Environmental Geotechnics
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Lecture - 12
Contaminant transport in soils

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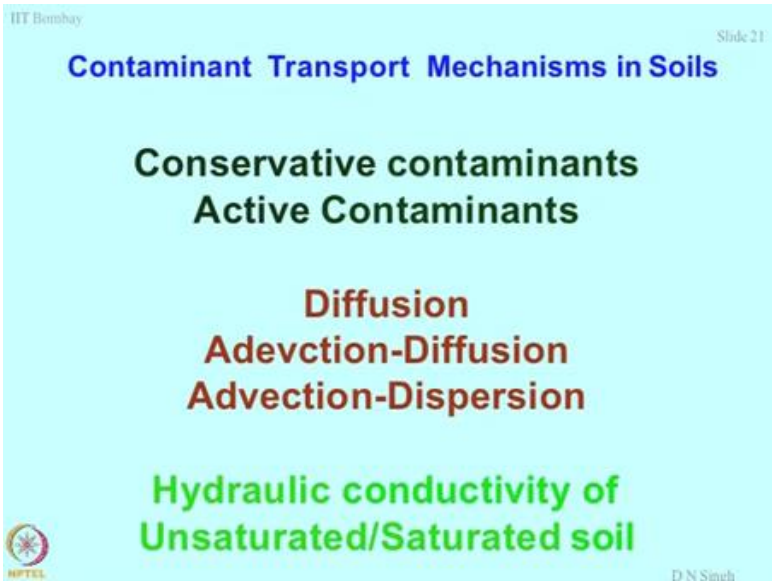

Let us now deal with some issues related to contaminants transport mechanisms in soils, and why it is becoming so important? We talked about two types of contaminants that is conservative contaminants and active contaminants. From the name can you make out something, what should be the difference between these two types of contaminants?

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You say this guy is very conservative, what is the meaning of that?

He will not interact with anybody; he will not talk to anybody, all right. So, a conservative contaminants or contaminant will what it will do? It will not react with anything. A good example of a conservative contaminants, sodium chloride which we use every day in your food; it is a contaminant, yes. By definition, what is the contaminant? If you take 1 spoon it is ok, if you take 2 spoons, 3 spoon, 4 spoons, why not sea water then, all right.

So, conservative contaminants are the contaminants, which are not going to react with geo materials porous media as such. Unfortunately, most of us, try to use this contaminant for modelling our studies. So, most of the papers will find in literature where sodium chloride has been used to model contaminant transport. So, my question to them is sodium chloride cannot be a contaminant in real words, because it's a conservative contaminant.

What about active contaminants? Sometimes they are also known as reactive contaminants. They will react with porous system. What is the meaning of reaction?

Student: They will alter the properties of the system (Refer Time: 02:24).

What is easy to change, change yourself or change others?

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If you can change others, you will be a revolutionary; the easiest thing is to change yourself. So, what active contaminants do? They change themselves, they do not change porous media all right. So, idea is they have affinity towards porous system. So, when you pass them through the medium, certain fraction of these contaminants get associated with the porous system ok.

What is the meaning of this? If I have a bulk of soil and if I add let us say, some 5M of a contaminant, slowly and slowly it will percolate into the system and it will come out from some somewhere. If I do the analysis of the leachate, it will show you a molarity of let us say 2M.

What is the meaning of this, where 3M molarity has gone? This has been retained by the soil. Now, why it has been retained by the soil, because contaminant is reactive clear, it has a reacted with the soil and reactions could be of any type, this we will talk later on its a big subject. I am just trying to give you an idea that how would you model this type of interactions.

Now, this type of interaction is also defined as partitioning and those of you who might have heard of distribution coefficient or partitioning coefficient (K_d). So, K_d is the term which defines what phase of contaminant is going to get associated with porous system and what will not get associated with the porous system. Now, this concept we are

utilizing quite a lot in our research for porous media characterization all right; that means, if I allow a certain contaminant to pass through the porous system, what fraction of the contaminant gets retained in the soil mass and what does not get retained comes out based on the input and output, we can define as sort of a efficiency parameter.

