Geotechnical Engineering I
Prof. Devendra N. Singh
Department of Civil Engineering
Indian Institute of Technology-Bombay

Lecture-07
Soil constituents-II

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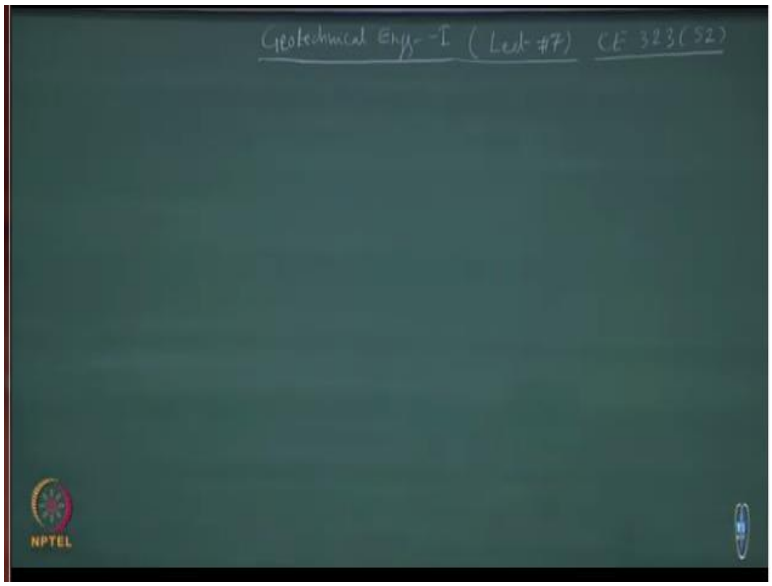

So, we have been discussing about the soil constituents.

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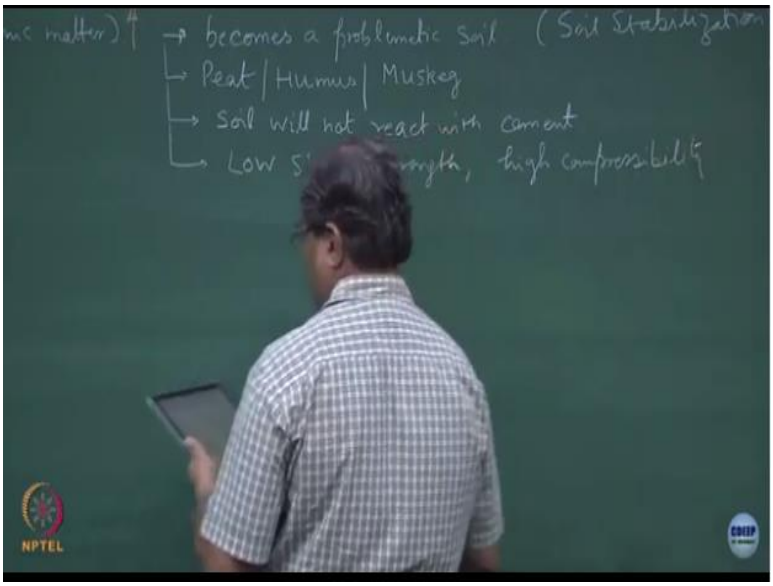

And I had talked about solid phase, liquid phase and gaseous phases and we were discussing the organic matter and soil. So, one of the biggest issues with organic matter is that if organic matter

is present in substantial. So, as the OM increases I use normally this sign alright. So, as this content increases this becomes more and more problematic for geotechnical engineers.

So, later on we will realize that the more the organic content in the soil you cannot even modify this. So those of you who might get a chance to work on ground modification or soil stabilization, these are big subjects I am not going to go in the details of these. But those of few who are very curious to learn about it please do google search and you will get lot of information regarding soil stabilization and ground modifications. These are the techniques which are now a days used for making infrastructure in the challenging and problematic soils as I discussed the other day.

Peat is the most notorious thing Peat, Humus we are discuss about the muskag also other day. So these are the soils which have posed a serious problem to the professionals. So higher the organic matter the problems become difficult to stabilize. The big issue is that as the organic matter increases the soil would not react with cement. So most of the marine clays which have a substantial amount of marine clay as organic matter it is very difficult to stabilize them.

But I am sure you must be seeing in contemporary world most of the stabilization or most of the construction is going on in the coastal regions, government of India sagar mala project is a very good example. So all along 11000 kilometers of the coastal line they are trying to create infrastructure, this is just like you know in Hindi you call it dhal dhal or in English you call it muck. On the other day somebody was sitting here and he was you someone else I do not know.

See we were talking about you know muck remember maybe first or second lecture. So this is the type of the soil which is very difficult to negotiate with. So most of the construction which is going on the coastal region requires a stabilization one of the ways of stabilization could be grouting, why I am teaching you all these things develops that these are the subjects which have to be practiced by people like you.

Many of you say that no jobs, I can assure that they are so many jobs, they are so many specialize things to be done which cannot be done by the right guys. So these are the area when

which you can think of exploring the possibilities. Another issue is that this material has a very poor shear strength and very high compressibility alright. The next constituent of the soil would be yes water.

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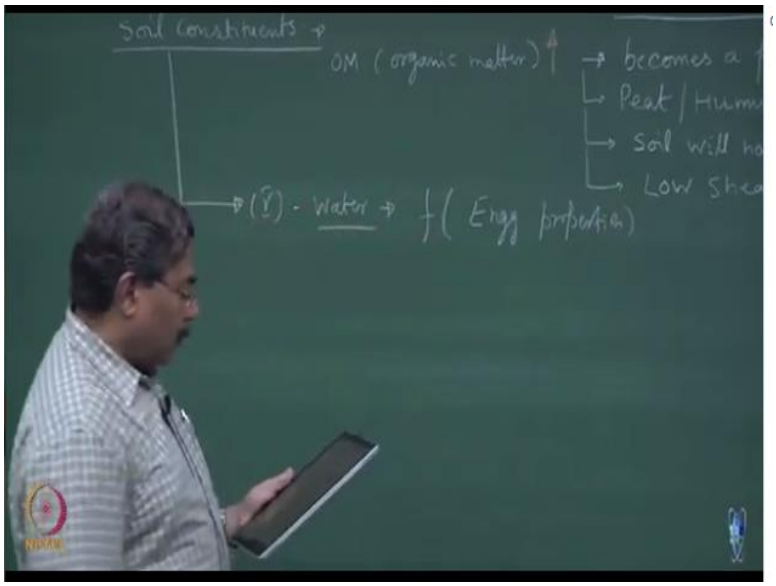

And what number was the water in the list of constituents 45 this would be 5 alright, very soon and we will realize you know how water influences the overall characteristics of the soil when will discuss these things in details. You will come to know that water is the component or the constituent of the soil which controls it is all engineering properties. And when we talk about the engineering properties these are mostly shear strength.

This is what I will be discussing in the second course shear strength is a dedicated chapter maybe I will spend about 16 to 18 lectures on you know defining and how determine the shear strength the big subject in soil mechanics. The compressibility, and hydraulic conductivity and when you come in the domain of the research you will realize all sorts of conductivities could depend upon the moisture content including how heat migrates in the system, how current migrates in the system, how electromagnetic flux will migrate in the system.

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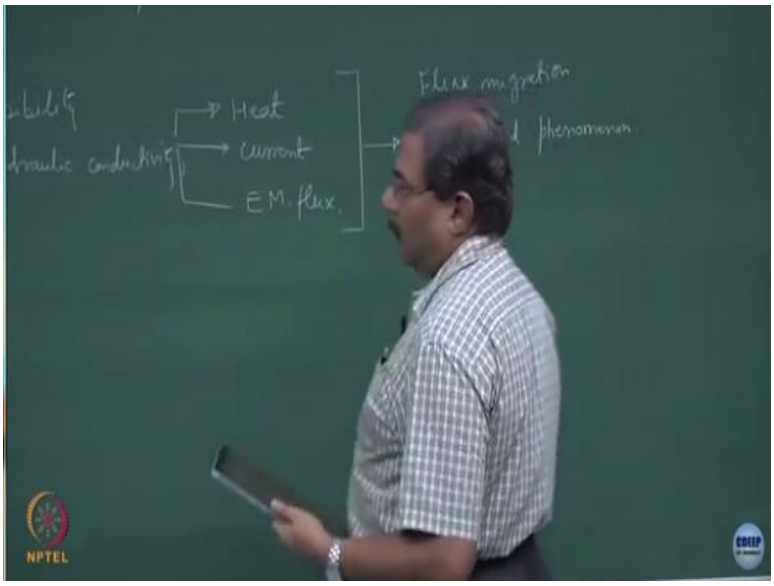

Well, this is the beyond the scope of undergraduates soil mechanics or geotechnical engineering I will not be discussing this. This is the recent discussion in geomechanics, we call this as a you know flux migration and the flux could be of thermal, electrical, electromagnetic, it could be bacterial, it could be whatever you may think of a combination of the 2 and this forms the couple phenomena.

In western world lot of people of working these areas they have lot of funds and they want people like you to join their research groups. So situation is not so bad as you think.

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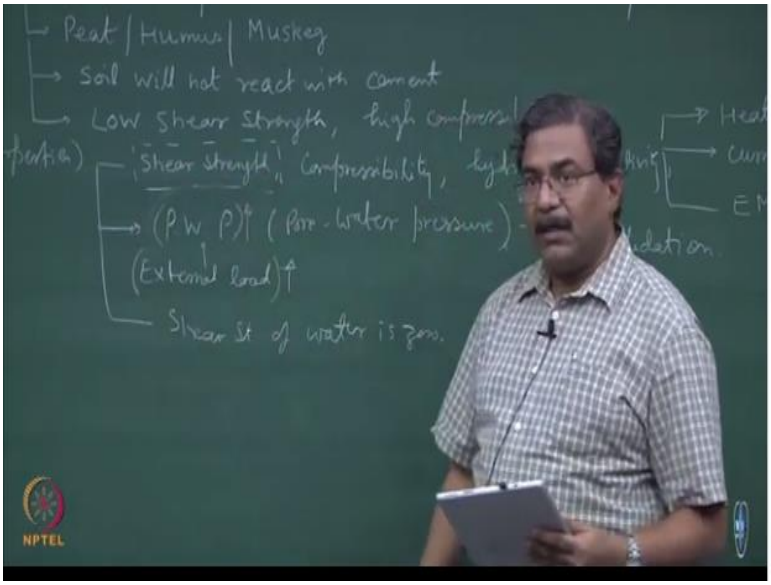

Here shear strength is basically the strength of the soil mass, once it gets sheared. So suppose if I take a piece of paper alright and normally the word which uses the tear alright.

