Geology and Soil Mechanics
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Lecture - 15
Soil Compaction & Permeability

So, welcome back. So, in the last lecture we just started one problem which is more towards practical sense and some practical related issues were getting solved in the last problem. So, there actually we have analyzed borrow area A and we have seen that how much was the total cost coming if you choose borrow area A.

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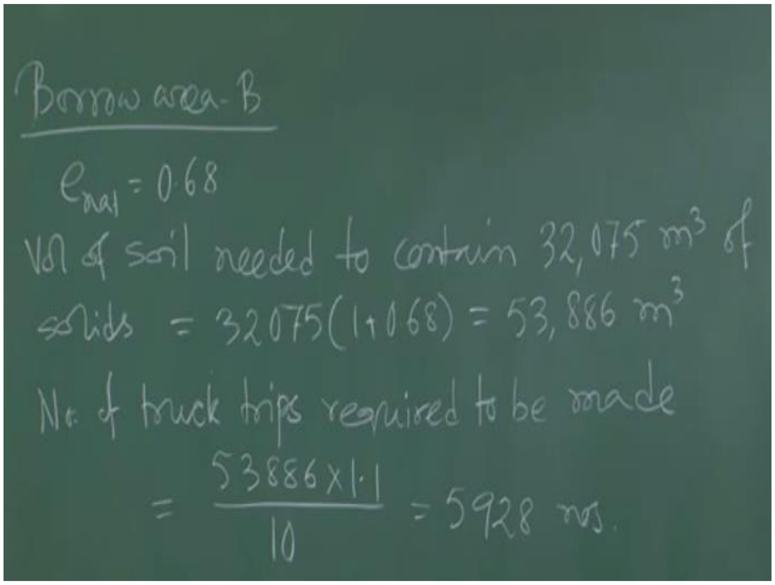

Now similarly if you choose borrow area B, so basically for borrow area B your e natural is given as 0.68. So, volume of soil needed to contain that remains same 32,075 cubic meter of solids okay. That will be coming as 32075 multiplied by 1 + 0.68 which comes around 53,886 cubic meter. So, this much volume needs to be transported from borrow area B if you choose borrow area B okay.

So, number of truck trips required to be made is equal to by using or by considering the allowance of 10% increase that 53886 into 1.1 divided by 10. So that comes around 5928 number of trips okay to transport, to excavate, to transport I mean to transport the soil from borrow area B. So, this much or this many number of trips, truck trips you need to transport the soil.

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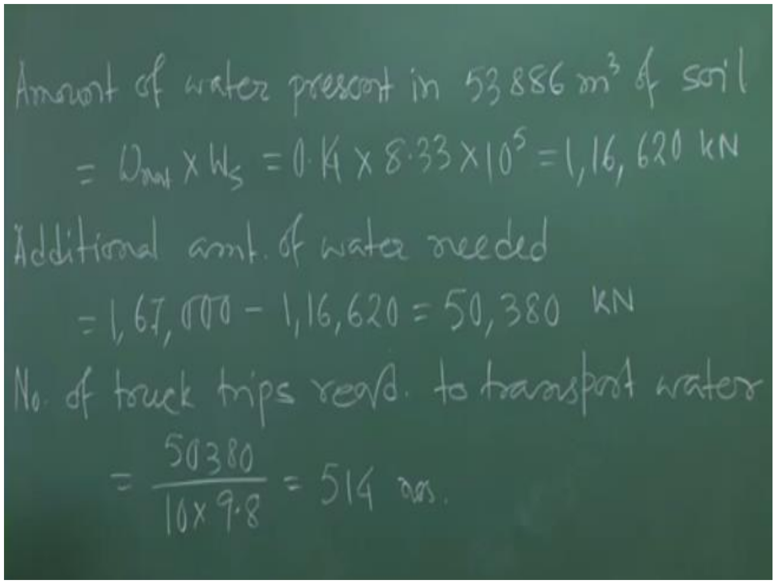

Now amount of water present in 53886 cubic meter of soil is equal to what? So, natural water content multiplied by the weight of soil solids. So, what is your natural water content of borrow area B, that is given in the problem 14% multiplied by what is the weight of soil solids, that already has been calculated in the last lecture, 8.33 into 10 to the power 5 which comes around 1,16,620 kilo newton.

So additional amount of water needed is equal to this much of water is really required for constructing the embankment, 1,67,000 and this much of water is present in the soil if you choose borrow area B. So, this much of water you need to transport by trucks, so 50,380 kilo newton okay. So, number of truck trips required to transport water is equal 50380 divided by 10 into 9.8 which comes around 514.

