Soil Science and Technology
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Lecture – 16
Soil Water Movement

Welcome, friends to this week 4 of this course that is Soil Science and Technology. And in this week, we will be covering different aspects of soil water. We will be covering the flow of liquid water into the soil and different measurement of soil water. And we will also cover layers and then soil temperature and different related numerical problems.

So, in this first lecture, we will start the flow of liquid water into the soil and we will try to finish it. And this flow of liquid water into the soil and then we will go to the next topic of soil water. That is the different content different, you know, gravitational water. What is the plant available water and then what is bulk, what is field capacity, what is permanent wilting point; we will cover in the next lecture also.

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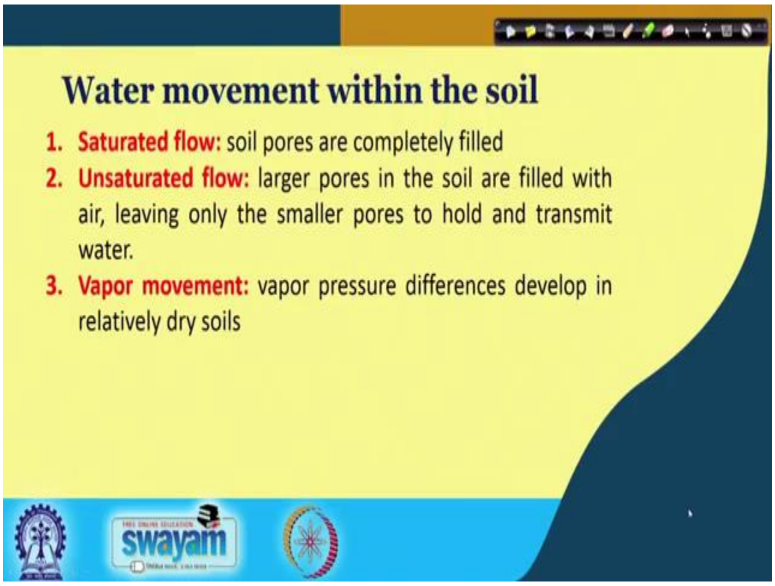

So, let us start with this flow of liquid water into the soil. And in this lecture, we will be basically covering different saturated and unsaturated flow and vapor movement within the soil so and their different aspects. So, water movement within the soil can be of three types.

One the first one is saturated flow, the second one is unsaturated flow and the third one is vapor movement. Now, in case of saturated flow, the major characteristics of saturated flow is soil pores are basically, you know, are completely filled.

So, saturated flow occurs when the soil pores are completely filled, unsaturated flow occurs when larger pores in the soils are filled with air leaving only the smaller pores to hold and transmit water. So, this is the difference between saturated flow and unsaturated flow.

And finally, another type of movement is called vapor movement. And vapor movement basically occurs due to vapor pressure differences developed in relatively dry soils. So, let us start with the saturated flow.

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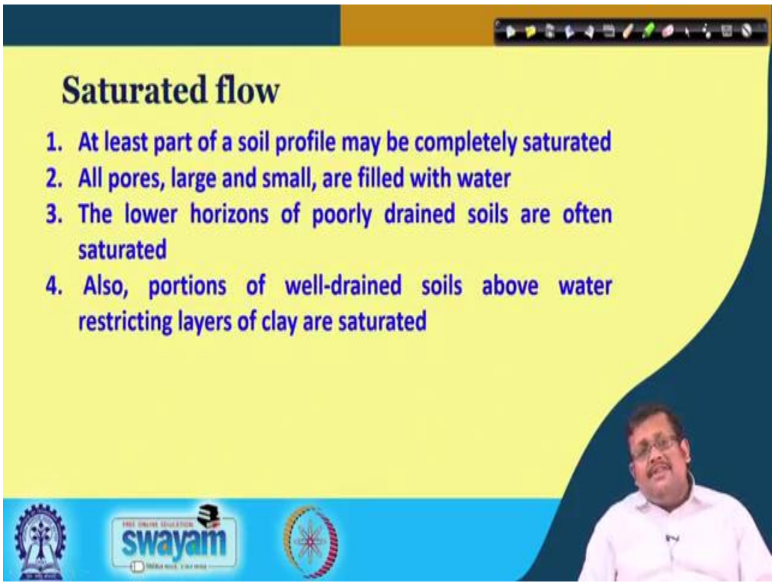

So, saturated flow is basically at least part of the soil profile may be completely saturated. For occurring the saturated flow, a part of the soil profile maybe completely saturated, all pores both large and small pores. That means, macro pores and micro pores should be filled with completely filled with water and the lower horizon of poorly drained soil are often saturated you must know that.

