Geology and Soil Mechanics
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Lecture - 10
Classification of Soils and Clay Mineralogy- B

Welcome back. Welcome back to the course Geology and Soil Mechanics. So, in the last lecture we just stared the soil structure and clay mineralogy and there we have seen different types of clay minerals and different units like your silica block silica sheet and alumina sheet.

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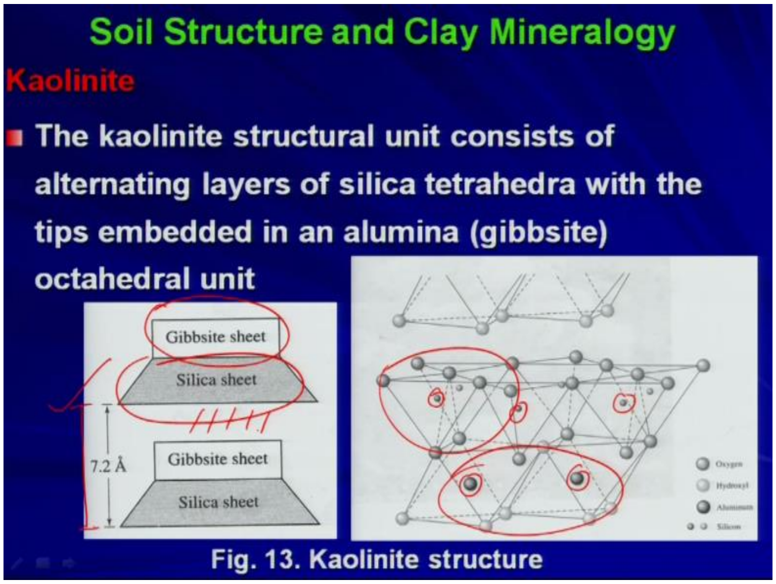

Fig. 13. Kaolinite structure

So now we are talking about the actual clay mineralogy. So, as we have seen in the last lecture that there are 3 major groups in the clay minerals. One is kaolinite group, another one is the montmorillonite group, and the last one is the illite group. So, in the kaolinite group you have the kaolin clay mineral. So, the kaolinite structural unit consists of alternating layers of silica tetrahedral with the tips embedded in an alumina that is the gibbsite octahedral unit.

So, you have silicon silica tetrahedral and you have the one unit of alumina or the gibbsite octahedral unit and they are combined each other to form the kaolinite structure. So, if you look at the structure, so basically as we just discussed you have one silica unit here and one gibbsite sheet. So, these 2 sheet basically will form the kaolinite structure. Similarly, at the bottom you have the gibbsite sheet and silica sheet and so on all the sheets will be stacked together to form the kaolinite structure.

So, if you see the actual this is the symbolic representation, this is this one is the symbolic representation for kaolinite structure whereas if you if you want to see all the atoms how they are oriented and all then you can see here, so this is your silica sheet okay and this one is your gibbsite sheet or the octahedral sheet. So, they are getting stacked together. So this is one silicon atom inside as we have seen for the silica sheet and this is your alumina atom as we have seen for our gibbsite or the alumina sheet.

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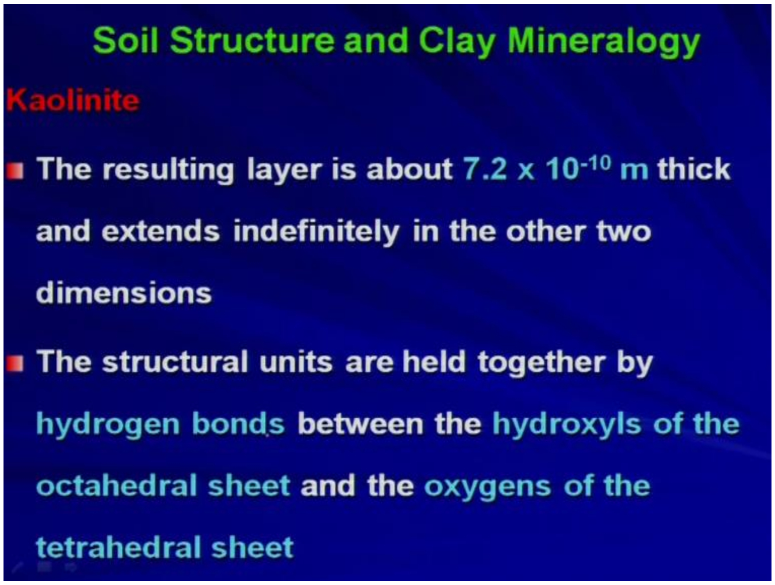

And the resulting layer is about 7.2 into 10 to the power minus 10-meter-thick and extends indefinitely in the other 2 dimensions. What does it mean? So, if you see so this thickness of the layer is 7.2 angstrom that is 7.2 into 10 to the power minus 10 meter and it is expanded in other 2 directions indefinitely. The structural units are held together by hydrogen bonds between the hydroxyl of the octahedral sheet and the oxygens of the tetrahedral sheet.

Now this hydrogen bond basically is getting formed at this face, so now the hydrogen bond is getting formed between the octahedral sheet and the silicon sheet and basically this bond this hydrogen bond is getting formed between the hydroxyl of the octahedral sheet as we know in the octahedral sheet you have the hydroxyls at the corners at the tips. So, the hydrogen bond will be getting formed between this octahedral sheet hydroxyls and oxygens of the tetrahedral sheet. So, in tetrahedral sheet in the tip you have the oxygen atom so they will be forming some hydrogen bond and then they will be stacked together to form the kaolinite structure.

