Soil Science and Technology
Prof. Somsubhra Chakraborty
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture - 21
Silicate Clays

Welcome friends to this new lecture of Soil Science and Technology and we are going to start a new week of lectures and we will be starting week 5. And from this week we will be starting soil chemistry and other chemical processes related to soil and last week we have covered different soil physical processes.

So, from this week onwards we will be covering different soil chemical process. So, in this lecture we will be we are talking about a most important soil fraction that is clays and their internal structure. So, basically they are made of silicate you know that is why we will be calling them Silicate Clays.

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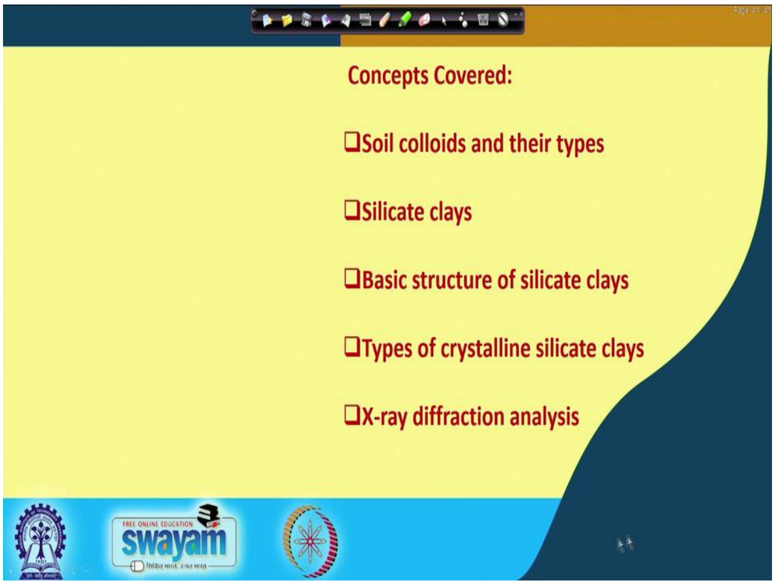

So, let us start today's lecture and in this lecture you know it will take probably consecutive two lectures to complete the silicate clays. But, we will try to cover this following concept we will follow below, we will try to cover you know the soil colloids and their types and then what are the silicate clays.

And then we will cover what are the basic structures of silicate clays, then we will discuss about types of crystalline silicate clays and then X-ray diffraction analysis. So, let us start with the colloid.

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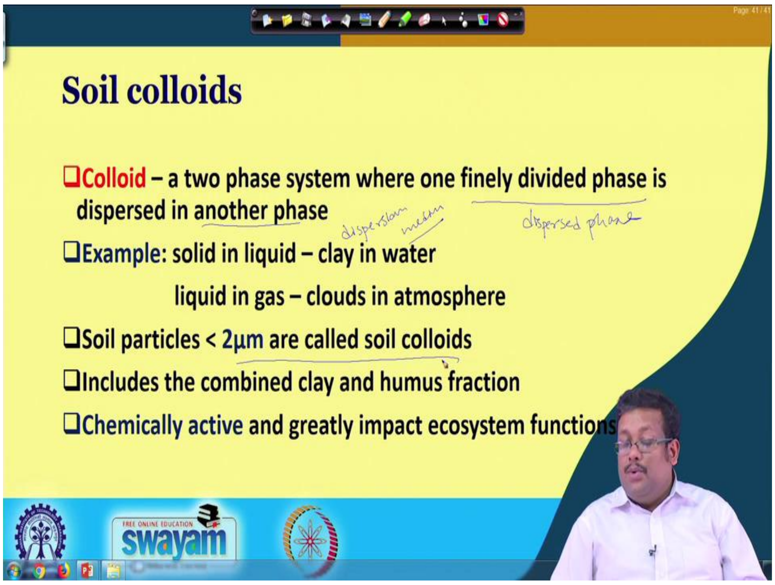

So, you know I hope that you know that a colloid is a two phase system where, not only nowhere only you know one finely divided phase is dispersed in another phase. And the phase which is you know finely divided phase is called dispersed phase and this you know the other medium is called dispersion medium. So, colloid it is basically two phase system where you know dispersed phase is dispersed in dispersion medium. So, example let us see some example some common examples are you know clay in water which is basically solid which is dispersed in liquid dispersion medium. And also cloud in atmosphere where basically liquid is dispersed in the gas.

And remember that in case of soil so, if we narrow down to the soil we will see that you know all the particles which are having you know size less than 2 micron or 2 micrometre are called the soil you know soil colloids. Now, these particles which are less than 2 micron in size basically combine both clays and humus fraction; we will see in a couple of slides what are their distributions. And then you know; obviously, there are majorly two types; one is soil inorganic colloids and soil organic colloids. And, in soil inorganic colloids basically clay and different iron and aluminium oxides basically are there whereas, in case of soil organic colloid it basically composed of humus fraction.

So, you know these soil colloids are very much chemically active and they greatly impact you know eco system functions. So, we will in coming you know in coming days we will learn that how they impact different soil chemical as well as cement soil physical process.

