Soil Science and Technology
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Lecture – 13
Soil Consistency and Soil Water

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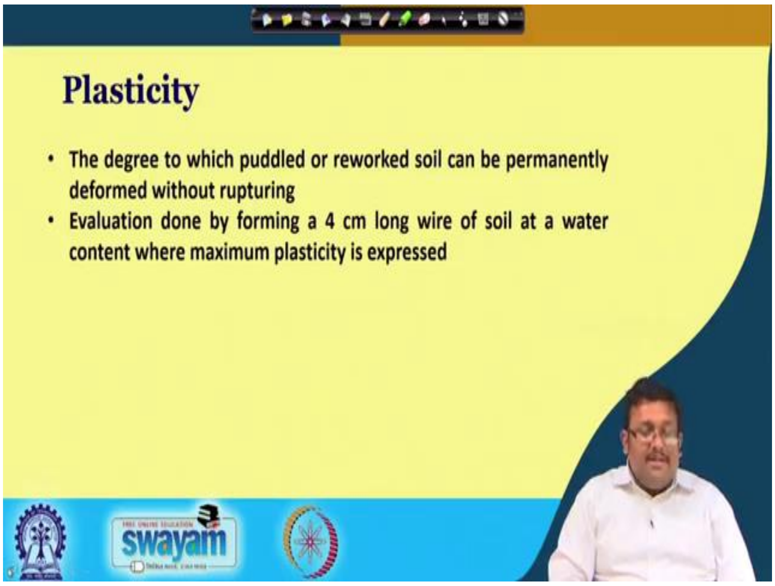

Welcome friends to this new lecture of a Soil Science and Technology and today we will be discussing from the slide where you left in the last lecture. So, in the last lecture we started discussing about soil consistency and I told you that soil consistency is the ease with which we can mould soil to any shape.

And soil consistency is basically the manifestation of soil cohesive and adhesive forces and you know this wet soil consistency is basically expressed in terms of by the stickiness or plasticity. And in the lecture I have discuss about different stickiness classes starting from you know very sticky to moderately sticky and highly sticky in low and less sticky and all these things.

So, today we will discuss about the plasticity; now plasticity the definition of plasticity is the degree to which the puddled or reworked soil can be permanently deform without rupturing. So, it is an important that is the soil cannot be ruptured and basically we evaluate these thing by forming a 4 centimeter long wire of soil at a water content where maximum plasticity is expressed. So, let us see what are the different plasticity indices.

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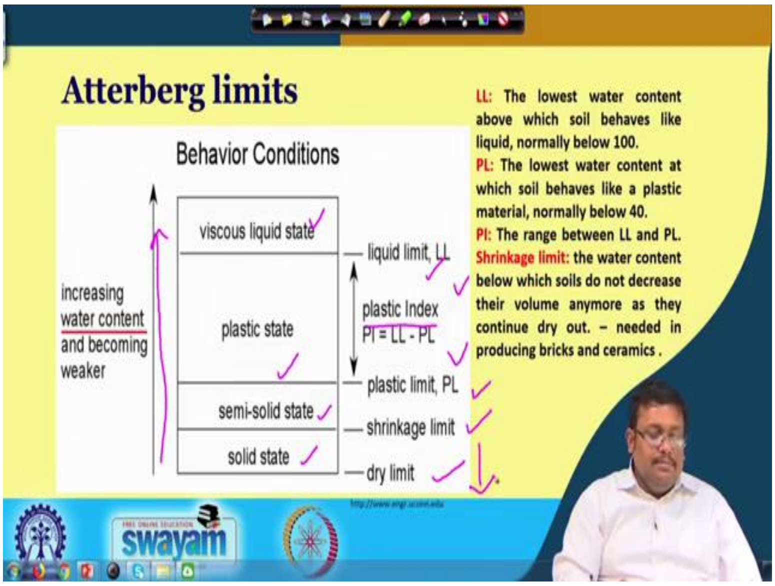

So, this is called Atterberg limits and in this Atterberg limits we can see we are seeing the plasticity be changing in the plasticity behavior of soil with increasing moisture content. So, you see that here you can you can see there are five different steps; five different stages or states I would say.

First of all this is the solid state, then semi solid state there are plastic state and viscous liquid state. So, as you are moving from dry soil to very wet soil the state of the soil is continuously changing. And accordingly there are different limits. So, there are 4 different limits you can see starting from dry limit and then shrinkage limit and then plastic limit and finally, liquid limit.