And remember that the portions of well drained soils above water restricting layers of clay are also saturated. So, again saturated flow occurs when, you know, soil profile is completely saturated. And part of the soil profile may be completed saturated and all the pores, both micro pores and macro pores are filled with water. And lower horizon of a poorly drained soils are often saturated. Whereas, the portion of well drained soils above water restricting layers of clay are also saturated.

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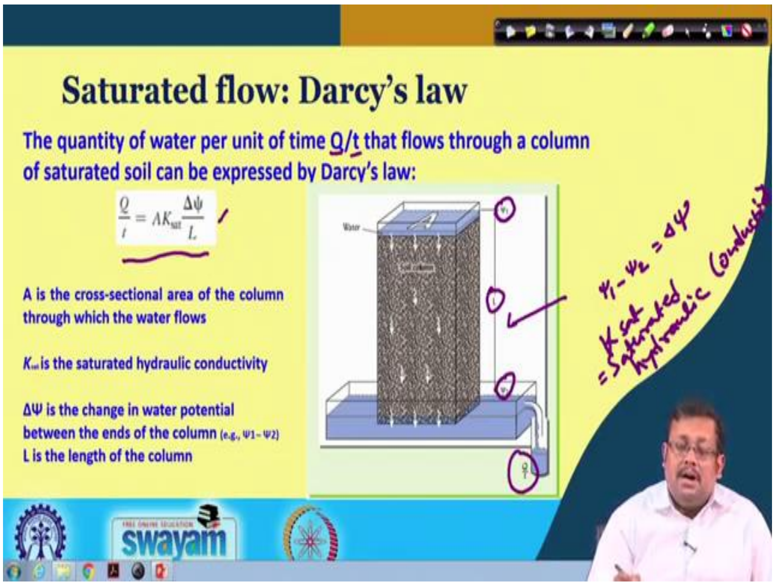

Now, saturated flow of water within the soil basically obeys a law; we call it Darcy's law. Now, the quantity of water according to Darcy's law let us see, the quantity of water per unit of time, that is, if we denote the quantity of water by Q and time as t. So, the quantity of water per unit of time, that is Q by t that flows through a column of saturated soil can be expressed by Darcy's law.

That is Q by t equal to A multiplied by K_{sat} and multiplied by delta psi over L. Now you see there is a soil column in this picture ok. And the length of the soil column is L denoted by L. And the cross section is basically A. This cross sectional area of the water column is A through which water flows. And the potential at the top of the soil column is psi 1.

Whereas the potential at the bottom of the bottom of the soil column is psi 2 so, as you can see, water is moving through this soil column. And finally, it is, you know, there is an outlet where water is emitting at a rate of Q by t. So, here K_{sat} in this equation K_{sat}. So, we already know Q is the quantity of water, t is the time. Here A is the cross sectional area, delta psi is basically the difference between potential at the 2 points. So, delta psi is basically the change in water potential between the ends of the column. So, and L is the length of the column.

So, the K_{sat} is basically the saturated hydraulic conductivity. Saturated hydraulic conductivity. It is very much important for different irrigation and other soil water movement purposes also, we will discuss. So, this is called Darcy's law. Let us see what is the implication of saturated hydraulic conductivity.

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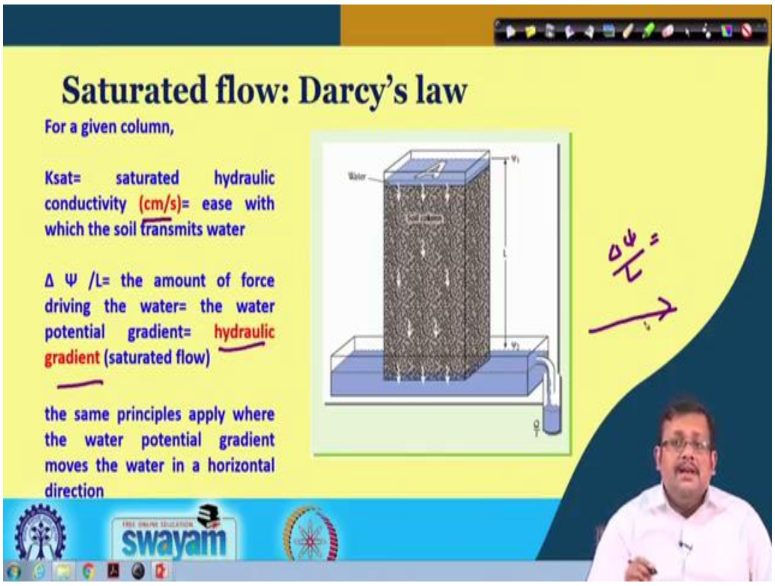

So, for a given column, this K_{sat} or saturated hydraulic conductivity is expressed in the unit of centimeter per second. And basically it denotes the ease with which the soil transmits water. Now you know this term that is delta psi by L; it basically shows the amount of force or the amount of force that driving the water. We call it sometimes the water potential gradient and in case of saturated flow, it is termed as hydraulic gradient. It is very very important.

