Environmental Geotechnics
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Lecture – 14
Basic concepts of analysis

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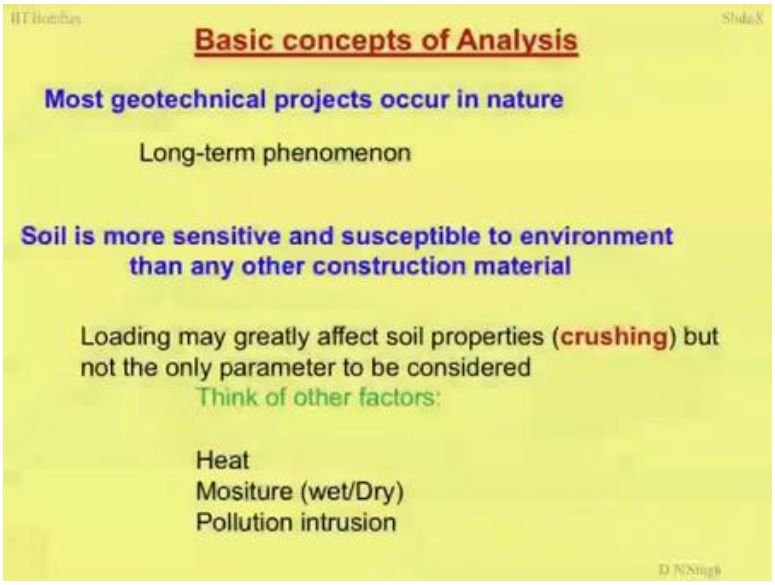

Now, let us talk about the bit of basic concepts of analysis. So, the issue is that most of the projects with which we deal they occur in nature and the second issue is that soil is more sensitive and susceptible to environment than any other construction material, all right. So, in what way these two concepts should challenge the you know the philosophy of engineering sciences; you are sitting in a room not directly exposed to the nature but think of foundations embankments there is no shield, they are directly expose to the environment. Is it not?

So, that is why I say that most of the projects dealing with geotechnical engineering they occur in directly nature, there is no protection. Even if you are making embankment, it is getting influence from the water table rise, changes, fluctuation or from the rainwater. And soil is highly sensitive, we have discussed this issue and susceptible to environmental changes than any other construction material either steel or concrete or whatever you may polymers.

So, because of this when we say that all the activities take place in nature, we are more interested in long term response. Unfortunately, what we have studied till now in the realm of classical geomechanics; it is always short term response. That is one of the reasons why structures have failed in the past.

A simple analogy would be how much time you spend when you are doing hydraulic conductivity test. Say at the most few days or not even few days few hours. So, that is why the question is if you conduct hydraulic conductive test for few months, what will happen to the hydraulic conductivity of the same soil mass. It may increase, but I am of the school of the thought that it will decrease.

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I do not know. There could be several answers to this to prove your hypothesis. Yeah, but idea is the common fact is that something is going to change; the pore structure itself is going to change, all right.

Now, when you say soil is very sensitive and susceptible to the environmental changes, than any other construction material, what we do is we talk about loading is it not mechanical loading. So, we say that loading may greatly affect soil properties and till now we have talked about crushing. You agree with this or not. In what way? Can you define this? See the best way of doing this type of study would be, whenever you are doing a direct shear box test, do the test, take out the material and conduct particle size distribution again. So, direct shear test without PSD has no meaning. You keep on doing this test to understand what type of alterations in the state of the material you have done because of shearing. I hope you will appreciate this point.

Particularly, when you are dealing with coarse grained materials the after stage of shearing is not same as the one with which you started. So, this concept normally is use when we talk about shear strength of the material where the stress strain relationship becomes asymptote after certain time. They are never straight lines though you have been told in your under graduate courses, is it not.

Why it is so? The main reason is because of particle crushing. So, after a certain stress level the crushing of grains will take place, the properties of the material are getting changed and you cannot compare the material properties for that shear strain parameters,

for all this stress strain together. So, you have to define this stress ranges in which you are working and the parameters which you are getting. If I teach your CE 634 course, I spend lot of time in explaining this phenomenon. So, that time you should remind me if I if I take that course for you.

So, basic idea is loading may greatly affect soil properties. Here we are talking about mostly the mechanical loading but is not only the parameter. So, this is where actually we should think out some other parameters like thermal loading and because of thermal loading how moisture content is going to change.

