Availability and Management of Groundwater Resources

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Lecture - 26
Law of Groundwater Movement, Darcy's Law and Application (Continued)

Welcome to you all in the part 2 of model 6, law of groundwater movement Darcy law and application. So, we have seen that the water movement in the aquifer is following certain law and according to the law the water moves from one aquifer to another aquifer. For knowing about the availability of the groundwater resources the concept is very important because it is not essential that in one formation you are having a good amount of groundwater resource.

But it will vary from place to place and from its different height also. So, in the last lecture we have seen that this pressure head; that is the hydraulic gradient, plays very, very important role for the water movement. So, in this part 2 module we will discuss a greater detail about some few more concepts which are very important for knowing about the groundwater flow behaviour inside the surface as well as some of the factors which are very important for the permeability.

Because movement whenever the word movement is there definitely it is very well related with the word permeability. So, we will see in this part the factors which are affecting the permeability. However, we have discussed in brief in the past lecture also but here it is just I have extrapolated the different phenomena different factors which are which are very essential for the movement of the groundwater flow inside the earth's surface.

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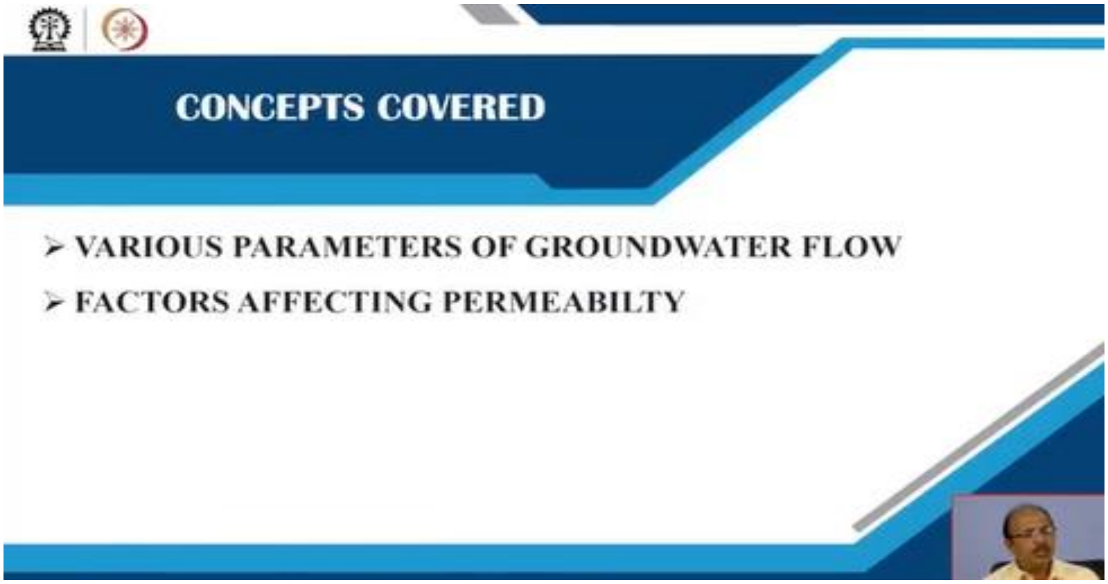

So, this groundwater generally the resource the ground resource is having some sort of velocity.

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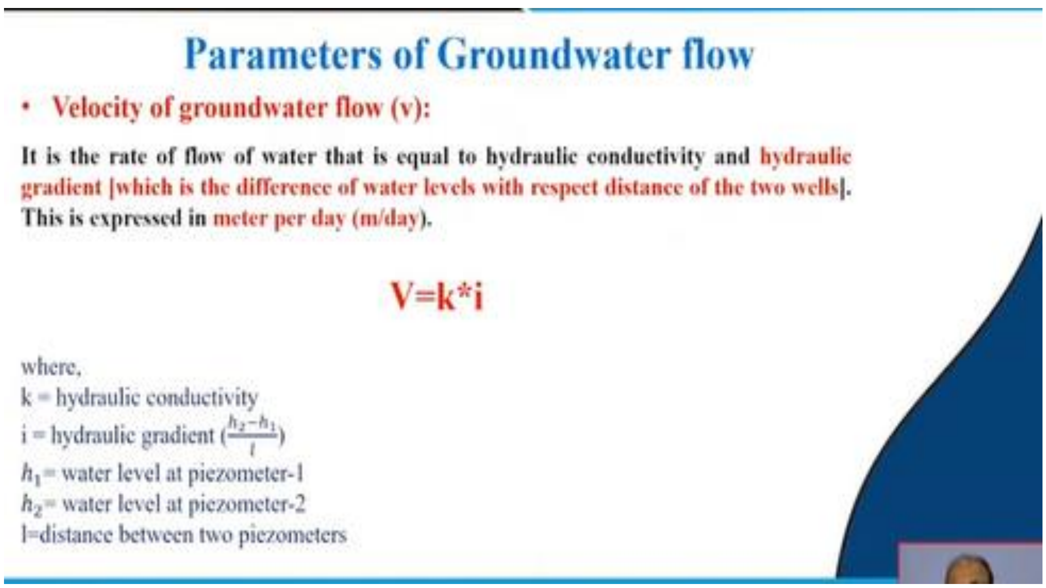

