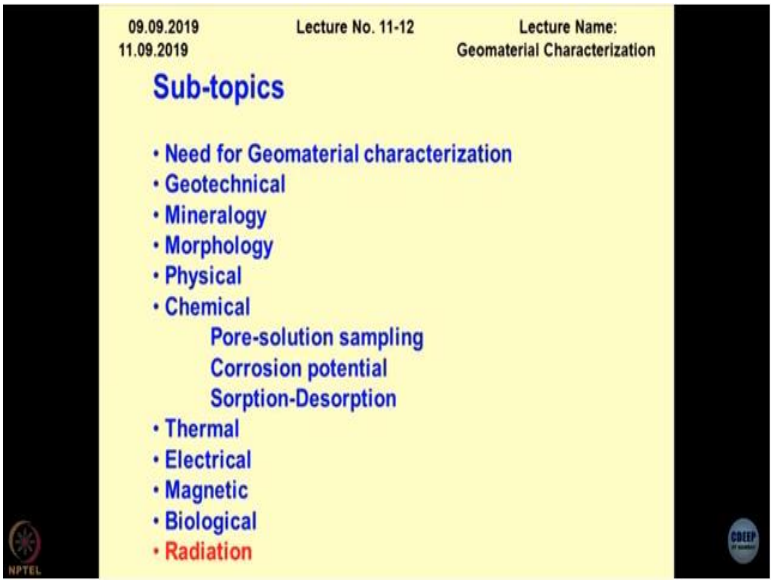
Environmental Geomechanics
Prof. D. N. Singh
Environmental Geotechnology Laboratory
Department of Civil Engineering

Lecture – 25
Geomaterial characterization -I (Mineralogical characterization)

(Refer Slide Time: 00:15)



Until now in conventional geomechanics, whatever you have studied is a part of the geometrical characterization. Mostly the characterization dealt with the geological characterization the way the soils are form, the genesis of formation, type of weathering, type of deposition, type of agencies which are responsible for the formation of science. Then you use different types of classification schemes to understand the behaviour of the material USCS, ISSCS, AASHTO, USBR.

These are the techniques to characterize the geomaterials. Then you also talked about the mineralogical characterization but not in full and chemical characterization. Conventional geomechanics does not deal with much, and of course, the morphological characterization is not done much under the realm of conventional geomechanics. But of course, compressibility, compatibility, consolidation characteristics, and ultimately the shear strength characteristics.

These are all different types of characterization schemes which are utilized to characterize geomaterials. So, in this context, if you really want to study the holistic characterization scheme or the plan of action, we have already talked about the need for geomaterial characterization. First being a geotechnical engineer, our emphasis would be to understand how geomaterials should be characterized for their geotechnical characteristics followed by the mineralogy.

Because the geotechnical characteristics are heavily dependent upon the methodology of geomaterial followed by the morphology. Morphology is the granulometry also sometimes we talk about the particle shape, roundness, flakiness and regularity, irregularity and so on. Then we will be talking about the physical characterization schemes. What are the physics of the material? Because geotechnical properties will also depend upon the morphology and physical characteristics could be same.

And these two characteristics influence geotechnical properties quite a lot. Then we will have a prolonged discussion on chemical characterization of geomaterials where we will be talking about pore-solution sampling which is quite contemporary and then a corrosion potential of the soils, modern-day infrastructure, and particularly the industries which are conveying either a fluid or material in solid form.

A good example would be the conveyance of fly ash in the dry form in the pipelines. It could be in the wet form also; it could be in the dry form also. So, these pipelines are the lifeline of the nation, and in conventional geotechnical engineering, we are not done much justice with the buried pipeline design. Apart from the mechanical load how these pipelines get corroded in due course of time is a matter of great concern to most of the companies which are dealing with conveying anything through the pipe.