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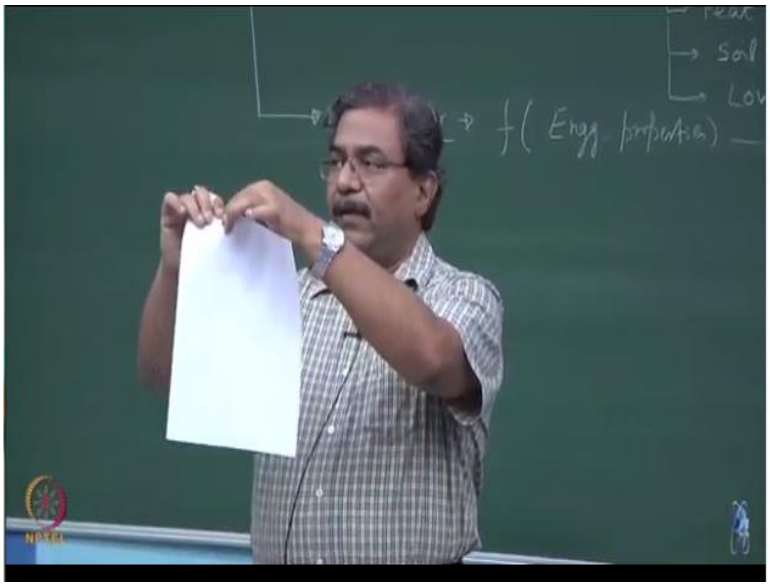

So what I am doing look at the motion of my hands, the motion of the hands is opposite direction, clear 1 and this on the other side is a tearing process but tearing itself is initiated because of the shearing at a plane. And as I said this something which is to be discuss separately when earthquake comes this is the strength which is required in the material otherwise then everything will become like liquid.

You remember we were talking about the liquefaction of the soil, that the soil behaves like liquid ok. So here we use another term because of the presence of water we call this as PWP Pore water pressure which is very equivalent to the blood pressure of the human body. So what happens suppose your blood pressure shoots up, you see somebody and you know you feel very angry, annoyed, hyper active.

So what happens you start sweating your blood you know your blood vessels immediately through lot of blood on your face, face becomes red. And if blood pressure shoots too much what was going to happen, you collapse same thing is going to happen in soils also. If by any chance the pore pressure becomes extremely high the system becomes a critical patient to be treated by a

surgeon alright and what are the surgeries, these are surgeries either I will modify the situation or I will enhance the properties.

Other way, low blood pressure what happens most of the people collapse because of the low blood pressure also. So this pore of pressure is a tricky thing, in geo mechanics most of the time the pressure will develop in the soils in the pores. We will be talking about what are the pores clear, so most of the time the water, pressure develops in the pores because of the external loading.

A good example would be there is a railway track and there is a train let us say 45 bogies, politicians would be say that we will make it 55 bogies, 65 bogies, 100 bogies is it not. And geo tech engineer says no it is not possible to have more than 45 bogies why there is an answer to this because there will be tracks have been designed in such a manner that when the rails move the type of code of pressure which is going to develop will sustain the external loading appropriately clear.

From here comes the or from this is the starting point of the professionals like you who might get converted into earthquake specialist soil dynamics. You will be dealing not with a static situations, you will be dealing mostly with the impact, vibrations, movement of vehicles, movement of traffic, missile coming and hitting a shielded object is all dynamic cases clear.

So I will be very interested in seeing that these type of situations how they are going to enhance or decrease the pore of pressure of the material. The logic is or the funda is if I am dealing with the coarse grain materials like sands, gravels clear even if the pore of pressure develops it will dissipate fast. There are guys who are very sensitive you say something there will be gently cry after that everything becomes normal 2, 3 minute they are forget everything.

So these soils which are coarse grain are blessed, they dissipate pore of pressure which gets develops because of the external loading quickly hence damages done less. On the other side there are guys who keep everything in their heart and mind. So you say something today and the

reaction will come after 5 days, there are personalities correct. So most of the fine grain materials would have a severe problem of pore of pressure developing because of the external loading.

So suppose I am doing a railway track in the coastal bell from Bombay to let us say coaching alright where you are passing through the marine clays. You have to very careful about this pore of pressure you have to dissipate it clear. If this remains inside the system and it becomes very high there will be a loss of strength as I said people may collapse ok. Normally we will be talking about this things in details when we discuss consolidation mechanism, it is a phenomena where if I apply the load the pore of pressure develops immediately in the soils.

And then depending upon the material property the type of a person you have to wait how long this guy takes to release all the emotions clear, to release all the pore of pressures and then we will modulate accordingly. So this is a something which is we will be discussing for at least 3, 4 lectures minimum. So logic says if you apply the external loads alright the pore of pressure should build up.

So the moment external loads are applied the pore of pressure goes up ok. Now as a surgeon, as a doctor, as a professional, as a knowledgeable person I have to tackle the situation how best I can tackle the situation. One important thing about the water is that water cannot take shear is it not, is this correct. Water can be only compressed it cannot be sheared because this is the property of the material. So imagine the size which have enough moisture in them we are discussing about the water, water is also sometime known as moisture content alright.

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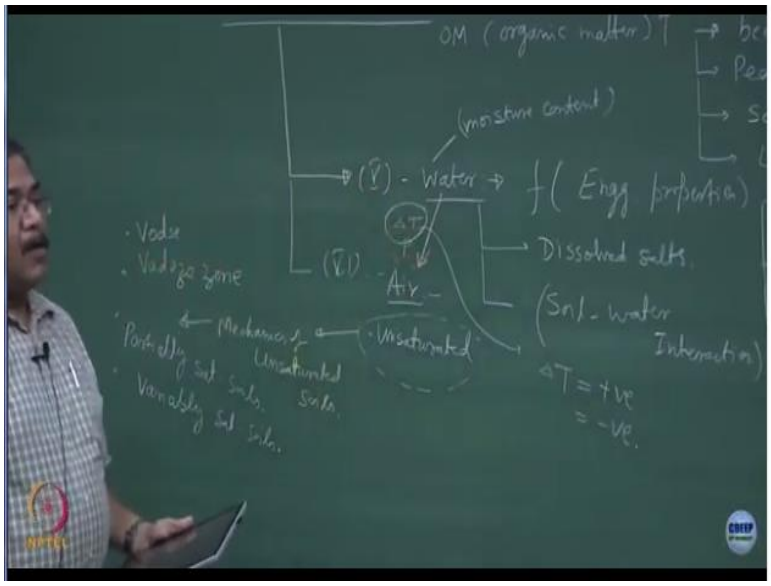

So the more the water, more the moisture content the chances of pore of pressure getting in fine grain soils are higher as compared to the coarse grain soils. The moment you externally loaded pore of pressure becomes very high, a strength is getting lost. The question is what water is doing, water takes only compression or the compressive loads, it cannot take any shear stresses. In fact more the moisture content, more the water content the shear strength is going to be absolutely less.

And thus the reason if you go and enter into a moisture deposit chances are that you will sink you cannot walk, clear. I gave this analogy last lecture also, you are on a beach and you know it is a dry sand and if I ask you to run you cannot run. But suppose the sands become wet and you can drive the car also on that, next time when you go to Zurich please try this then only you will learn soil mechanics.

So what water does, water reinforces the material also, it acts as a reinforcement what you are using in the concrete in the form of the rebars and the steel. So the more and more water which is present because of the capillary action gives more shear strength. So water is the main thing and we have to study quite in details how it has to be model. Water is the carrier of dissolved salts, minerals alright.

Now I think you can realize this, if I want to stabilize if I want to modify the soils, what I will be doing I will take some cements slurry, water is the carrier and I am injecting dissolved salts into the system to make it strong very similar to the one which doctors do by injecting a you know ampule or something injection in your body if you are having deficiency or if you are having some decision so on.

There are lot of similarity between all these things, now it so happens when we talk about the dissolve salts there are few passive salts, there are few active salts, so carbonates, bicarbonates, sulfides, chlorides these are the ones which are naturally occurring in the water. And this gets impregnated I hope you understand the what impregnation means they become a part of the system.

So they get impregnated into the soil and hence soils would have salts coming from different agencies. So for that matter if you take a sample from Powai lake or let us say from bay of Bengal or anywhere from water body. If I squeeze out the soil and whatever solution comes out is just like the reflection of what type of problems the soils would be having and how to treat them, this is what is known as pore solution sampling where the blood sampling is done from your body.

Doctors and pathologist take few drops of blood and they give you all parameters correct. So similarly I can take out some part of the pore water I can analyze, I can diagnose the problem. So this is a big science and big work which is going on everywhere in the world. This water is also responsible for soil water interaction alright. That means look at the dams where you are storing water, so there is no fun in creating a body of the dam through which the water percolates all the time, I cannot store water then is it not.

So the whole idea is that I should be storing water in a embankment or a dam body which is impervious. So when soils come in contact with water there is a interesting interaction which goes on, some of you who will be go for higher studies or profession you will realize soil water interaction. This could be soil structure interaction, this could be soil fire interaction, this could

be soil microbial interaction, this could be soil what else it could be, soil contaminant interaction, very nice.

So keep on replacing or adding terms to this and this becomes an interaction problem. An interaction problems are mostly solved by the concepts of mechanics is this part ok. Then comes the air, air and water these are opposite to each other. So if water gives shear strength to the system, strength of the system, the more and more air if it is present in the soil mass the system becomes first of all unsaturated.

So suppose if I say that soil mass has lot of air in it and very less moisture, so this becomes the state of unsaturated soil and this state of the soil I am not going to discuss in third year soil mechanics or geotechnical engineering. Those of who are interested please visit my lab, see what are the special equipment which are required to model the unsaturated state of the soils, it is totally different world altogether and I am not going to cover this air.

So this is the unsaturated soil mechanics or mechanics of unsaturated soil but please remember this is more realistic than the one which you are going to discuss in the entire course. Because what we are going to discuss is a simplification of the real life situation which is extremely complicated. Because the dynamics of the air inside the soils is going to be extremely complicated and you require different tools to study this or measure this.