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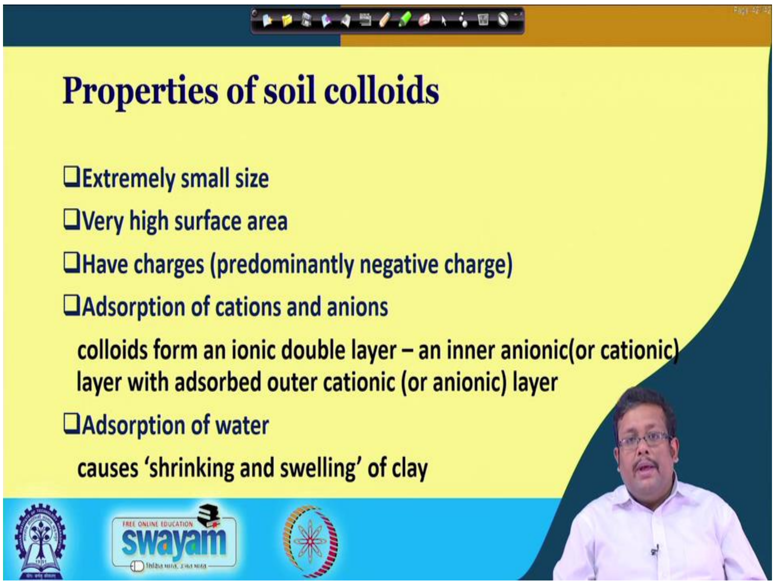

So, let us go to the properties of soil colloid. Well you know there are certain properties of soil colloid; obviously, it they are very extremely small in size and also they have very high surface area, you know they have very surface area and they you know have charges which are predominantly negative charge. And obviously, you know there will be adsorption of cations and anions and you know in these soil colloids the surface of the soil colloids.

Now adsorption is a surface phenomena in against you know as compared to absorption. So, adsorption is a surface phenomena where all the cations and anions are attached to the surface of this organic colloids. So, colloid from an ionic double layer we learn what are the ionic double layer and you know basically you know the ionic double layer consist of a inner anionic or cationic layer with adsorbed outer cationic and anionic layer we will discuss that later on.

And; obviously, another major property of these soil colloids are you know they can adsorb water and due to adoption of water they can produce different shrinking and swelling of clay. And you have learned from soil classification that this vertisols which are having you know high amount of clay. They can they can exhibit this shrinking and swelling properties. And we will discuss what are the reason behind these shrinking and swelling properties of the clay.

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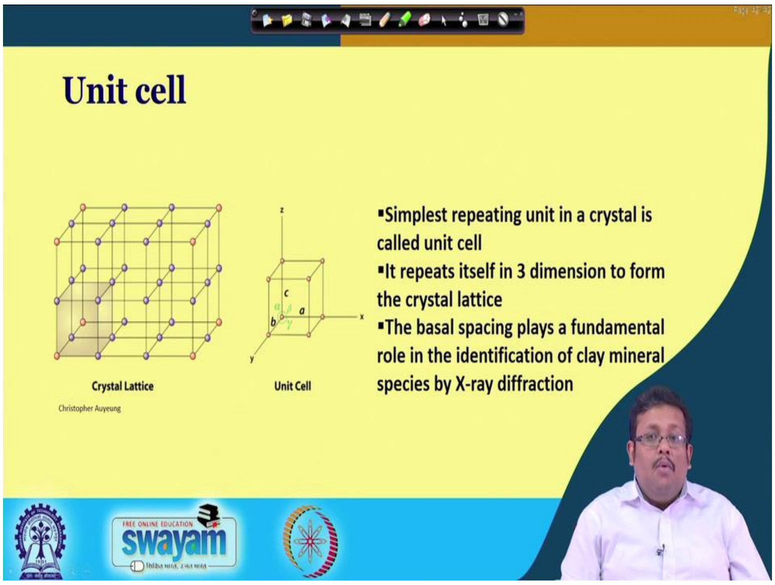

So, let us go to the next slide and see: what is unit cell this is very important concept. Now, if you consider let me show you. So, if this is a crystal lattice, this whole is a crystal lattice, now you know about lattice and crystal. And each crystal lattice is made of some simplest repeating unit we call it the unit cell.

Now, this is a unit cell. Now, these unit cell will repeat itself to create this whole crystal lattice and it repeats itself in three dimension to form the total crystal lattice you know both in x you know in x direction y direction as well as in z direction. And remember that the basal spacing plays a fundamental role in the identification of clay minerals specimen by X-ray diffraction; what is a basal spacing? The basal spacing is the spacing between two successive similar planes of atoms and we will discuss that later on.

So, this basal spacing is very much characteristic feature for individual clay mineral and based on this basal spacing we can differentiate one clay mineral to other clay mineral, we will discuss that later on. So, you have basic idea: what is unit cell and what is crystal lattice? So, similar you know construction of similar construction can be found in clay also we will see that in a while.