And that efficiency parameter happens to be a fingerprint of porous system; this fingerprint is a very important word. So, just by seeing the fingerprint of this contaminant porous system, we can understand how the phenomena is going to take place, is this part clear all right. So, these are the attributes of the contaminants. Some active contaminants would be strontium, copper, lead, chromium, zinc, most of the elements which are being discharged from industries, chemical industries or electro plating industries, they have a tendency to react with the soil mass.

The second important step is what type of mechanism is going to take place, all right. So, you have talked about till now advection. What is advection? Movement of water from one point to another point, but if hydraulic conductivities are very very small, then advection alone will not occur; then this becomes a diffusive contaminant transport. So, most of the contaminant transport in soils will take place through diffusion; if porosity is bit more, it could be advective diffusion contaminant transport.

A simple example to understand, how you can create advective diffusive contaminant transport would be any guess? Where advective transport is, what you are doing in the laboratory right now; take a soil sample, connect it to the water tap and find out the hydraulic conductivity, the simple advection process. If you change the concentration of water which is passing through the soil mass, rather than having freshwater you pass through sodium chloride of certain concentration.

And then later on see, what is the concentration of the input contaminant and output contaminant, you get hydraulic conductivity definitely, but at the same time you get salt sorbing capacity of the soil mass also, clear. So, a bit of change in thinking you know, gives you more and more understanding of how the process taking place through the media. So, rather than doing hydraulic conductivity test by simple plain water or deionised water or maybe your deionized water, you can add salt into it and do the same experiment and see along the length of the sample, how concentration varies.

Advection-dispersion mechanisms, where dispersion takes place, wherever there is a flowing water, it gets mixed with some standing water table. So, the best example is whenever you are discharging waste from cities into the sea. So, the plume of water carries all the waste into the sea clear. And what happens at the at that interface? There is the standing water and there is a water which is moving with some velocity. So, there is a mechanical mixing. So, whenever there is a mechanical mixing going on, it is known as dispersion and which will depend on the velocity of the flow of the fluid and other attributes of the chemicals and so on.

Most of the time we do not talk about advection-dispersion phenomena in geotechnical engineering. One of the interesting ways to understand this would be diffusion and advection-diffusion processes can be used to again characterize porous media, how can you guess? I can define few numbers, like Reynolds number, Peclet number you know and these numbers will tell me, what type of contaminant transport is going to take place through system.

We are aware of Reynolds number; this defines advective contaminant transport. If you add diffusive term also, it should be Peclet number, how heat is going to flow through the media, I can have a thermal flux number clear and so on. So, then I can control these mechanisms better.

The last but not the least is hydraulic conductivity of unsaturated and saturated soils. So, this is the porous media, where we talk about hydraulic conductivity of the system. What type of mechanism is going to take place and then what are the attributes of the contaminants? So, you have contaminant attribute, you have porous media mechanisms and then attributes of the porous media in the form of either hydraulic conductivity or saturated conductivity or unsaturated conductivity.

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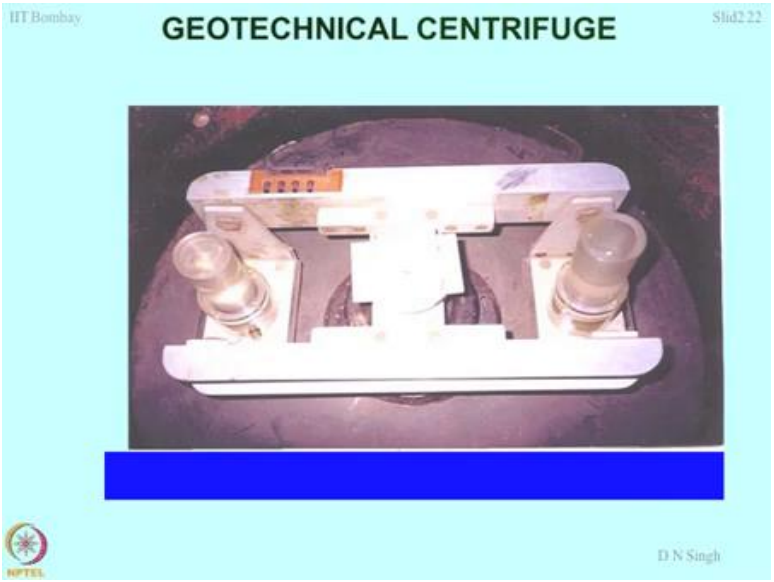