The soil, oil, gas, solid, semi-solid, dredging industry, and so on. We will talk about sorption-desorption from this point onwards that how these mechanisms are utilized to quantify the soil contaminant interaction. So, until now, whatever I have been discussing was abstract. I have been only creating situations where the contaminants come in contact with geomaterials and then

the question all that happens then? Once you start dealing with the sorption-desorption mechanisms, you can quantify this interaction.

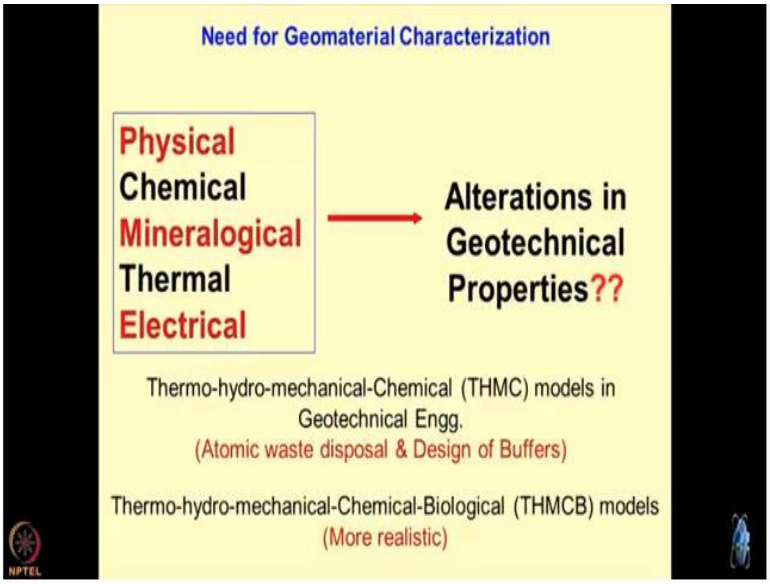
And once it has been quantified, it can be utilized the way you want it to. Then we will be talking more thermal characterization of geomaterials. Next would be the electrical characterization of geomaterials followed by magnetic characterization of geomaterials, and this would be followed by biological characterization of geomaterials. But as I said, biological characterization is yet in a very nascent stage in geotechnical engineering.

So deliberately I am not going to deal much with the biological characterization and same is the case with magnetic characterization also. So, I would not be dealing much in details and similarly the characterization of geomaterials based on the radiation. So, these three are I am not going to talk about in this course. These are very active research areas in which my students are working, and we are still trying to evolve various processes associated with this.

You must have realized that when I have created this list of geomaterial characterization most of the emphasis is on how environmental energy field is going to influence the geomaterials and a good example would be thermal, electrical, magnetic, biological, and radiation processes apart from the mechanical energy field which we talk about. So, you will be surprised to know that how much information has already been created and this answers one of your question which you are asking sometime back that what is the state of the characterization schemes?

So, the foundations have already been well laid only thing is that stuffing has to be done and make these methodologies which we have proposed and the type of instrumentation which we have created has to be more and more generalized.

(Refer Slide Time: 06:10)



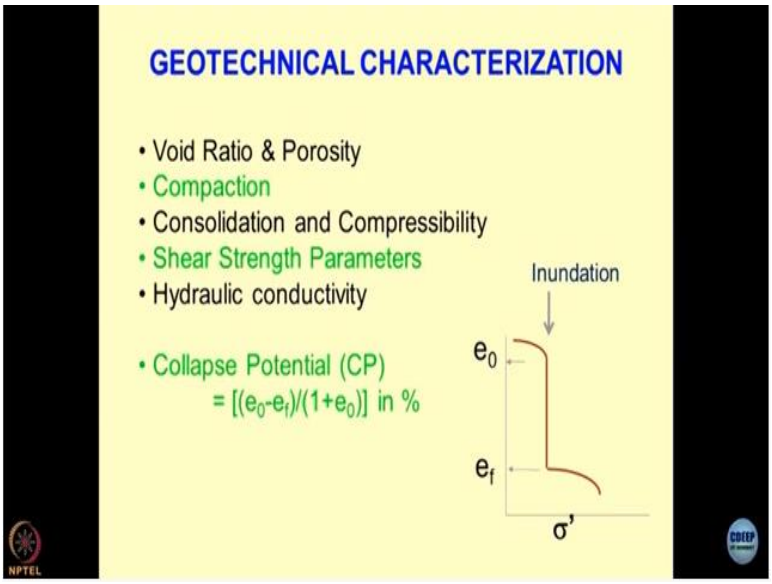
So, needs for geomaterial characterization has already been discussed in the previous lecture. And all physical, chemical, mineralogical, thermal, electrical, energy fields would alter the properties of the geomaterials, particularly geotechnical properties. So, this is what the big question mark is how to study these effects? How to quantify them? How to utilize them in day to day practice. So, you may say from this point onwards the R&D and most of the real-life problems how they have been sold? They have been tackled by our group I am going to talk about.