So, as you rightly said that because of heating the moisture gets redistributed gets changed, so that means, the properties of the soil are going to be different before cracking and after cracking and that is why cracking characteristics are studied in details. Similarly, how pollution load. See the word missing here is not physically missing. If you read the sentence as pollution load intrusion, all right, so this becomes a sort of a loading which is equivalent or much more higher than mechanical loading. So, this is where we say imposition of thermal flux, electrical flux, mechanical flux, chemical flux and so on and then we are trying to see what is the response.

So, these are the concepts of analysis which we have been using without bothering much. We agree or no. Anything apart from this which comes your mind.

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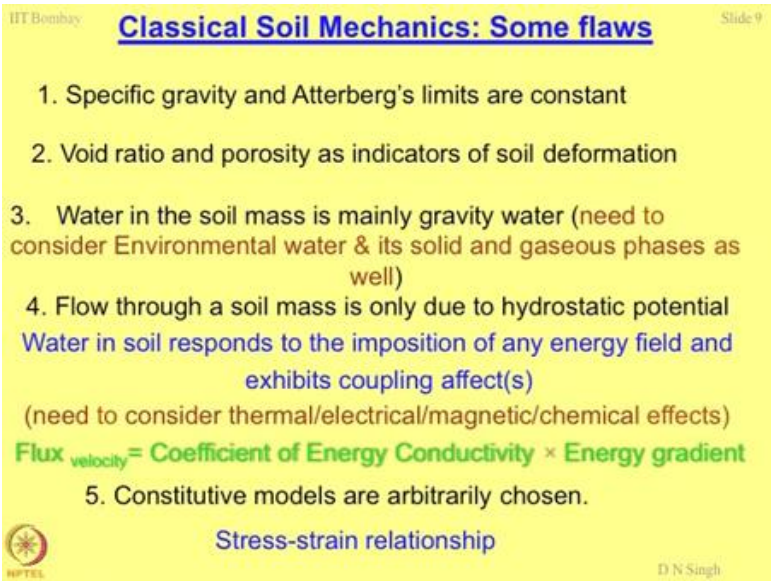

What are the flaws in classical geomechanics? The first flaw is we always assume specific gravity and Atterberg limits to be constant. Do you think it is so, or it should change or what should happen?

So, all the time you have been finding out it's Atterberg limits by using distilled water. But a real life simulation would be when you take contaminated water and see how much reactive the soil would be and what would be the effect of Atterberg limits when you are changing the interaction properties, and what is the culprit in this interaction. We are not talking about the purest form of the water, we are talking about the contaminants which are present in the water and how do they reflect in engineering properties of the soil mass. Lot of studies have been done by researchers where they have use organic compounds, inorganic compounds, hydrocarbons to see what is the influence of this type of interaction. Any idea why specific gravity should change?

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I think I showed you a slide in the previous or the previous to previous lecture where you are talking about the mineralogical alteration, because of the etching of the glass, remember I had shown you fly ash particle on which some zeolites have got you know generated or developed. Now, this is what is known as etching of glass. Some people make paintings using glass etching, you know they etch the glass, erase the glass.

So, the silica which is present in the glassy form gets etched because of hydroxides of sodium and potassium. Also known as silica dissolution Mr. Jha is doing fantastic work in this area. So, whenever he presents his seminars you should come and attend if you want to learn this subject more. So, what he is doing is trying to dissolute the entire fly ash in sodium hydroxide and we are working on silica reduction technology (SRT). So, how silica can be reduced from fly ash, so that we can get more alumina and iron.

So, what this shows is you just think of peeling of onion, clear. So, what happens to the denseness of the onion? It increases as you peel it off. The same thing is happening to the soil grain, if you keep on etching it by using regular application of hydroxides, the first layer which gets etched, the second layer which gets etched, the inner layers are going to be very densely packed and that is how your specific gravity increases.

Some of the structures which are known as cenospheres they have double surface inside surface and the outside surface. Now, if you do this type of etching too much the ball of the cenospheres gets opened up, and then what happens the specific gravity will increase. You think of a ball which is filled up with air, all right, so its volume is more but the weight is less. You open it up and fill it with water what happens the volume remains same, but the weight is more, clear. So, this type of mineralogical alterations keep on happening in nature and that is the reason why a specific gravity of minerals will not remain same. But like these are, this is these are the things which we are talking in realm of micromechanics, where micromechanics and nanomechanics interfacing with our materials and our subject.

