Geology and Soil Mechanics
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Lecture - 09
Classification of Soils and Clay Mineralogy- A

Welcome back. So, in the last lecture we have seen that how to classify the coarse-grained soil and how basically you will be getting the different notations or different say symbols for different types of coarse-grained soil.

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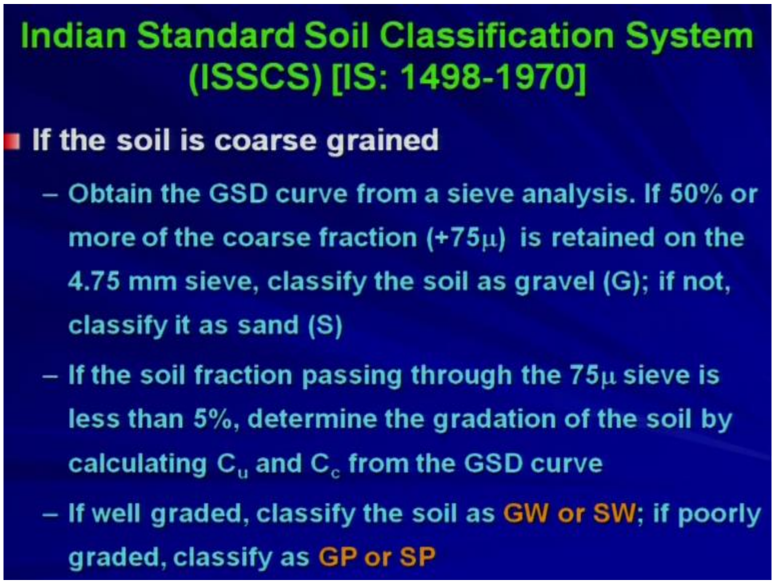

Now still we will continue with the coarse-grained soil. So, as we have seen in the last lecture that if the fine contents is less than 5% that means if the material whatever I mean if you have got some soil sample and whatever is passing through 75% micron if that is in the coarse-grained sample, if that is less than 5% then you need to concentrate more on the gradation characteristics of the coarse-grained soil and based on that you have got GW or SW, similarly GP or SP.

Now if the soil is coarse grained, obtain the GSD curve from a sieve analysis, that is very true. If 50% or more of the coarse fraction that is 75 that is passing through so already we have seen in the last lecture but still we will continue this thing to get the continuity. So, obtain the GSD curve from a sieve analysis if 50% or more of the coarse fraction that is greater than 75 micron is retained on the 4.75 mm sieve, classify the soil as gravel; if not classify it as sand as we decided last time.

If the soil fraction passing through the 75 micron sieve is less than 5%, determine the gradation of the soil by calculating C u and C c from the GSD curve because at that time the gradation will be the predominating factor to define the classification. If well graded, classify the soil as GW or SW; if poorly graded, classify the soil as GP or SP.

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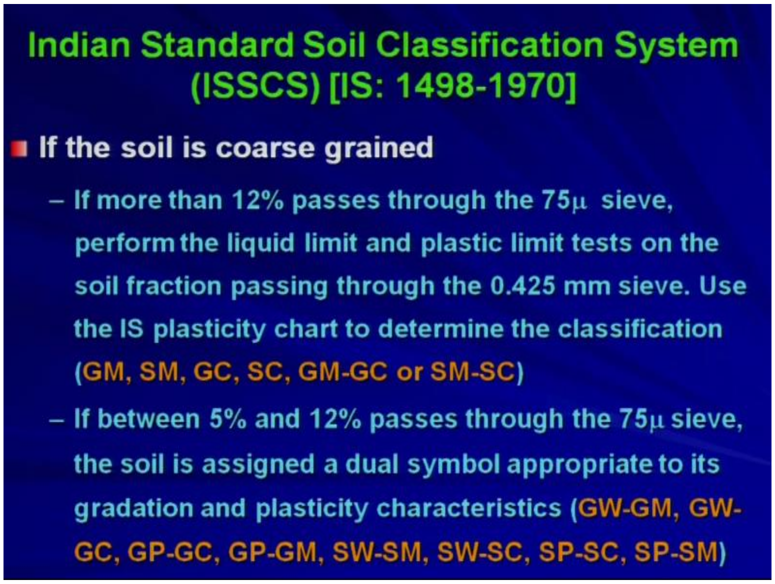

Now if the soil is coarse grained, now we are earlier we have seen if the fine contents is less than 5%. Now if more than 12% passes through the 75 micron sieve that means if the fine content is more than 12% perform because at that time the fine will be also participating in the classification or in determining the property of the soil. So, perform the liquid limit and plastic limit test on the soil fraction passing through the 0.425 mm sieve that is 425 micron sieve. Use the IS plasticity chart to determine the classification.

So, you have 3 categories. One is your, in the coarse-grained soil sample there are 3 categories. One is that the fine contents is less than 5%, one is the fine content is more than 12% and one is in between 5% and 12%. So, now we are dealing with more than 12%. So, if your fine content in the coarse-grained soil is more than 12% then basically the fine content will try to participate in the property determination of the coarse-grained soil.

That means you may get some plasticity or you may get some kind of coarse fine-grained soil property. So, you need to perform the liquid limit as well as the plastic limit test and you need to go back to the IS plasticity chart to determine the soil symbol. So, and the symbol could be GM or SM or GC or SC. Here actually your gradation is not coming into the picture. Please try to understand. If the fine content is more than 12% your gradation is not the predominating factor whereas your behaviour of the fine contents will be predominating factor like such that is why you have got the symbol like GM. What is GM? That is silty gravel. What is SM? That is silty sand. Similarly, GC that is clayey gravel. SC that is clayey sand or GM-GC if it comes very close to A-line okay.