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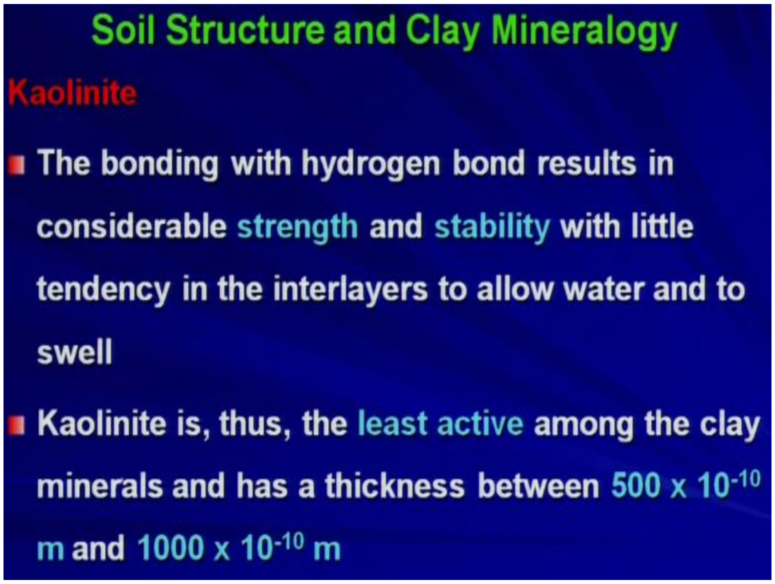

The bonding with hydrogen bond results in considerable strength and stability as you know that hydrogen bond is very stable and very strong so that will impart the considerable strength and stability to the structure with little tendency in the internal layers to allow water and to swell. So that means in the interlayer basically the hydrogen bond, your hydrogen bond is very strong so that is why it will not allow to enter water inside the interlayer okay.

So, this hydrogen bond will not allow any kind of foreign things inside the structure. So this has become very stable and strong. So, kaolinite is thus the least active because you are not allowing any foreign material or any foreign thing inside your own structure so it is it has become very 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 basically, this is the thickness of the kaolinite structure or the kaolinite unit and this is very least active because of the hydrogen bond. Hydrogen bond will not allow any kind of foreign material or the water to come inside the interlayer and to swell the structure because if you allow the water to come inside the interlayer that water will try to increase the volume and increase the volume of the structure and ultimately the clay as a whole will be increased, will be increasing in volume.

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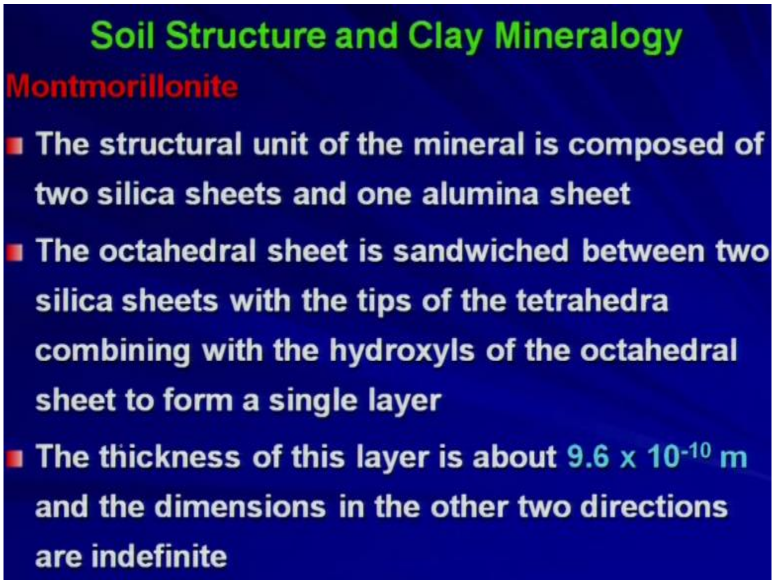

Now coming to the second kind of clay mineral that is montmorillonite. The structural unit of the mineral is composed of 2 silica sheets and 1 alumina sheet. So, you have 2 silica sheets and 1 alumina sheet. In case of kaolinite you have same, one silica sheet one alumina sheet, but in case of montmorillonite you have 2 silica sheets and 1 alumina sheet.

The octahedral sheet is sandwiched between 2 silica sheets with the tips of the tetrahedra combining with the hydroxyls of the octahedral sheet to form a single layer. So, what does it mean. That means your octahedral sheet, the alumina sheet or the gibbsite sheet, that is getting sandwiched between 2 tetrahedral sheet that is the silica sheet and the that will form the single layer.

The thickness of this layer is above 9.6 into 10 to the power of minus 10 meter whatever 2 silica sheet and 1 alumina sheet and that will form the whole layer and that layer thickness is 9.6 into 10 to the power minus 10 meter as we have seen in the case of kaolinite that was 7.2 into 10 to the power minus 10 that is 7.2 angstrom; here it is 9.6 angstrom and the dimensions in the other 2 directions are indefinite.