Sometimes this is also known as vadose zone, many of you go for you know summer trainings and internship and particularly those of you who go to France I mean I get the feedback that we are not teaching you guys properly, I get most of the feedbacks on different parts of the world about our students . So remember this subject is also known as vadose zone modeling, so if you end up in ENPC or EPFL Switzerland.

So there nobody understands mechanisms of such soil, this is what is known as a vadose zone, sometime they write it as vodse also both are correct do not fight with them alright vadose or vadoze. Sometimes we also call this as a partially saturated soils there are different names given

to this partially saturated soils. Sometimes people also call this as variably saturated soils also alright.

Those of few who may get a chance to work in nuclear industry particularly or with thermoactive structures which are being talked about these days, you know entire west is doing lot of research on energy geotechniques, I think I talked about this earlier. So this is where you will be using all these terms, so what happens if a saturated soil mass if you start with it comes and contact with the heat flux what is going to happen the water present in the soil will get converted into air phase is this correct.

So at elevated temperature or pressure also, I hope you understand this, so I have created 2 situations. If I elevate the temperature of the soil the water which is present in the soil pores will try to get converted into vapors and these vapors will migrate. Second thing is what I will do it with the pressure I have to drop down the pressure, I have to increase the pressure, drop down the pressure you are right.

So then what is going to happen, all your points which you have studied in chemistry and physics, sublimation point, freezing point, vaporization point all what else salt concentration point. All those can be applied over here, so look at this see simply what I have done I have just used 2 terms and the realm of the means the scope of the subject changes completely, are you realizing.

These are very interesting material, so the moment you hit it up or suppose if I say no I am going to freeze it – delta T the conation changes completely. So those of you who might go to Canada, Germany all these western world we are most of the time the soils remain frozen, this becomes the frozen state of the soil mechanics, correct or frozen state of the size and what is the mechanics of that arctic regions, polar regions lot of research is going on in this area.

In our won country in the north east, in the Himalayan reaches you know there are lot of research centers which are doing research on frozen state of the soils. So please remember we are not all these things in detail because these are the research ideas is this ok, any question. No, when you

are doing this water to air the saturation is decreasing, water saturation is decreasing, when you are heating it delta T.

Let me create 2 situations out of it, so delta T is positive and this is negative alright, so in this case when it is delta T is positive you are doing heating the saturation of the soil is going to change. And when you are freezing it we talk about the saturation of ice content or ice content in the soil. So depending upon the regions in which you are you have to establish the material properties accordingly, is this part clear.

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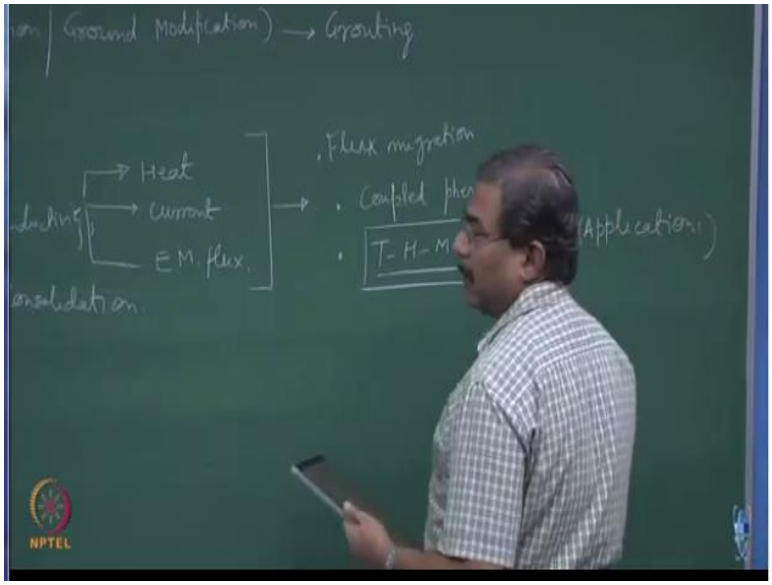

This also opens up interesting concept check an net who are the guys working on THMC chemical coupling, thermo hydro mechanical chemical biological coupling. So you have lot of scope for practicing in geotechnical engineering alright, the application comes here, read this whenever you get time please read this. And I am sure once you going to the applications part you will realize how much powerful these subjects are.

Sir what does the shear what happens to the shear strensive air content increasing oh very nice. This pore of pressure which we were talking about is a component of 2 types of pressures one is the water and second one is the air alright.

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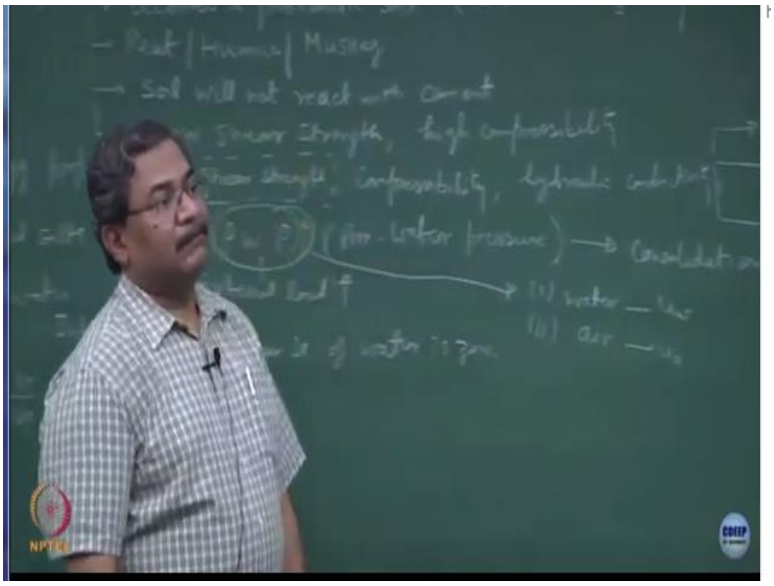

So as long as we deal with the conventional subject, we say that there is no air by forcing the material to be saturated, remove all the air. But in real life it is not going to happen, so this water will contribute uw pore of pressure and this will contribute to u air. So the correct modeling of the soils would be when you measure this also compute this also and take it in to your account but for god sake please forget about unsaturated soils right now is this ok.

But now you are much ahead of your third year, fourth year state as like this thing people do not know even at the PG level believe me. But once you know this now you device several equipments so that you can measure pore of pressure directly and these experiments are very very expensive our lab has all these facilities ok. So another phase you know or the constituent of the soil would be minerals what are the minerals which are present in the soil.

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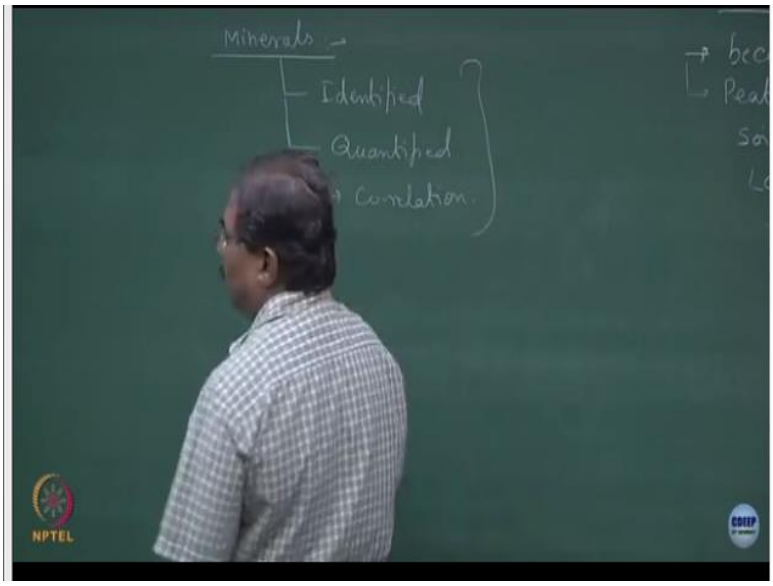

The logic is same as I said last time you know.

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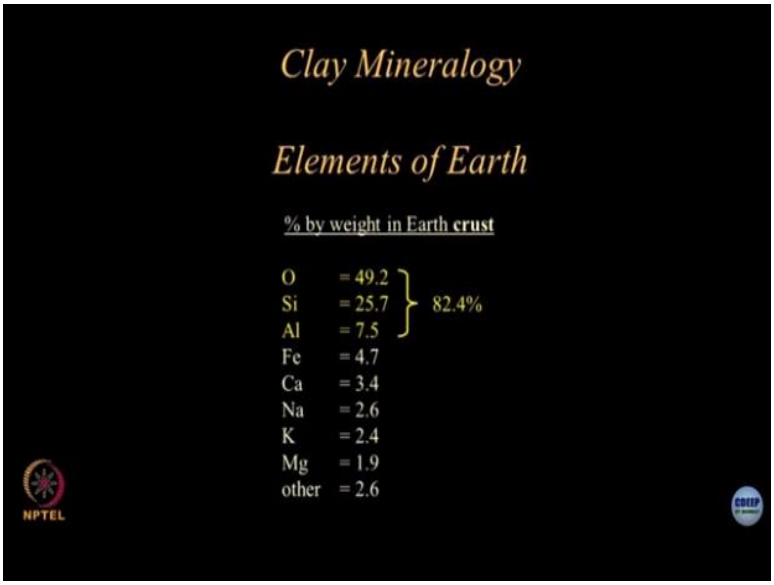

If you have minerals in the soil just like the minerals in your body particularly for those of few who are very much eager to be good industrialist or good researchers interdisciplinary practitioners. So for all of you, you know this is going to be useful see the first thing is that minerals are to be identified and later on they have to be quantified. The characteristics of the soil would largely depend upon the type of minerals it has and I hope you can realize that most of the minerals could be a genetic link between the soils in the rocks, somebody ask this question long back.

So the way the weathering is occurred, the way the transportation is occur, the way the mineralogy has changed over the years, millions of years clear. The system is going to behave a perform. So first thing is identification, second is quantification and third could be correlation, this is more of a doctors profession is it not. You do the diagnosis first identify by symptoms or by doing diagnostic text, quantify the problem since how many days you are having the symptom.

And then remediation, correlation, understanding the issue then so on, so if so happens that most of the elements of which the crust of the earth is constituted are listed over there. So these are the elements of earth normally please get some time to go through the facilities which are available in IIT-Bombay very unique facilities these are known as XRD, XRF, SEM. So you take the sample of the soil and put it in these type of equipment do the analysis and you will find that these are the elements which we are interested in.