Then you will be getting the dual symbol GM-GC. So, it could be silty gravel or clayey gravel okay or SM-SC. Again, this is coming very close to A-line and it could be SM or SC that is silty sand or clayey sand. If between 5% and 12% passes through the 75 micron sieve, that means if the fine content is between 5% and 12% then the soil is assigned a dual symbol appropriate to its gradation and plasticity characteristics. Then you have to see both gradation as well as plasticity characteristics.

That means the gradation alone will not dominating the classification process or plasticity alone will not dominate the classification process. So, you will be getting the dual symbol for the coarse-grained soil that could be GW-GM. that means well graded gravel and the silty gravel. Similarly, GW-GC, GP-GC, GP-GM, SW-SM, SW-SC, SP-SC, SP-SM. So, these are the possible dual symbols for coarse-grained soil okay.

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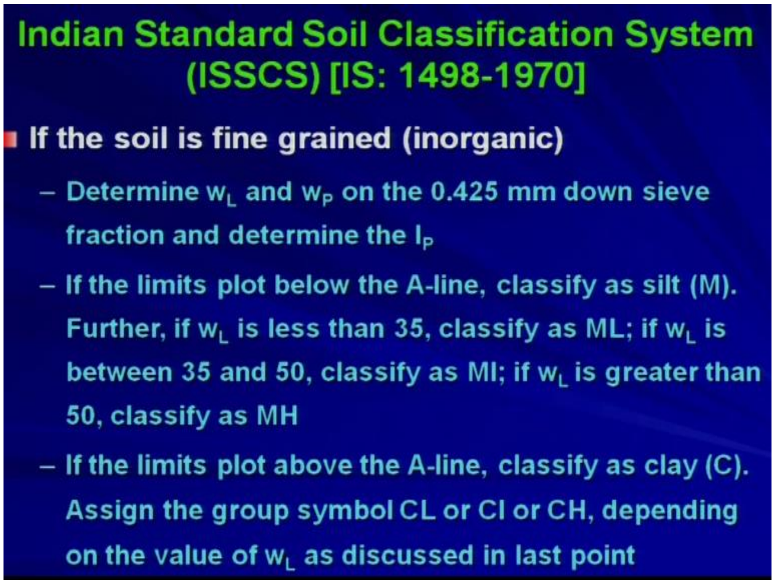

Now coming to the fine-grained soil. If the soil is fine-grained and of course you are dealing with inorganic, we are not dealing with organic because organic soil if you have so at the very first instance we take it out because when we classified the soil as organic or fine or coarse, at that time the organic soil is a different category right and we take it out so that whenever we are dealing with fine-grained or coarse-grained they are all inorganic. So, if the soil is fine grained, inorganic of course, determine the liquid limit and plastic limit on the 425 micron down sieve fraction and determine the plasticity index.

So, you do you perform the liquid limit test and plastic limit test to obtain the liquid limit and plastic limit and obtain the magnitude of plasticity index and then if the limits plot below the A-line, then classify as silt as we have seen, we have discussed enough on the plasticity chart.

Further if liquid limit is less than 35, classify as ML, low plastic silt. If liquid limit is between 35 and 50, classify as MI, that is intermediate plastic silt. If liquid limit is greater than 50, classify as MH that is high plastic silt.

Now if the limits plot above the A-line, then what will happen? It will be clay, it will be classified as clay, so classify as clay. Assign the group symbol as CL or CI or CH depending on the value of liquid limit whether it is below 35% or it is in between 35 and 50 percent or above 50% based on that you will be getting CL or CI or CH as discussed before for the silt.

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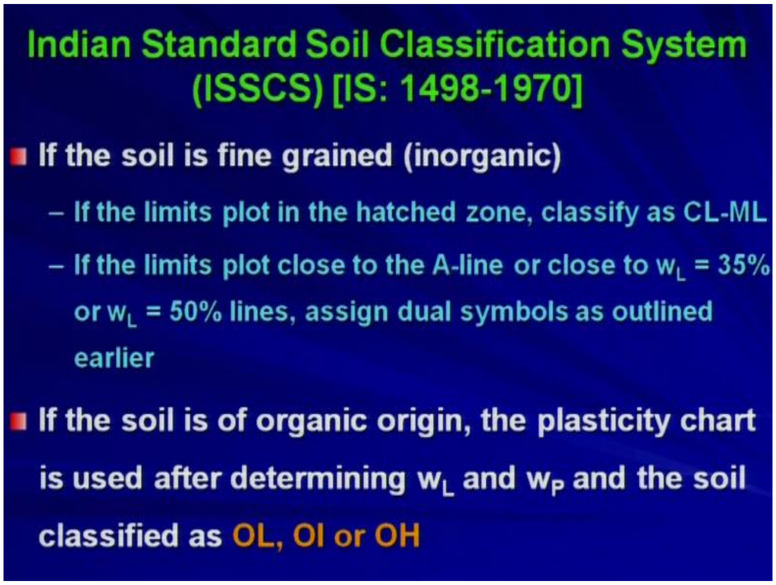

If the limits plot in the hatched zone, in the plasticity chart, already we have seen classify the soil as CL-ML, so it will be getting the dual symbol, already we have discussed this thing. If the limits plot close to a line or close to liquid limit equal to 35% or liquid limit equal to 50% lines assign dual symbols as outlined earlier.

If the soil is of organic origin, so now we are coming to the organic soil. So, if the soil is of organic origin, the plasticity chart is used after determining liquid limit and plastic limit and the soil classified as OL, if it is low plastic organic soil then it is OL, if it is intermediate plastic organic soil then it is OI or OH right.

So, if you get the organic soil you simply perform the liquid limit and plastic limit test and you obtain liquid limit and plastic limit and then you find out the plasticity index, you go back to the IS plasticity chart and there you see where it is coming, whether it is below 35%, whether the liquid limit is below 35% or between 35 and 50 percent or above 50 %. Based on that you classify OL, OI, or OH.