This is the geotechnical centrifuge which is now being used by many of you or will be used by many of you, where we can have two buckets and we can keep the sample on both the sides as a counterbalance and then we can simulate the mechanism.

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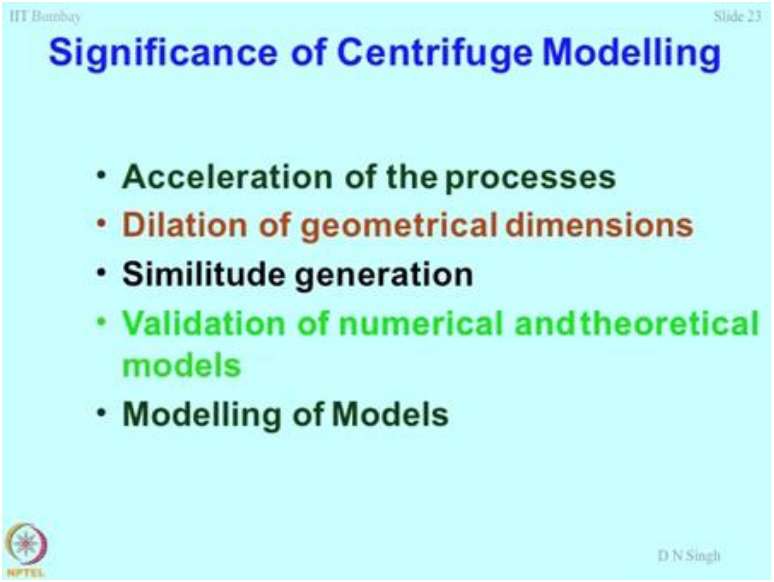

What is the idea of doing this type of modelling? You accelerate the processes, only in physical processes. So, diffusion is not really a physical process, so lot of people say that diffusion cannot be modelled in centrifuge, because diffusion happens to be a chemical process, but what my research group has shown that diffusion can also be modelled.

So, there was a up to 2002 to 2003 people used to believe that diffusion cannot be modelled, but then our papers came and we showed them that diffusion can be modelled very easily in centrifuge. So, it became advective-diffusive contaminant transport using centrifuge modelling; you have to go through the papers, then they you get the answer to your how.

Dilation of geometrical dimensions, similitude generation, validation of numerical and theoretical models, this is where actually a lot of efforts have been done right now, centrifuge modelling results are being used to check how good your mathematical models are. Particularly I am sure that you must be aware of the limitations of numerical algorithms, any software for that matter if you use.

So, there is a school of thought which forces people to check the validity of these models. And then of course, modelling a model which gives you more in depth understanding of how models are behaving in the environment, which is accelerated value.