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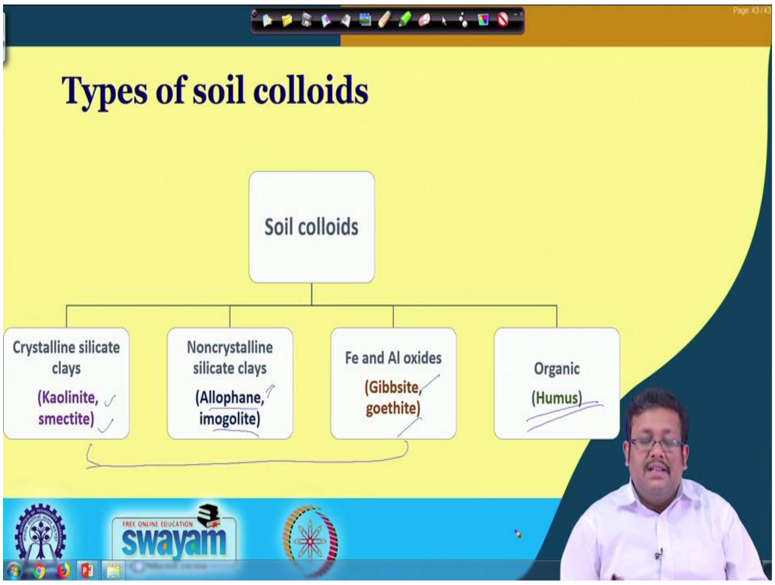

So, let us go to the next slide and see: what are the different types of soil colloids. Well soil colloids can be differentiated into four different you know four major groups. One is crystalline silicate clays, another is non crystalline silicate clays, then you know iron aluminium oxides and finally, organic colloids or humus. So, this crystalline silicate is basically composed of some clay minerals like kaolinite and smectite will discuss their structure and properties later on. Non crystalline clay mineral means they do not have any crystalline structure so, some examples are allophane and imogolite allophane mainly occurs in the volcanic soils.

Iron and aluminium oxides are you know some examples are gibbsite and goethite and these three basically you know collectively called as a soil inorganic colloids. Whereas, soil organic colloid composed of humus and we will discuss humus in the later you know in while will discuss, while we discussing soil organic matter in later part of this course.

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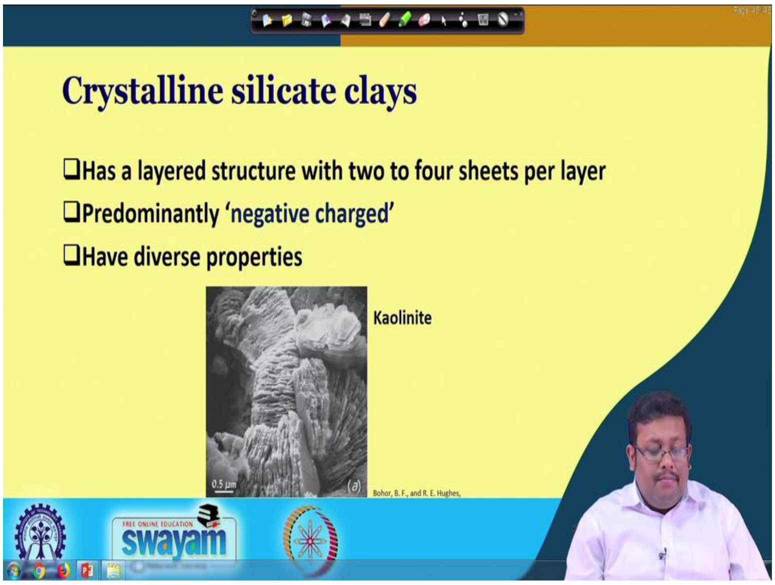

So, we have learned about the different types of soil colloids. So, let us go and see what are the, what we mean by crystalline silicate clays. Now, crystalline silicate clays also has a layered structure with two to four sheet per layer. And you know if we see these a crystalline layer you know clay mineral this is kaolinite one of the most prevalent clay mineral. So, this is the kaolinite structure under the electron under the electron microscope and you know you will see these you know they are made of these sheets like in structure.

Say hexagonal sheet like structure. So, these hexagonal sheet like structures stacked upon each other at to form this total silicate crystal. And remember that this crystalline silicate has layered structure as we can see here these are individual layers so, with two to four sheets per layer. So, we will see in details about you know we will see in details about their structure.

So, let us you know also they are predominantly negatively charged remember that these crystalline silicate clays develop this huge amount of negative charge. And, how they develop this negative charge we will discuss later on due to different types of chemical process. And, also they have diverse soil property so, they have diverse properties we will we will also discuss that later on.

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Now, another important you know class of solid colloid is non crystalline silicate clays. The non crystalline silicate clays because they do not have any ordered and crystalline structure and they have high amounts of positive and negative charge they develop both positive and negative charge. And they have high water holding capacities and low stickiness you know you have already learned about the stickiness and different classes of stickiness in soil consistency lecture.

So, these non crystalline silicates are clays are having you know low stickiness and one predominant example of these non-crystalline silicate clays is allophane and these allophane basically occurs in volcanic soils.