So, let us discuss them one by one. So, in the liquid limit is basically the lowest water content above which the soil behaves like liquid and it behaves like a viscous liquid you know viscous liquid state. And generally it is less than 100 percent moisture content. And another important limit is plastic limit or PL and it is basically the lowest water content at which the soil behaves like a plastic material. And it is basically you know occurs at around in the 40 percent of moisture or lower than 40 percent of moisture.

And there is a another term called plastic index and plastic index is basically the difference between liquid limit and this plastic limit. Another limit is there that is called shrinkage limit and shrinkage limit is basically defined as the water content below which the soils do not decrease their volume any more as they continue to dry out. And so below the shrinkage limit you will not see any further you know decrease in the soil volume as you are going continuously removing the water.

So, this is called shrinkage limit and this is very much important from the point of view of bricks and ceramics industries. So, these are 4 different limits which are important for which are called Atterberg limits and which are basically showing the different states of soil with increasing moisture content or in other words it is basically shows different plasticity conditions. So, let us see what are the different plasticity; what are the different types of plasticity classes?

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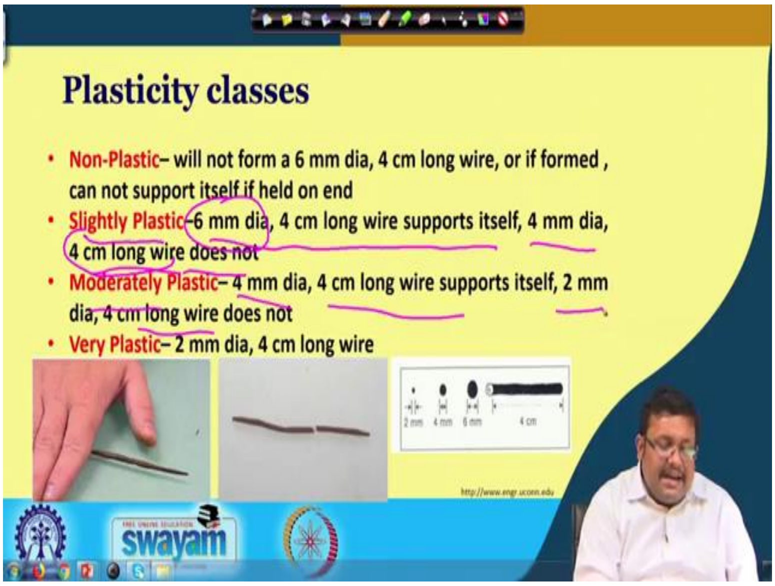

So, generally we see there are 4 different plasticity classes starting from non plastic then slightly plastic then moderately plastic and very plastic. So, non plastic is when we cannot form a 6 millimeter dia 4 centimeter long wire or if found it cannot support itself if head on end. So, basically what happens we take a small amount of soil and then we start to roll it to form a wirelike structure and in this case the wire diameter should be 6 millimeter. And if we can if we can you know in the non plastic case; the length of the wire cannot be 4 centimeter.

So, it will break down before it reaches the 4 centimeter or if it is form it cannot hold it; you know it help you know if it is a form it cannot held itself in one end. So, this is called non plastic condition, another is called the slightly plastic condition and the slightly plastic condition where 6 millimeter dia and 4 centimeter long wire supports itself. So, we can make these 6 millimeter dia and 4 centimeter long wire by rolling the soil with our hand.

However, if we make a 4 centimeter long wire with 4 millimeter dia; it cannot be made. So, in case of slightly plastic soil we can create a 4 centimeter long wire with 6 millimeter of diameter; however, we cannot make 4 centimeter long wire with 4 millimeter diameter. The third one is called moderately plastic and the moderately plastic is we can create 4 centimeter long wire with 4 millimeter diameter; however, we cannot create 4 centimeter long wire with 2 millimeter diameter.

As you can see as we are going from non plastic to slightly plastic to moderately plastic to very plastic; the diameter is continuously going down. And finally, in the very plastic condition we can create 4 centimeter long wire with 2 millimeter diameter; so, these are 4 different plasticity classes. So, by rubbing and creating a wire I mean two to form a wire with the soil we can generally we can literally define their plasticity classes.

So, by this we have completed this soil porosity and consistency lecture and hope you have learnt something new. And we will be dealing you know will be discussing several numerical problems of this porosity and other soil bulk density and soil particle density in the coming lectures.