And remember that, this principles of water movement through this, you know, saturated soil columns also, you know, also the same principal also applies; when the water potential gradient moves the water in a horizontal direction. So, this is a point to remember.

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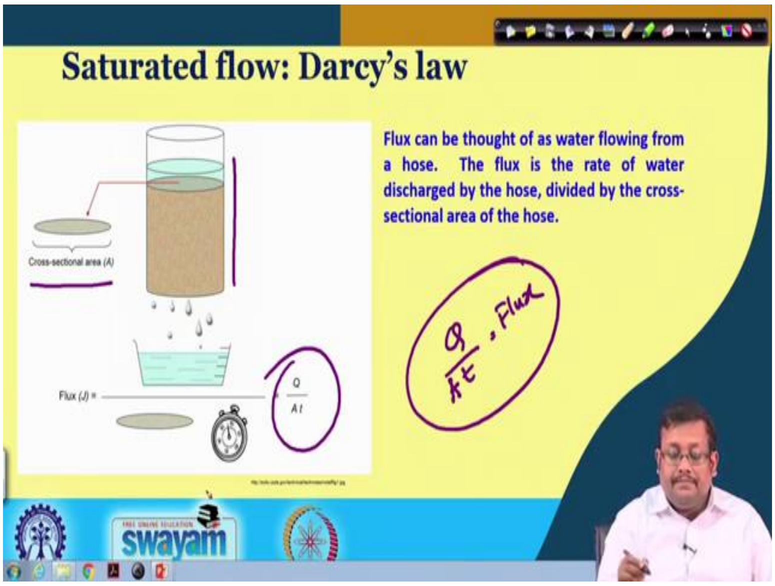

So, let us see what is the practical implication. Now, in case of saturated water flow, this flux this flux is basically Q by t, Q by t equal we call it flux of water. Now this flux can be thought as a water flowing from a hose, when we are watering the garden through a hose, the flux can be thought as a water flowing from that hose.

Remember that, the flux is the rate at which water is discharged by the hose which is divided by the cross sectional area of the hose. So, flux is basically Q over A into t. So, it is the rate of water discharged by the hose by the cross sectional area of the hose. So this is called the flux. So, this is the, if we consider this is the hose and; obviously, this is the cross sectional area A so, flux can we calculated as Q by, you know, Q by A multiplied by t.

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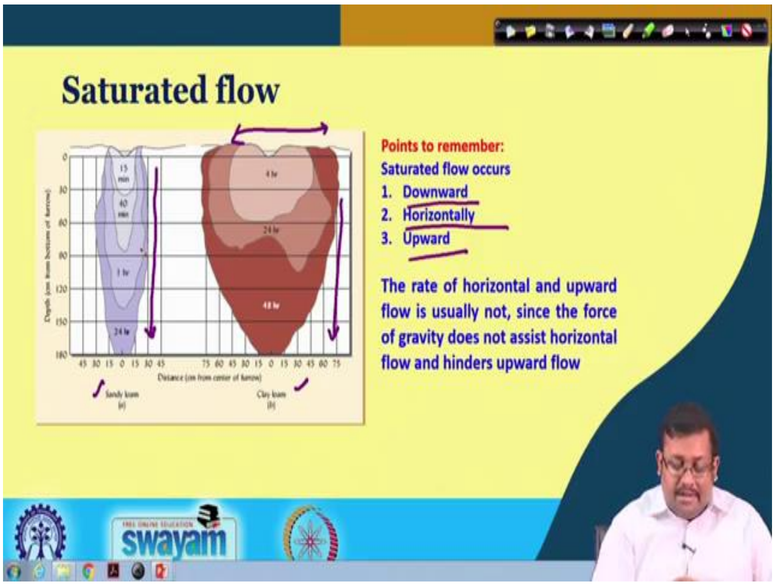

So, let us see what are the important points to remember in case of saturated flow. Remember that so remember that, in case of saturated flow, saturated flow can occurs both downward, horizontal and upward direction. However, the rate of horizontal and upward flow is usually not similar than that of, you know, than that of a downward flow.

Because the force of gravity does not assist horizontal flow and also hinders the upward flow. So, because of this reason, the rate of horizontal and upward flow is not equal to the rate of downward movement of water though a saturated water saturated soil column. Now if you see this picture I have shown here two example; one is sandy loam soil another is clayey soil. In case of sandy loam soil, you see the rapid downward movement of water through the saturated, you know, in case of saturated flow.