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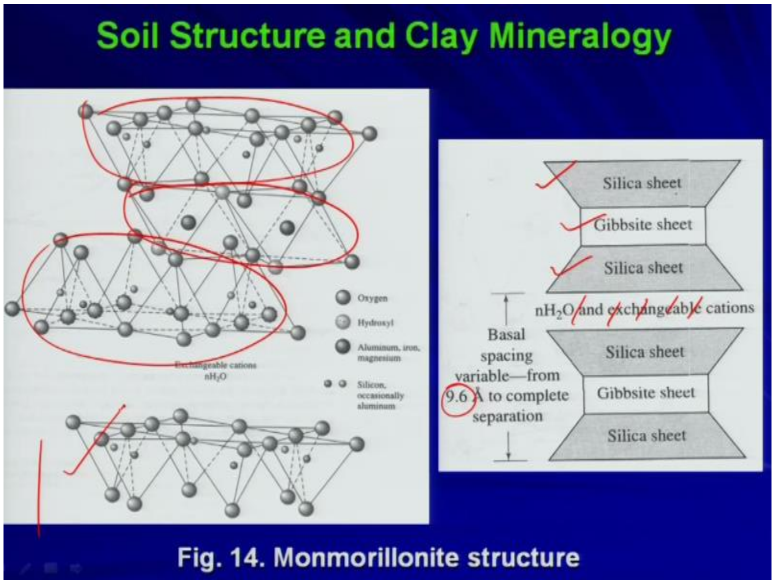

Fig. 14. Monmorillonite structure

So now if you see the structure, so symbolically we can say this is your first silica sheet and this is your second silica sheet and this is your alumina sheet or the gibbsite sheet that is getting sandwiched between these 2-silica sheet and the total thickness of the layer is 9.6 angstrom. Now if you see in the atomic structure point of view so you can see here so this is your silica sheet.

This one the middle one is your gibbsite sheet that is getting sandwiched between 2 silica sheets and this is another silica sheet and you have the interlayer, so this is your interlayer situation and I mean another unit is coming here so this is your another unit. So, this interlayer is allowing some water or some exchangeable cations to come inside the interlayer.

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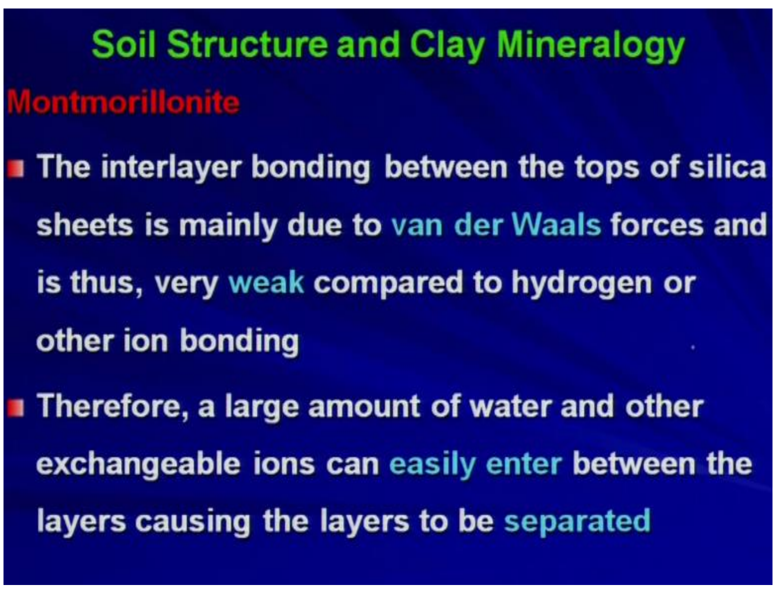

The interlayer bonding between the tops of silica sheets is mainly due to the van der Waals force and is thus very weak compared to hydrogen or other ionic bond. So, in case of kaolinite we have seen we had the hydrogen bond at the interlayer and that is why it was very strong and very stable so which was not allowing any water to come inside but in case of montmorillonite the interlayer that bonding is happening because of the van der Waal force which is very weak from our chemistry knowledge we know that van der Waal force will be very weak and that bonding will be very weak and it will allow the water to come inside.

Now the van der Waal thing van der Waal bonding is happening at this. So, the tops of 2 silica sheets along this interlayer you will be getting the van der Waal bonding which will be very weak. Therefore, a large amount of water and other exchangeable ions can easily enter between the layers causing the layers to be separated. So now because of the weakness of the van der Waal bonding at the interlayer it will allow water to come inside and once it allows the water, water will come inside or any exchangeable ion will come inside and it will try to push the structure and it will try to swell the structure so that and ultimately it may get separated.