So, let us wrap up this porosity and soil consistency lecture here. And let us start a very important topic today that is called soil water it is very very important you know you know topic as for as the soil is concerned.

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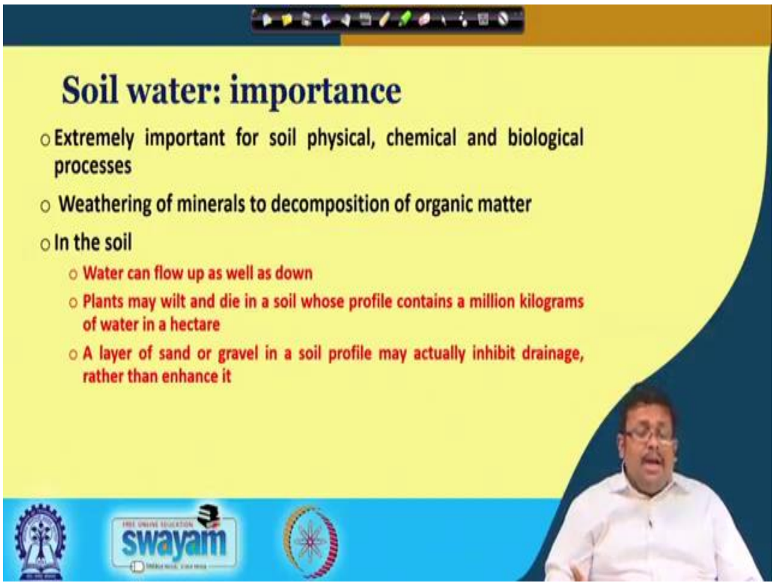

So, in the you know will we will first try to give you an idea about soil and it is important properties as for as the you know soil water in and it is different interaction is concerned. And then we will talk about the soil water energy concept and then we will try to talk about different you know different ways to measure the soil water content. So, let us start with the soil water why we need to know; why you need to learn about soil water. Well soil water is extremely important for soil physical, chemical and biological processes you know a water is a very important physical force for creating physical weathering.

And also it creates it is an indispensable for chemical or and biological weathering and also for you know sustaining different microorganisms and macroorganisms into the soil. And also water is very much important for weathering of the minerals and decomposition of soil organic matter. So, without water the weathering of the minerals and decomposition of organic matter cannot be achieved. So, in the soil water shows some bizarre characteristic; for example, you can see the soil water can flow up as well as down. And also plant may wilt and die in soil whose profile contains a million kilograms of water in 1 hectare.

So, this is another bizarre characteristics of soil water. And thirdly you will see a layer of sand or gravel in a soil profile may actually inhibit drainage rather than enhance it. So, these are some so you know bizarre characteristics of soil water and we will discuss their reasons later on.

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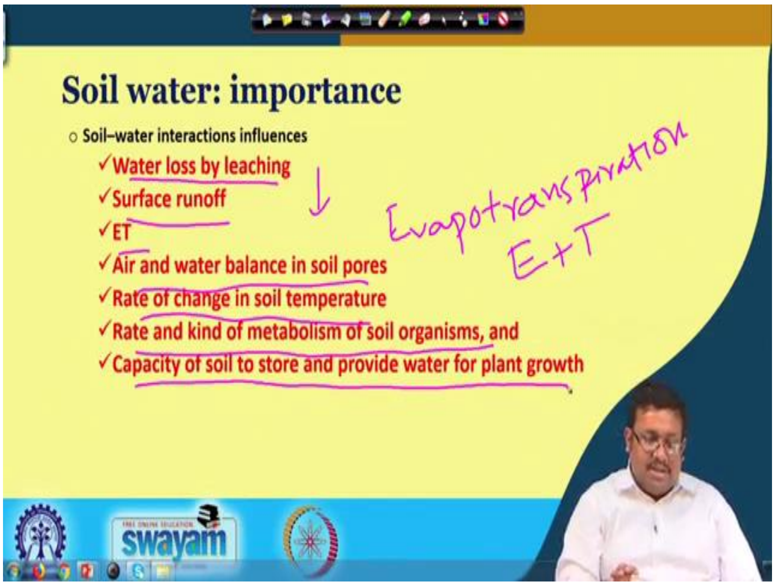

Another importance of soil water is the soil water interaction influences you know water loss by leaching as well as; water loss by leaching then you know leaching is the downward movement of salts through the soil solution through the soil solution. And then surface runoff ET is basically evapotranspiration evapo transpiration which is basically a combination of evaporation from the soil surface and transpiration from the plant surface.