So, how to find out the velocity of ground flow inside the earth surface? So, it is the rate of flow of water which is equal to the hydraulic conductivity and hydraulic gradient that is the difference of water level with respect to the distance of the two wells. So, if you will just recall the previous lecture the hydraulic gradient you have seen the two different tubes were there and the two different tubes have the different hydraulic head and the distance between the two head tubes is generally; it was giving your hydraulic gradient.

So, hydraulic gradient is nothing but; it is the difference of water level with respect to distance of the two wells. Just if you will consider for the well it is for two wells what is the difference of water level with respect to distance. So, generally the velocity of ground flow small v is determined in meter per day. So, the formula

$$V = k*i$$

where i is the hydraulic gradient that is the difference in the pressure head.

$$i = \frac{h2-h1}{l},$$

k is the hydraulic conductivity, h1 is the water level at piezometer 1 and h2 is the water level piezometer 2, l is the distance between the two different piezometers. So, if the two different piezometers are here so in this piezometer the head is h1 say this is the water level of this. So, this is h1 and this is h2 now, water level at piezometer is h1 this is the water level. We have seen that the water level remains at a point because of the difference of the pressure.

So, as per the atmospheric pressure it the water level will also fluctuate within the well or within the tube. So, l is the distance, if this is the two different piezometers. So, this is l is the distance of between the two piezometers. So, we can find out what is the velocity of groundwater flow from one well to another well. If suppose this is the two well so from one well to two well what is the velocity of groundwater flow?

So, it can be find out by multiplying the i, i is the hydraulic gradient with your k and k is the hydraulic conductivity. So, with this formula we can find out your velocity of groundwater flow underneath the aquifers in the form of wells what we are seeing on the surface. So, generally this is the some more important concepts related to the groundwater movement or flow.

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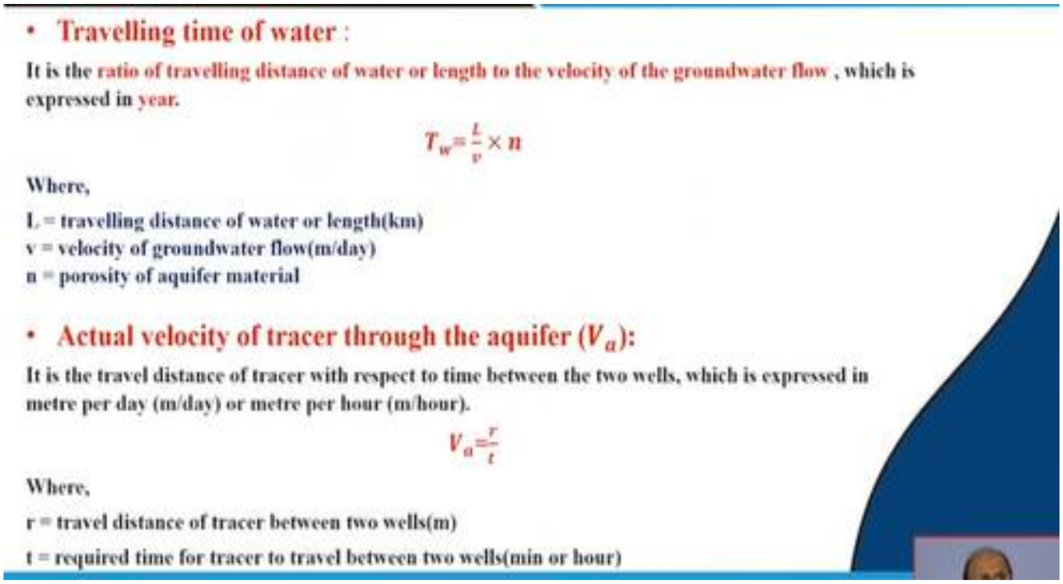

Now next is the traveling time of water; how much time it is taking, what is the length. So, it is the ratio of traveling distance of water, traveling time water is the ratio of the traveling distance of water or length to the velocity of the groundwater flow. So, this is just the ratio and it is travelling time water is generally expressed in year. Because we have seen in the previous slides or some previous lecture also, we have discussed that underneath the earth surface from one aquifer to another aquifer generally the movement of the groundwater remains very slow.