I think I also discussed the THM model where how thermo-hydro-mechanical coupling is becoming a very important feature in geotechnical engineering, contemporary geotechnical engineering. And I gave examples from atomic waste disposal and design of buffers. That is a good example of how the geotechnical aspects of the material would change, once you create a situation where the geomaterials interacts with the aggressive environment and aggressive environment would be extremely high chemical concentrations, extremely high thermal gradients, extremely high electrical gradients and so on. And I think I have also discussed about what is the importance of THMB and THMCB also. So, C is missing here. I think you should add here.

This should be thermo-hydro-mechanical models. Next should be thermo-hydro-mechanical-chemical models THMC followed by thermo-hydro-mechanical-chemical-biological models

THMCB. So, this is what the recent trend is and people are trying to work on add chemical part to these models.

(Refer Slide Time: 08:07)



So as far as geotechnical characterization is concerned, you usually talk about the void ratio and porosity of the geomaterials how to compute them. Of course, there are the latest developments in the field of even computing the void ratio and the porosity. And as I have been telling in the past that conventional equipment are not used for determining the void ratio and the porosity anymore.

Because this is the era of instrumentation and particularly electronics. So, people want to measure all these things under in-situ conditions. Similarly, compaction also one of the days when people used to do compaction controlled by taking the course of the sample or by sand displacement. Look at the type of infrastructure which is being developed in the country right now 2000km of the infrastructure is being developed every day. That is what the statistics are.

So how many core samples you can take at what depth? So, this also has changed now to more of recent instrumentations where people are using different types of probes, nuclear density probes, gauges, thermal probes and electrical probes to compute the initiative densities. Consolidation and compatibility is of great importance to the geotechnical engineers and there are techniques

by which people measure the initiative consolidation characteristics and compressibility of the soils.

This is where somewhere hydraulic conductivity also comes in the picture ou are designing the systems it is not the hydraulic connectivity, but the conductivity of the flux which I emphasize in one of the lectures is becoming more
critical. So hydraulic conductivity is the flux of water when it is flowing through the porous media. It could be thermal flux; it could be magnetic flux, it could be chemical flux, it could be radiation flux, it could be biological flux and so on.

Shear strength parameters how to obtain further geomaterials and normally we conduct a triaxial test, shear box test and if we want to find out the in-situ characteristics, there are several types of tests like when shear and flat jack and what else you are aware of dilative meters are normally used to get the shear strength characteristics. There is something which is not normally covered in the conventional geomechanics is the collapse potential of the soil.

Particularly this subject becomes very important when you are dealing with the soils which are sandy materials like in the middle east region where you have desserts, and you cannot conduct shear strength test to obtain the shear strength parameters. In our country also now most of the infrastructure is being developed in the Western part of the country. A lot of oil exploration is going on in the dessert area and 9, 10 big oil fields have been established you should read in google and try to understand what the challenges these oil companies are facing when they have to do infrastructure design on soils which are collapsible are?