We call them as percentage by weight oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium and others alright. And what you will notice is that oxygen, silica and alumina would constitute about 80 to 90% of the everything where these type of investigation become important. In a profession like me where something has failed contractor has use the wrong material and I want to catch him these are become a legal case where I have to submit a report in the court that well all these things went wrong.

And hence we should be panelize the damages should be charge and so on all these type of negotiation, arbitration which are happening in the code of law. People like you and me have to help the court. So this is what is known as elemental analysis, all the minerals are containing these elements number 1 clear.

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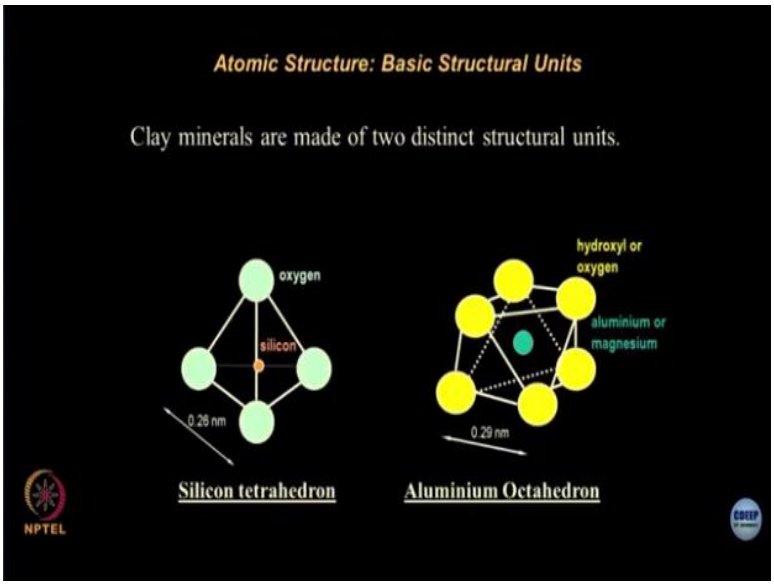

Now we have to talk about the atomic structures, you thought that after 10, +2 chemistry and physics this is not going to haunt you ever is not like this. The basics of the soils are you know again the atomic structure of the material. So the clay minerals are made up of 2 distinct structural units, the first one is known as tetrahedron and the second one is known octahedron you must be aware of all these in chemistry course you must have done clear tetrahedron and octahedron.

So there is nothing difficult to study, silicon is here look at the atomic size 0.26 nanometers, you have silicon at the center and then 4 oxygen atoms clear. And then when you have aluminum octahedron you have alumina or magnesium and followed by either hydroxyl ion or it could be oxygen atom is this correct. So these are the basic units, rest of the things is the combination of this, so we have octahedron, we have tetrahedron and combination of these are going to form clay minerals.

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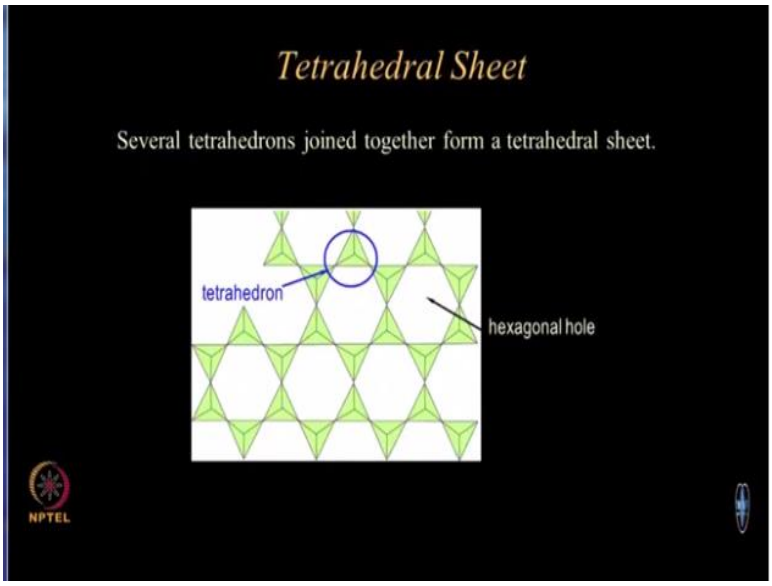

So this is a tetrahedral sheet remember the spelling tetrahedron and tetrahedral. So when several units of tetrahedron set together they form a tetrahedral sheet. So look at this, this is sort of a bridging you know, so what is going to happen in the holes which are getting created, these are the parking lots. Other day I gave you an example about you know the skin care, so you use clays and you put them on skin and then you peel them off, so what happens. All your side negative charges which are present in the skin, bacteria it gets remove why, where they are going parking places holes.

Now these holes are also very responsible for accommodation of water molecules, so suppose if I want to make metrogel the basic structure of the mineral will remain same. I will create more and more hexagonal spaces parking lots where the water molecules will go and sit because of hydrogen bonding. I can replace this water by ions also potassium chloride, hydro chloric acid, calcium hydroxide and so on whatever, it depends upon in what profession you are.

So these are the places where most of the ions will go and sit, so the more and more ions which you can pack into this space make clay a geolyte. And then it has a medicinal value then it has a chemical value then it becomes a you know what you call it as catalyst, you had catalyst for different processes alright. So it is all the parking place which you create by synthesize in the laboratory which is going to create this type of situation.

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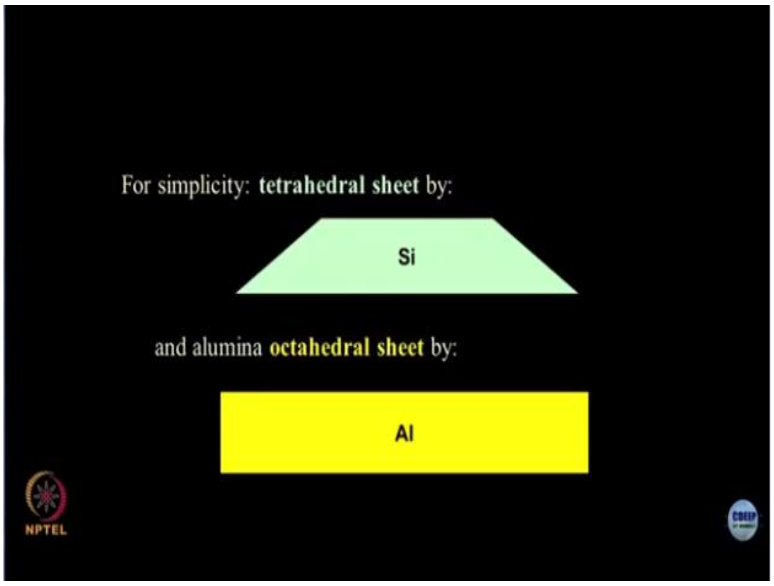

Next for the sake of simplicity this is how we denote the sheets, so a tetrahedral sheet is normally depicted like this alright (()) (34:28) and silica. Because remember there is a third dimension also associated to that which goes up to infinity. So all these minerals will be having infinite length as compare to their thickness and the height and this is the alumina octahedral sheet yellow color clear.

Now the question is suppose if you are making the toughs for cricket pitches and cricket control board will ask you give me a soil which should behave like this for 5 days or for let us say one full day, T20 match. Water holding capacity is the most important thing, that means this mineral should be holding the water despite all mechanical damages which the system is undergoing. Despite all the mechanical impacts which system is going to undergo clear when you through a ball is of some weight momentum transfer water coming out of the plates or we call them as plates also very thin sheets.

So you have to design like this clear, then somebody says on the pitches I will have grass also alright somebody say no this pitch should not have grass. So what type of minerals are going to present which are going to act as nutrients for the vegetation is also very important question. I can feed all these things and I can do engineering with the minerals. So these are new subject in our you know realm our zone our interest where you can create different type of minerals for their different requirements.

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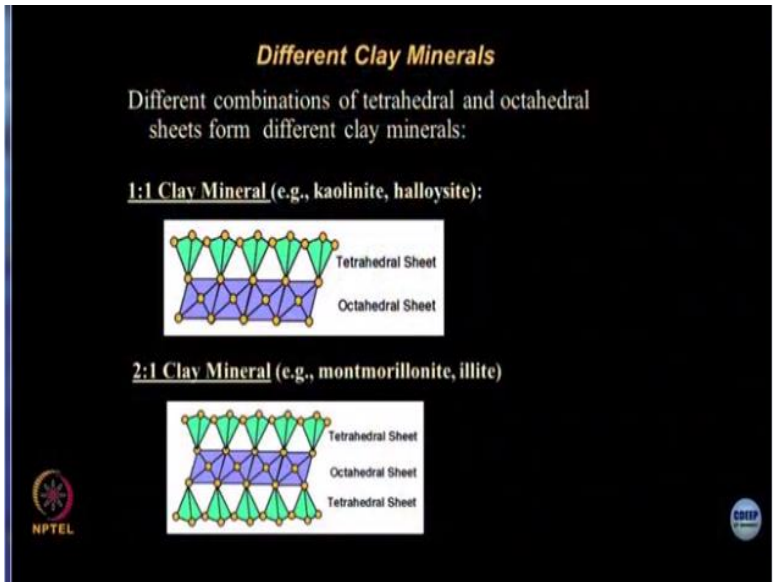

Now see what happens if you have different clay minerals we can create either kaoline or halloysite, this is the first group, this is the clay mineral. Most of the powders which we use white color be it in washing powder, be it in soaps, detergents anywhere toiletries, cosmetics they all kaoline alright what powder does. It absorbs sweat clear, so these minerals would have some capacity that there is a octahedral sheet and then on the top of this you have it tetrahedral sheet this become say kaolinite or halloysite.

Sometimes this is also known as 1:1 clay alright 1 silica, 1 alumina combination of the 2 this becomes kaolinite or halloysite . Sometimes we have 2:1, so we have 2 tetrahedral sheet 1 tetrahedral sheet you know composited into this system those of you are very interested in this please read.