So, the travelling time of water is generally determined by

$$T_w = \frac{L}{v} \times n$$

Where,

L = travelling distance of water or length(km)

v = velocity of groundwater flow(m/day)

n = porosity of aquifer material

So, with this formula we can find out the traveling time of water underneath the earth surface. Now actual velocity of tracer to the aquifer. Now tracer is the substance through which we are generally adding to know about the just the flow path of the movement of the water inside the earth's surface. So, how we can calculate the actual velocity of tracer through the aquifer? It is the travel distance of tracer with respect to time between two wells.

So, if two wells are there one well two wells two different wells are there; so in two different ways. What is the time between the two ways tracer distance of this with respect to time between the two ways which is generally expressed in meter per day or meter per hour. So, we can see here the actual velocity

$$V_a = \frac{r}{t}$$

Where,

r = travel distance of tracer between two wells(m)

t = required time for tracer to travel between two wells (min or hour)

So, these two important your parameters for finding out the actual velocity of tracer to the any aquifer.

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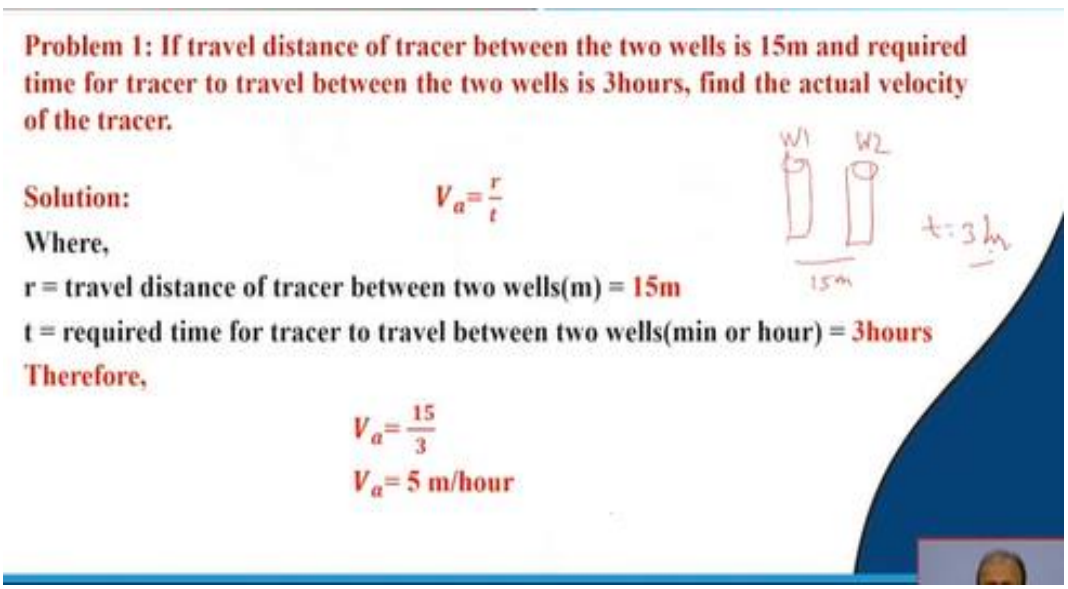

Now next problem 1: If travel distance of tracer between the two wells is 15m and required time for tracer to travel between the two wells is 3hours, find the actual velocity of the tracer.

Solution:

$$V_a = \frac{r}{t}$$

Where,

r = travel distance of tracer between two wells(m) = 15m

t = required time for tracer to travel between two wells (min or hour) = 3hours

Therefore,

$V_a = \frac{15}{3}$

V_a= 5 m/hour

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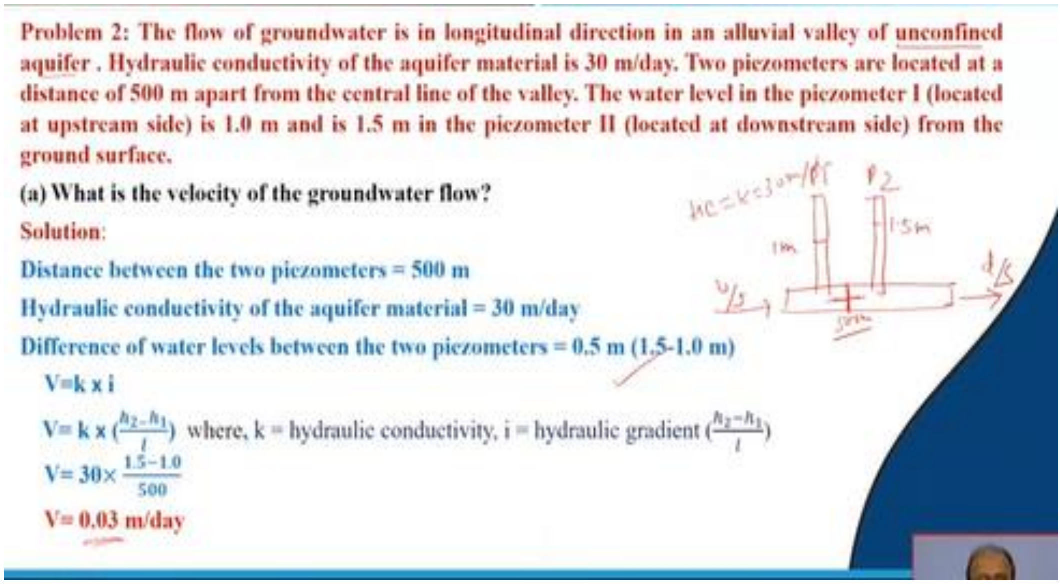