However, this rapidity is quite less in the downward direction in case of clay loam soil which is more fine textured soil. However, their horizontal movement is quite high than that of this sandy loam soil which is coarse textured soil. So, depending on the textural classes also the direction of saturated flow also differs.

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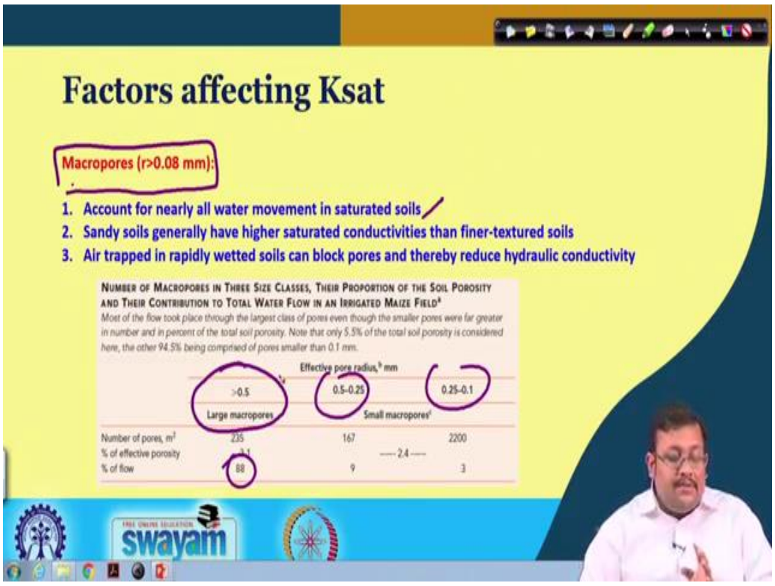

So, so what are the important factors that affect the saturated hydraulic conductivity? First of all, the macro pores. The macro pores are, you know, those pores we have already discussed this macro pores. Macro pores are those pores which are having a, you know, radius of greater than 0.08 millimeter.

Now these macro pores account for nearly all water movement in saturated soils. And remember that sandy soils in a know so this, you know, I have, you know, again let me tell that these macro pores account for nearly all the water movement in case of saturated soil. So, this can be, you know, more, you know, evident from this table.

Where you can see the number of macro pores in three size classes, their proportion of soil porosity and their contribution to total water flow in an irrigated maize field. You can see that most of the flow took place through the largest class of pores that is large macro pores. And there are other smaller pores we call them small macro pores and you can see percentage of flow 88 percentage of flow is accounted by this large macro pores.

So, these results also support the idea that nearly all water movement in the saturated soil occurs through macro pores. Now, sandy soils generally have higher saturated conductivity than fine textured soil. Because obviously in case of sandy soil, the number of macro pores are quite high. And air trapped in rapidly wetted soil can block pore and thereby reduce the hydraulic conductivity. So, this is also very important in case of, you know, macro pores.

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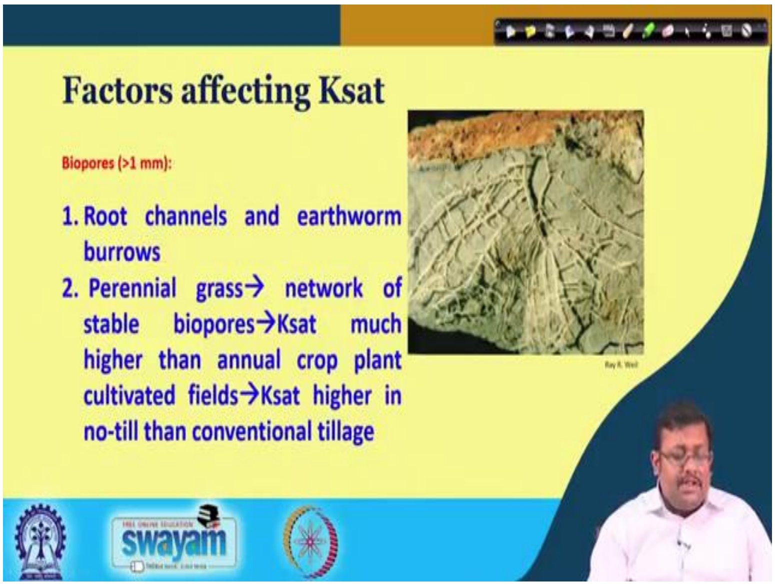

So, what are the important aspects? So, another important macro pore is called bio pores. We have already covered bio pores in our previous lectures. So, another important type of macro pores are bio pores and bio pore we have already learned about bio pores in our previous lecture. Now bio pores are generally having a radius of greater than 1 millimeter.