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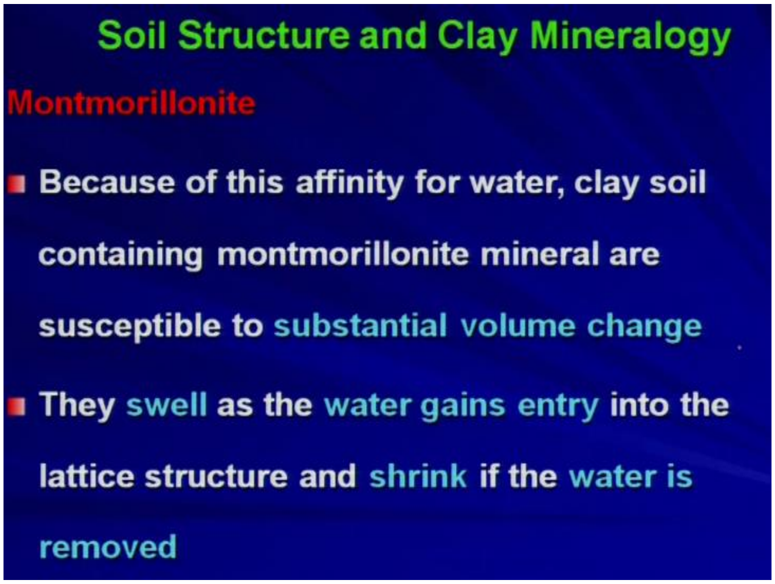

Because of this affinity for water, because the interlayer is getting van der Waal bonding and that is very weak and that is why it will allow water to come inside the interlayer and because of this affinity for water, clay soil containing montmorillonite mineral are susceptible to substantial volume change because once you are allowing water inside the matrix or inside the structure it will try to I mean increase the volume of the whole structure because it will enter at the interphase and it will try to push the upper block and the lower block that means upper structure and the lower structure in the substantial rate. They swell as the water gains entry into the lattice structure and shrink if the water is removed.

So, this is very I mean critical thing for the montmorillonite type of clay mineral because it is allowing water, so water will be getting inside the interlayer, it will try to push the structure and ultimately you will be getting some volume expansion that is swelling in the matrix.

So, they swell when the water gains entry into the lattice structure. So, it will swell excessively and it shrinks when the water is removed. So, if the water is getting removed from the interlayers immediately it will try to shrink. So, this shrinkage and swelling both is both are the problem of montmorillonite type of clay mineral.

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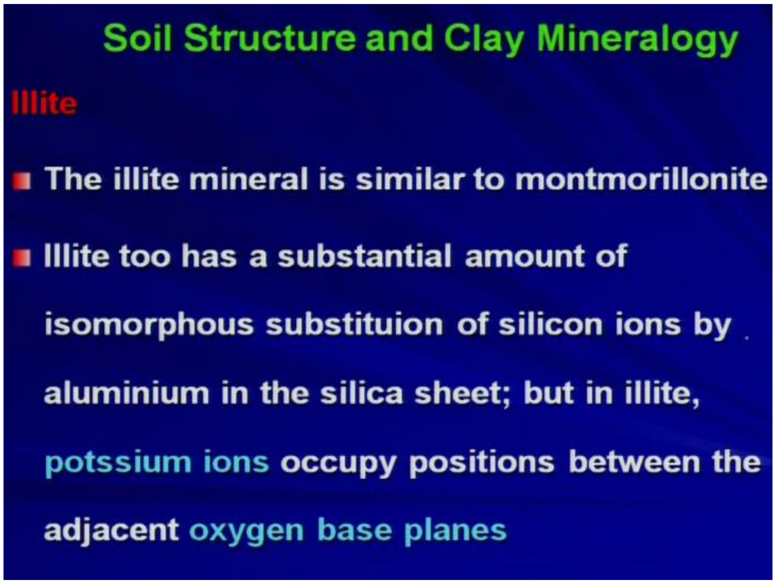

Now coming to the illite, that was the last type of clay mineral. The illite mineral is very similar to montmorillonite. You have 2 silica sheets and 1 alumina sheet which is getting sandwiched between 2 silica sheets. Illite too has a substantial amount of isomorphous substitution, by this time we know what is isomorphous substitution of silicon ions by aluminium in the silica sheet. So in the silica sheet you may have substantial amount of isomorphous substitution by the silicon by the aluminium ions but in illite potassium ions occupy positions between the adjacent oxygen base planes.

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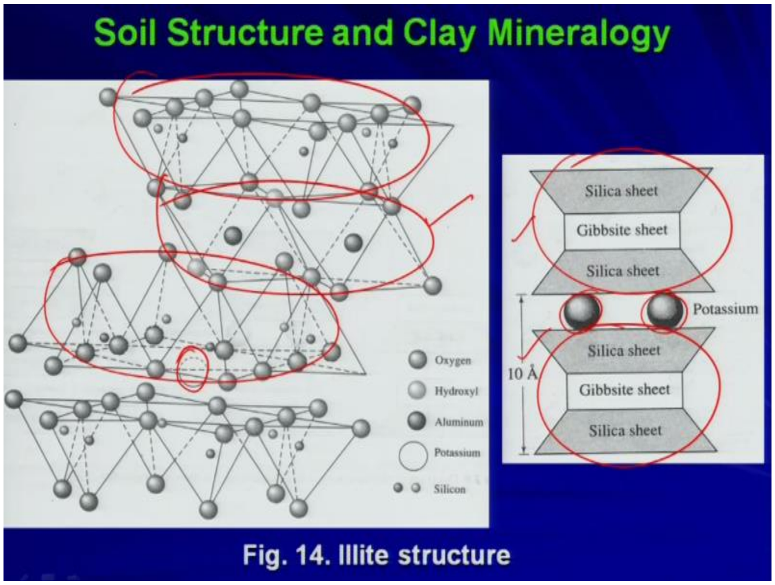

Fig. 14. Illite structure

Now what does it mean? So, if you look at the structure, you have the same structure like montmorillonite, there is no issue for that whereas instead of your water or maybe some exchangeable ion you have the potassium at the interphase which is bonding to lattice structures okay. So, if you look at, so this is your one silica sheet, this is one your gibbsite sheet, and this is another silica sheet. So, this is getting sandwiched between these 2 silica sheets and you have potassium in between.