Now second numerical we will see the flow of groundwater is in longitudinal direction in an alluvial valley of unconfined aquifer. Hydraulic conductivity of the aquifer material is 30 m/day. Two piezometers are located at a distance of 500 m apart from the central line of the valley. The water level in the piezometer I (located at upstream side) is 1.0 m and is 1.5 m in the piezometer II (located at downstream side) from the ground surface. What is the velocity of the groundwater flow?

Solution

Distance between the two piezometers = 500 m

Hydraulic conductivity of the aquifer material = 30 m/day

Difference of water levels between the two piezometers = 0.5 m (1.5-1.0 m)

$$V = k \times i$$

$$V = k \times \left(\frac{h_2 - h_1}{l}\right)$$

where, k = hydraulic conductivity, i = hydraulic gradient ($\frac{h_2-h_1}{l}$)

$$V = 30 \times \frac{1.5-1.0}{500}$$

V= 0.03 m/day

So, in this way if we are having the concept, we can just solve the situation also, we can solve the problem also.

Only thing we have to frame our concept in the mind because our ultimate goal is to have the knowledge of availability of groundwater resources inside the earth's surface.

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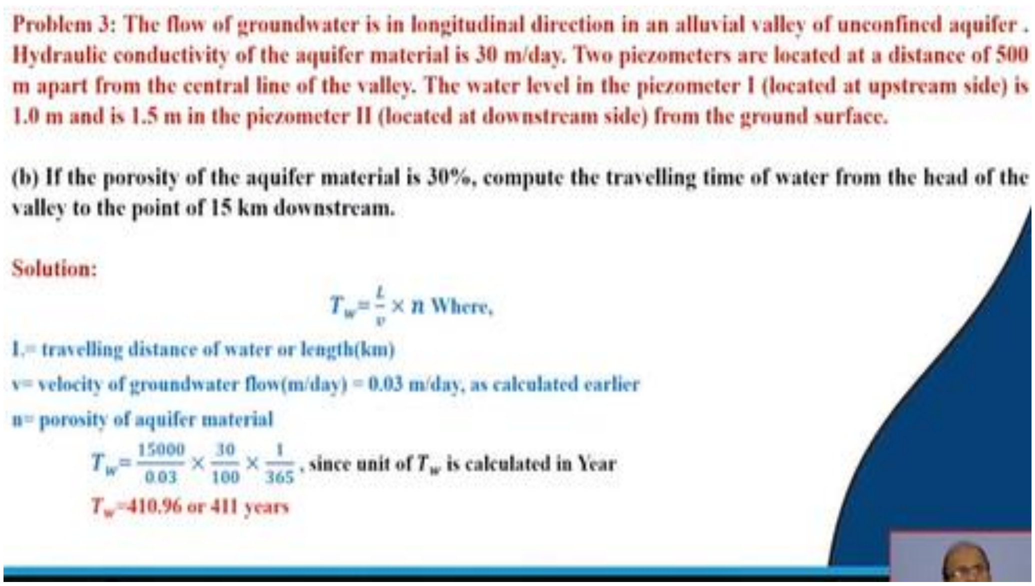

So, now this is the problem 3, The flow of groundwater is in longitudinal direction in an alluvial valley of unconfined aquifer . Hydraulic conductivity of the aquifer material is 30 m/day. Two piezometers are located at a distance of 500 m apart from the central line of the valley. The water level in the piezometer I (located at upstream side) is 1.0 m and is 1.5 m in the piezometer II (located at downstream side) from the ground surface. (b) If the porosity of the aquifer material is 30%, compute the travelling time of water from the head of the valley to the point of 15 km downstream.

Solution:

$$T_w = \frac{L}{v} \times n \text{ Where,}$$

L= travelling distance of water or length(km)

v = velocity of groundwater flow(m/day)

v = 0.03 m/day, as calculated earlier

n= porosity of aquifer material

$T_w = \frac{15000}{0.03} \times \frac{30}{100} \times \frac{1}{365}$, since unit of T_w is calculated in Year

T_w= 410.96 or 411 years

So, through this process we can find out the traveling time of groundwater flow inside any formations. If the porosity, hydraulic conductivity itself are given in the for the area.