And you know that these bio pores are basically root channels and earthworm, you know, created through root channels and earthworm burrows. And these bio pores help in saturated water flow and also it affects the water, you know, saturated, you know, water, you know, hydraulic conductivity. So, if we consider perennial grasses so, in the perennial grasses are responsible for creating a network of stable bio pores.

So obviously the saturated hydraulic conductivity in case of soil which supports the perennial, you know, which supports the perennial grass will be much higher than that of a, you know, with than that of soil which is maintained under annual crop plants. Because for growing the annual crop plants you have to up root all the perennial grasses and as a result you are breaking down all the bio pores also.

So, once we have breaking down the bio pores; obviously, the saturated hydraulic conductivity is going further down. So, again in case of soil which is maintained at the perennial grass, the saturated, saturated hydraulic conductivity is quite higher than that of, you know, the soil which is cultivated with annual crop plant.

And that is the reason that the saturated hydraulic conductivity is higher in no tillage condition than that of conventional tillage. So, this is another advantage of using conservation tillage or in other words no tillage than that of conventional tillage.

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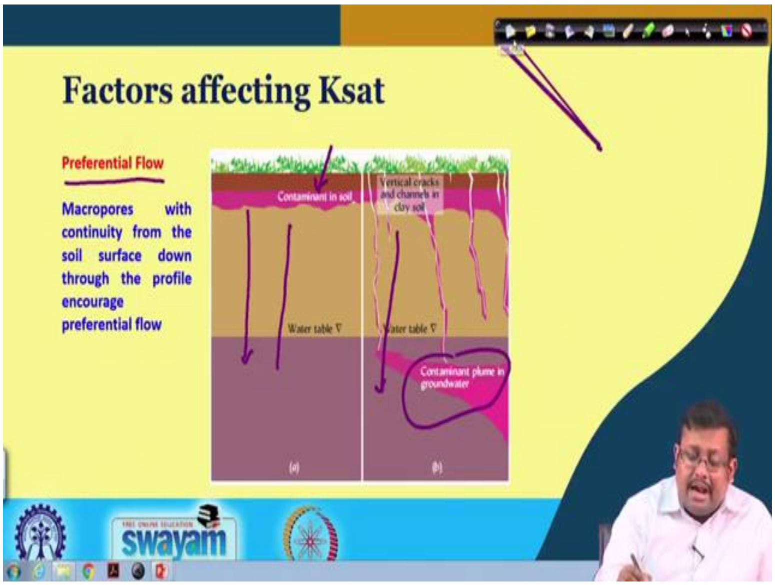

So, let us see what are the other factors affecting saturated hydraulic conductivity. So, saturated hydraulic conductivity let us see such, you know, there is another important term called preferential flow. So, I have shown here two pictures; in the first picture what happened, there is a, you know, there is a contaminant, you know, there is a deposition of contaminants into the soil or there is a spillage of contaminant into the soil.

And it is generally thought that these contaminant will take time to reach into the water table which is far below the soil. However, the macro pores it has been found after certain period of time that this contaminant has been already leached, are already, you know, already reached the water table and contaminating, you know, and you can see the contaminate plume in the groundwater. And this occurs because of vertical cracks and channels in the clay soil. So, macro pores with continuity from the soil surface down through the profile encourages the preferential flow.

So, this is also very important if there is a flush of rain fall; obviously, that will help in movement of contaminant through the soil and ultimately it reaches into the groundwater to contaminate the groundwater. Preferential flow is very much important which also affect the saturated, you know, saturated hydraulic conductivity.

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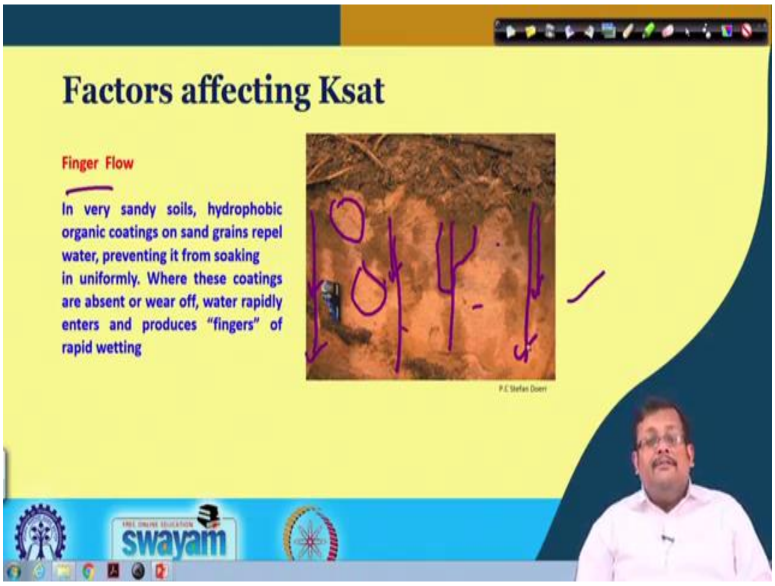

Another important term is called finger flow. Now finger flow is as you see in this picture in very sandy soil, hydrophobic organic coatings on sand grains repel water. Because you know when there is a hydrophobic, it will repel the water and when there is a hydrophilic it will attract water.