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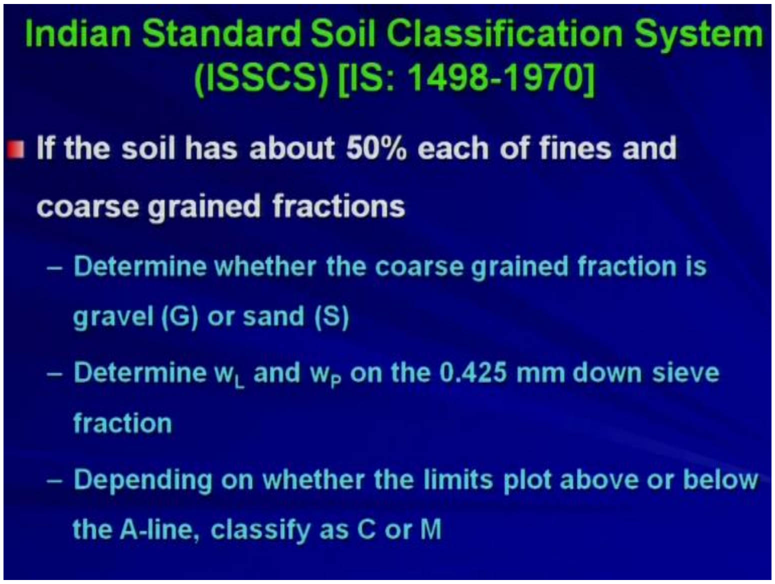

If the soil has about 50% each of fines and coarse-grained fractions. So, basically, we have discussed that if the percentage retained on 75 micron is more than 50% then it is coarse-grained soil. If it is if the percentage finer than 75 micron is more than 50% then it is fine-grained soil. Now if it is 50-50 like 50% retained 50% is coarse grained, 50% is fine grained, then what will happen? Then determine whether the coarse-grained fraction is gravel or sand.

So, you take whatever is retained on 75 micron sieve and then based on that you do you perform the sieve analysis again which is retained on 4.75 mm or below 4.75 mm and based on that you classify that as gravel or sand. Determine liquid limit and plastic limit on the 0.425 that is 425 micron sieve down fraction. Depending on whether the limits plot above or below the A-line, classify as C or M.

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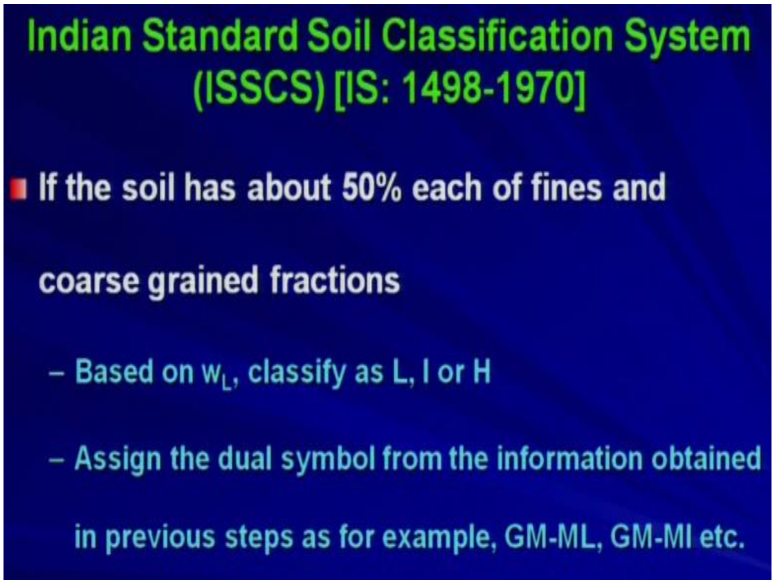

Based on liquid limit classify as L, I, or H whether it is less than 35%, above 50%, or between 35 and 50 percent. Based on that you give the symbol L, I, or H. Assign the dual symbol from the information obtained in previous steps as for example GM-ML that means silty gravel and low plastic silts. So, similarly GM-MI something like that.

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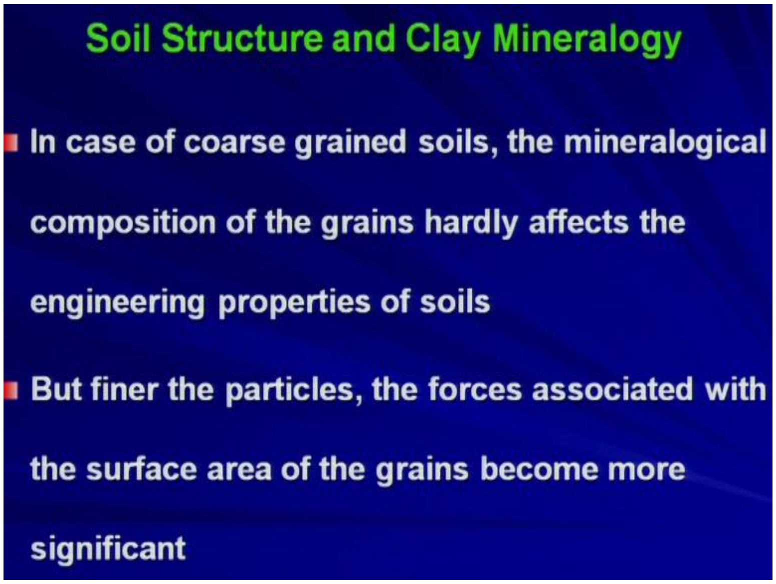

Now coming to the soil structure and clay mineralogy. So, if you understand this thing then you will be knowing or you will be really appreciating that why you are getting the plasticity in the fine-grained soil, why not in the coarse-grained soil and why the coarse-grained soil is basically determined or basically classified based on the gradation. Why the gradation is very important for the coarse-grained whereas the other things is basically governing the property of the fine-grained soil.