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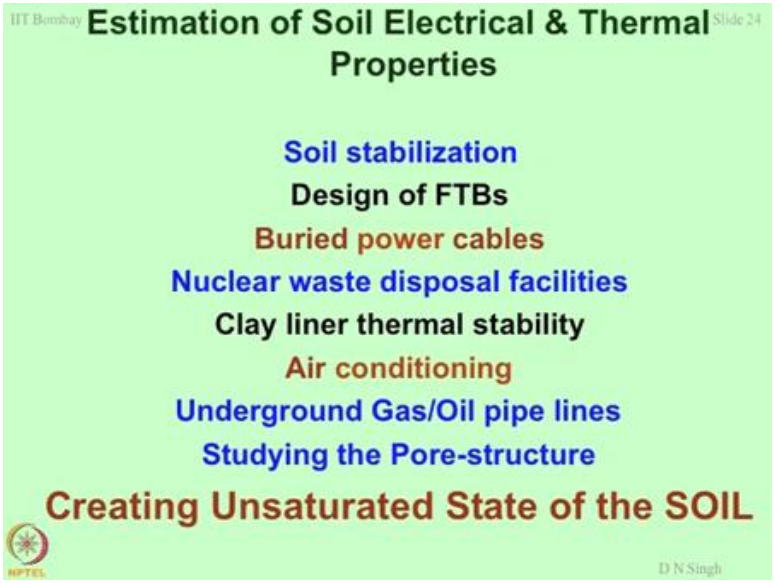

Well, this is a parallel thinking in geomechanics, you know sometimes people call this is as paradigm shift also. You understand, know the meaning of this word; something which is different than conventional. So, this is where actually we found that soil electrical and thermal properties can be utilized in understanding the response of the porous system very well. And conceptually these properties would be very useful, if you

talk about soil stabilization. Any guess, why soil stabilization requires these properties to be studied?

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There are some chemicals which are exothermic or endothermic. So, if you are using these chemicals for ground modification, the temperatures of the ground is going to change and that is where you require thermal property. I hope you will appreciate the electrical and thermal terms are inter linked with each other, you pass electricity the temperatures will rise and converses also true, but not in soil is not a superconductor clear. So, converse may not be true as such as on date.

Design of fluidized thermal beds, now fluidized thermal bed is a technology by which you can reduce the resistivity of the soil mass for doing some insulation work or you know electrical impedance if you want to increase and so on. For buried power cables, nuclear waste disposal facilities where you have high temperatures which are interacting with the soil mass and altering its property.

Clay liner thermal stability, lot of people say that a waste landfill happens to be reactor, it is a live entity; where lot of reaction is going on inside, so when reactions are going inside, lot of temperatures are generating inside, it is a reactor, so that means, this system should be in equilibrium with environmental conditions. So, this is where you required to assess the thermal reaction, which are going on inside a landfill.

And how these reactions are going to change or influence the properties of the soil mass. Air conditioning systems, so that your air conditioning costs are less. Underground gas and oil pipelines, if temperature are very high, there could be a situation where you cannot transmit gas or oil through the pipelines, is it not; what will happen? They will evaporate or sublime reactions may take place.

Studying the pore structure of the soil, this is what actually we are trying to profess that you can study pore structure by using both electrical properties and thermal properties, it is a recent concept in geomechanics. The most important use of these properties is those of you who will get a chance to work on unsaturated soils, you will find that these are the Brahma Astra, both otherwise there is no way to study the unsaturated state of the material, because you cannot do any conventional test, where water directly penetrates

into the soil. So, we are of the opinion that both electrical and thermal properties of the soils can be utilized to characterize, the unsaturated state of the soil mass. Just quickly to show you, how unsaturated state of the soils can be studied.

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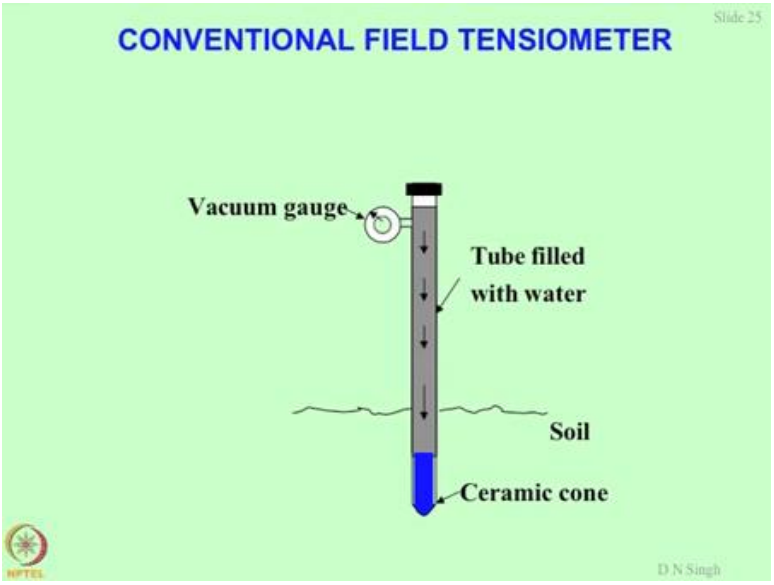