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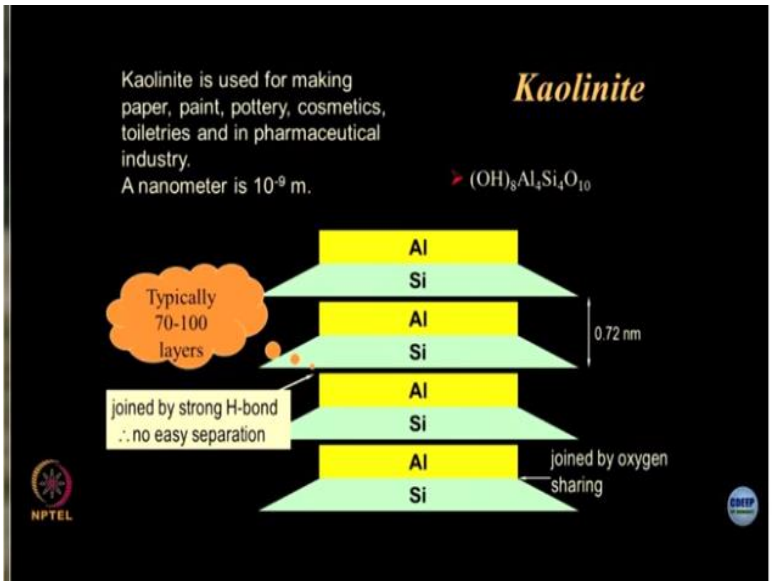

It is a typical structure of kaoline and I am sure you will be surprised to see what are the applications of the kaolinite read this which I have written over here. Kaolinite is use for making paper, paint, pottery, cosmetics, toiletries and in pharmaceutical industry. These industries cannot survive unless an expert geotechnical engineer is there to help them. And then later on comes the exogenic process which is nothing but your shear strength parameters.

Go to a factory where the biscuits are made or you know chapatti is the way the chapatti is are done. So what you are doing you are rolling them and then you are sometime if I do it I will make sure that the chapatti gets torn off clear. But when experts hand do it gets rolled beautifully in a circular, very thin sheet. So there is a difference in experience and practice, so these are another application of shear strength.

So I will make a dough of these minerals and I will extrude them to get vim bar, soap bar, lipsticks of different sizes whatever, clear, papers of different sizes and so on. So this is the structure of the kaolinite 1 and nanometer is 10 to the power -9 meters. This is the formula for kaolinite alumina, silica sheets put together typical spacing 0.72 nanometer. And this could be because of the oxygen shearing and typically 72 to 100 layers are there and as I said they will extend into infinity.

And kaoline is the very stable material and that is the reason it is used for making potteries. So chances are that kaolinite will not absorb much because there is a hydrogen bond between the 2 combination of alumina and silica and hydrogen bond is a very strong bond, you cannot break it so easily. So that is the reason for making potteries kaolinite or kaolinite is used alright and this is a stable system.

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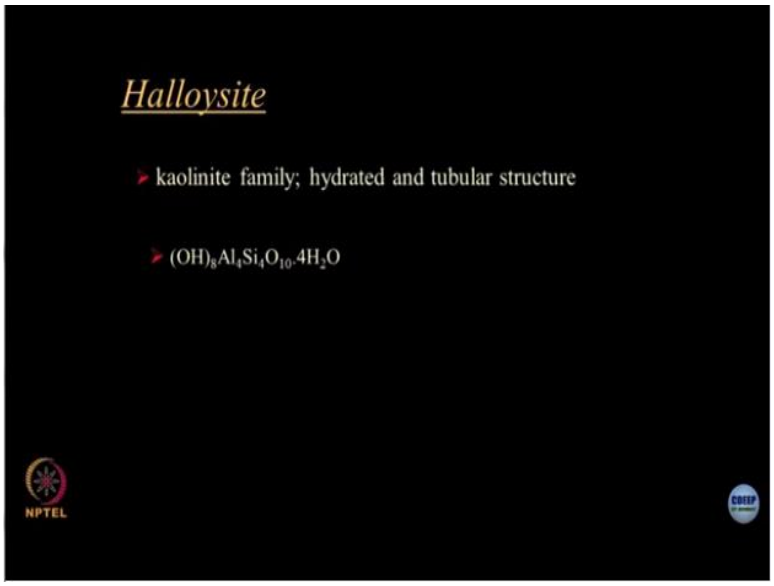

Then comes halloysite, halloysite is another mineral which is of kaolinite family this is hydrated and it is of tubular structure. Most of these minerals are either platelets or tubular structures if you can remember this formula you can remember. The only difference between kaolinite and halloysite is that there are 4 water molecules which get added up to the kaoline alright.

So this becomes hydrated, so calcium oxide put it in water hydration occurs calcium hydroxide gets formed alright, is this ok.

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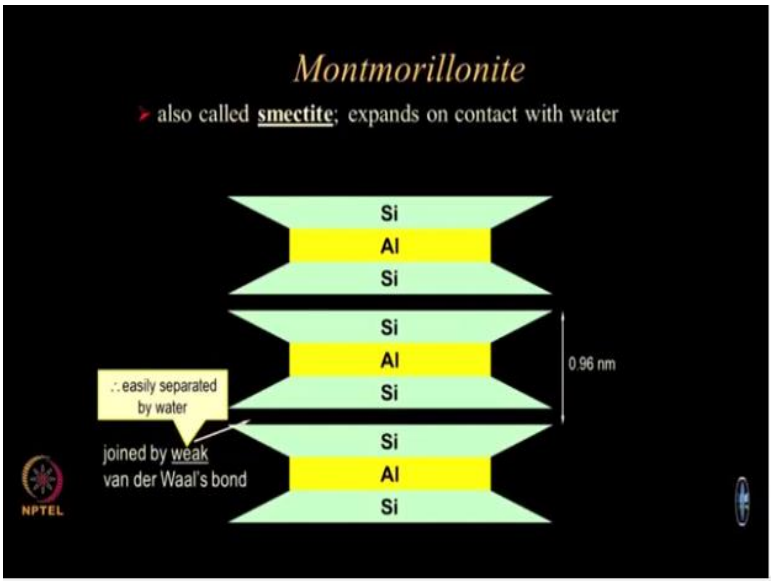

Then comes the montmorillonite, people have special interest in this because this is a mineral which is hyperactive, it has lot of values you know in present day science and technology and. But it use to be a treated as a curse sometime back, so you go to the central parts of India Maharastra, Madhya pradesh, Karnataka where you have black cotton soil the constituent of the black cotton soil is montmorillonite, it has various strong affinity towards environmental changes.

During rains it will accumulate water in it becomes fat and when rains go it shrinks any building which is sitting the black cotton soil deposits montmorillonitic soils is bound to get distressed crack, foundations will fail. And the reason is this is silica alumina silica combination and in between the platelets you will have water and this water is weakly attached because of van der wall's forces.

So I hope you remember from your 10, +2 chemistry, a hydrogen bond is much stronger than van der wall force correct. So this is how it goes, so to the more strength and the more stability comes because of the weak bonds as compare to the kaolinitic material. So because of the system the water enters into these platelets by spacing and the water hunger for this mineral is extremely high alright, it has lot of value in agriculture.

But as far as civil engineering practice are concern people would not to by-pass this because they do not want to keep any foundation on this type of systems. But in sports is becoming useful because this is what is known as smectite. A smectite is one type of montmorillonite which is to be added to make pictures very stable for the required duration alright. And then you as I was giving you the logic captains they want to water the pitch after the first innings are over, second innings are over and so on. And they want to roll with a light roller, heavy rollers all the dynamics will come into the picture.

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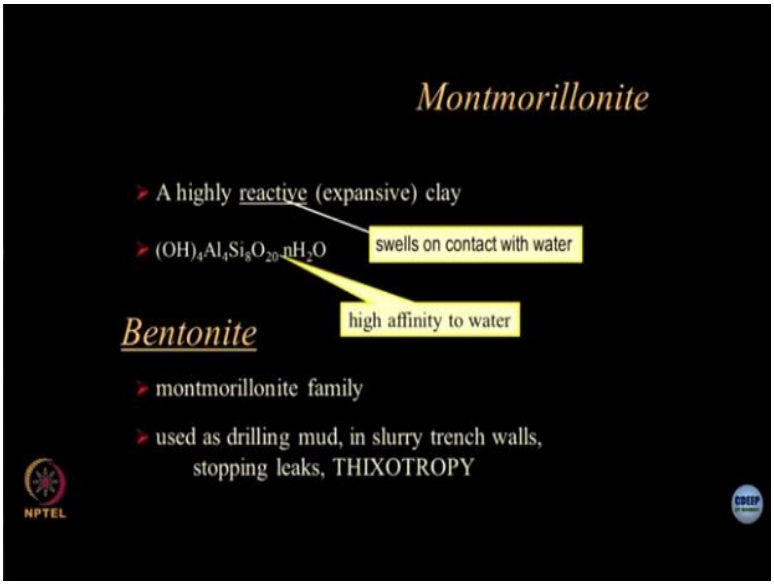

A little bit more on the montmorillonite because this is of a special interest is a highly reactive expansive clay it is as I said last time it is not expensive it is expansive it expands. And this is the formula for the montmorillonite n times water molecules indicates that n could be any number clear. So it has a special hunger for water pentonic is one of the montmorillonite which we discuss earlier it is used in drilling slurry trench design, leakages.

Most of the putties which you use you know different types of putties which are use for sealing the cracks are made up of bentonite. And this shows thixotropic effect and if you remember this is the material which is normally use in nuclear industry for depositing or the disposal of the nuclear waste.

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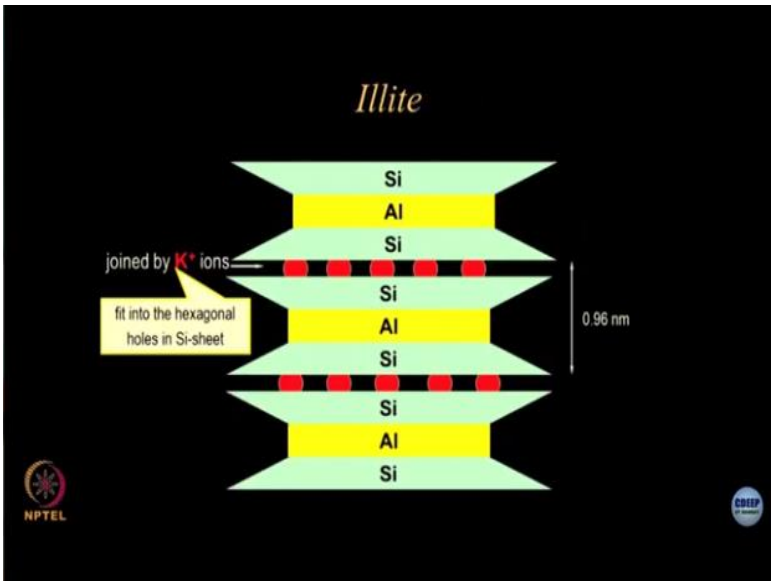

Then comes the Illite is another interesting mineral where the spacing between the alumina, silica alumina sheets would be filled up with potassium ions. So normally potassium ions go and sit over in between and again this is a very weak bond as compared to the hydrogen bonding or van der wall forces. So this is how the mineralogy is taken care of.