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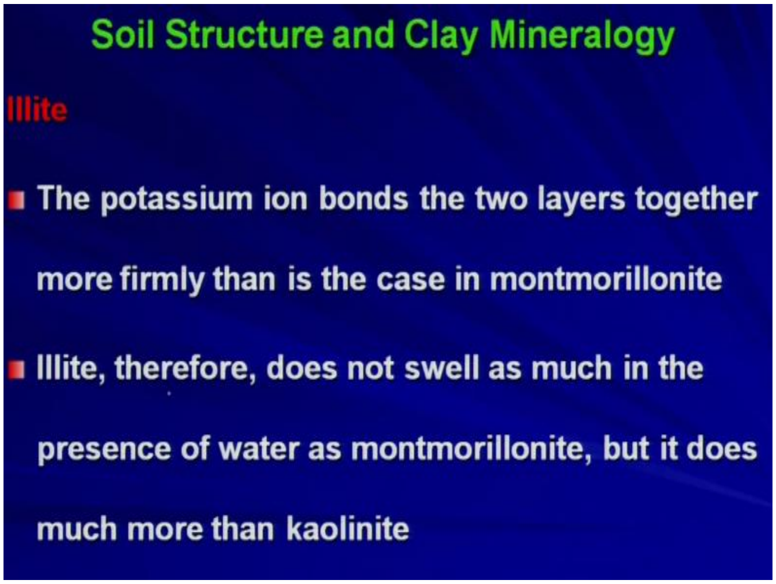

The potassium ion bonds the 2 layers together; the potassium ion bonds the 2 layers together more firmly than is the case in montmorillonite. So, in the montmorillonite we had the van der Waal bonding but this potassium ion in case of illite, it will try to create the bond which is little more stronger than that exist in montmorillonite. Illite, therefore, does not swell as much in the presence of water as montmorillonite because that because of the strong bond which is created by the potassium at the interlayer, it will not allow that much water to come inside at the interlayer and so that is why it will not be that much active under the water absorption okay whatever you have seen for the montmorillonite.

So therefore, it does not swell as much in the presence of water as montmorillonite, but it does much more than kaolinite. So, whatever you have seen for kaolinite because of the hydrogen bond it was very strong. It was not allowing any kind of water inside the interlayer but it is not the case for illite. So, if you see the I mean swelling point of view that montmorillonite will be swelling maximum then illite comes then your kaolinite. So, kaolinite does not swell at all.

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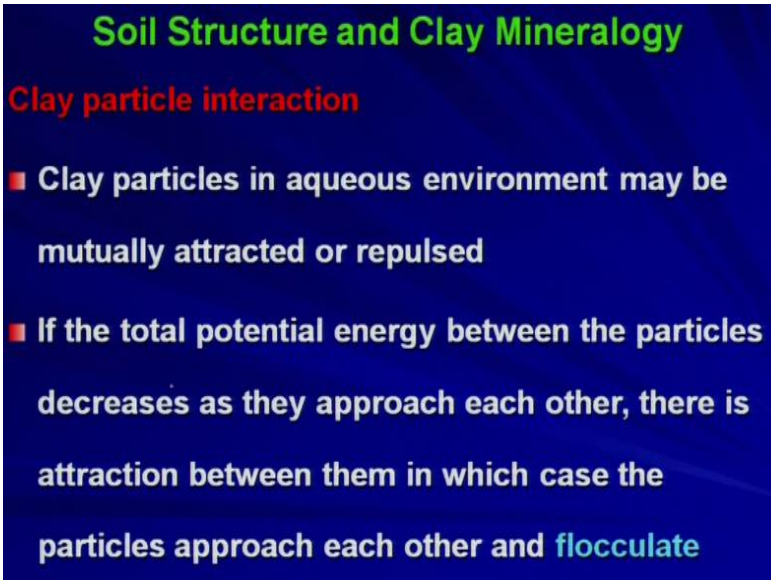

Now coming to the clay particle interaction, so how they interact? Clay particles in aqueous environment may be mutually attracted or repulsed because you have the structure of the clay minerals or the clay I mean structure in such a way that it will be having some charge on the surface and because of that in the aqueous region because I mean if you put the if you put water inside the clayey type of soil then basically because of the charge available in the water and the charge available in the soil so you will be having some charged environment and which will create some attraction or repulsion among the particles.

If the total potential energy between the particles decreases as they approach each other, there is attraction between them in which case the particles approach each other and flocculate. So that means if the potential energy is getting decreased then the particles will be attracted to each other and it will be flocculating basically, making a flock kind of thing, I mean something like that it will make some group okay.