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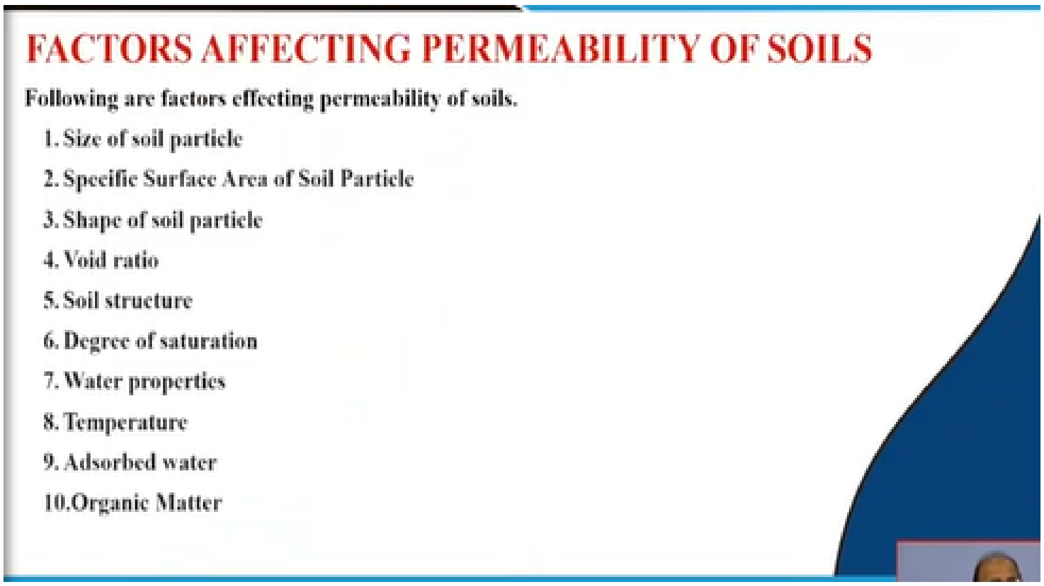

Now what are the factors which are important for your which are affecting the permeability of soil. Because the groundwater will flow through the soils through the porous media only. So, it needs some media for its movement. So, previously also we have discussed the factors but here just I have expanded those very factors because these are very important for knowing about the groundwater movement inside the earth's surface.

So, size of the soil particle, then the specific surface area of soil particle, then shape of the soil particle, wide ratio is also one of the important factors, soil structure, degree of saturation, water properties, temperature and absorbed water and organic matter. So, many factors are playing very important role. So, we can just think over that; something that some places we are having plenty of groundwater but at different places or at some other places we are not having groundwater.

So, these are the basic reasons because different factors are playing an important role and permeability is rated with the movement only, ability to transmit water is known as permeability or transmissivity also, these are related with the movement only.

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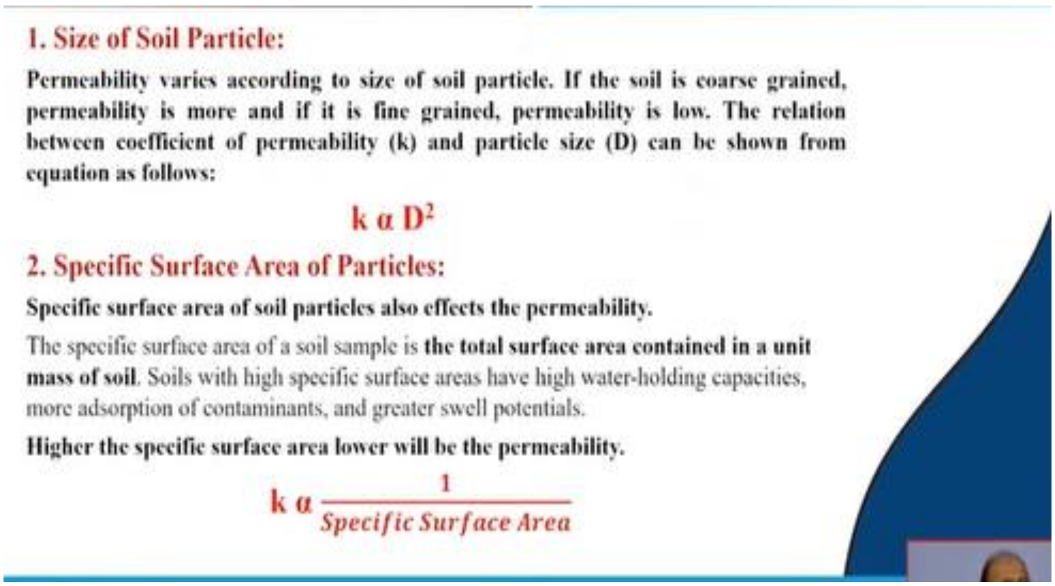

So, one by one we will discuss this thing. So, size of soil particle, permeability varies according to the size of soil particles. So, it is varying according to the size of soil particles. If the soil is coarse grained permeability is more and if it is fine grained permeability is low. So, the relation between coefficient of permeability and the particle size can be shown from equation

$$k \propto D^2$$

So, this is a very important relation because if the material will be coarser definitely the permeability will be more, if the material will be finer permeability low. Now a specific surface area of soil particles also affects the permeability. The specific surface area of a soil sample is the total surface area contained in a unit mass of soil. So, this is called as the total surface area. Now soils with high specific surface areas those soil which are having high specific surface area will definitely have high water holding capacity.