So, evapotransportation and also air and water balance in soil pores; we will discuss that later on and rate of change in soil temperature and the rate and kind of metabolism of soil organisms and capacity of soil to store and provide water for plant growth. So, these are very much the soil water interaction influences all these important processes.

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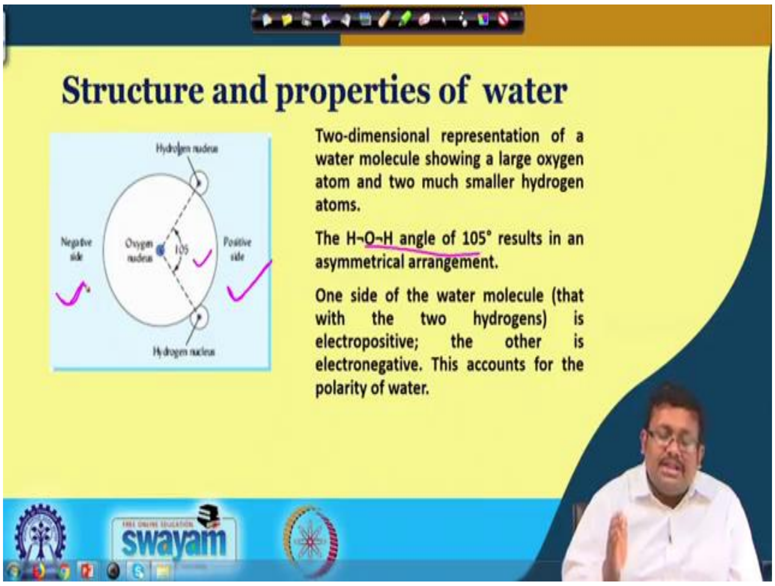

So, let us see the structure of water and their important properties. So, if you see there is a two dimensional structure of soil water and it is a two dimensional representation of soil water molecule showing a large oxygen atom and two much smaller hydrogen atom hydrogen atoms. So, you know you can see here the H O H angle is 105 degree. So, this 105 degree angle between these oxygen nucleus and two hydrogen nucleus creates a asymmetrical arrangement.

And as a result of this asymmetric arrangement one side of the water molecule that with the two hydrogen for example this side shows positive you know electropositive nature electropositive behavior; however, the other side showing the electro negative behavior. So, as a result of creating this electropositive side and electronegative side soil water; sorry water shows dipolar characteristics. So, this is the asymmetrical structure which is responsible for polarity of water all right.

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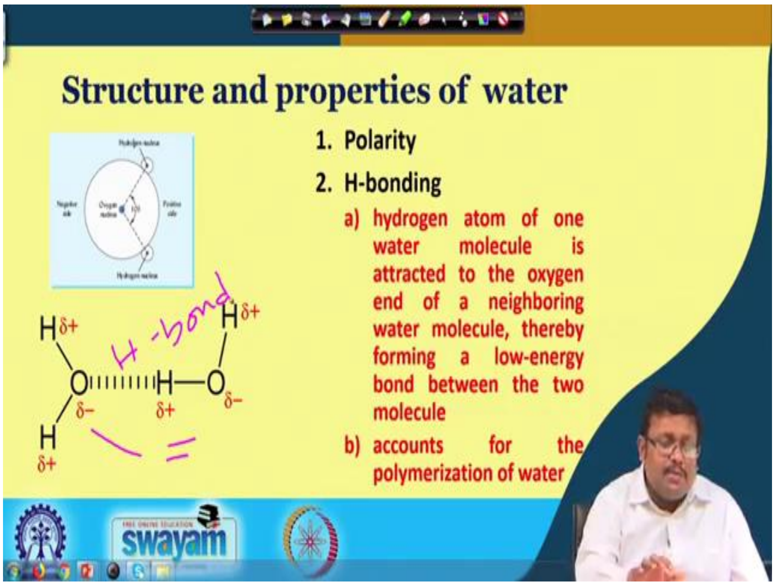

So, the important properties as we discuss the important properties of the soil; soil polarity is very much important and also the second important is hydrogen bonding. Now, what is hydrogen bonding? Hydrogen bonding is a bond which forms between the hydrogen atom of one water molecule and oxygen atom of a neighboring water molecule.