The second issue, I think you will agree or you may disagree the void ratio and porosity as a indicator of the soil deformation. How do you define deformation of the material? In your consolidation theory you have talked about only void ratio reduction but do you think with the background which I am giving you I am contaminating your mind do you think that this is valid further. When your skeleton of the soil itself is not stable is undergoing changes there is no sanctity associated with the void ratio and the porosity, now these terms are nothing but volume of voids divided by volume of solids. But volume of solids keeps on changing. So, your void ratio, porosity and related parameters do not remain same over a period of time, clear.

Now, most of the time we consider that soil water is mainly gravity water which is not true. We talk about double layer theory in clays. So, the water which remains adhere to the clay mineral, which is very difficult to remove from the soil mass. We do not talk about this viscous water at all. We just talk about the water which is freely movable, and this is where actually the need is to consider environmental water, we will talk about these states of water and its different forms. Like your solid state of the water which is nothing but ice frozen water, gaseous phases of water like vapours and so on as well, is it not.

So, we talk about hydraulic conductivity at the same time we should be talking about gas permittivity or gas diffusivity, and this gas could be the vapour, so it could be the contaminated vapours of water. The fourth issue is very important, flow through a soil mass is only due to hydrostatic potential but then the question is how your saltwater intrusion is taking place in aquifers.

So, this is where actually it is very important to understand water and soil response to imposition of any energy field, and it exhibits a coupling effect, and this is where you have to consider the thermal flux, electrical flux, magnetic flux, chemical fluxes. So, basically the challenge towards you know new generations or what you guys have to deal with in your professional career would be you come up with the model which says that flux velocity should be equal to coefficient of energy conductivity multiplied by energy gradient.

You find that this equation is resembling to what you have studied till now.

Darcy's law: $v = K \times i$.

So, when you say coefficient of energy conductivity how did you define k? It is the hydraulic conductivity and that is K. So, K is the intrinsic permeability of the porous system and on which the energy gradient is nothing but hydraulic gradient, so delta h/l

So, if you change the flux the type of the flux what is going to change? The energy gradient is going to change and there will be some equivalent form of the coefficient of energy conductivity. So, when you say flux all right, if I say concentration flux velocity should be equal to sum coefficient of concentration multiplied by energy gradient of concentration. So, this model has to be generalized.

In what way this is going to be beneficial? You must have heard of application of electro-osmosis for consolidation, accelerate consolidation. Nowadays, some people are working on vacuum consolidation. Professor Rajgopal from IIT Chennai he has worked a lot in this area. We apply vacuum to the clay and then consolidation gets accelerated. So, what is that you are doing? The free water drains off because of preloading.

But then the water which is adhering to the clay can be removed by applying an energy which is going to be more than the molecular bond between water and clay platelet. You got this idea. So, based on this concept you can apply some electrical field, magnetic field or vacuum to suck out that water which is highly viscous and which will not flow out because of the application of external stresses.

Another biggest problem is that constitutive models are very arbitrarily chosen. What is meant by constitutive models? Stress strain relationship, that is right. So, when the when

you are seeing that the material properties do not remain same this becomes a very dicey thing when you say stress strain relationship is same for the material. So, basically what I am projecting here may seem very revolutionary, but then this is the need of the hour. I mean like you have to really talk about these issues.

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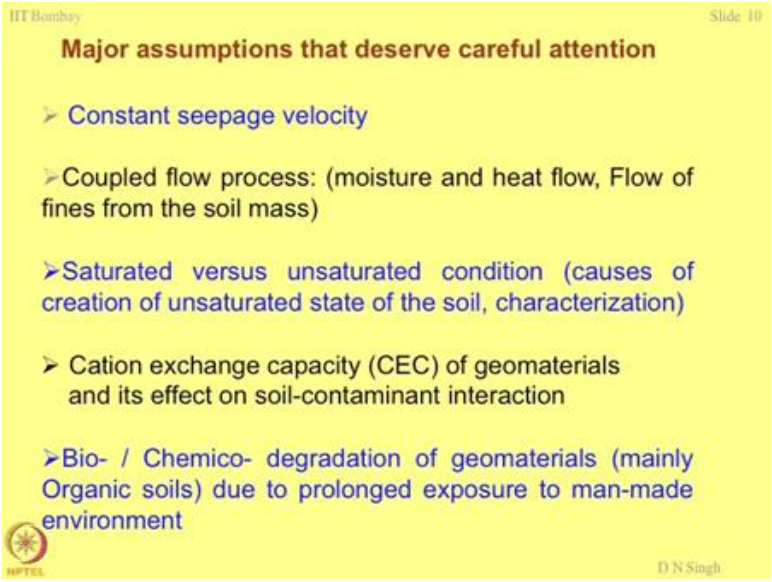