So, hydrophobic organic coatings are there in case of very sandy soil over the sand. So, as a result of this hydrophobic coating, it will prevent the soaking of soil by water uniformly and where these coatings are absent or weared off, water rapidly enters and produces fingers of rapid wetting.

So, you can see in this picture; obviously, this is a very sandy soil and this sandy soil may contain some hydrophobic hydrophobic compounds. And these hydrophobic compounds are present in all over the places and these hydrophobic compounds will basically prevent. They may be present here, they may be present here. So, all these hydrophobic compounds are prevent basically or repel the water, repel water.

So, preventing the, from soaking it uniformly. Otherwise, it will it would have been uniformly soaked. So, when these coatings are absent or weared off water rapidly enters. So, you can see in this area these coatings are weared off. So, water is rapidly moving through this finger like zones. So this is called finger flow of water. So, this is also very much important.

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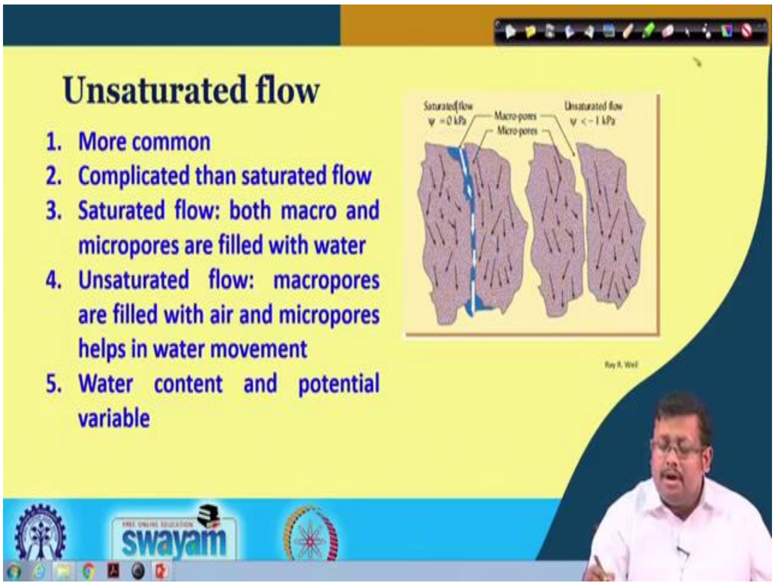

So, let us see about unsaturated flow. Now remember that unsaturated flow is more common than that of saturated flow and it is complicated than that of saturated flow. Remember in case of saturated flow, it occurs when macro pores both macro pores and micro pores are filled with water.

However, in case of unsaturated flow macro pores are filled with air and micro pores helps in water movement. And remember that these in case of unsaturated flow the water content and potential are variable. So, as you can see in case of saturated flow the potential is 0.

So, both the macro pores and micro pores are filled with water. And in case of unsaturated flow when there is a less or negative potential, all the macro pores will be drained and only the water will flow through these micro pores. So, this is an example of unsaturated flow. And this is very important from the point of view of soil water movement.

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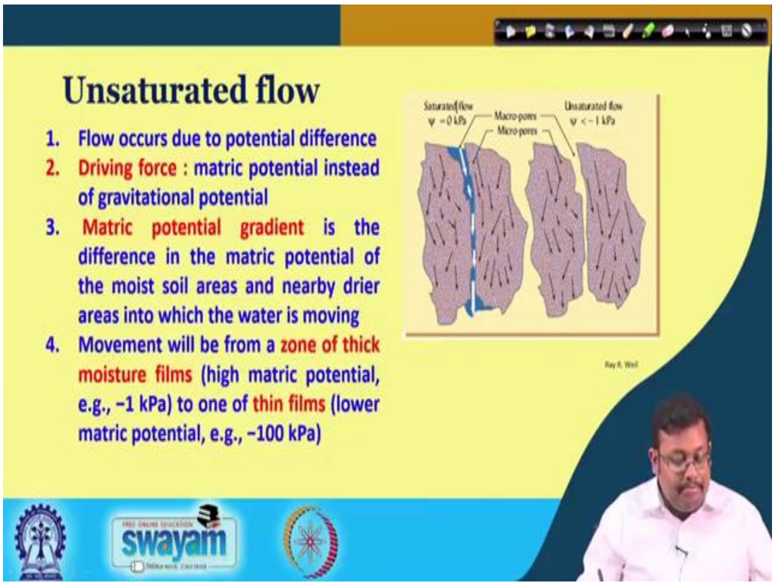

So, this unsaturated flow occurs due to potential difference and in case of unsaturated flow remember the driving force is matric potential instead of gravitational potential. So, in case of saturated flow you remember that we are calculating this, you know, hydraulic gradient where this length is, you know, very much important.