So, what is meant by collapsible soils? Normally the instability caused in the wide ratios per unit volume is defined as the collapse potential in percentages. So if you look at this graph normally what is done is you take an oedometer ring, and in oedometer ring, you pack the dry soil at a certain density granular soils, not the cohesive soils and then at certain stress where you are interested in finding out how much the material would collapse in terms of its voids you inundated. So as if I am trying to simulate something which is happening in nature.

You imagine there is a heap of industrial by-products which is lying, and a lot of the sudden rains come. So, this is what actually we are getting in the laboratory. How much is the structural collapse of this type of heaps going to occur? This could be municipal solid waste also where people are interested in. So, sigma prime would be the effective stress at which the inundation is done and because of flooding or because of the interaction of the geomaterial with water how much void ratio has changed? This is the collapse.

So, people who are working in dessert areas utilize this scheme for dealing with their design and execution of the projects. So e_0 is the initial void ratio, and e_f is the final void ratio at a given sigma prime and $1+e_0$ is the unit volume of the soils. You must have studied in geomechanics. So, because we are dealing with the industrial by-products quite a lot, we have to deal with the collapse potential based classification scheme.

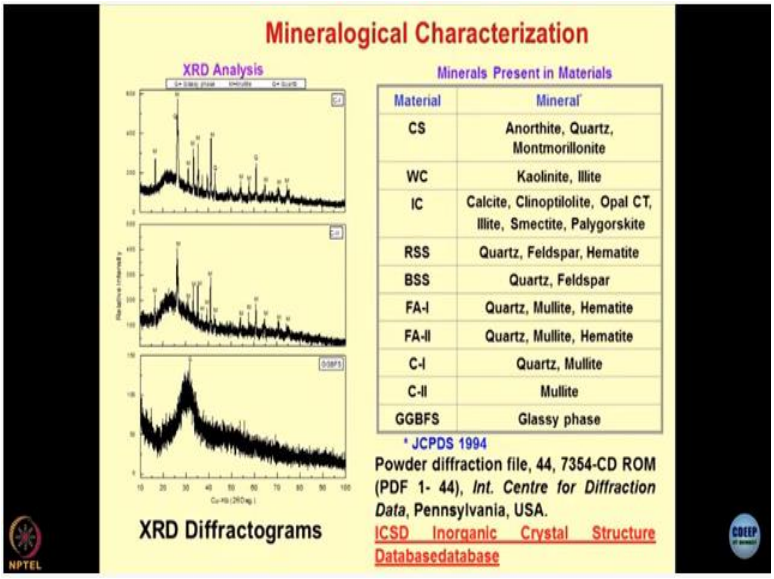
(Refer Slide Time: 13:18)

The second in the series is the mineralogical characterization. Normally XRD is done for mineralogical characterization of geomaterials and nowadays you have very advanced tools which are used for obtaining the x-ray diffraction patterns of the geomaterials. So, these are the types of machines which we have in IIT, Bombay and several other institutes. Government of India has created advanced instrumentation facilities which we call as SAIF sophisticated and advanced instrumentation facility which is created by DST at the five locations in the country.

The region was that it is a regional facility where people can do advanced testing of the geomaterials. So, most of our results depend heavily on the facility with SAIF provides. So essentially what is done is? You take a sample and bombard this sample with the x-rays and then record the diffraction pattern. So, I will show you how the analysis is done. The second in the series is scanning electron microscopy.

I will also show you today how scanning electron microscopy is done to realize the orientation of the grains which you might have studied only in the books. But you might not ever realize that how the real-life pictures look like? So, by using XRD and SEM we can find out the mineralogical characteristics of the geomaterials. Sometimes these could be EDX**.** So, we can have the diffraction pattern at the same time and I am seeing the environmental scanning of the material depending upon the requirements.

(Refer Slide Time: 15:10)



This is how the results look like. So, if you look at the XRD analysis. These are known as XRD diffractograms. I can utilize this information in several manners. First of all, as a civil engineer, I would like to use the inert materials in the foundation systems. I do not want to use a material which is very active chemically or physically, I would not say. So XRD is a technique where I take some sample and by using the Bragg's law if you remember 2d sin theta = n lambda in your physics course you must have studied 10 plus 2 or maybe later on in the engineering.