Now in case of coarse-grained soils the mineralogical composition of the grains hardly affects the engineering properties of soils. So, if you take the gravel, if you take the sand then those type of soils, basically those are the coarse-grained soil. So, mineralogical composition of those type of soils are not very much predominant to determine or to affect the engineering properties of that particular type of soil whether it is gravel or sand.

But finer the particles, the forces associated with the surface area of the grains become more significant because if you consider the fine particle because clay, silt these particles you cannot see by your bare eyes okay. So, if finer the particles, so if you if you going to from silt to clay it will be more finer so if but finer the particles the forces associated with the surface area because then it will be kind it will be a kind of plate and on top of the plate you will having I mean if you consider the surface area of the plate then those plates basically those surface area of the grains become more significant.

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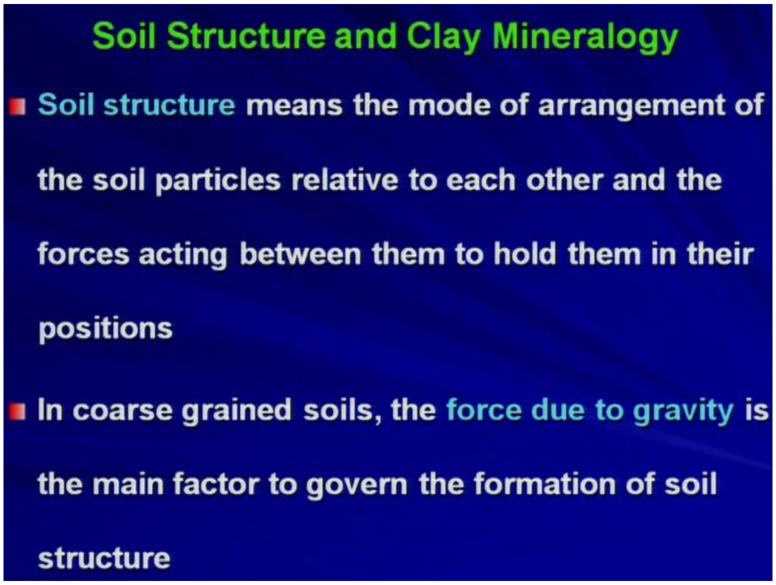

Soil structure means the mode of arrangement of soil particles relative to each other and the forces acting between them to hold them in their positions. So, basically soil structure when we are talking about, it basically tells that how the soil particles are getting arranged in a matrix in a in a soil matrix and the forces acting between them. So, I mean what the forces basically will try to attract the soil particles or so that the whole domain if we see globally this is my soil domain or the soil matrix how they are getting formed. So, this basically the forces acting between them to hold them in their position. So, these are the things we will talk about or will be covered in soil structure determination.

In coarse-grained soils, the force due to gravity is the main factor to govern the formation of soil structure. It is very I mean simple. Suppose if you take the sand sample and if you drop from different heights of the I mean if you say if you take a container and in the container, you are filling the sand from different heights. You will be seeing that the soil structure or the packing of the sand will be different because the force due to gravity is the main culprit or main governing factor which will define the soil structure.

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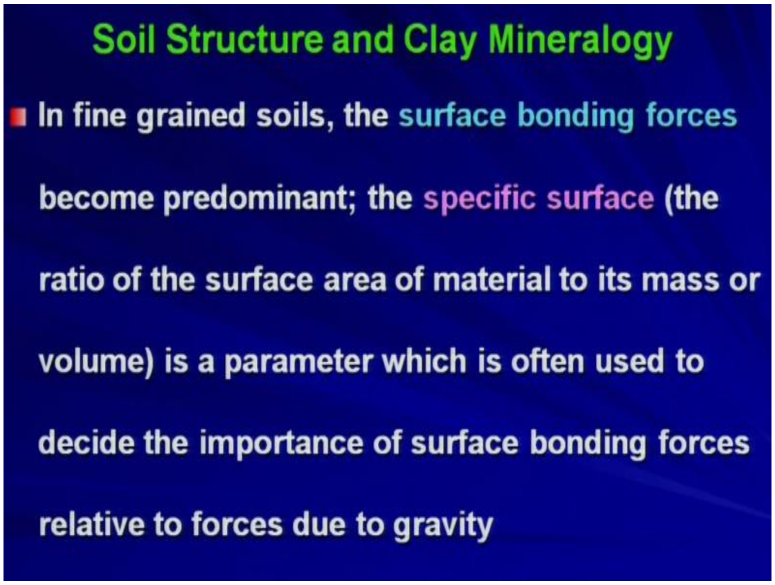

But in fine-grained soils the surface bonding forces become predominant okay because you have the surface area, it will be like a plate or platelet kind of thing and the surface bonding forces will be the predominant factor and the specific surface ratio of I mean specific surface which is nothing but the ratio of the surface area of material to its mass or volume is the parameter which is often used to decide the importance of relative to forces due to gravity.

So, in case of fine-grained soil, forces due to gravity is not the predominant factor whereas your surface bonding forces will cause or will make or will alter the packing or alter the soil structure.

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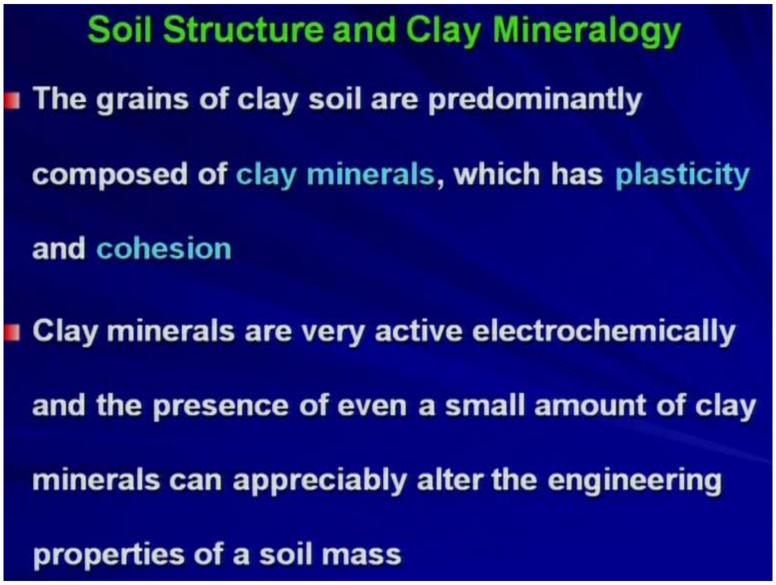

The grains of clay soil are predominantly composed of clay minerals because if you see this this thing can be seen in some electronic microscope that the clay grains or the clay soil grains are predominantly composed of clay minerals. So, there are different minerals available and those particles or those say grains are made of those clay minerals which has plasticity and cohesion.