So, you can see that the hydrogen atom of one water molecule is attracted to the oxygen end of the neighboring water molecule. And all these occurs due to the asymmetric arrangement of soil water molecule asymmetric arrangement of water molecule and as a result dipole nature of the water molecule.

So, thereby forming a low energy bond; so this is called hydrogen bonding and remember that this is a low energy bond and a low energy bond between two molecules and this hydrogen bonding is responsible for polymerization of water. Because, all these water molecules you know cluster among themselves clustered by using different hydrogen bond. So, this is the responsible for polymerization of water molecules.

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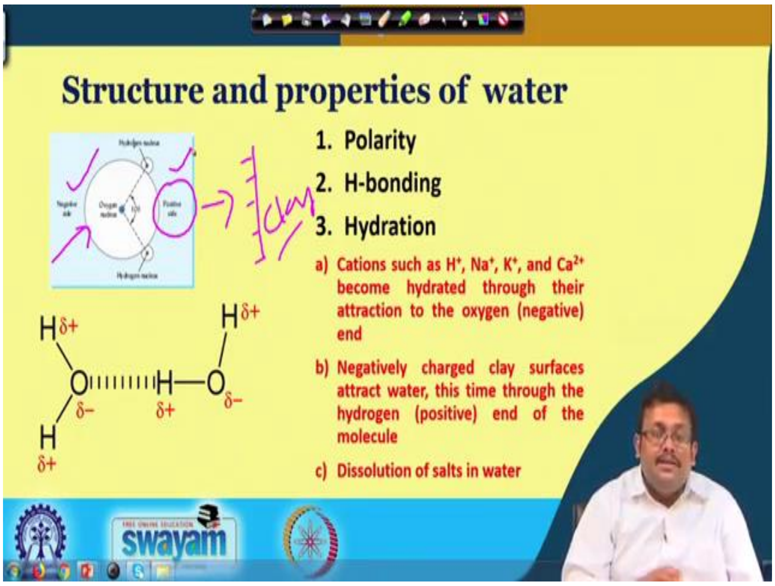

Another important property of soil is hydration; now you know that the cations such as you know H plus sodium, potassium and calcium becomes hydrated through their attraction to the oxygen or negative end. So, since these are positively charged; since these are positively charged cations.

These cations will attract to these negative side of the water molecule; they will attracted to the negative side of the negative end of the water molecular rather. And then negatively charged clay surface attract water with and this times to the hydrogen end of the molecule. So, this hydrogen end of the molecule is positive electropositive and it is get attracted to the negatively charge clay surfaces.

And we will discuss how these negative charge develop in the clay surfaces later on. So, as a result of this attraction also these water molecule get absorbed over the clay surfaces. And so the third important aspect of hydration is due to this polarity nature of the water molecule.

When there is a you know when there is a salt present the salt easily dissociate or dissolutes within the water due to polarity nature of the water. Because, you know soil basically contain some cations and anions and cations will be attracted to the electronegative end that is this end and the anions will be attracted to this electropositive end there by dissoluting in the water. So, this is responsible for hydration.

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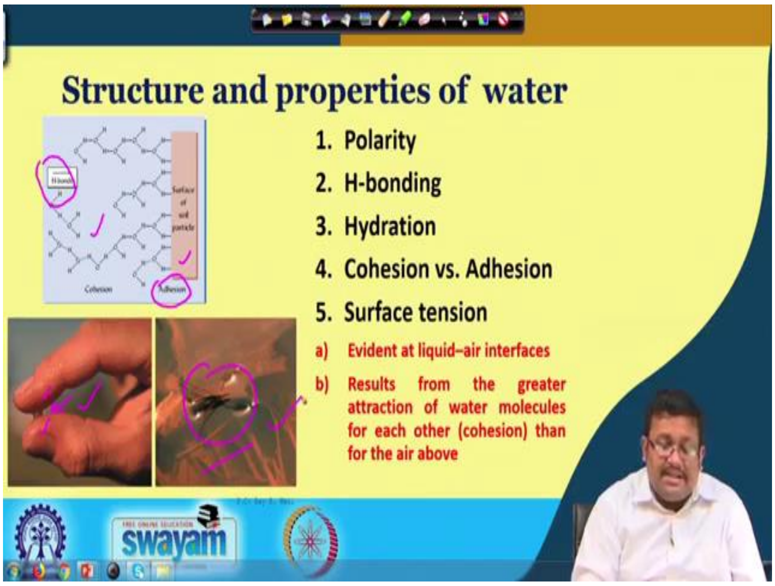

So, another important is cohesion and adhesion is you can see in this picture this is showing the manifestation of cohesion and adhesion. Obviously, the cohesive forces we can see basically developed due to the hydrogen bond between the individual water molecules.