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The another mineral which is known as chlorite, so this is a 2:1:1 type of a clay mineral and we have vermiculite, we have attapulgite. And all these are the minerals which are present in the soils it depending upon your requirements you can work on them.

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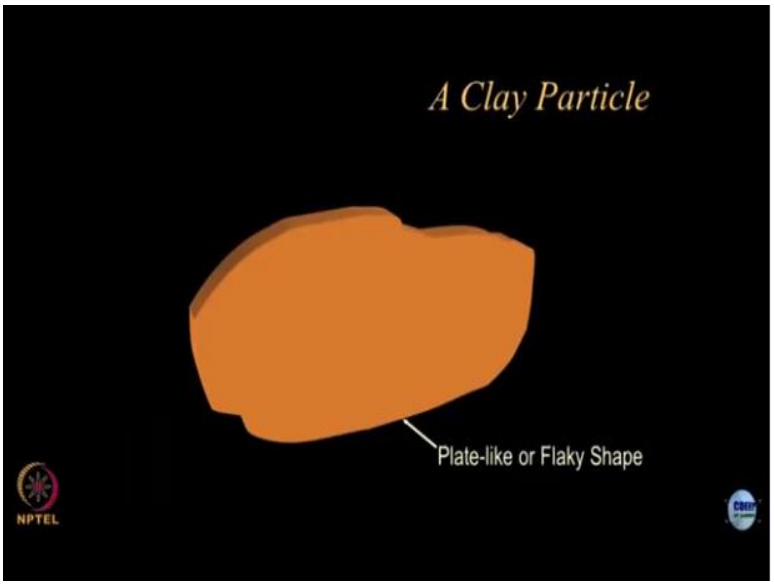

Now let me talk about the clay particle because I wanted to start the discussion on particulate nature of soils, clay particles are platelets alright.

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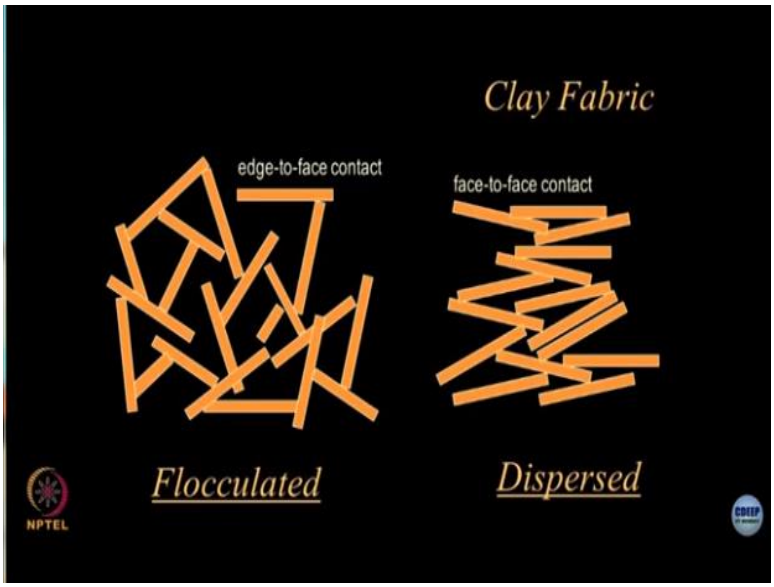

And when they are platelets they would have a fabric. As I define last time fabric is nothing but the texture. Now this is a subject which is in focus much more focus and attention of the researcher being faced. Pharmaceutical guys and I hope you understand pharmacy is the profession where you know the money is too much both ways. They deal with this type structures a lot, what is the interest, can you imagine well.

These are the structure which have been created in which I can fill anything, so these are the porous structures. Now what I am showing here are the platelets which is a depiction of a clay mineral or a clay sheet. Now clay sheets might sit like this that this is the sheet the face is touching the edge of another sheet and edge is touching the face of another sheet, this is what is known as edge to face contact.

When I will start discussing the mechanisms of movement of water in soils, I will be referring to this as flocculated structure. If you compact the soil alright suppose if I confine it in a volume and if I compact it. So all these platelets are going to get aligned, very obedient alright, so this is what happens, you must have heard about the card pack, card pack house structures alright.

So the moment you take a card structure you press it from both sides compact it a bit all the plate becomes align this is what is known as a dispersed face to face contact. So face is in touch with another face porosity is less as compare to the initial status.

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I will revisit all this, this is something which is normally use as scanning electron microscopy for those of you who will be interested in such studies. If you want to see the alignment of the particles of the fabric of the clay particles, a scanning electron microscope is the tool which is use to see what type of arrangement of the grains which I showed you is existing in the system.

I am not going to go into details of all these things these are slightly out of context for undergraduates. But you should be aware of because this is where the R and D is and this is where the text are for our profession.

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These are the images just now I showed you some schematic diagram and here what you can see is the kaolin fabric look at this. I mean sometimes you must have seen when you keep the lobes of the bread one over the other is it not, this is how it looks like. Look at the sheets of kaolin these are the sheets of kaolin alright they are just tagged one over the other. And there is lot of porosity pores which are getting created in the system.

So this is a typical soil fabric, so fabric word is used for 2 things, one is orientation of the particles, shape of the particles and the type of pores which are incased in them, you understand. So sometimes that I was discussing about control drug delivery is it not, what would I like to do, I would like to inject drug into these cavities which are at nanometer level and they become medicines for me, they go in the body and slowly they will release.

So go another days when people use to take pills and the you know capsules we choose to react immediately and that reaction use to be fatal for the body. Now a days you create a system through which the xgrus, xgrus means something which comes out is slow, control, regulated fine. So imagine you need not to eat food, you just eat few capsules what your astronauts do.

In those minerals they must have tagged nutrition so much that each capsule will slowly release in your stomach and it will go in the blood vessels and you can stay without eating anything for whole day, is this correct.

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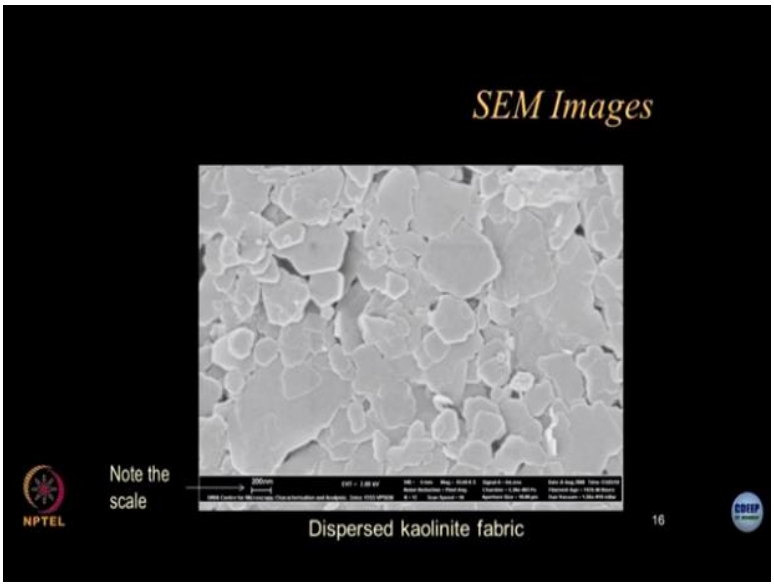

Another view of how the plate limits, platelets look like you know this is another fabric, beautiful plates staged with each other. Look at this edge to edge alright, look at this platelet and this platelet edge to edge, face to edge this is the face and this is the edge ok. Bundles of the sheets of minerals lying one over the other, first storey, second this is the first storey, second storey on the top of this, this is there complete stack is like this.

So face to face to face to face to face clear, in between whatever face is there can be utilized by soil technologist. Just to give you a feel of this please remember the scale this is 200 nanometers alright. So all these studies are submicron studies, you have to have lot of patience, you have to have lot of time to sit down take images quantify them. Many of few who are trying to work on artificial intelligence associated with agricultural projects.

There are lot of projects going on the country where by looking at the color, by looking at the shape, morphology, people are trying to work out on what type of agricultural dozer should be given to the vegetation, lot of projects going on. They use many times SAR photogrametry also,

SAR images remote sensing data they use. So all these are you know can be utilized by the guys who are in the profession.

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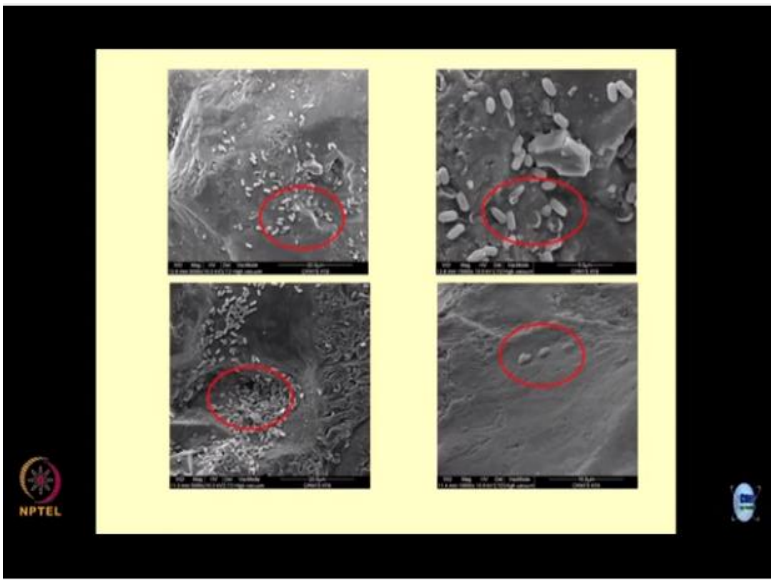

Those of few might be interested in microbial studies because I talked about microbes, I thought I will just show you how the microbes look like can you identify these microbes. All these white, white capsules which you have seeing over there these are the microbes 20 micron is this much. So imagine the size of the microbial activity, this would not be even 1 micron or something like that alright.