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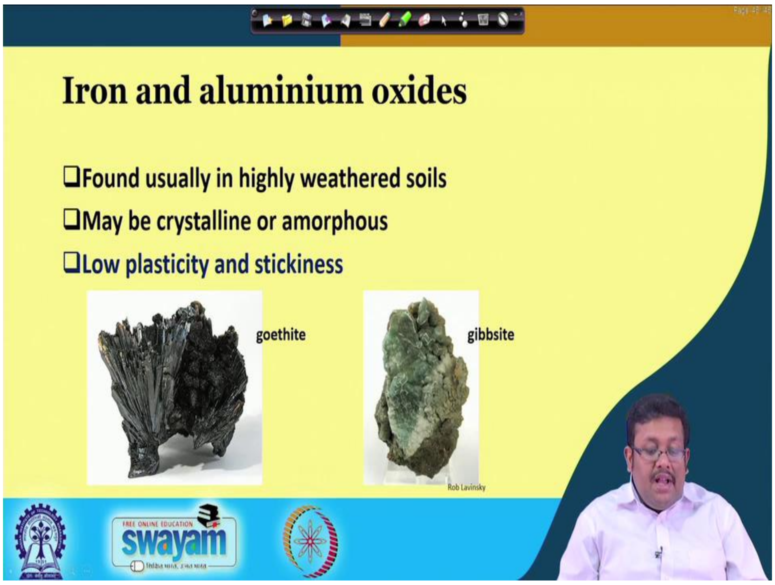

So, the third major class of soil colloid is iron aluminium oxides and they are basically found in highly weathered soils and they may be crystalline or sometime amorphous and they have low plasticity and stickiness. So, you can see some iron aluminium oxide; obviously, gibbsite is goethite is one of the major iron oxides which is present into the soil as well as gibbsite which is one of the major aluminium oxide which is present in the soil.

So, these are also considered as soil colloid because they show different types of properties you know which you know different types of properties generally shown by colloids.

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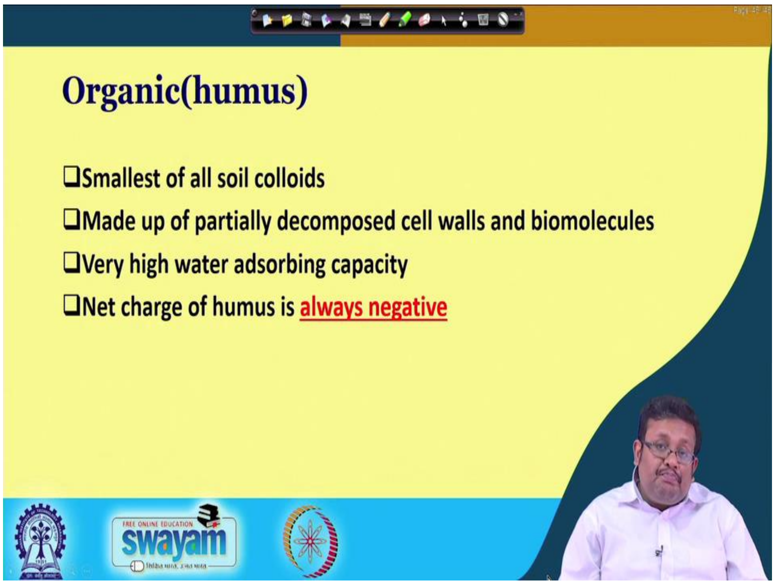

So, the final one the organic one is humus. So, this is the smallest of all soil colloids and these are basically made of partially decomposed cell walls and biomolecules will discuss their structure later in this course. And they have very high water adsorbing capacity and also net charge of humus remember that it is always negative. So, we have you know we have covered the basic overview of different soil colloid classes.

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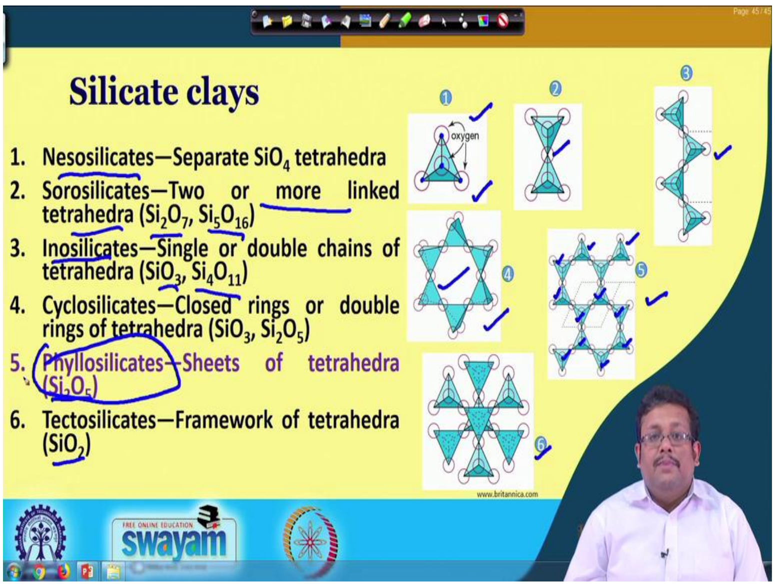

So, let us go ahead and see what are silicate clays. Now, you know all the minerals if you see which are present in nature you can classify them into six major categories; starting from nesosilicate then sorosilicates, then inosilicates, then cyclosilicates, then phyllosilicates and then tectosilicates. So, what is you know what is the building block of this type of structure? Well in any silicate mineral the basic building block is called silica tetrahedra.