And ultimately these water molecules are absorbed over the surface of the soil particles because in the last slide I have already told you because these surface of the soil particles develop negative charge. And as a result the positive end of this water molecules attracted to this negatively charge colloids or negatively charge soil particles and they attach.

And as a result there is an adhesion. So, adhesion is basically when water molecule attached to the soil or clay; clay particle and when water molecule they attach to another water molecule that is cohesion. And; obviously, you can see the manifestation of cohesion in this picture where you can see water in you know in between thumbs and index finger; obviously, it is showing boat adhesive nature of the water and also cohesion you can see which is forming the continuous water in between these two fingers.

Continuous this is basically showing the cohesive nature and as well as when the water is you know sticking with the skin that is the manifestation of adhesion. So, another important aspect is surface tension now surface tension; obviously, occurs at the liquid and air interfaces. And remember that it results from the greater attraction of water molecules for each other or in another words it is a cohesive forces than for the air above.

As you can see this insect is moving over the water surface and it is creating some depression. Just like there is an elastic membrane over the water surface and you know otherwise in you know I mean instead of sinking; they are forming this depressed water surface. And this depressed water surface is basically due to the cohesive nature of the water molecules. And due to the cohesive nature of the water molecules there is a some bends and this is an expression of surface tension. So, this is another important property of water.

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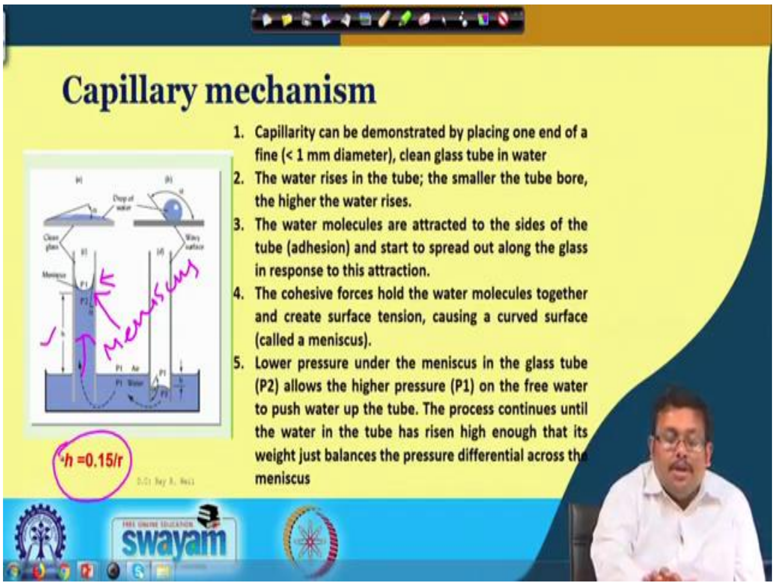

Let us discuss another important mechanism of water that is capillary mechanism. So, if you have a tube with a fine tube with less than 1 millimeter in diameter; less than 1 millimeter diameter and clean glass tube.

So, if you push that that glass tube into the water just like here; you will see that the water will rise into the tube and; obviously, the smaller the tube bore the higher the water rises. So, in other words there is an inverse relationship between the height of the water inside the tube and the diameter of the tube.

So, there is an inverse relationship and obviously, the water molecules are attracted to the sides of the tube due to the adhesive nature as you can see size of the glass due to the adhesive nature and I will start to spread out along the glass in response to this attraction and the cohesive force.

So, two types of force are basically you know acting here; one is adhesive force between the glass and the water and the cohesive force of water molecules. And remember that the cohesive forces hold out water molecule together and create a surface tension. Because and as a result of the surface tension it causes a curved surface and this is this curved surface we call it a meniscus.

And this is called the curved surface is called meniscus. And remember that the lower pressure under the meniscus in the glass tube allows the higher pressure of the free water to push the water into the tube here. And the process continues until the water in the tube as risen high enough that it is weight just balances the pressure differences across the meniscus.

This is called the capillary the height of the water inside the tube is basically follows this relationship and there is a derivation of this relationship; obviously, we are not going to that details hm. So, generally this relationship is present when there is a capillary mechanism. So, capillary mechanism is very important as for as the water is water property is concerned.