So, now you have understood that why the clay soil, clayey soil or the fine-grained soil is giving me the plasticity because of its clay minerals. Clay minerals are very active electrochemically and the presence of even a small amount of clay minerals can appreciably alter the engineering properties of a soil mass okay. So, clay mineral is very important factor to determine or to define the engineering properties of your fine-grained soil.

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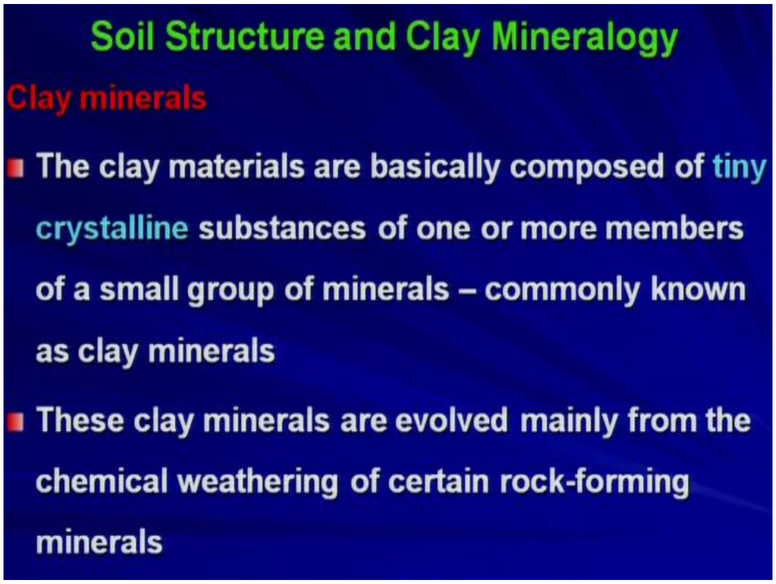

Now coming to the clay minerals. Now the clay materials are basically composed of tiny crystalline substances of one or more members of a small group of materials commonly known as clay minerals. So, they are known as I mean this is the definition actual definition of clay minerals. The clay materials are basically composed of tiny crystalline substances of one or more members of a small group of minerals commonly known as clay minerals.

Now these clay minerals are evolved mainly from the chemical weathering of certain rock-forming minerals and already we have seen in the very first class that what is our chemical weathering. So, from the chemical weathering of the rock you will be getting basically your soil is getting formed and if it is if you consider the clayey type of soil so clay minerals are nothing but the outcome of the weathering process of rock.

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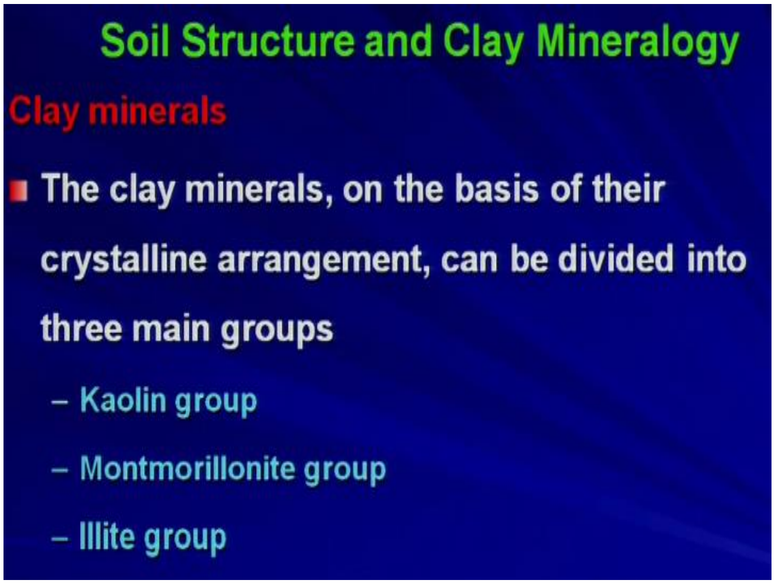

The clay minerals on the basis of their crystalline arrangement can be divided into 3 main groups. So, how they are oriented, how their crystalline structure is there, so based on that there are mainly 3 groups. First one is Kaolin group, second one is Montmorillonite group and third one is Illite group and we will be discussing these groups separately.