Now let me show you just. So, if we let me increase the size of the marker a bit so, that it can be visible alright. So, this is the example of silica tetrahedra. Now, the silica tetrahedra is basically composed of one silicon atom at the centre followed by four oxygen atoms at four corners making a tetrahedral structure. So, basically it is SiO_4 or silica tetrahedra structure.

Now, when a silica tetrahedral structure you know appears into in the nature as a separate I mean they are separate entity. So, in that case we will call them nesosilicate. So, nesosilicate that basically composed of only one silica tetrahedra. The 2nd category is called sorosilicates. Now, sorosilicates are basically two or more linked tetrahedra and these tetrahedra are basically joined by sharing their apical oxygen as we can see here. So, these an example of the sorosilicate and obviously, the basic structural unit of sorosilicate is either Si_2O_7 or Si_5O_{16}.

The 3rd is inosilicates or inosilicates; now inosilicates is basically single or double chains of tetrahedra and the basic building you know basic structural unit is either SiO_3 or Si_4O_{11}. Now you can see this is an example of inosilicates where you know it is basically composed of single or it is basically single chain of tetrahedra which formed by sharing their apical oxygen. And the fourth one is cyclosilicates and this is an example of cyclosilicates. Cyclosilicates are basically single I mean closed rings or double rings of tetrahedra as you can see this a closed ring of tetrahedra and this is an example of cyclosilicates.

And the fifth one is the most important and this is called phyllosilicates. Now pyllosilicates are basically you know they are they looks like sheets of tetrahedra and you can see these are you know all these tetrahedra are sharing their oxygen to form a sheet like structure or tetrahedral sheet. And these type of sheet like structure you can see in the phyllosilicates and this phyllosilicate name comes from phyla or leaf like structure and the basic unit of this phyllosilicate is Si_2O_5. And why we are highlighting this phyllosilicates? Because, all the clay minerals which we will be discussing all the clay minerals belongs to these phyllosilicate structure.

And the final one is tectosilicates; tectosilicates is most stable because it is composed of a framework of tetrahedral structures and the basic you know unit is SiO_2. Some examples are primary minerals like you know quartz is very important example and these are widely spread in the nature. So, these are the basic classification of silicates and you know this is we call silicate clays and because another name is phyllosilicates.

And these are other silicate minerals and these minerals are mainly present in primary minerals and also this tectosilicates also present in primary minerals. So, we have covered what are the different types of silicates.

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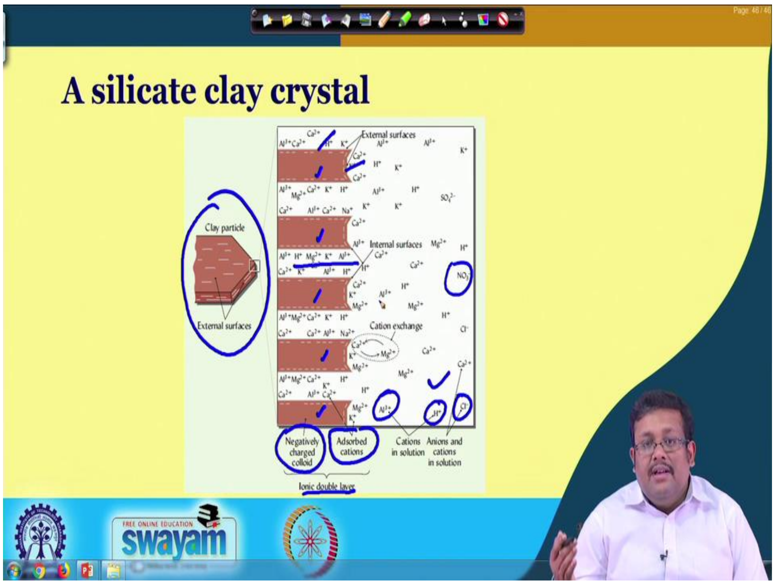

So, let us go ahead and see how a crystal lattice of soil you know a crystal clay lattice looks like. Now, a crystal clay lattice basically looks like you know these this picture and as we can see basically a clay particle or clay crystal is basically made of these unit cell, these are unit cell.

So, these unit cell basically produce ionic double layers and in between the you know let you know ionic double layers by how? Because these individual you know these individual unit cell is you know develop high amount of negative charge at their surface we will discuss how later on. And as a result of the development of negative charge at their surface all the different types of cations are adsorbed at their surface and as a result they form ionic double layer.

So, basically negative negatively charged colloid when it when it is surrounded by different adsorbed cations then it forms the ionic double layer. Not only that and you know there are two types of surfaces; external surfaces and internal surfaces; obviously, in between two layer you will see the internal surfaces. So, it is an internal surface and external surface is this and these are some examples of external surfaces.

Obviously, these are present in direct contact with soil solution and these soil solution basically composed of you know they basically contains different types of cations as well as different types of anions like chlorine and you know different you know like chloride nitrate and so on so forth. So, this is basically a structure of silicate clay crystal which is made of you know which is made of this layered structure. And in between the layer there is called the inter layer space and external surface also available and all these spaces are accessible for different cations and anions which have present in the soil solution for adsorption.

