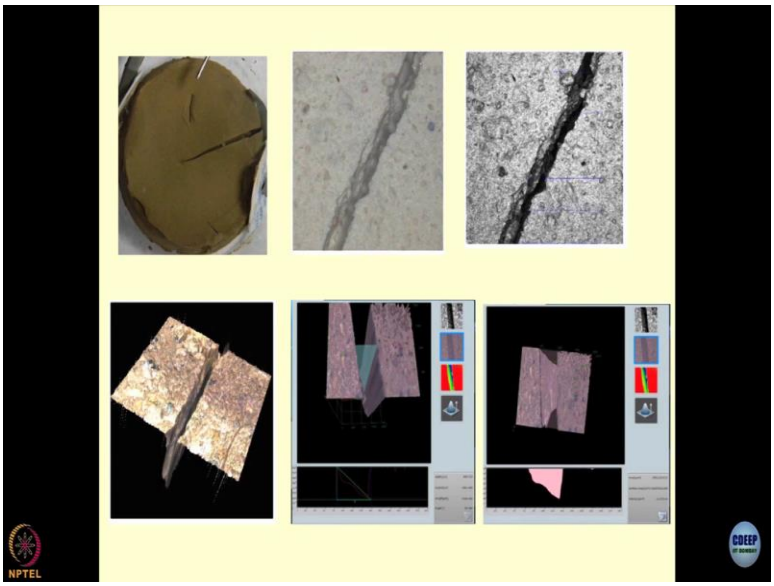

If I start with the sample, you can see very clearly the cracks growing in different directions; I wanted to study the depth of the crack which gets developed. This is how the greyscale model

has been developed out of the real-life picture. And this is how we can slice the crack at different locations. So I hope you can realize that there is a sort of a valley formation which is quite visible, all this is happening at the micro nanoscale, because most of the airline cracks cannot be seen by naked eyes.

And that is why you required very high-resolution laser photography or microscopy to do these type of studies. This work was done by my PhD scholar, Dr. Uday Kala and hope you can realize now, this is the third-dimensional modelling of the cracks which have been done, and this is how we develop a lot of mathematical models. And we propose the relationships where tensile strength can be related to the length width and depth of the cracks provided the soil properties are known.

These type of studies are becoming very contemporary in environmental geomechanics; I hope you can realize so this was the initiation of the work which we did in our laboratory, as I said, most of the disposal facilities be it radioactive or landfills or domestic waste or toxic waste facilities. There people want these type of studies to be done so that the best possible solutions can be provided.

Now, in the current era, where research is heading towards the gas migration in geomaterials, which was done by my another PhD scholar, and some part of this is now being done by Jasmine, my another master's student. I hope you will realize that unless we are sure about the cracking characteristics of the soils, the gas migration studies cannot be done. Because if cracks develop in the geomaterials, there are chances that the gas may short circuit the entire porous media. So, it is not only the area of the cross-section of cracks which is very useful for us is the third dimension also, which is very important, which would tell you whether the migration in the system is through the porous media or it is bypassing the porous media and coming out of the cracks. So, these type of studies now I am expanding, and I am collaborating with different companies who are very eager to come up with the solutions so that they can apply it in real life.

I would say this is something which is the future of environmental mechanics; I hope you must have got an idea about where these type of studies are being done. Now, another interesting

thought came to our mind that let us find out what are the tensile stresses which are developing in the thin films. So, we got motivated by seeing the process of chips manufacturing potato chips, lays.

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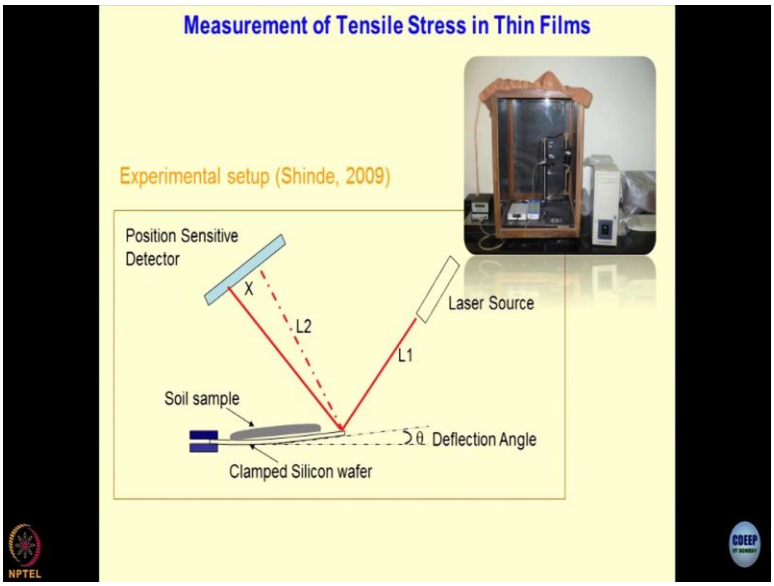

The first requirement of making the chips is that the chips should be easily packable. They should not get damaged, and they should be thin. Imagine a chip which is quite thick. What will happen, people will not accept it. It has to be thin. It has to be crisp. At the same time, when you are marketing it, when you are transporting it should not get crumbled. So, this was the idea which we had when we approached these companies who are manufacturing chips that what type of knowledge they use.