So if I know the lambda is the wavelength of the wave which I am using to bombard on sample I can find out the d and d happens to be the intermolecular spacing of the atoms or the lattice structure what we call as. So, you must have studied the lattice structure of the crystal a, b, c. So, these things are becoming very prominent nowadays. So, if you look at one of the diffractograms on the Y axis, we have the relative intensity, and on the X-axis we have copper K alpha is a filter through which the X rays are channelized monochromatic you must have studied in your physics courses how to create a light in the monochromatic form? And then so this happens to be the 2θ where θ is the angle of incidence of the waves. So, if you can fix theta and if the wavelength of the ray which you are using you can compute d. $2d \sin\theta = n\lambda$ is the Braggs law.

Now corresponding to 2θ value, we get different peaks of the minerals. So simply by looking at the XRD patterns, I can make out whether the material is active or inert. So, the thumb rule says the more and more peaks you have in the material; this material is going to be crystalline clear. A crystalline material would not react on its own unless you do some chemical treatment or unless you pulverize it.

We were talking about ultra-high active fly ashes, ultra-fine fly ashes and this is what I told you that either you can use a classifier to separate different particles and of different densities and different shapes or what you can do is? You can apply different type of fields. It could be airfield; it could be density separation by putting the electromagnetic electric field or whatever electromagnetic fields.

So, these other techniques that people are practising and the more and more peaks you get the material is bound to be a crystalline inert material, a good material to be utilized for creating foundations, fillings, reclamation. But if you have a material like this where you do not have distinct peaks. The story is different. So, what this indicates is that this material is going to be a highly reactive material and we call this material as a material which has a lot of glassy phase in this glass.

So, if you take cement and if you do the XRD, you will get something of this art. There is no distinct peak over here. So, and a lot of hazy XRD pattern shows that this material has the

potential to be a good pozzolanic material. Because when you have more glass present in the system, the system becomes reactive. So, this is one of the ways to differentiate between the activity of the material active and passive minerals.

So in any walk of life if you are a hardcore geotechnical engineer or you are a material scientist working in the field of cement and concrete technology or design of resins, filters, different types of catalysts you will have to depend upon this. This also gives me an opportunity to interact with people from different departments and different streams because our interests are common. I just want to characterize the material.

So nowadays the world has changed earlier we used to sit down and up to the fourth decimal place of theta value we used to match the minerals in the present in the soil and this has to be very tedious also. Earlier students of mine they have spent 3, 3, 4, 4 months altogether characterizing one soil. Can you believe this nowadays it is a matter of a few hours? So, we have these types of soft wares which are known as JCPDS files now there is a powder diffraction file. There is a CD ROM.

And sometimes people use ICSD inorganic crystal structure database. The results are listed over here. So, for different types of soils. What you observe is that mineralogical composition in a qualitative manner can opt. And since Dr. Susha's thesis, we started getting the quantitative mineralogical phases also.

So, this is something one stage ahead of what is happening in today's world, our lab has been quite active, and we are much ahead of what the practices are in the market right now. So I can do the qualitative analysis of the phase of the minerals, and there are soft wares which are available and known as expert high score, EXPERT high score. So if you get time, just google it, and you will realize how these type of soft wares are being used to quantify the mineralogical phases.