This is a conventional filled tensiometer, of course, when you will come for environmental, sorry Experimental Geotechnics course, laboratories work they will show you this setup again. So, this is a tube which is filled up with water, it is inserted in the soil mass and there is a ceramic cone. So, water goes into the soil and then there is a tension which gets created and this tension is measured with the help of vacuum gauge. So, this is a old method of finding out the tension of the soil, negative pressures which are developing in the soil. Unfortunately, you can use this setup only for measuring tensions of the order of 80MPa, 80KPas, sorry.

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So, this is where actually we went for this type of setups which are slightly better, you can measure only up to 100 kPa. These are the standing water columns in which you fill the water and there is a thimble, which goes into the soil mass and then put a E-sensor over here, electronic sensor and you can record what is the tension in the soil mass.

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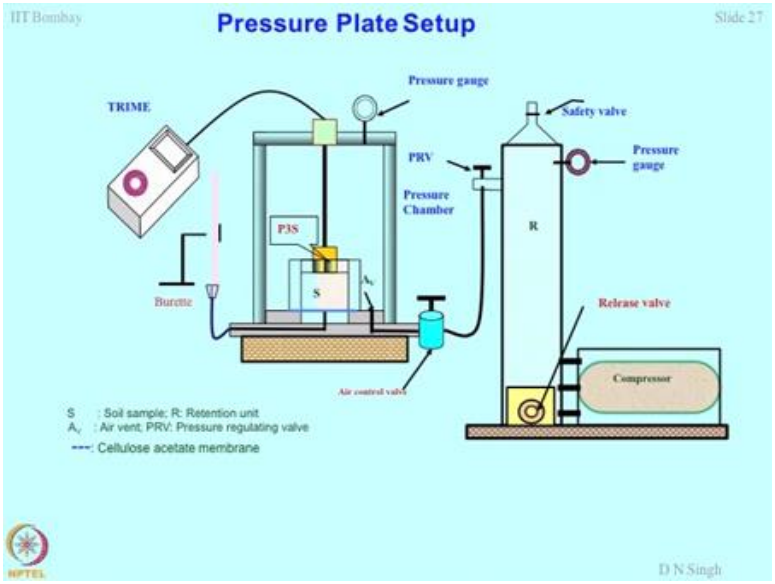

This was the assembly, which was developed by one of my master student it's a tri-axial tests which we are doing rather than filling the water in the chamber by pressurizing it. So, we are using air to create unsaturated state of the soil, what happens is the

compressed air supplies the compressed air into the chamber and this chamber pressurizes the sample and there is a membrane kept below the sample, which is known as cellulose acetate membrane, I had showed you the other day.

The property of this membrane is that only water can go out, but air will not enter. So, this system becomes an unsaturated soil and we are studying the moisture content online by using a TRIME or a TDR probe, but I think you can appreciate that these are very very intricate setups to get unsaturated state of the material.