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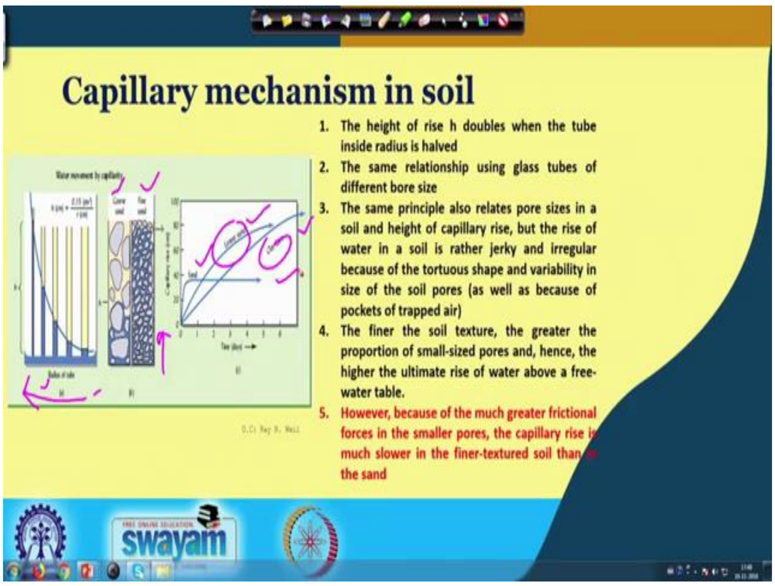

And capillary mechanism of water also shows us manifestation in the soil water. So, remember that as I have already told you the height of the rise h; the height of the rise h it doubles when the tube inside the radius is half. And as you can see when we are decreasing the radius of the tube; obviously, in this way; the height of the rise is getting almost doubled in the successive tubes. And the same relationship using glass tube different bore size and the same principle also relates pore size in a soil and height of capillary rise.

But, the rise of water in a soil is rather jerky or irregular because of the tortuous shape and variability in the size of the soil pores as well as because of the pocket of the trapped air. So, you can see here there are two different types of soil one is coarse sand another is file sand. So; obviously, in case of coarse sand there are only macro pores and in case of fine sand; the pore size is quite small when as a result the capillary rise of water is quite high in case of fine sand then that of coarse sand.

However, the rise of the water is not as regular as you can see in the left most picture and this is a somewhat irregular because of water trapped. And you know irregular nature on you know and tortuous shape and variability in the size of the pores. And remember that the finer the soil texture the grater the proportion of small size pores and hence the higher and ultimate rise of water above the free water level.

So, as you can see in this picture; obviously, we can see as the you know that finer the soil texture; obviously, here three different types of soil sand, loamy sand and clay loam and clay loam is; obviously, more finer in soil texture. And they; obviously, contains lows or small size more small size pores and the height you know higher the ultimate rise of water above the free water level obviously, in this clay loam soil there will be capillary rise; higher capillary rise than that of other two you know coarse texture soils.

However, because of much greater frictional forces in the smaller pores; the capillary rise is much slower in the finer texture soil than that of the sand. As you can see the both of this soil like you know clay loam is a fine texture soil and loamy sand is a coarse texture soil. And the capillary rise in case of clay texture is much slower than that of fine texture the capillary rise of water in clay loam is much slower than that of coarse texture loamy sand.

So, this slide basically shows a representation or the application of capillary mechanism in soil.

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So, capillary movement in soil water can be can be occur in both the direction. So, you can see here there are two different pictures I have given one is surface run off collection basin you can see here. And in this surface run off collection basin; obviously, you can see the water is moving or capillary water is moving both in horizontal direction and in vertical direction and in the stream bank; obviously, water is moving through capillarity in a vertical direction. So, that is you know that implies that the capillary movement of soil water can be in both directions.