Some of the major assumptions that require very careful attention are we have always assume constant seepage velocity. Where do we use this concept or this type of assumption? Seepage velocity does not change, coefficient of something does not change, it remains constant.

The coupled process we do not talk about at all, that is moisture and heat flow, simultaneously taking place in the system. So, the moisture is flowing because of heat which is flowing into the soil mass there are lot of practical situation. Even if you think of creating solar ponds so, one side of the solar pond you have thermal flux which is very high, the other side of the of the solar pond has no thermal flux. So, heat is migrating. What you want to do is you want to maintain the moisture content. So, that the shear strength of the clay liner is maintained otherwise the entire thing will collapse.

Flow of fines from the soil mass. We have been talking about this quite a lot is it not this also a coupled phenomenon. The seepage is taking place and there is a mass migration from the soil mass itself. So, we have assumed in all the analysis that control volume remains is a control volume, but truly speaking that is not happening either your void

ratios are not same, porosity is not same, the fines are migrating out and the seepage is taking place.

Another issue is we do not differentiate between saturated and unsaturated state of the soil. We talk about three phase system soil, water and air. But then what is the cause of creation of the unsaturated state of the soil? When you talk about heat flow in the soil mass this could create an unsaturated state of the material. So, this is where the characterization of unsaturated state of the material becomes very important and soil mass may not remain saturated all the time.

Another interesting thing is cation exchange capacity of geomaterials we have not talked about much, why? We always work in laboratory with passive soils like kaolin, white clay or the soils for which the activity is very less, cation exchange capacity is very less. This also known as ion exchange capacity. But this is the most crucial parameter when we talk about soil-contaminant interaction and you have to study this attribute very precisely.

The assumptions are that we do not take into account biochemical degradation of the material at all. We always assume the soil mass to be you know living forever which is not true, as you are saying about the organic soils, that is right. So, bioactivities are too much or the material is too much prone to bioactivity and degradation may take place. That is the reason when you lay the foundation. The thumb rule says that get rid of this material fill it with some good foundation material and construct the building on that.

So, bio-chemico degradation of the materials in mainly organic soils due to prolonged exposure to manmade environment requires a very special attention. See we all realize that, yes these are the major issues and they have to be inculcated in our models.

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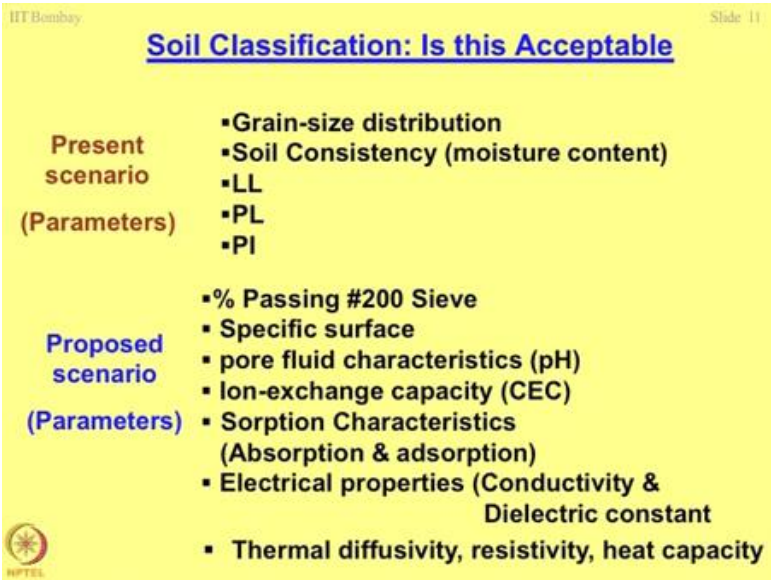

So, the question is that this soil classification with which you are working whether it is acceptable or not. The present scenario or the parameters which you are using a grain size distribution. Soil consistency, basically is nothing but the moisture content the form of liquid limit, plastic limit and plasticity index. What else should be added here.