However, in case of unsaturated flow, this matric potential is very much important than that of a gravitational potential. And matric potential gradient is the difference in the matric potential of the moist soil areas and nearby drier areas into which the water is moving. So, water will always move from higher matric potential to lower matric potential.

Lower matric potential means the attraction for water from the soil matrix is quite high. So, water will move from higher matric potential to lower matric potential areas in case of unsaturated flow. And movement will be from a zone of thick moisture films; obviously, higher matric potential, example by this 1 kilo Pascal to 1 thin films to one of thin films that is lower matric potential that is minus 100 kilo Pascal.

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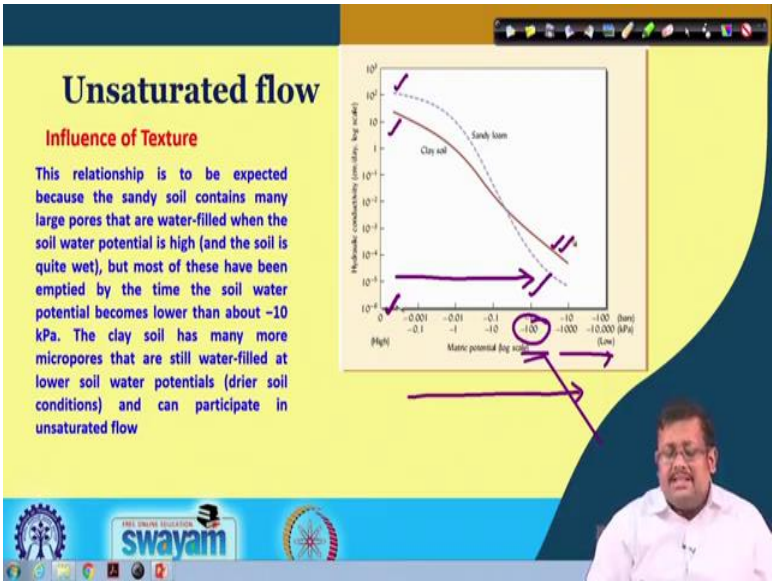

So, this slide shows the influence of texture as you can see we have plotted here the matric potential with log scale in the x axis and at the y axis there is a hydraulic conductivity. So, you can see that there is relationship is to be expected because we can see at higher matric potential or I would say at higher matric potential means high water content.

Obviously, the hydraulic conductivity is quite high in case of sandy soil then that of a clayey soil and the trend, you know, alters and the trend reverse when the matric potential is quite low that is low moisture content. So, this relationship is to be means quite, you know, expected because in sandy soil contains many large pores that are water filled when the soil water potential is high and the soil is quite wet.

But most of these have been emptied by the time the soil water potential becomes lower; that means, in this zone. So, when the soil water potential lower down from 0 to minus 100 kilo Pascal. Obviously, you know, these larger macro pores will emptied first leaving only the micro pores which are present in clay soil. So, the clay soil has many more micro pores that are still water filled at lower water potential at this point.

So, in the drier soil condition and in this condition they can participate in unsaturated flow. So you can see at lower matric potential or in another words the lower moisture content, these clay soil are taking part, you know, are mostly important for unsaturated flow of soil water.

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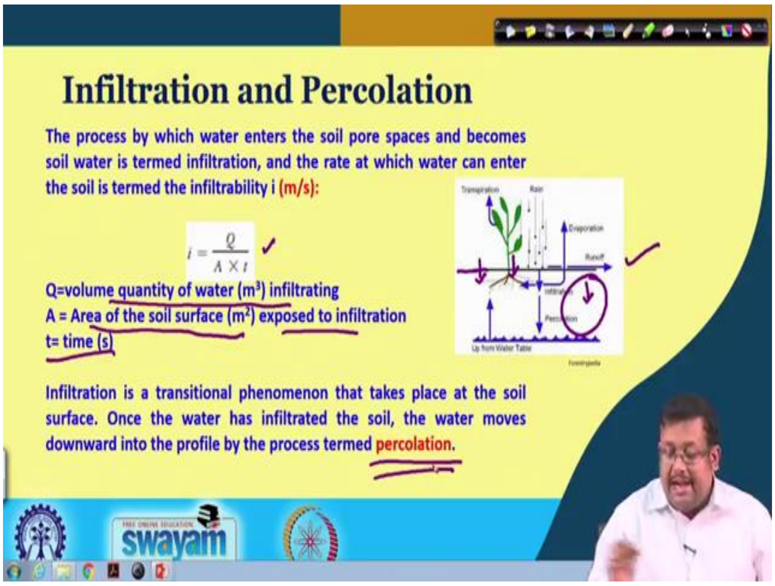

Another important term is infiltration and percolation. Now infiltration is the process by which water enters in the soil, water enters the soil pore space and become soil water. And the rate at which the water can enter into the soil is termed as infiltrability and we generally termed these as small i. And remember the form the unit of infiltrability is meter per second.