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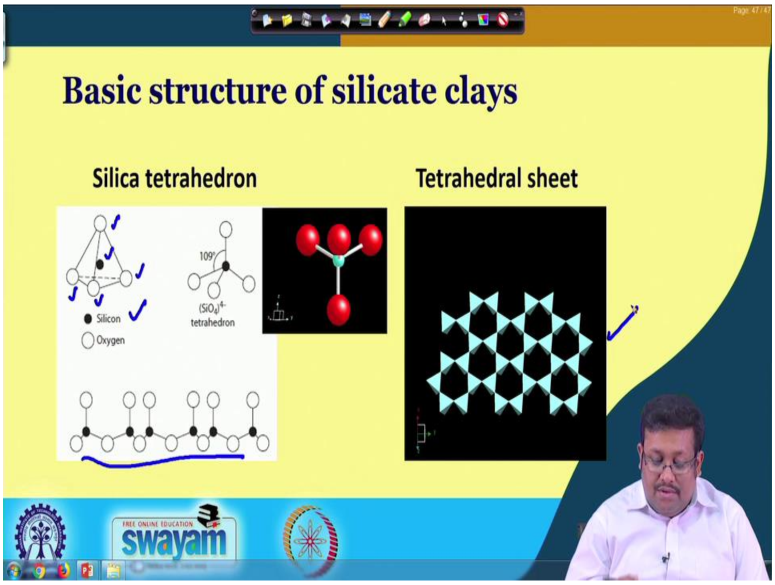

So, let us focus on silica tetrahedra and their related structures. So, as we can see as I have discussed that this is the silica tetrahedra which is composed of four equidistantly placed oxygen atom and in the inside there is a silica atom.

So, and the building block is; obviously, SiO_4 minus and the angle is 109 degree and this an individual silica tetrahedra.

So, when all the silica tetrahedra share their one oxygen with the adjacent tetrahedra they form a sheet like structure just like this. So, this called a tetrahedral and this is one of the major important sheet which is you know which composed the you know you know which actually builds the soil you know soil clay structure. So, so, this is silicate tetrahedra.

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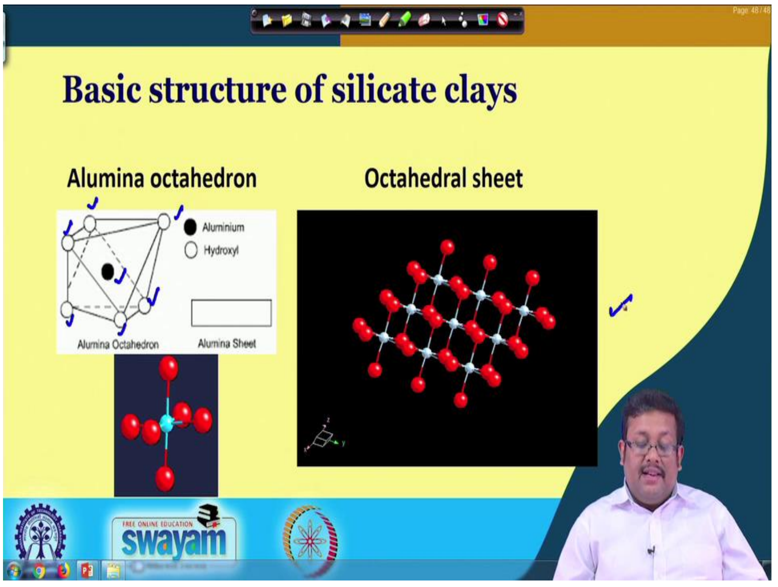

So, if you go to the next slide let us see what is another building block. So, another building block in soil is the aluminium octahedra and this aluminium octahedron the individual aluminium octahedron is basically made of the central aluminium and which is surrounded by 6 hydroxyl you know hydroxyl anions or hydroxyl groups making a octahedral structure.

So, the central cation is either aluminium sometime it is magnesium will discuss in which condition it magnesium occupies the central position. And remember that all the other surrounding you know hydroxyl group they create a you know a octahedral structure. So, that is why we call it either aluminium octahedral or magnesium octahedral. So, all these aluminium know when couple of aluminium octahedron share their phases and sides with the adjacent octahedra they form also a sheet like structure we call it octahedral sheet like structure.

So, we have the tetrahedral sheet and we have octahedral sheet. So, based on the arrangement of this tetrahedral sheet and octahedral sheet in unit cell there are different types of classes of silicate clays that we will discuss later on.

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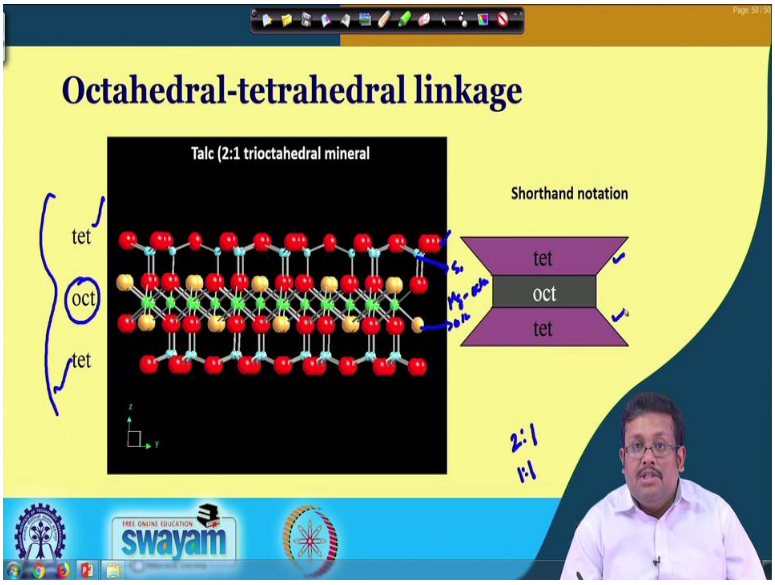