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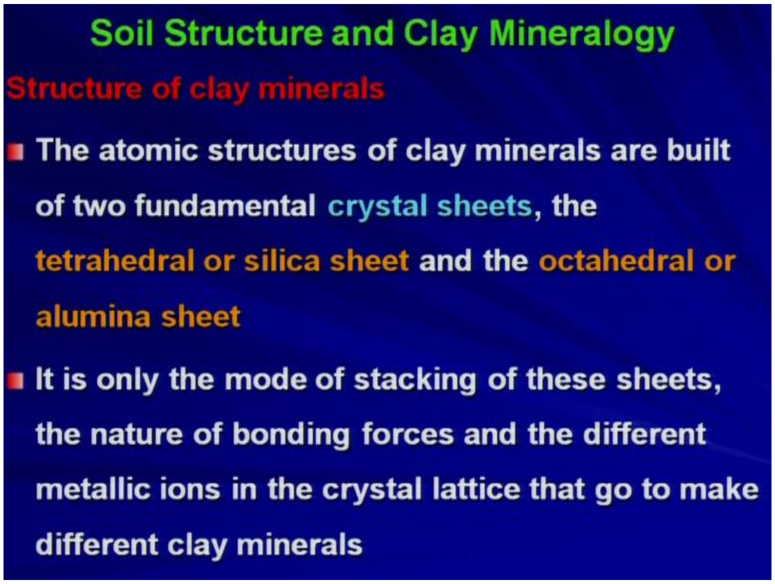

Structure of clay minerals. The atomic structure of clay minerals are built of 2 fundamental crystal sheets. So, if I mean whatever clay minerals you have seen, Kaolinite Kaolin or Montmorillonite or Illite. So, the atomic structure of the clay minerals are built of 2 fundamental crystal shapes I mean not more than that, 2 fundamental crystal shapes. One is tetrahedral or silica sheet. Another one is octahedral or alumina sheet.

Now what are these sheets. It is only the mode of stacking of these sheets. That means how they are getting stacked these sheets because one after another these sheets will be stacked and then based on that you will be getting different clay minerals okay. So, this is the basic unit of the clay mineral that is tetrahedral or silica sheet or octahedral or alumina sheet. Now it is only the mode of stacking of these sheets, the nature of bonding forces and the different metallic ions in the crystal lattice that go to make different clay minerals.

So, what are the things will cause different clay minerals from this crystal sheets. First one is the stacking of these sheets, how they are getting stacked; the nature of bonding forces, I mean what type of bonding forces is there, whether it is hydrogen bond or whether it is Van der Waal bond something like that based on that and the different metallic ions in the crystal lattice. So, I mean in that crystal lattice what are the different ions are present so based on that you will be getting different clay minerals like Kaolin or Montmorillonite or Illite, so we will see that.

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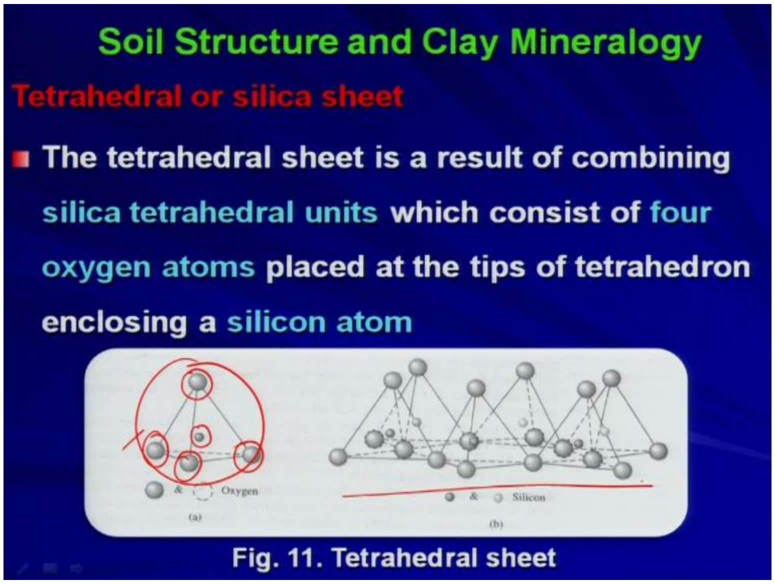

Fig. 11. Tetrahedral sheet

Now tetrahedral or silica sheet, how they look like and what are their shapes. The tetrahedral sheet is a result of combining silica tetrahedral units which consist of 4 oxygen atoms placed at the tip of tetrahedral enclosing a silicon atom. So, if you look at this figure, so basically this is the typical figure of your tetrahedral. So, this is the tetrahedral. You have 4 oxygen atoms, first one, second one, third one, and fourth one and you have only 1 silicon atom inside okay so which consist of 4 oxygen atoms placed at the tips of the tetrahedron enclosing a silicon atom.

So, that will form the basic unit of the clay minerals that is basically known as tetrahedron unit or silica sheet because it contains silicon inside so it is known as silicon sheet and they will be getting stacked. So, if you consider only the tetrahedral sheets so they will be getting stacked by this way okay.

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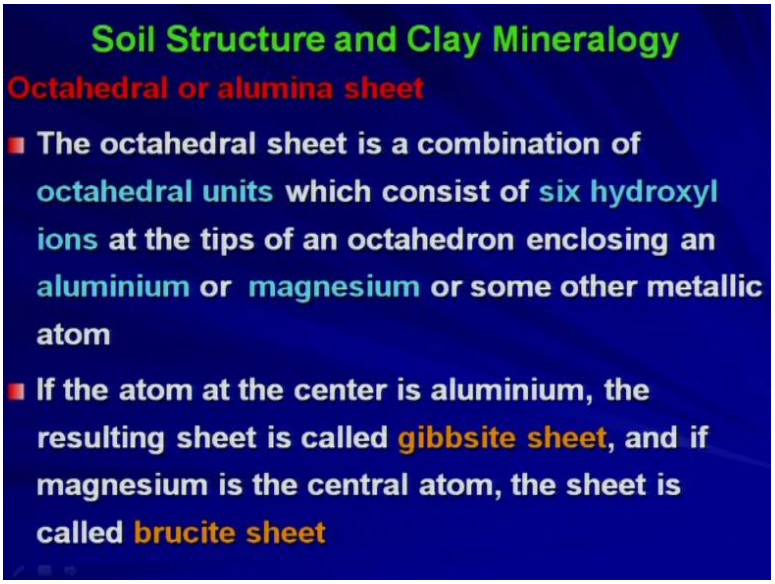

Now coming to the octahedral or alumina sheet. The octahedral sheet is a combination of octahedral units we will see that so this is a combination of octahedral units which consist of 6 hydroxyl ions at the tips of an octahedron enclosing an aluminium or magnesium or some other metallic atom okay. So, at the tips you have 6 hydroxyl ions whereas inside you have aluminium or magnesium or some other metallic atom.