So, more absorption of contaminants will be there and greater swell potential is also there. So, this is about the specific surface area particle. Higher the specific surface area lower will be the permeability, this is the concept that if the specific surface area will be higher definitely the permeability will lower. So,

$$k \ \alpha \ \frac{1}{Specific\ Surface\ Area}$$

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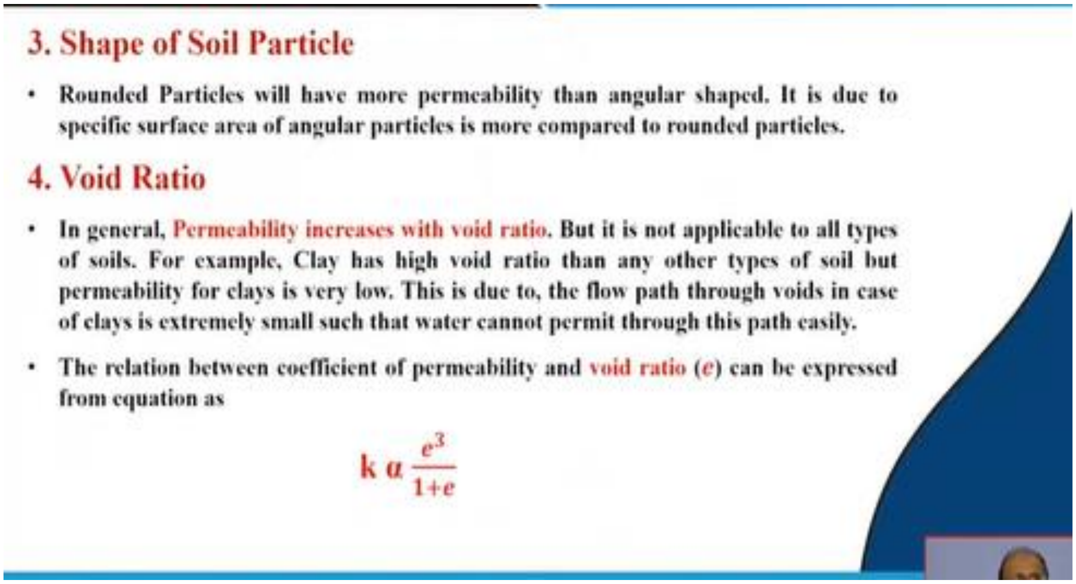

Now shapes of the soil particle, rounded particles generally have more permeability than the angular shaped and it is due to the specific surface area of angular particles which is compared by the rounded particles. So, rounded particles will have more permeability. Now void ratio, in general permeability increases with void ratio. But it is not applicable to all types of soil it is very important; it is not applicable to all types of soil.

Permeability generally increases with void ratio but for certain examples say for clay it is not applicable. You can see for example clay as high void ratio than any other types of soil say clay, silt, sand, gravel, pebble, cobble, older these are some of the sizes of the soil. So, clay has high void ratio then any other types of soil but permeability for clay is very low. That is why in the very beginning I have told you that whenever we are getting clay during the withdrawal of water say just, we are doing some sort of boring for taking out water from our well.

So, if we are just encountering the clay layer, we are avoiding the place, just we are shifting the place of the boring. Why? Because it is having high porosity. Since it is having high void ratio so more amount of water will remain stored here but problem is that its permeability is very low. So, maybe those amount of water will be used for certain period but after that what will happen? It is having no chance to either receive water not to send water to any aquifer.

So, that is why clay has high void ratio than any other type of soil but permeability for clay is very low. This is due to the flow path through voids in case of clay is extremely small so that the water cannot permit to; this path easily. And the relation between the coefficient of permeability and void ratio is generally expressed as

$$k \, \alpha \, \frac{e^3}{1+e}$$

So, we can see that permeability increases with the increase in void ratio.