And you will be surprised to know that most of the research in geomechanics has been done on cracking characteristics of the soils by using the starch which has been extracted from potatoes. So, these are known as artificial soils. So, they have used the starch from the potato, and then they have treated this as a homogeneous material to study the crack formation in the soils, but what we did is we went on with the real-life situations. We used a very sophisticated setup, which is again laser operated system.

This was done by my master's student Sudarshan Shinde. And what we did is we used the concept of the cantilevers, and these cantilevers are clamped at one side of the system and then

there is a silicon wafer silicon wafers are extremely sensitive systems which will deform when you put a small drop of clay. So, clays are dissolved in water, and one or two drops of the clays are taken in the suspension form and pored on the silicon wafer.

As the drying takes place, the silicon wafer bends and the movement or the displacement of the tip of the silicon wafer is measured with the help of the laser source on a detector. So, if I know that from the initial to the final state, the deflection in the beam is x, L1 and L2 are the geometrical parameters of the laser source and the detector. Theta is the detection angle. I can interlink everything.

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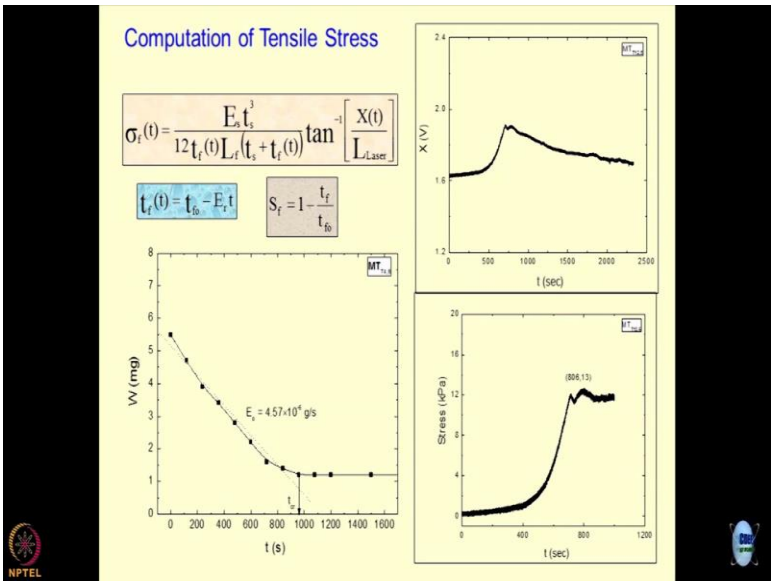

And I can obtain the σ_t as this function. So, x upon L is nothing but theta term, and I can find out what is the final thickness of the clay film if the initial is known and Er is the evaporation rate multiplied by the time. So, if you take the sample in the petri dish and expose it to the environment as the weight loss occurs after a certain time the weight of the petri dish becomes constant, this is a critical time the slope of this line is going to give me the elastic modulus.

Which I can substitute over here, and I can get the final thickness of the film. T_{f0} is the initial thickness, T_f is the final thickness, and then x is a function of time and x is the function of σ_t also, and x is the deflection incidentally if you remember, x is nothing but the deviation of the

laser beam. So, the more and more evaporation of the drop of clay particle or the clays occurs the bending takes place in the silicon wafer and x increases and this how the tensile strength is getting mobilized.

So, this is a plot of x vs v_t, which can be correlated with σ_t vs time. So, wherever we have the peak that is the tensile strength of the material. So, this was an interesting effort which was done by my master's student Sudharshan Shinde.

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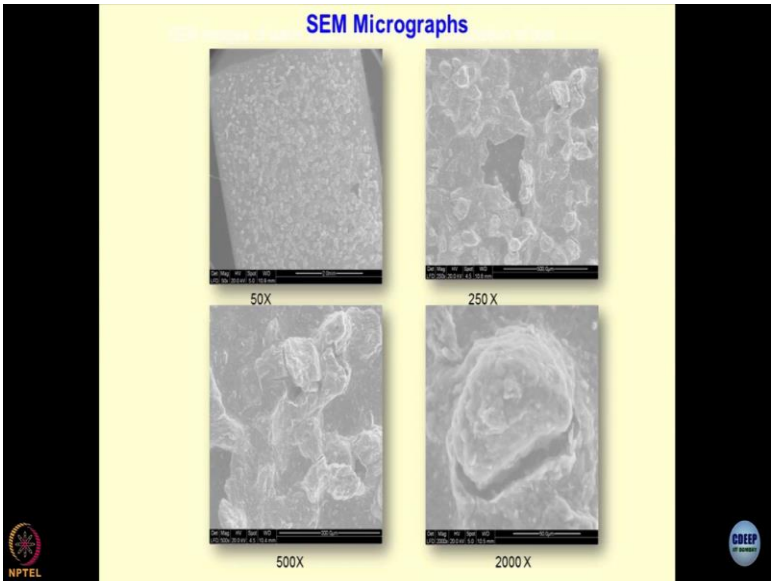

And we did the complete SEM micrographs of the process to understand how the cracking gets initiated in the clays, this is the initial sample and hope you can realize that there is an opening up of a crack at different magnification this is how the crack initiation occurs. And if you see it at very high magnification, this is how the cap gets opened up this cracks develop in the whole system we wanted to make a video of the entire process. It requires very expensive setups for that.