So now a days people are talking about this a lot, this is at 5000 magnification of the images, scanning electron microscopy these are closer view I just wanted to see how the clay platelets are adhering the bacteria, densely populated colonies of bacteria in the soils you know. So what they are going to do, what type of failure they are going to create this is a profession which is known as forensic in geotechnical engineering, why systems are failing though they were design in the best fossil manner, clear.

So we can show what type of movement and where the concentrations are and the way you want to interpret it, I mean you become a forensic expert why failure is occurred.

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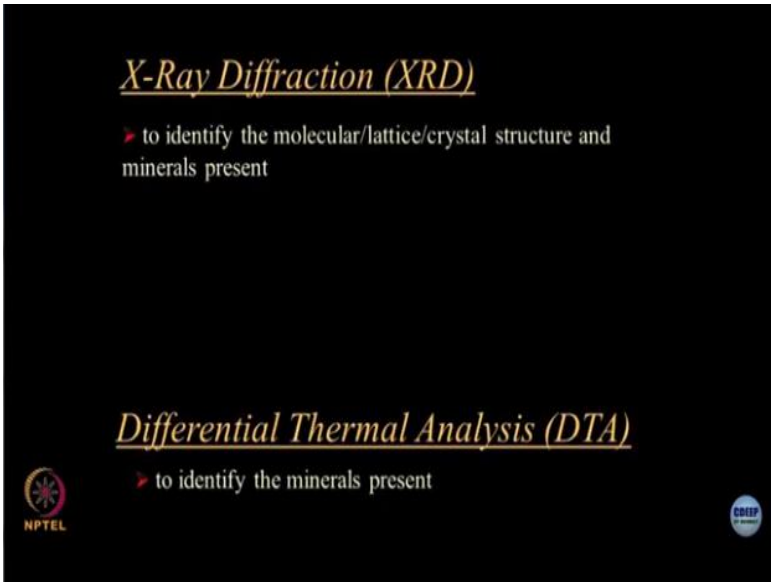

Then comes the X-ray diffraction because you must have notice that most of the minerals have a elemental composition and they are oxides mostly SiO2, Al2O3 and so on. So the question is how are you going to find out the oxide composition of the soils. So this is what is done with the help of X-ray diffractometers, we call them as X-ray diffraction analysis XRD analysis, how many of you know brax law, what is the application of brax law with respect to this.

So when you are studying 10, +2 physics you simply mugged it up know, now the applications are coming. So your 2D sin theta = n lambda agreed. So what is n number of wavelength or whatever lambda is a wavelength and 2D sin theta what is D distance between to 2 layers of particles tax very good, so atomic distance, clear. And sin theta, theta is angle of incidence of the x rays, so you take the sample keep it on a platform and allow the X-ray to fall on this with some angle theta that you can measure.

And you know what type of wave you are using which type of filter you are using copper k alpha or you know nicrome, chromium whatever that you know. So you know the wavelength of the wave and it is hitting the sample and whatever the reflected wave is. If I can capture it on a electron sensor or if this electron beam is captured on a analyzer, I know the pattern, so I will show you what type patterns you get.

And then you can know quickly what are the elements which are present in the system. So whether you are from a sorry you know jewelry shop or you are a artist whatever everybody uses XRD analysis you must have seen, you go to jewelers what do they do. They will put the jewel there and then immediately tell you what is the component of the carbon, how much is the gold, silver and so on, I will show you how to read these things quickly.

So if you want to know the molecular lattice and crystal structure of the minerals then you have to do XRD analysis. Now this is becoming more research oriented, I hope you are realizing, the concepts are same but I want to identify you remember minerals how to identify them. All these are identification tools, then quantification, software are there now a days you are lucky. That you just feed the data and you know what is the composition of the soil in terms of the minerals.

And then I can give a sort of a prescription how to utilize this, there is something known as the DTA differential thermal analysis. So every mineral will have a specific heat and that is the keyword clear. So whatever minerals you are using, so suppose if you join tomorrow oil and gas industry where they have very much eager to design slurries which can be injected up to let us say 10 kilometer deep inside the seabed.

So that I can seal the well, check it on net deep cementic slurries it is a beautiful subject lot of money is there. There is lot of companies who sponsor and who hire people for designing deep cementing slurries. So what should be the component of these slurries, how what type of liquid should be utilize, what is their thermal property, what is their pressure bearing and all these things you can study by doing this test.

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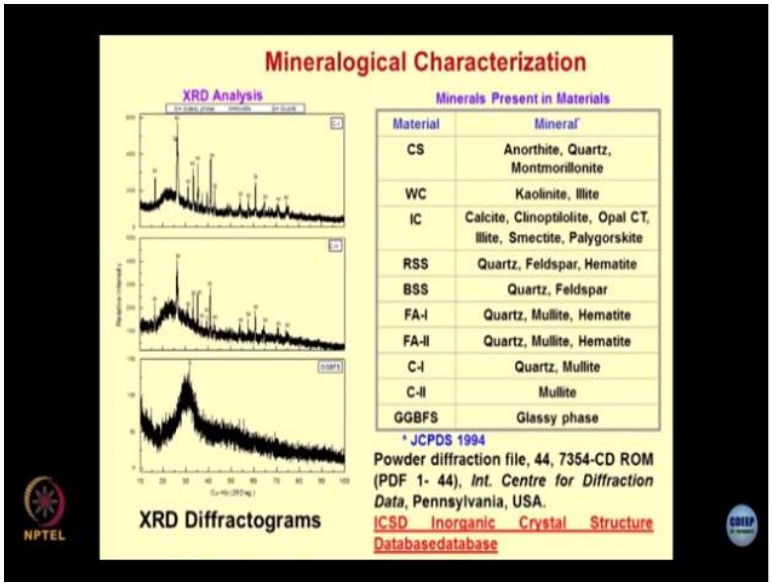

So typical diffractograms you find all these type of diffractograms normally in hospitals is it not when you meet a surgeon what he does or she does. So cardiogram, cardiogram is a sort of a record of how your heart is functioning, same thing you are doing here. So D is the atomic spacing in Brax law that is what I am trying to find out, so these typical graphs look like this on y-axis you have relative intensity and the X-axis you have 2 theta value of a ray clear, what I have to do is expose the sample get these type of a diffractogram.

I can I will be knowing theta and the peaks of the minerals which are present in the system fortunately all this is done a days with the help of softwares. So if you click over ICSD you will go to a web page which deals with the database of minerals.

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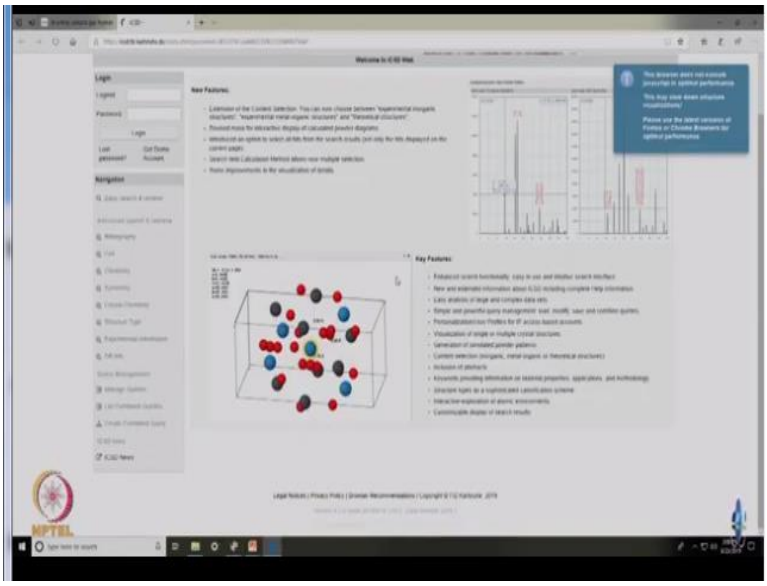

There was a time and my students you should sit down and match the D value up to fourth decimal place, they spend months together. Now things are very straight of the art it is a matter of few minutes when you can get the results. But yes, how to use the results judiciously is the big question, this is what is known as inorganic crystal structure database. Quick reflection of the graph which you are going to get, sometimes you get peaks crystalline material very inert.

Sometimes you get hazy pictures without any clear peaks, so that is the difference you know this type of material is a good classy face material, this can be utilize as a cement. The more and more peaks you have, the more and more crystallinity very stable system. So as a geotechnical engineer I would like to utilize the soils which are crystalline in nature not amorphous. This is the amorphous nature, this is a crystalline nature, clear.

But suppose if I change my profession and if I doing let us say medicine pharmaceuticals I do not want crystalline in. These are going to scratch my intestine from inside is it not, I cannot use it in the detergents, I cannot use it on in a washing soaps. So what I have to do, I have to use a amorphous face of the material which is soft, gentle, very high cation exchange capacity, very high surface area, clear.

So this is the difference depending upon your profession you can select the right one ok. So having done the minerals now let me touch upon the particulate nature of soils.

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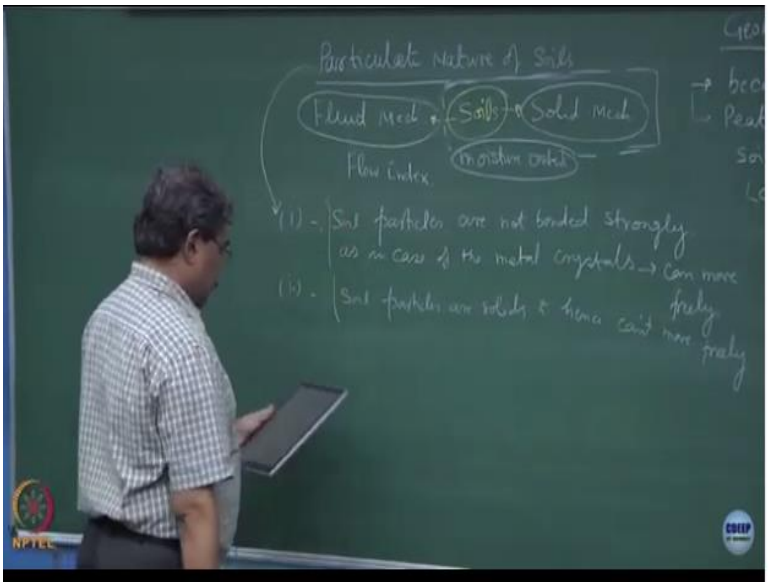

Soils by virtue of their nature or particulate in nature until now you have done fluid mechanics alright and at the same time you have done solid mechanics also. I have wonder that why should we study the mechanics of soils, very interesting philosophy, it is a wonderful material and it is a all rounder. So most of the captains prefer all rounders you know in their team, given a chance this material can behave like solids and it also can behave like fluids, did you understand this concept.