The question is where I am going to use all this information. We have been talking about the application of geomaterials in buffers for the radioactive as disposal. This is a very interesting

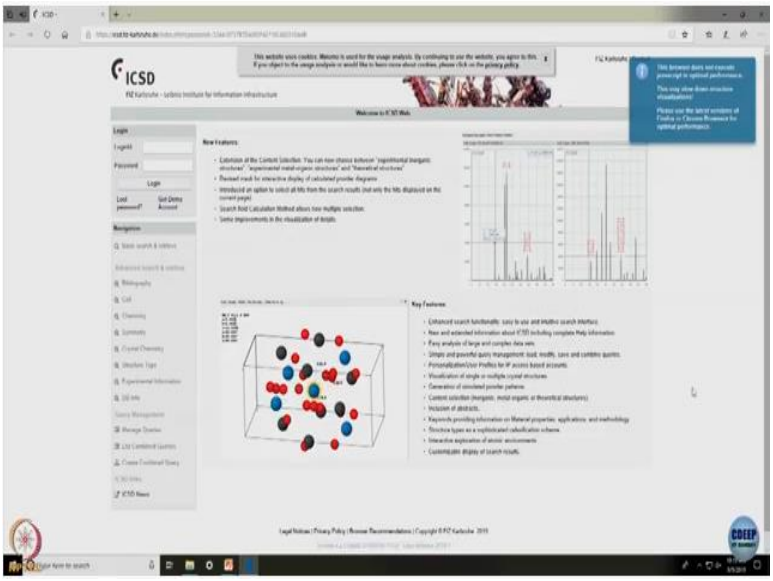
and practical problem but a multi-phase problem. The structural stability of the material should be good number 1. At the same time, chemical affinity and the reactivity of the material should also be extremely high.

So this is a system when you are dealing with nuclear waste disposal. The material is supposed to be at the mechanical loads, thermal loads, chemical loads, biological loads, and radiological loads. Now I think you understand where these types of studies are being done. And this is where you have to select minerals also. So gone are the days when naturally occurring minerals is to be used in the industry.

Because nowadays people are they are very demanding. So every nation has its own demand for creation of a mineral of a certain specific value for various applications. So suppose there is a breach of the atomic power plant, and most of the atomic activity comes in the water in the sea. Because most of the establishment is on the seashores. The chances are the entire seabed or the sands on the shore may get contaminated.

It is a very practical problem for which you have contacted sometime back by from by a country. And they wanted us to create minerals of a certain specific value. We will be talking about this later on. So these are the things which are happening in the realm of geotechnical engineering. I am sure you must be finding it a big story, but this is what is being done. So if you click on this, you will find that there is information which is available on the website about ISCDS.

(Refer Slide Time: 23:31)



This is what is the need of the hour. So good geotechnical engineering can only be done once you start from the mineralogical characterization of soils or the minerals. This show how lattice also can be quantified. So you can just go through this site and try to learn what are the facilities which are available in today's world. I hope you can realize that when people join my group, it becomes for them a challenge to cope up with what has already and what is being done.

Because our expectations are extremely high good from the people, but unless expectations are high things cannot be done. This is the first thing people are supposed to learn. If I quickly analyze this data which is present in the table, you will find that most of the geomaterials would have quartz, illite, kaolinite, calcite, feldspar, hematite. So, hematite is the one which is mostly present in the fly ashes.

It comes as an impurity in the coal. RSS is the red sandstone, and BSS is the brown sandstone from different parts of the world we collected this. IC is the chalk sample which I got from Israel. Because Israeli chalk has very high porosity and their aquifers are mostly chalk-based aquifers. What different projects are studying the formations from different continents and C1 and C2 are the cenospheres which you separate out from the fly ash by different techniques.

So classifiers which I have talked about is one of the ways you can do density separation. You can do filtration from the lagoons. These are all subjects where young guys are doing lot of

entrepreneurship. And for your information, the cenospheres are the pure quartz. They can be utilized for substitution for pure silica in the electronic industry. So if you check it on the net you will find at least there are 350 applications of cenospheres which are in the market right now.

These are the subjects which are picking up at the moment. So one of the most challenging tasks which I think I may give it to you is supposed if these are the materials which are naturally occurring and if I ask you to use filter out a certain type of mineral and sell it in the market. And it is something very interesting, very commercial question that from the soil which is laying here and there. How can I produce a mineral? And people are working on it.