Now, you have a fair idea about what we are discussing. So, this model do you think is sufficient or good enough to handle the properties of the geomaterials. We use grain size distribution, physical classification, just see if the sample or do hydrometer that again is an interaction and then talk about its consistency limits where you allow soil to come in contact with water.

So, the question is what should be the proposed scenario. The proposed scenario which should include parameters like this, percentage passing 200 number sieve, it is nothing but the clay content of the soil, all right. A specific surface; last, I think how many years we have been following this system, almost 50 years. So, there is a need to change the classification scheme. So, that is why you will find most of the researchers are trying to reclassify soil mass or geomaterials and we have one of those, we are contributing in this direction, specific surface. Pore fluid characteristics, particularly pH of the pore fluid. See human body is very sensitive to pH, you know acidity is a major disease in human bodies. The same is this case with soils also. So, there corrosion gets accelerated when

pH is even if you cross the limit of 4.5 less than 4.5 or even if you go beyond 7.5 you will notice that stability of the soil becomes a very big issue.

Cation exchange capacity, now this is the keyword in present day scenario. Everybody is talking about CEC of the geomaterial, how easily a soil can exchange ions with contaminant. So, this is the formation of your soil-contaminant interaction, if you want to study how contaminants are going to interact with the soil mass or vice versa, this happens to be a mathematical term which will define this tendency, all right.

Then sorption characteristics, I think in second or third lecture somebody was talking about absorption and adsorption. So, put together these two words we call them as sorption characteristics. Our group has now lot of work related to cation exchange capacity and sorption properties of the geomaterials and now we are working on electrical properties and thermal properties. So, electrical properties when we say these are electrical conductivities and dielectric constant.

When you saw these TDR probes and FDR probes in my laboratory, I had told you that the basic principle on which they work is dielectric property. So, you add more water to the soil mass, what happens to the soil? It becomes a good conductor or bad conductor, what is your feeling? In your 10+2 physics you must have used semiconductors or the capacitors, all right. So, Quartz is a good capacitor. It will not allow charges to pass through, clear.

So, when I store a charge storage capacity increases, so that means when you have more water into the system what will happen to its dielectric constant, it will increase. So, for water dielectric constant is 81 and for air dielectric constant is 3. That is the reason you put some dielectric material in the capacitor so that the charge can be retained, otherwise you would have you would have filled all the capacitors with what with air. So, charge retention capacity will be very less unless you put some dielectric material in it.

So, this is a very good parameter on which based on which you can characterize soils. And what we have been doing is as I told you the other day we are utilizing these properties to define the fine grained materials and coarse grained materials and differentiate between them. And another leap in this attempt would be if you can identify the level of contamination associated with the fine grained soils and the coarse grained

soils. What I will do in this course is, I will touch upon these issues a bit under the heading characterization of the soil mass by using advanced techniques.

And of course, the thermal properties can be talked about in terms of thermal diffusivity, how easily thermal flux gets defused from one point to another point. If you go to the old monuments you will find that they remain very cool from inside, is it not, even in deserts like Rajasthan, Udaipur and all these areas what is the reason. The type of the soil cover which they have used are perfect, all right.

So, this is why thermal properties of the soils are given due weightage. They were given due weightage in the past, but present day generation, forward and again we are coming on the track. So, we are talking about the resistivity and heat capacity of the soil. So, if you include these parameters and reclassify the soil that would bring you somewhere, all right. So, this is a challenge ahead.

I will stop here. So, this is what the ideal situation would be. And incidentally this type of classification will take care of physical properties. Specific surface is nothing but physico-mineralogical properties pore fluid cation exchange capacity would be chemical properties, so we have physical chemical mineralogical properties. Sorption is nothing but a chemical property, mineralogical property, and electrical and thermal property. So, this will be a complete characterization of the soil mass based on different energy fields, clear.

So, if you have input from all these studies you can put this in your PEF, particle energy field concept and you can get solutions to the problems which you are dealing with, all right.

Thank you.