Now if the atom at the center is aluminium okay, the resulting sheet is known as gibbsite sheet and if the magnesium is in the central atom, then the sheet is called as brucite sheet. So, if I say the gibbsite sheet that means this is the octahedral sheet or the alumina sheet which contains the aluminium inside. If I say the brucite sheet that means this sheet will consider or will contain the magnesium inside.

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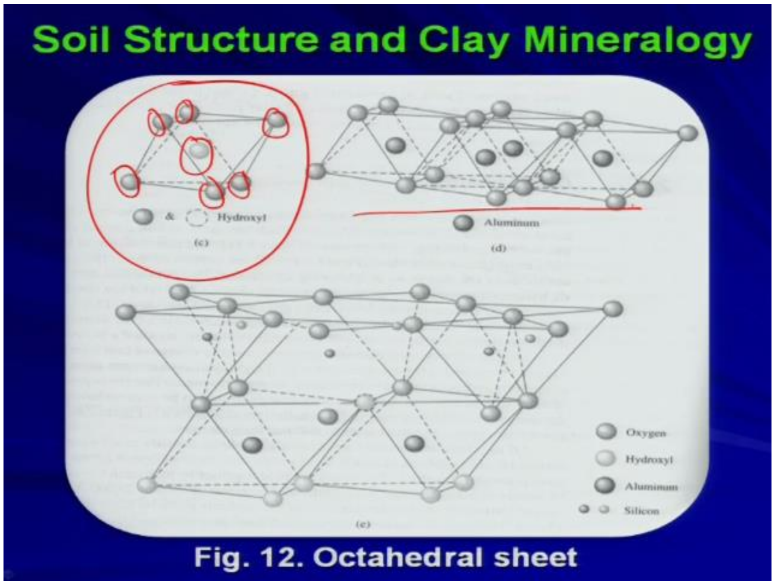

Now this is the complete picture of the octahedral sheet. So, if you look at this, this is your octahedral sheet. So, this is the octahedral and at the tips you have 6 hydroxyl ions 3, 4, 5, and 6 and one inside aluminium ion okay. It could be aluminium, it could be magnesium, or it could be any other metallic ion; based on that you will be getting different names. If it is aluminium then it is gibbsite. If it is magnesium then it will be brucite and they will be stacked or they will be connected to each other in this fashion okay.

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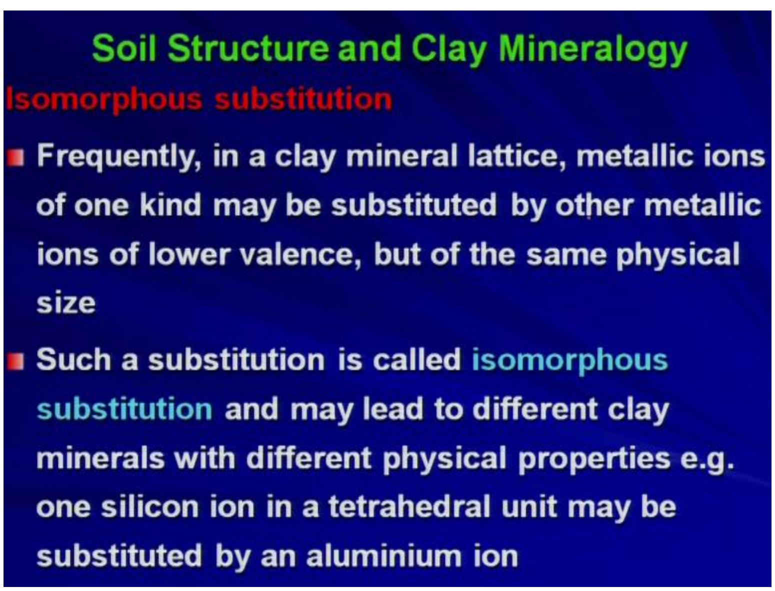

Now coming to what is known as isomorphous substitution because you need to know little bit of chemistry to understand these things. So, frequently in a clay mineral lattice, metallic ions of one kind may be substituted by other metallic ions of lower valence, but of the same physical size.

Such a substitution is called isomorphous substitution and may lead to different clay minerals with different physical properties for example one silicon ion in a tetrahedral unit may be substituted by an aluminium ion. So, these kind of substitution is possible and because of this substitution you will be getting, the main sheet is remaining same but because of this kind of substitution you will be getting different properties in the clay mineral.

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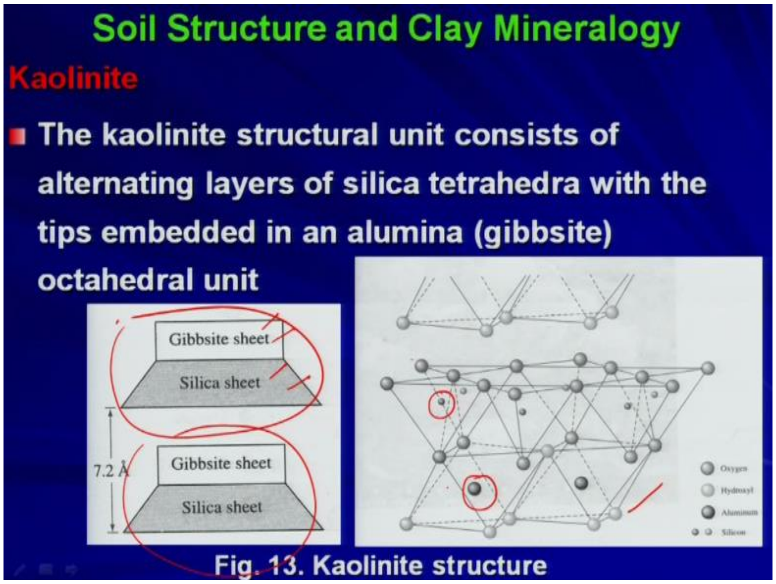

Now coming to the clay minerals, now kaolinite. This comes under kaolin group. So, the kaolinite structural unit consists of alternating layers of silica tetrahedra with the tips embedded in an alumina that is gibbsite octahedral unit. Now if you look at this, so this is the this is a kind of say symbolic expression.