So, let us go ahead and see how this tetrahedral octahedral linkage. So, if we consider a unit cell if we consider this an unit cell these unit cell is basically we call it 2 is to 1 trioctahedral mineral. Now, why we are calling 2 is to 1? Because, you can see in the middle there is an octahedral sheet which is sandwiched between two tetrahedral sheet.

So, that is why we call it 2 is to 1. So, 2 stands for 2 tetrahedral sheet and 1 stands for 1 octahedral sheet. So, how they linked together, you can see these red solid you know structures are basically denoting oxygen whereas, these are silicon and these are basically magnesium. So, magnesium this basically magnesium octahedra and in the magnesium octahedra these yellow balls are basically hydroxyl and these reds are basically oxygen.

So, basically these tetrahedral sheet and octahedral sheet joined together by sharing their apical oxygen together. By sharing their apical oxygen these octahedral sheet and tetrahedral sheet joined and as a result they form this 2 is to 1 structure. Sometime you will see the structure is 1 is to 1 structure; that means, there will be only 1 octahedral sheet and only 1 tetrahedral sheet. So, based on the number of tetrahedral sheet and octahedral sheet in an unit cell we can differentiate clay into 1 is to 1 type of clay and 2 is to 2 type of clay. Now, what is a shorthand notation of this clay structure? Obviously, you will see since it is a 2 is to 1 structure this is tetrahedra this is tet stands for again another tetrahedra and in between these an octahedra sandwich. So, now probably you have understood what is 2 is to 1 and minerals.

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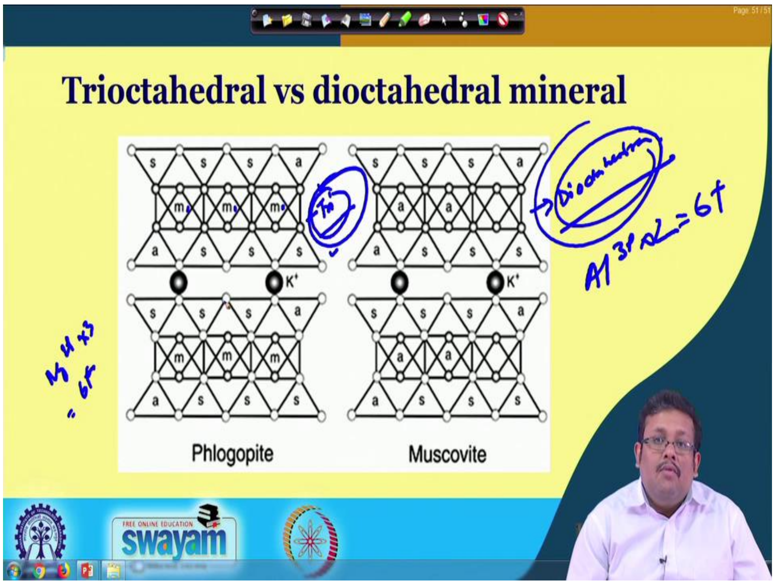

Now, another you know question comes why we are calling it trioctahedral and what is dioctahedral? Now, you see as a result of these tetrahedral and octahedral arrangement there are; obviously, you know in this case we are calling it dioctahedral and in this case you know we are calling it in this case it is trioctahedra and this is called dioctahedra.

Now, trioctahedra and dioctahedra why we are calling it dioctahedra because you see there are three octahedral positions. Octahedral positions are this one is the first octahedral position, this one is the second octahedral position, this one is third octahedral position. So, when all the octahedral position all the three octahedral positions are filled with cations then we will call it trioctahedral.

And when two third of this octahedral position are fill as can see here then we will call it dioctahedral structure. Now in case of trioctahedral; obviously, to satisfy there will be the magnesium because Mg^2 plus multiplied by 3. So, there will be 6 plus whereas, the similar charge can be produce in dioctahedral when there will be aluminium three plus multiplied by 2.

So, 6 plus so; obviously, the net charge is same; however, the numbers of cations are different. Here the aluminium is prevalent in case of dioctahedral structure whereas, in case of trioctahedral structure you will see magnesium is prevalent. So, I hope that you can understand now: what is the difference between trioctahedral structure and dioctahedral structure.