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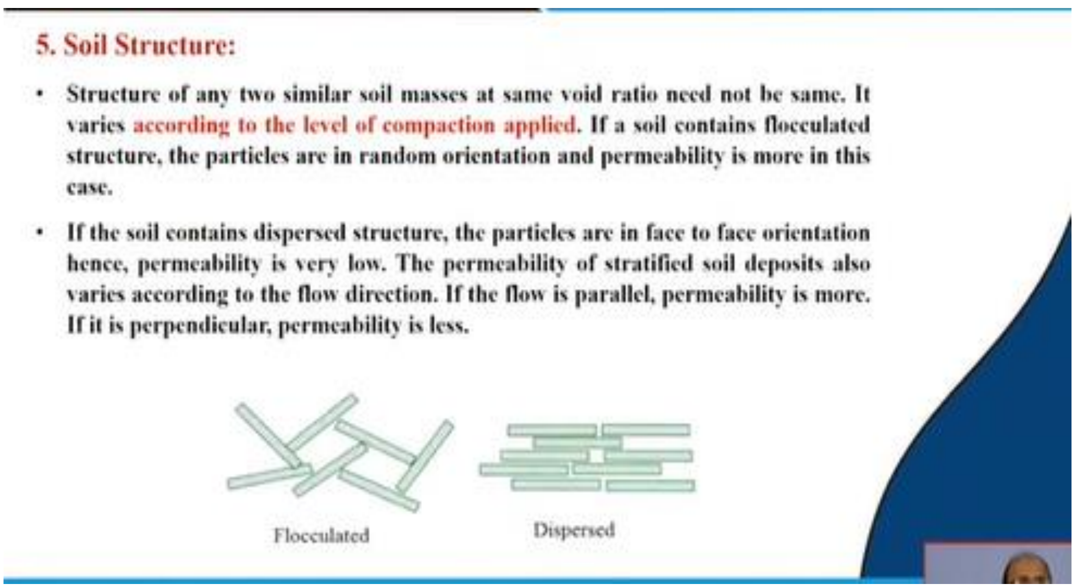

Now next is the soil structure, structures of any two similar soil masses at the same void ratio need may not be the same. It varies according to the level of compaction applied, how much the level of compaction is there. If a soil contains flocculated structure say we can see this structure is flocculated structure, then what will happen? Permeability is low here. The permeability of stratified soil deposits, this is the stratified soil deposits what is happening?

It also varies according to the direction, flow direction. If the flow is parallel then permeability is more, if it is perpendicular then permeability is less. So, this usually happens we are discussing this point because these all are very well related with the groundwater movement. And the module 6 is related with the groundwater movement and Darcy law only. So, here what we have seen that the if the soil contains some flocculated structure definitely the permeability will be something different.

Whereas the particles in random orientation the permeability is more in this case. So, this thing generally happens. Now in this we have seen that the soil contains dispersal structure. The particles are in phase, two phase orientation hence permeability is very low. We can see phase two phase orientation permeability is low but the permeability of stratified soil sample also varies according to the flow direction.

If the flow is parallel permeability is more if the flow is perpendicular permeability is less. So, this is the concepts related to the soil structure.

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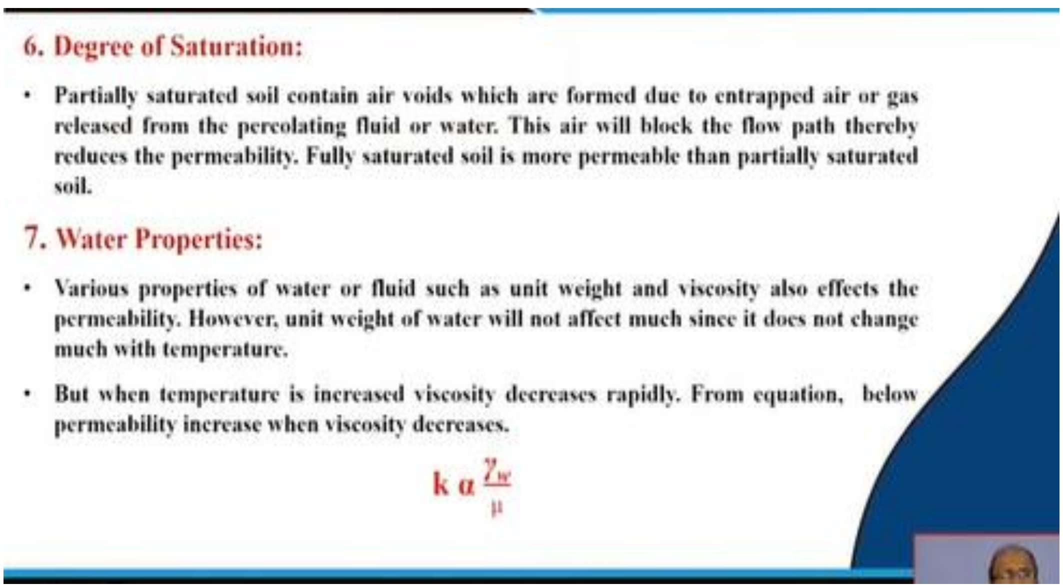

Now, degree of saturation, partially saturated soil contains air voids if the soil is partially saturated not fully saturated. If partially saturated soil will be there definitely air voids which are formed due to the entrapped air or gas released from the percolating feed or water. So, where during the percolation of the fluid or water that will be filled up by air or gas, this air will block the flow path. If it will block what will happen? There will be the permeability will become low.