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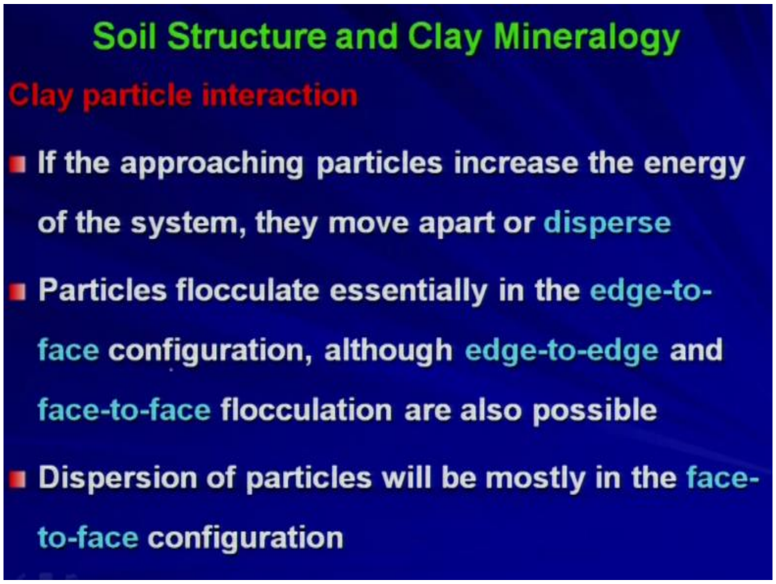

If the approaching particles increase the energy of the system, they move apart or disperse. Then if the potential energy is increasing then the particles will move or will move apart or disperse. Particles flocculate essentially in the edge-to-face configuration. So, we will come to that point later on in the next slide what you mean by edge-to-face configuration okay that means the edge of the particle will be flocculated to the face of the next another or the surrounding particles so something like that although edge-to-edge and face-to-face flocculation are also possible.

Dispersion of particles will be mostly in the face-to-face configuration. So, when the soil particles will be getting dispersed, at that time your dispersion will be happening or the configuration will be happening in the face-to-face that means all the particles will be parallel along the face or with respect to face of the particles.

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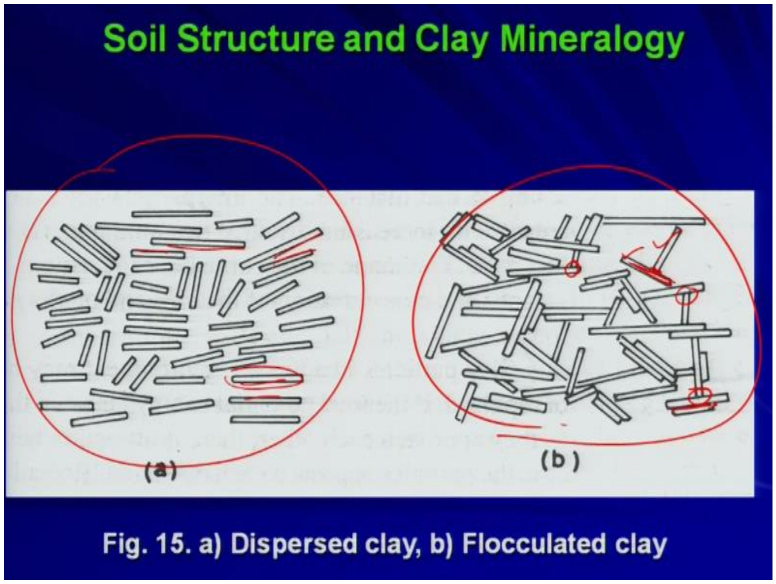

Now if you look at this figure, so this is the dispersed structure or you can see the configuration is face-to-face that means this is the face of one particle, this is the face of another particle surrounding particle; this is the face of one particle, this is the face of another surrounding particle. So, this configuration in the dispersed state the configuration is face-to-face configuration.

Again, if you look at this particle, so this is the face and this is the face of the nearby particle. So, this configuration is known as face-to-face configuration whereas in case of flocculated clay so that is this is your flocculated structure. Here you can see as I told you that you will be getting most of the time edge-to-face configuration. So that means if you consider this particle so this is the edge of the particle and the nearby particle this is the face of the particle. So, this particle is having some edge-to-face contact with the surrounding or the nearby particle.

Similarly, most of the times you will be getting edge-to-face contact, something like this, something like this or if you come here you can see here. So, most of the times you will be getting edge-to-face configuration in case of flocculated structure. However, as I told you, you may get edge-to-edge configuration or face-to-face configuration like this you are getting face-to-face configuration whereas in somewhere else you will be getting edge-to-edge configuration.

Well, so now we will be taking one problem on the soil classification system whatever we have seen in the last lecture.

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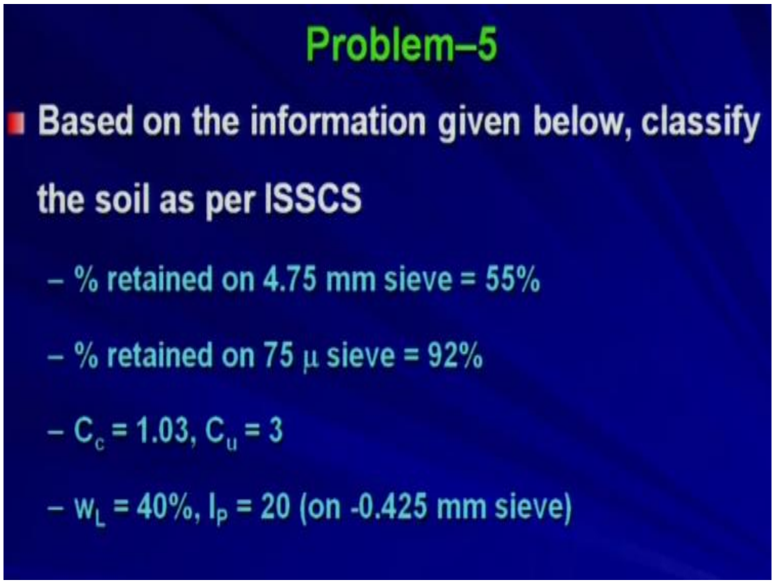