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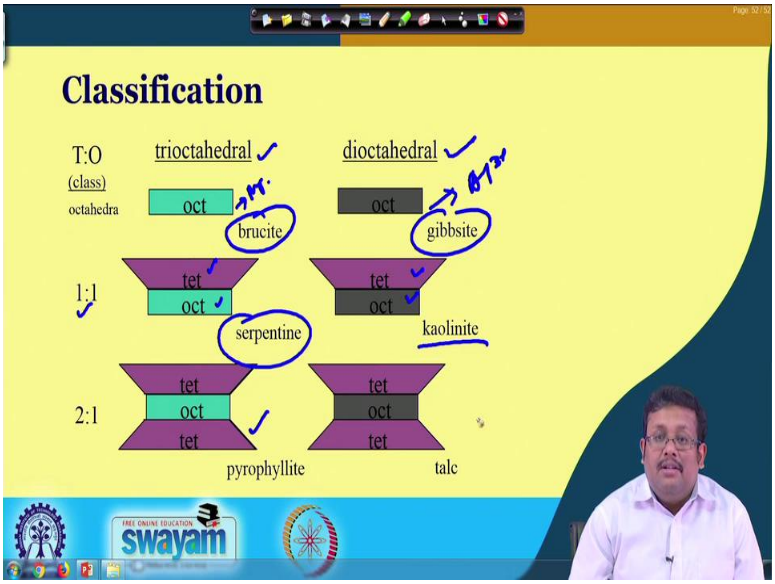

So, so, based on these 1 is to 1 layer or 2 is to 2 layer and whether it is trioctahedral or whether it is dioctahedral you can differentiate the so, you know you can differentiate the soil clays into the following categories. So, obviously, the broad categories are trioctahedral and dioctahedral and among the broad categories of trioctahedral if it a soil is only consist of a octahedral sheet there is no tetrahedral sheet. And in case of a trioctahedra it will be only composed of magnesium and in case of dioctahedral stracture it will be composed of aluminium 3 plus as I have already told you.

So, example is gibbsite $Al(OH)_3$ and brucite is magnesium hydroxide and you know trioctahedral 1 is to 1 type of mineral is example serpentine you can see only one tetrahedra and only one octahedra. Here there is only 1 tetrahedra another you know 1 octahedra; however, the difference is in this case this is dioctahedral example is kaolinite. Kaolinite is one of the major clay mineral and if we consider 2 is to 1 type of mineral; obviously, the 2 is to 1 type of trioctahedral mineral example is pyrophyllite whereas, 2 is to 1 type of dioctahedral mineral is talc. So, these are some broad classification and with some examples.

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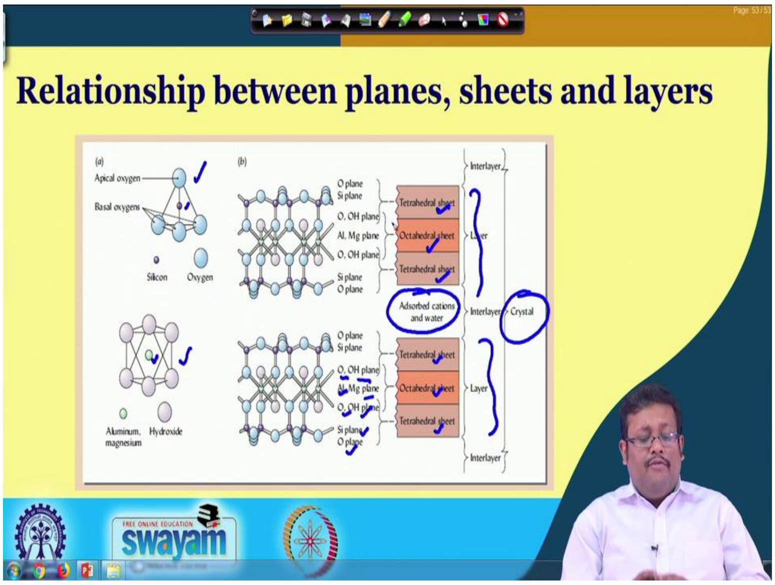

So, let us you know go and final these have final slide for this lecture if you see these are relationship between plane sheets and layers. So, if we consider this is basically silica tetrahedral sheet and you can see some basal 3 oxygen and 1 apical oxygen and in you know this is a silicon atom. And; obviously, in case of you know in case of octahedra the central atom is either aluminium or magnesium followed by you know surrounded by 6 hydroxyl anions.

Now, this is a unit cell structure or layer structure in the layer you can see it is a 2 is to 1 type mineral so; obviously, 1 tetrahedral sheet 1 tetrahedral sheet 1 octahedral sheet octahedral sheet is sandwiched between tetrahedral sheet. Followed by a another repeating unit you know that inside clay structure these unit cell will repeat itself to form a total clay crystal. So, there is another repeating layer and so, this is a layer and this is a layer and in between these two layer is called inter layer space and this inter layer space is where different types of cations and water adsorb.

And the total summation of these inter layer space as well as these layer structures are called the crystal. So, soil crystal is made of both these layers as well as these inter layer space. And; obviously, you will see different planes different planes of a 2 is to 1 type of mineral 2 is to 1 type mineral you can see you know at the basal at the base. You see both silica and oxygen plane where you know from silica tetrahedra followed by oxygen and hydroxyl plane and there therefore, aluminium and magnesium plane and then oxygen or hydroxyl plane and then again the repeating unit.

So, this is you know a overview of a soil structure or soil clay structure and will stop here and these are very much interesting thing and will learn new things in the next lecture. So, let us rap up here and then will discuss these more in our coming lecture.

Thank you very much.