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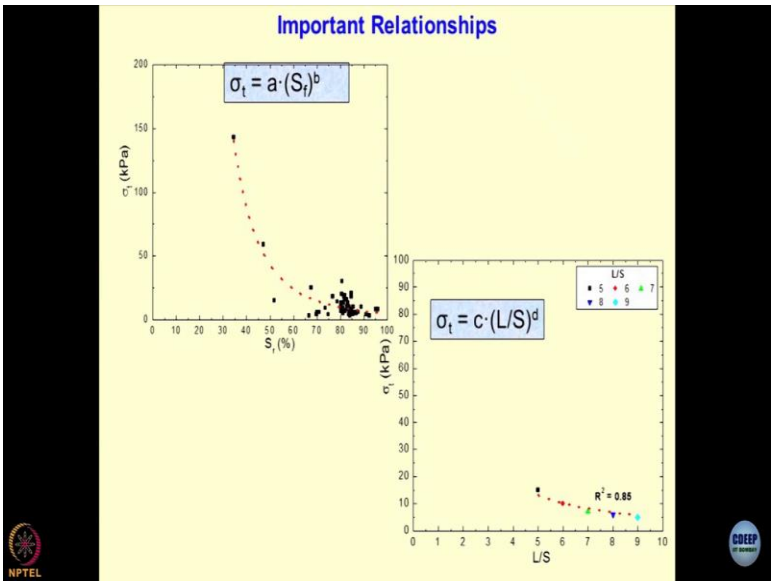

And from these simple experiments, we did some relationships where the tensile strength has been linked with the thickness of the film of the clay. And tensile strength has been with the L/S ratio that is the liquid to solid ratio of the clays. These are the topics of multi-phase geomechanics, those of you who might be interested or might land up doing this type of R and D would be dealing with these type of problems, which are very intricate, very very complicated and they test your nerves.

But then this is what the cutting edge research is internationally right now, one of the applications of all these studies, which I have talked about is the synthesis of self-healing and self-sealing minerals. I do not know whether you have come across these type of minerals or not.

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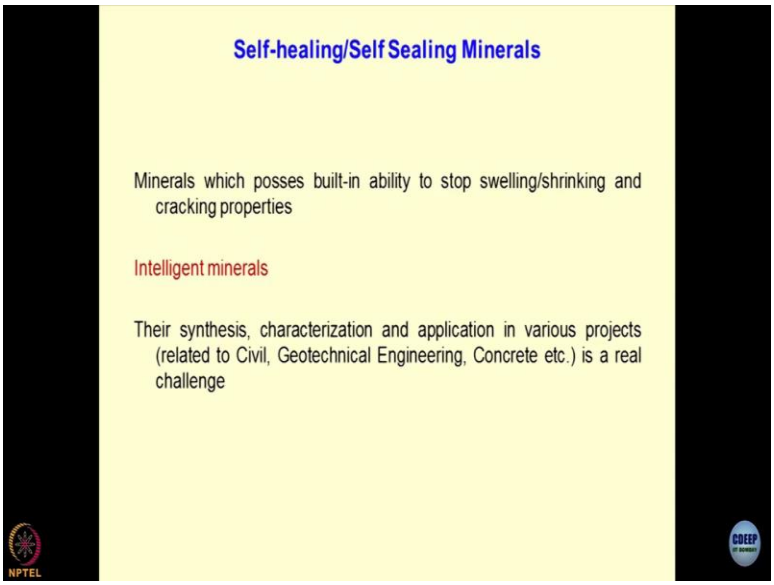

These are synthetic minerals, which are quite in demand in the market because these are also known as intelligent minerals. So, they understand the mood of the environment and the environment in which they are located. And then they behave accordingly. A lot of chemical processes are involved in creating these type of minerals, and I wish to synthesize these minerals in the near future. The beauty is these type of minerals have a backup memory.

So, if I include them in the clays or the concrete and in the case because of desiccation, the cracking takes place, these minerals immediately react and whatever fluid is contained in them spreads out, and they seal the cracks. So, imagine if your these type of minerals are included in the concrete and the turfs of the clays or the landfills this will be a boon. So, these minerals possess built inability to stop swelling and shrinking and cracking properties. They are known as Intelligent Minerals.

And their synthesis would be quite useful for various applications related to civil engineering, geotechnical engineering and concrete in real life. Unfortunately, a multidisciplinary area where we would like to do sit with the chemical engineers, environmental scientist and make minerals intelligent. So, through today is the discussion, what I have done is I have tried to give you an overall idea about where the subject is heading. And what all is happening in this area. I am sure that you must have realized that not needs to be done before this becomes a well-read well understood subject.