The problem says that based on the information given below, classify the soil as per Indian Soil Classification System. The things are given that is percentage retained on 4.75 mm sieve equal to 55%, percentage retained on 75-micron sieve is 92%, coefficient of curvature is 1.03 whereas coefficient of uniformity is 3. Liquid limit is 40% and plasticity index is 20. So, based on this information, so we need to classify the soil as per the Indian Soil Classification System. Now let us see how we can proceed to find out the classification of this particular type of soil.

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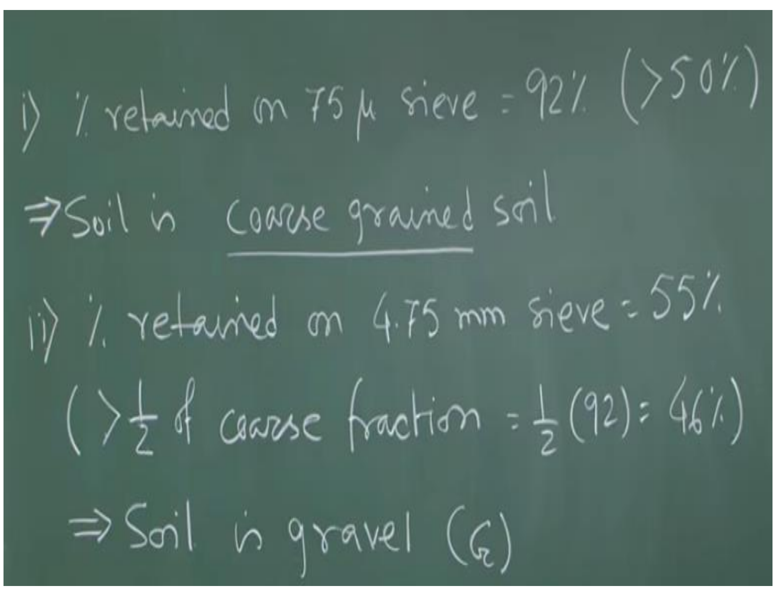

So, it is given percentage retained on 75-micron sieve equal to 92% right. So, which is basically greater than 50%. So, from our soil classification if you recall from our soil classification this soil is of course this soil is coarse grained soil. How could you say that because the percentage this is given in the soil classification system if you just go back to the last lecture you will see that percentage retained on 75-micron sieve if it is more than 50% then the soil will be classified as coarse-grained soil and that we have seen just now because your percentage retained on 75-micron sieve was 92% which is greater than 50%.

So of course, the soil will be classified as coarse-grained soil. So, this information we have got just now based on this retention on 75-micron sieve. Now next, percentage retained on 4.75 mm sieve equal to 55% okay. Now as we know half of coarse fraction that means 50% of coarse fraction will be your half of 92 which is coming as 46% right. So, based on the retention on 4.75 mm sieve basically what we can conclude that whether the soil is gravel or sand right. So that 4.75 mm sieve is crucial for classifying the soil as gravel or sand.

Now your half of the coarse fraction, what is the what is your coarse fraction? Coarse fraction is 92% which is retained on 75-micron sieve. Now half of the coarse fraction that is 46% is the half of the coarse fraction right but your retention on the 4.75 mm sieve is 55% which is greater than 46% right. So, what you can conclude from this. So, your soil will be classified as gravel. So from this you can conclude soil is gravel, that means G, so symbol first symbol we have got that is the prefix we have got as G.

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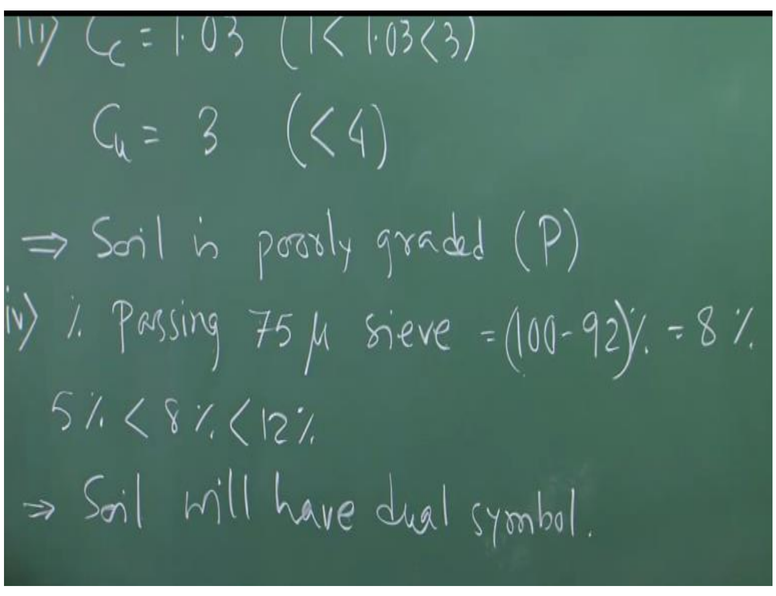

Now in the third information we have C c equal to 1.03 which is coming within this range that is okay but that is not enough to classify the soil or to tell something about the soil gradation right. So, you have another parameter that is C u which is 3 in the problem, it is given as 3. So, what this is less than 4. So, if you recall for getting the well graded gravel you need to have C u which is greater than 4 and you need to get C c which is in between 1 and 3.