So, infiltrability is basically expressed in this term. So, i equal to Q over A into t; so where Q is the volume of quantity volume of quantity of water in cubic meter infiltrating, A is the area of the soil surface in square meter exposed to infiltration and t is time in second. So, infiltration is the transitional phenomena and remembers that infiltration is the transitional phenomena that takes place at the soil surface and remember that once the water has infiltrated into the soil, the soil water moves down downward into the profile by the process termed as percolation.

So, you can see in this picture, this is the soil surface so when there is an infiltration; obviously, it will be a surface phenomena water will enter into the soil. And once water is enter into the soil, it will move down to the soil profile and this movement of water in the soil profile it’s termed as percolation. It is also very much important. And so this is the difference between percolation and infiltration.

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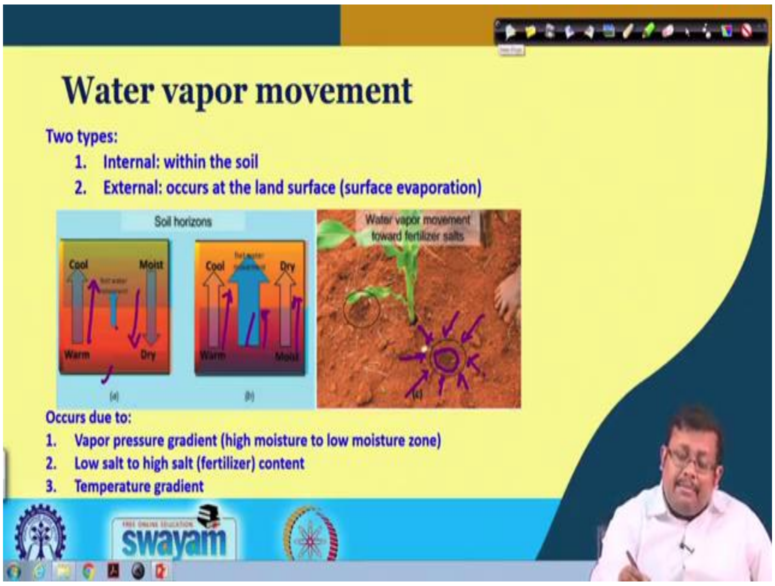

The last type of water movement is called water vapor movement. And water vapor movement can be of two types. One is internal which occurs within the soil, another is external which occurs at the land surface or we call it surface evaporation also. So, the water vapor movement basically occurs due to three major driving force.

The first one is vapor pressure gradient, that is, and vapor pressure gradient; that means, the vapor will move from the higher moisture to lower moisture zone. Obviously, when the moisture content is high; obviously, the vapor pressure will be high and when the moisture content is low, vapor pressure also will be low. So, vapor will always move from higher moisture content zone to lower moisture content lower moisture zone within a soil.

And low salt to high salt content, a low salt to high salt content or in other words, it is low fertilizer to high fertilizer content because when there will be low fertilizer content, there will be higher vapor pressure. Where as compared to when there will be high fertilizer content, there will be low vapor pressure. So, water will move from low salt or fertilizer content to high salt or fertilizer content. And thirdly is, water will always move from according along with the temperature gradient. That is, from high temperature zone to low temperature zone.

So, you can see this picture also it has been evident. So, in this first picture, you know, net water movement is basically nullified by, you know, opposite direction of this temperature gradient and moisture gradient. And here, the net water movement is quite high because in both the, you know, temperature gradient as well as moisture gradient acting in a single same direction. And finally, so the water vapor will move from, water vapor will move upward here and water vapor movement towards fertilizer salts is given, you know, showing in here.

So, in the Africa, these are small moist so peats where, you know, farmers are applying the fertilizers. And as a result, water vapor will move from, you know, the surrounding areas to this high fertilizer content area to further, you know, influence the reaction. So, this is how the water vapor movement occurs into the soil. And I hope that you have got a basic idea about different types of saturated flow, unsaturated flow and water vapor movement. And so let us wrap up here. And in the next lecture, we will start a new aspect of soil water.

Thank you very much.