Unfortunately the conventional geomechanics only deals with this state but most of the projects in civil engineering you will find are related with slurryfication of the soils making different types of you know emulsions. Different types of slurries, I give you an example of last time dredging. So those of few are going to be an expert in dredging would make a slurry of the soils which is going to be in the fluid state.

So I hope you can realize this interesting behavior of the soils, a material you can use the way you want, what is controlling these 2 transitions, the moisture content. You keep on increasing the moisture in the soils they get transited to a fluid state they start flowing and hence you have to study the fluidity of the soil. So we will use a term which is known as flow index of soils when we characterize the soil alright.

Because in a flowing state, I told you the examples in modern day geotechnical engineering practices wherever you want to make a slurry bentonite make a slurry put it in the piling put it behind the returning walls for stability and so on. Dredging, solids, now this is what actually we are going to concentrate more on. If I start from the fluid state of the soils and if I keep on drying the soil it gets converted to the solid state and again the interplay of the moisture.

Now what is meant by the particulate system is basically soil particles are not bonded, so when we say particulate nature that means the soil is treated as a consortium of particles of different sizes, different shapes different morphology or whatever. So these soil particles are not bonded strongly as in case of the metal crystals, so there are free to move freely. The second analogy is that soil particles are solids and hence cannot move freely, so this is a state of the solid system, this is a state of a fluid system.

Now little bit of the mechanics of the material because you are talking about the particulate nature of the soils. So henceforth now the discussion is going too much mechanistic, those of you who were having complains that this all abstract theoretical. Now should gear up for learning the mechanics part of this, I am sure you will find it equally critical if not I should use a word difficult.

You must have be hearing the names of finite element, discrete element, continuum and all these things some of you might be working also, how might have worked during your internship with the different universities. There are many guys who work in the continuum mechanics, discrete mechanics. So soils by nature are a consortium of discrete particles, is this statement correct.

Discrete particle means each particle has it is own identity but the beauty is that all these particles put together form a continuum this is ok, fine.

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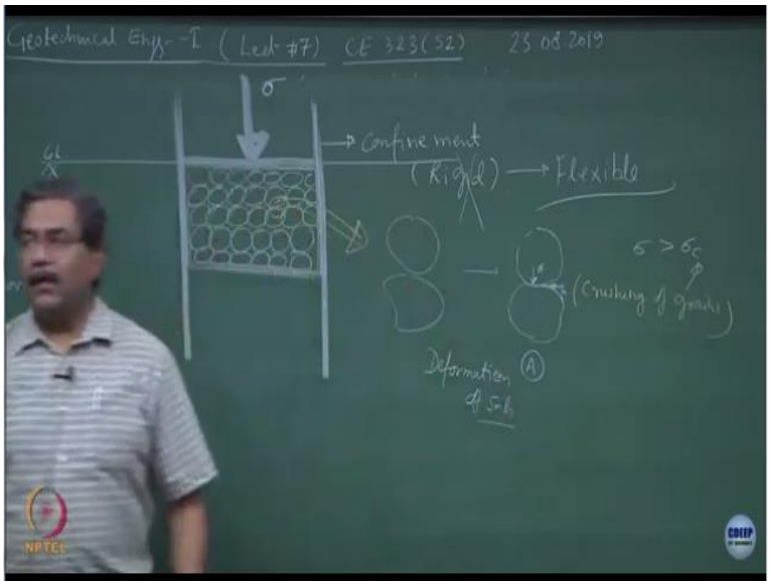

So suppose if I consider a control volume and for the sake of simplicity this contains soils, the way I am showing it is a general soil, rounded particles, very discrete particles a granular system. And this system is being compressed by applying a pressure and your JE Srinivas were done hundreds of example problems like this. but there is a difference what is the difference, the material is new, this material you have not studied yet had it been fluid you could have done easily pressure diagram you know constant pressure and hydrostatic pressure.

And we will sum it up and say this is a pressure now the trick start, so if I am applying stress normally I define normal stress as sigma. They are normal stress, now the system is very moody it all depends upon the confinement, learn these words. Because unless you learn these words there is no fun clear, so the subject makes you understand the terms and the terminology which are being used in the most technical field.

Now this is the confinement clear, had it been a homogeneous system I use the word discrete system it is not homogeneous system like fluid not like gases. Imagine if the confinement is rigid you have done all these mechanics, rigid body mechanics, solid mechanics you have done you are masters in that. Now suppose if I put a condition that this system is not rigid and this becomes flexible, now what you will do that is what we are going to study.

You agree, why it is flexible now, what I have done is very conveniently to make you understand what we are discussing. This is the ground level you remember and I have taken a small control section out of this. in ground very rarely you will find that the boundaries are going to be rigid unless you place sheet piles, agree. Now these sheet piles of the elements of the steel which are you must saying all along the highways you know they what do they do.

They embed 2 sheet piles thin sheets and then they can excavate in between they make basements, underground space, metro is being done by it now go and see that. So the chances are that you are not going to have the confinements which are rigid, had this been rigid and if I asked you how the pressure is going to get delegated inside the system. It was fairly simple, you would have taken a element out of this and you would have zoomed it saying this is a particle, this is a particle.

And when I am compressing them they come closer to each other and what is going to happen, if the compressive forces are extremely high then the crushing strength of the grains, is this ok. If the confining stresses are higher than the crushing strength of the grains what is going to happen up to a certain limit they will come close to each other. The pressure intensity will keep on increasing at this point and then the pressure will increase so much that this might be the situation, you understand.

They will come closer to each other first because you are compressing them in a rigid system, lateral deformation is 0, the only possibility is the whole system will move down get compressed. Particles will come closer to each other beyond the crushing strength of the particle the contact remains the stress keeps on building over here, the stage comes where the crushing takes place, this is the crushing of grains one mechanism in geomechanics.

You are designing the building foundations, the stress intensity so much which is much more beyond the crushing strength of quartz 20 mpa. The particles were get crushed if I draw the free body diagram that is the normal stress acting over here there is a shear stress acting over here clear. The normal stress is higher than the crushing strength and hence this is the first mechanism which controls the deformation of the soils is this part clear, deformation of the soils.

Now when we talk about it is understood that we are talking about the granular system there were the possibility that I might be having some fine grain particles also in this. So these are the fine grain materials clays, silts, fine sands. Now what is going to happen they provide a sort of a cushion, so this type of situation will not occur.

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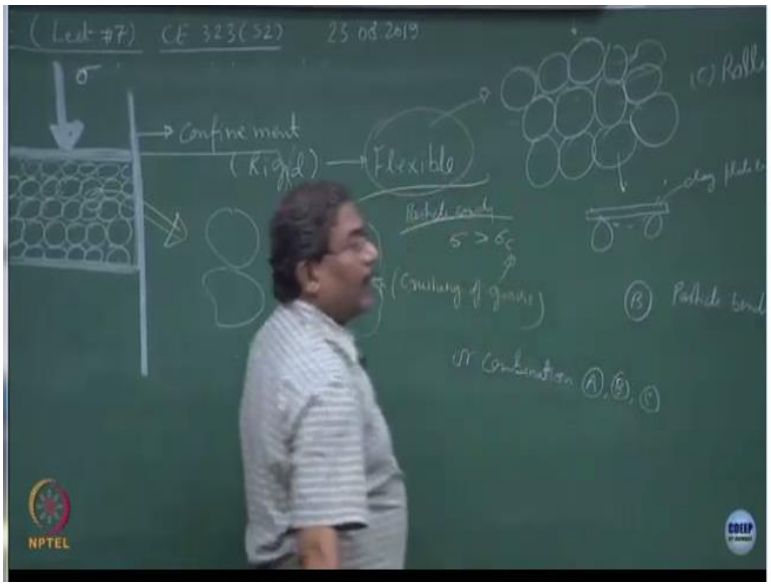

I can idealize the situation as a clay platelet which is supported on 2 coarse grain materials and I am sure you are doing this analysis a lot in a section analysis is it not, the loading comes and you know what is the deformation of the system. If I keep on increasing the stresses the stage will come where the clay platelet itself will break. So this is the second deformation mechanism for the soils, we call it as a particle crushing, this is what is known as particle bending.

And the third one is what is known as particle shearing or rolling. In this case the chances of rolling are going to be absolutely 0 why. Because I said this is the confine rigid system there is no lateral deformation. The only possibility is the more and more stress you apply the load which you are applying is getting converted into the form of the stress and this stress might create a shear stress and because of the crushing incapability of the material the system crush.

The moment this confinement becomes flexible which is the situation in most of the cases, now what is going to happen. And if I take the particulate behavior of the soils and suppose there is

consortium of particles. Now imagine if I am loading it from the top the boundaries are flexible it is a semi infinite soil mass both sides the soil mass exist infinite clear, what is going to happen.

This particle will push it create some space this particle gets shifted in the lateral direction and in the process it might so happen. That one of the particles might roll over and come and sit let me create few more particles to make my point clear ok. The moment you compress it you apply loading on this, the chances are this particle will go and come and sit over here like this, this may come out and this may come and sit over here like this.

This is what is known as rolling process, this is what I was writing here, so this is the sea mechanism. So deformation of the system which we were talking about which is a particulate in nature depending upon the boundary conditions would be either A, B or C or a combination of the 3 it is ok. So this would be either A, B, C or combination of A, B and C depending upon the constituents of the material the fraction or the you know the type of mechanism which is going supersede others would change, these are the hypothesis.

Henceforth the entire discussion would be only in this form, so what I have done, I have done 2 idealization first is the material granular material in cased in a rigid box. The boundaries are not going to deform when you make wells, foundation wells are you know very important bridges like Brahmaputra valley there are so many bridges which are being done. Most of the wells are being done by these concept, what I have to do.

I have to create confinement deep inside the river bed insert something, so that that soil does not deflect move out of the control volume and lay the foundation on the top of this you are happy now foundations are coming in picture. So onshore when you are working the situation could not be like this and this system might be flexible and hence all this is going to happen. So what we have done is material approximation and the mechanism approximation.