That means there is one silica sheet, another one is the gibbsite that is the alumina sheet and they are getting stacked together and then and this is the alternating arrangement basically so you get this kind of block and then another unit will be this and then they will be stacked together. It will form the kaolinite group. So, you have the basic sheet is this gibbsite and silica sheet. These are your basic sheets.

Now this basic sheets are getting stacked together in the alternating arrangement and they will be forming the kaolinite structural unit. So, now this is the symbolic expression whereas in the actual if you see the how they are getting formed so basically on top of that you this is your octahedral unit and on top you have the silica unit. So, then this silica unit is having the silicon inside and this is having aluminium inside and they are getting stacked together and they will form the kaolinite structural unit.

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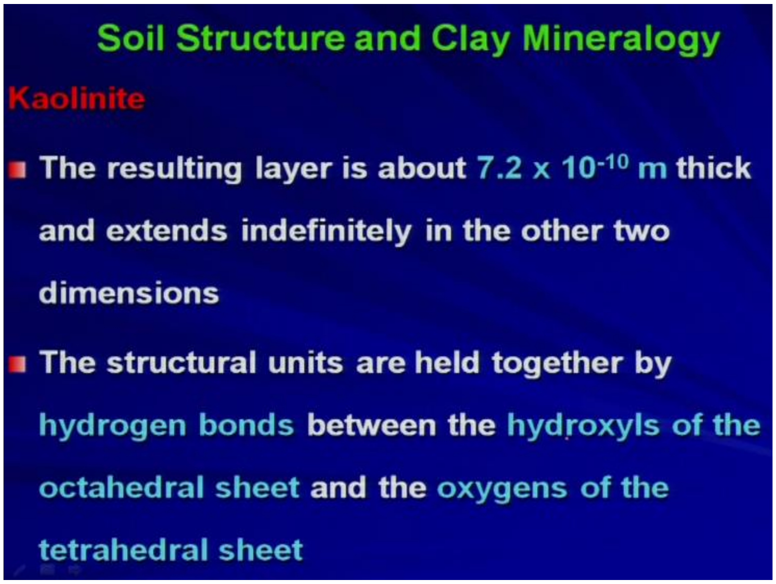

The resulting layer is about 7.2 into 10 to the power minus 10 meter thick because as we have seen just now we have seen you see this is the resulting this is the resulting unit. So, this resulting is the thickness, the thickness of the resulting unit is 7.2 angstrom which is nothing but 7.2 into 10 to the power minus 10 meter and extends indefinitely in the other 2 dimensions. So, in the other 2 dimensions it will be extending one by one unit will be stacked together and it will be continuing in other 2 dimensions.

Now structural units are held together by hydrogen bonds okay between the hydroxyl of the octahedral sheet and the oxygens of the tetrahedral sheet. So, basically this bonding in between these 2 thing your bonding is basically happening because of your hydrogen bond okay and this hydrogen bond is very strong. This hydrogen bond is basically getting formed between the hydroxyls of the octahedral sheet and the oxygens of the tetrahedral sheet.

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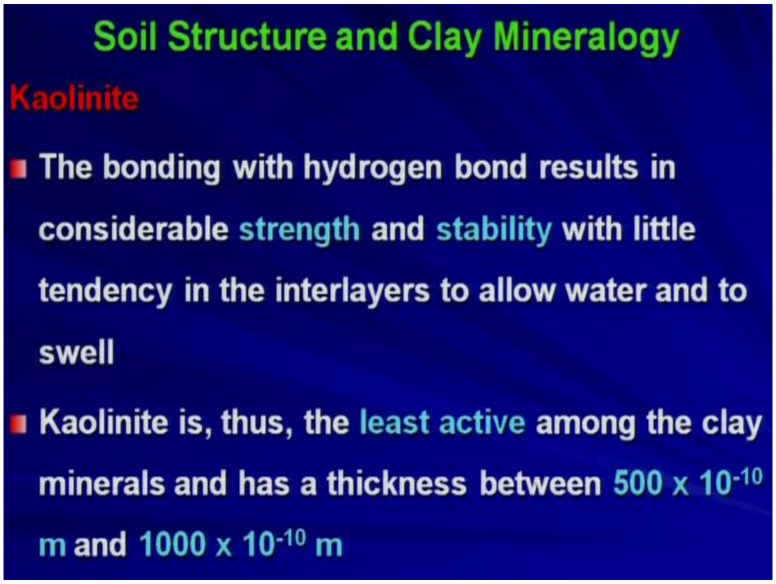

The bonding with hydrogen bond results in considerable strength as you know hydrogen bond is very strong so it results in considerable strength and stability with little tendency in the interlayers to allow water and to swell. That means the hydrogen bond is so strong, the hydrogen bond is so strong and it will not allow any water to come inside in the interlayer so that I mean if water is getting inside then you will be getting some volume increase of the swelling.

So, that is not happening at all because this water is not able to break this hydrogen bond and go inside the interlayers. So, it is very strong and stable bond. So, that will not allow water and that is why the kaolinite is generally very less active and very less I mean it will not be showing the swelling property or the shrinkage property.

The kaolinite is thus the least active among the clay minerals and has a thickness between 500 into 10 to the power minus 10 meter and 1000 into 10 to the power minus 10 meter. So, within this range basically the thickness of the clay minerals lie.

So, thank you very much. So, we will be seeing in the next class that is montmorillonite, Illite, and other things and then we will be taking one numerical example to understand the soil classification system. Thank you.