So, it reduces the permeability. Fully saturated soil is more permeable than the partially saturated soil. So, if the soil is fully saturated means full of water definitely it will be more permeable compared to the partially saturated soil. So, degree of saturation is also very important. Now water properties various properties of water or fluids such as unit weight and viscosity also affects the permeability.

However, unit weight of water will not affect much since it does not change much with temperature. But when temperature increase viscosity decreases rapidly, this is very important concept. When temperature is increasing viscosity generally decreasing. So, what will happen? Below permeability increase you can see from the equation below permeability increases when the viscosity decreases.

$$k \propto \frac{\gamma_w}{\mu}$$

So, permanently just increasing when the viscosity will decrease the permeability will increase. So, this generally happens.

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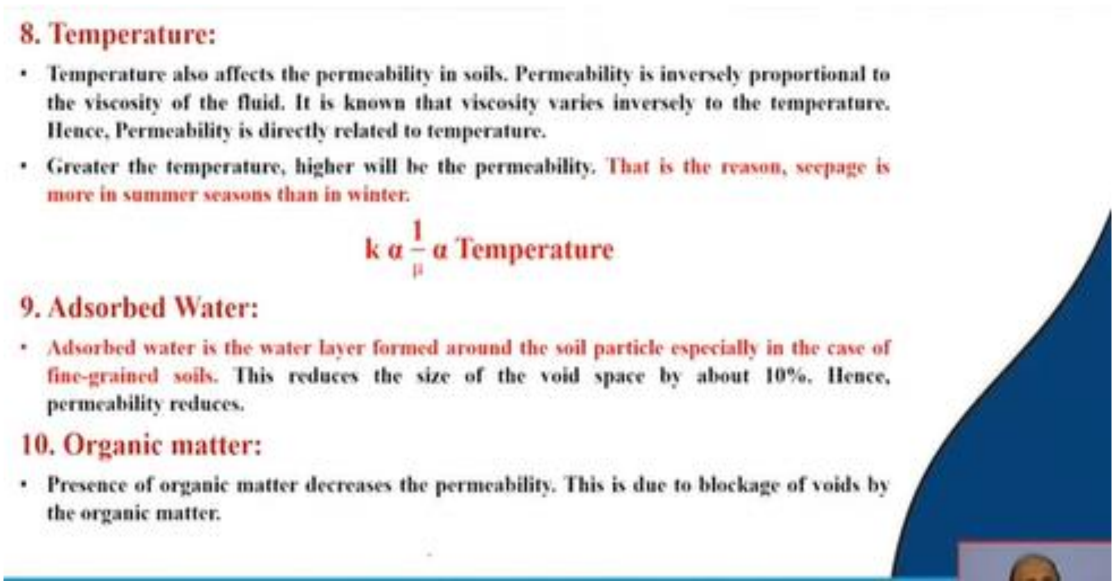

Now temperature, regarding temperature; it is also affecting the permeability in the soil. Permeability is inversely proportional to the viscosity of the fluid. So, we have seen now in the formula also we are seeing it is inversely proportional to the viscosity of your soil. So, what is happening? It is known that viscosity varies inversely to the temperature and this viscosity is varying inversely to the temperature.

$$k \propto \frac{1}{\mu} \propto \text{Temperature}$$

So, what is happening? So, generally permeability is directly related to temperature. So, greater the temperature higher will be the permeability and this is the reason seepage is more during the summer season than in winter season. Seepage is more during the summer season because temperature is high in the during the summer season so permeability will be higher. So, permeability will be higher means definitely the movement will be higher definitely the seepage will be higher.

But during the winter season it will be lower. So, this is also one of the important concepts for the ground flow. Now adsorbed water is the water layer formed around the soil particle. If this is the soil particle so whatever amount is being enclosed by the soil particle especially in the case of fine-grained soils. This reduces the size of the void space by about 10% generally. Hence permeability if there will be reduction in the size of the void space definitely the permeability will reduce so this reduces the permeability.

And the last important factors which are affecting the permeability is the organic matter. Because presence of organic matter decreases the permeability this is due to blockage of voids by organic matter. Why the decrease of permeability? Because of the blockage of voids of the soil material by organic matter; so, it also further reduces your permeability. So, these are some of the important concepts related to the groundwater flow movement.

Now in the next lecture we will discuss some more concepts about the groundwater flow and our important law that is the Darcy law. So, thank you very much to all.