So, the first criteria is getting satisfied whereas the second criteria is not getting satisfied. So, this soil or the gravel is poorly graded. So, soil is poorly graded. So, you have got the suffix as P okay. So, you have got the suffix as P. So, it is poorly graded gravel. Now let us see in the problem that do you have any information about the fine contents or not. So, let us find out that. Percentage passing 75-micron sieve is equal to 8%.

So, percentage passing 75-micron sieve is 8% okay. So, this comes between 5% and 12% right. So, if the fine content is less than 5% that will be classified as completely coarse-grained soil whereas if it is greater than 12% so that will be classified something else but whereas if it is in between 5%, 12% then what you will get, you will get dual symbol right. So, if you recall the from the lecture you will get dual symbol. So that information we have got just now. So, soil will have dual symbol because your percentage passing that is the fine content is between 5% and 12% okay.

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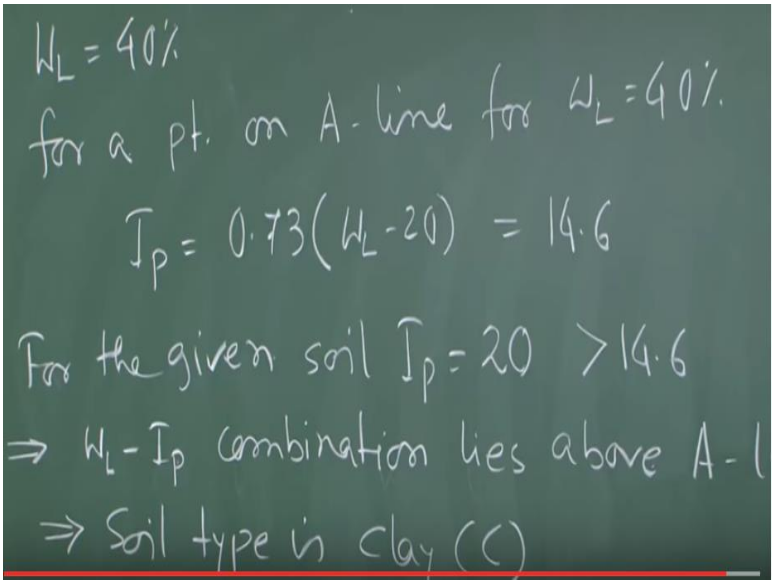

Okay now your liquid limit is 40%. Now for a point on A-line of your IS plasticity chart for liquid limit equal to 40% okay your I P should be what was the equation of A-line if you recall, the equation of A-line was 0.73 into liquid limit minus 20. So, from this I will get 14.6. Now if your liquid limit is 40% and your plasticity index that is I P is say 14.6 then you will get the point on A-line right but in your problem what is given? Your liquid limit is 40% but I P is 20.

That means the point is lying above the A-line, am I right? So, the point is lying for the given soil your I P is 20 so which is greater than 14.6. So, the point will never lie on A-line. So, your liquid limit and I P combination lies above A-line. So therefore, the soil type is what type of soil you will get if it lies above the A-line, you will get clay, so soil is clay. So, what will be the final classification of the soil?

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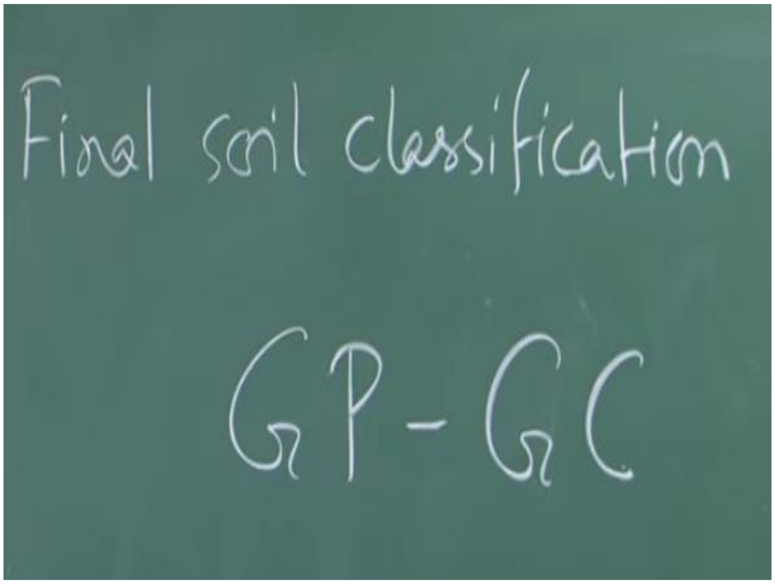

So, the final soil classification will be what? So, GP dual symbol GC. So, this is your final soil classification for the given problem. So, GP poorly graded gravel and clayey gravel okay. So, I hope that you have understood the problem okay. Thank you very much for this for your patience listening. Now we will be continuing in the next lecture. Thank you.