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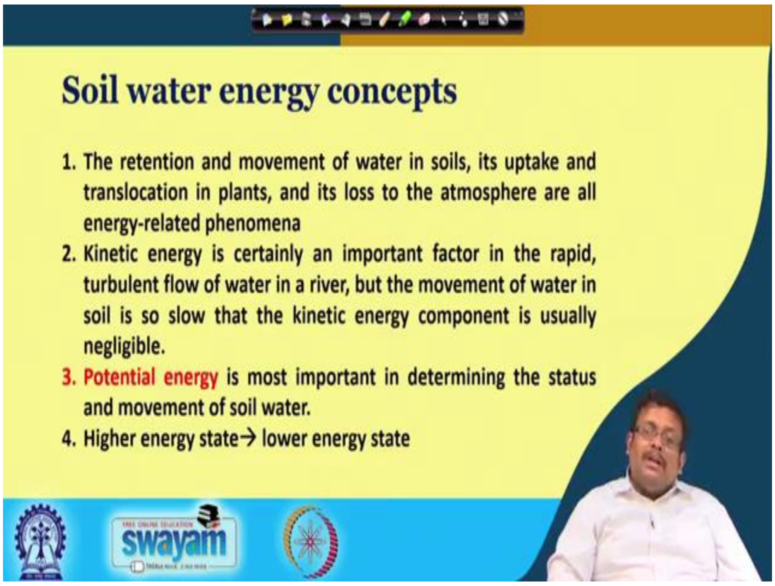

Now, let us start the soil water energy concept; the retention or movement of water is soil and it is uptake and translocation in plants and it is loss to the atmosphere are all energy related phenomena; obviously, just like any other processes like physical processes in the universe the water movement is also energy related phenomena.

Now; obviously, remember that the kinetic energy is certainly an important factor in the rapid and turbulent flow of water just like in a river. But the movement of water in soil is so slow that the kinetic energy component is usually very much negligible. And generally potential energy is most important in determining the status and movement of soil water.

So, remember one thing very important point that whenever we talk about soil you know soil; you know energy state where generally you know we are generally denoting the potential energy and remember that the soil water will always move from a higher energy state to lower energy state.

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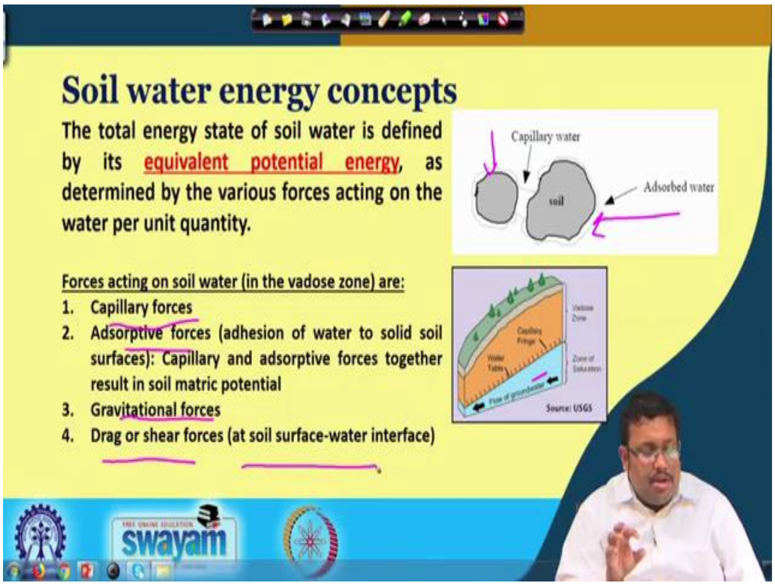

So, the total energy is state of soil water is defined by it is equivalent potential energy as determined by various forces acting on the water per unit quantity. And remember that there are forces acting there are several forces acting on soil in the vadose zone.

So, what is vadose zone? If you see in this picture; obviously, at the bottom there will be zone of saturation or groundwater; I just off the groundwater you will see the soil layer and at the you know interface between or at the juncture of this ground water and this soil there are some capillary fringe.

Capillary fringe are basically the movement of water through capillary and when it occurs up to very certain distance. Above the capillary freeze the unsaturated zone is the total unsaturated zone is called the vadose zone. And in the vadose zone; obviously, vadose zone already also contains the capillary fringe.

Now, in this vadose zone there are 4 different you know forces basically operates. One is capillary force another is adsorptive force remember there is this adsorptive force; it is basically adhesion of water to the soil surface as you can see these are adsorb water we have already discussed that. So, capillary and adsorptive force together results in soil matric potential; we will discuss the matric potential remember.

So, capillarity and this adsorptive force basically combine to form the soil matric potential. Another is gravitational forces due to gravitational attraction and finally, there are some drag or shear forces at soil surface water interface this. So, these are important forces which act on soil water and we will discuss this later on in our subsequent lectures. So, hope you have got a basic idea about water and it is important properties. And we just started the soil water energy concept and we will start we will try to finish this soil water energy concept in our next lecture. So, till then.

Thank you.