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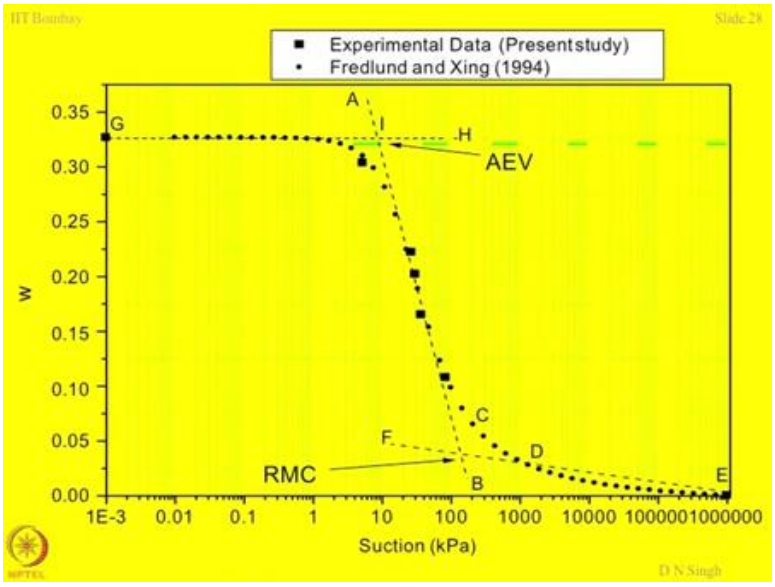

Ultimately, what we get from here is we get the moisture content versus suction graph. So, if you have very high suction, the soil is almost dry. So, the curve will always be starting with no suction, saturated state of the material and then as suction increases, the moisture content drops down. So, the more and more you squeeze the water from the sample just by applying some pressure, the moisture content reduces and you get a curve like this.

Lot of people believe that if you get a graph like this between w and suction which is known as soil water characteristic curve (SWCC), is just like your blood report of a patient and you need not to do any other test to understand how this system will behave. So, just by looking at this graph or the characteristic you can say, whether this is a fine grained soil or a coarse grained soil and how it is going to behave that is shear strength

and compressibility characteristics, people are working on this area. I will talk about this, later also.

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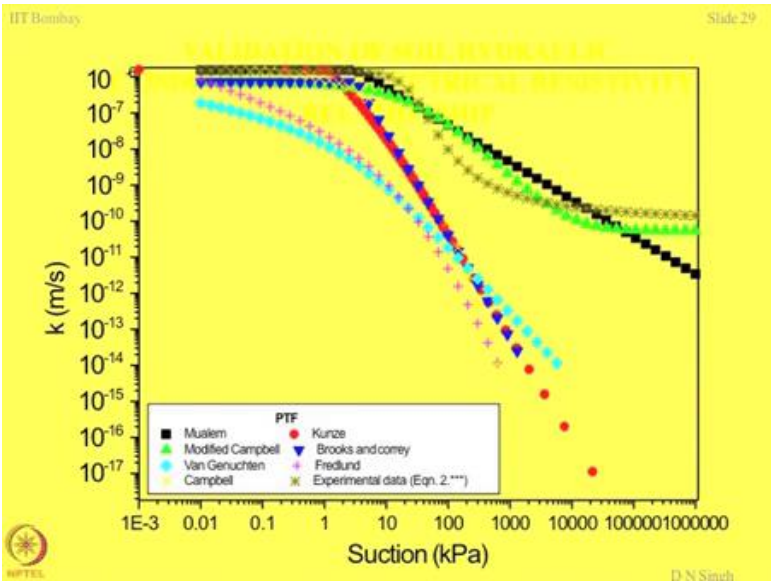

And ultimately using this relationship, people try to get hydraulic conductivity as a function of suction. So, this is a big subject in geomechanics where most of us are converging to ultimate aim is to study the unsaturated state of the soil, particularly in countries which are temperate. You go to the cold countries, where people are working in ice mechanics, they are not bothered about unsaturated state of the material, they are more interested in studying how ice, water, soil interaction takes place.

So, a one good thing is that you must be realizing that geomechanics is trying to answer, lot of local problems is it not and that is the very good achievement of the researchers and those who are involved in such studies and this is where actually we are standing right now. I hope with this I will end the basics or introduction of the subject which we are doing and I will start talking about now, the real geomechanics concepts related to geoenvironmental issues from next class onwards, all right.