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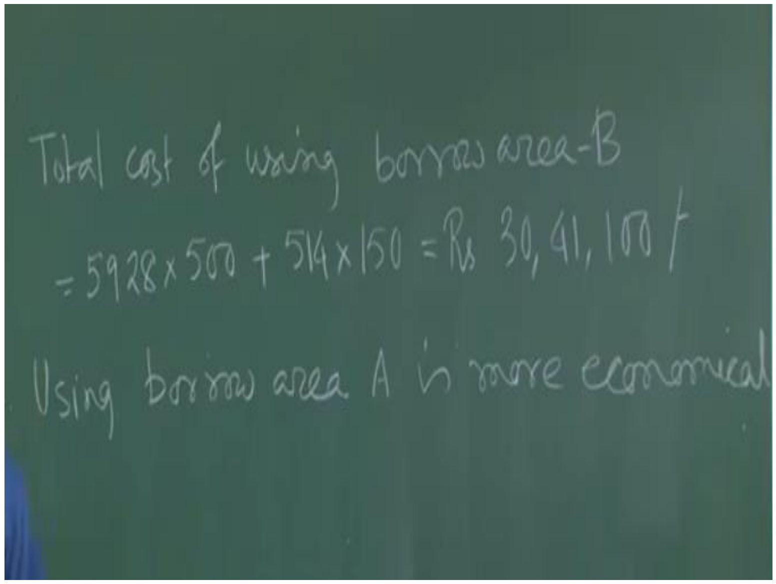

So, total cost of using borrow area B which comes around 5928 number of trips to transport the soil, excavation, transportation, and compaction into 500 that is the rate plus 514 that is the number of trips required to transport the water into rate is 150 which will come around Rs. 30,41,100 okay. So therefore, which one is economical? So, if you compare the cost, so the borrow area A is more economical. So therefore, using borrow area A is more economical okay. So, we will continue with the next topic or the next chapter that is on permeability of soil.

Well so now we are going to start the new topic in soil mechanics that is permeability in soil. Now what do you mean by permeability? Basically as you have seen from your earlier discussion that every soil deposit will be having some core space or the void space right and those void spaces or the core spaces are interconnected so you cannot have some discrete kind of void space so some void space is here and that is not connected to other void spaces so that will make some channel kind of thing okay and now if you allow or you put some water on top of that soil deposit now it that water will try to percolate through the void space and it will go out from the soil matrix.

Now this phenomenon or this concept is known as permeability. Now from your earlier say knowledge or from your earlier experience you can appreciate that in case of say granular soil or the sandy soil if you put water on top of the sandy soil now what will happen the water will immediately drain out. But if you do the same thing for some clayey deposit you put the water on top of some clayey deposit you will see that water will be retained for long time and slowly it will percolate.

So, these 2 I mean both the things are giving you the permeability concept but the depending on the different types of soil, different types of packing, different types of gradation you are getting different types of flow I mean property or the flow ability in the soil matrix right. So, these are the things or these issues we are now going to discuss and these issues are very important.

Now suppose you are considering, you are constructing one dam right and you are constructing a reservoir just behind that dam and if your reservoir bed is allowing the water to sieve through or to percolate through the soil matrix then you cannot retain the water in the reservoir. So, your whole purpose is gone. So, you need to know this permeability concept in a very well I mean designed manner so that you can design those kind of water retained, retained structure or where you want to have some issues where the draining of water is happening. So that kind of issues you can tackle.

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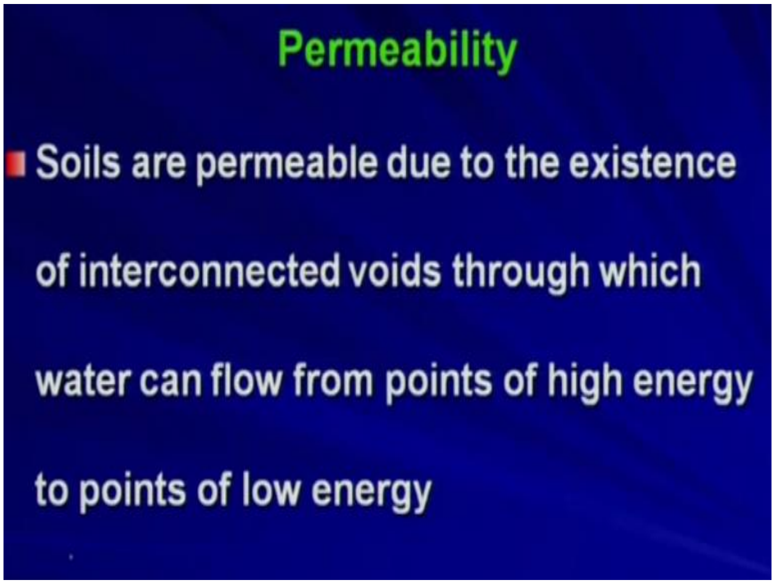

Now what is permeability? So, soils are permeable as I told you, soils are permeable due to the existence of interconnected voids through which water can flow from points of high energy to points of low energy. So, flow will not happen in the reverse direction right, from the low energy to high energy. As you know from the fluid mechanics or the Hydraulics point of view that water will only flow from high head or the high energy from the low energy. That means high pressure head or the high elevation head to the low elevation head through some head loss right.

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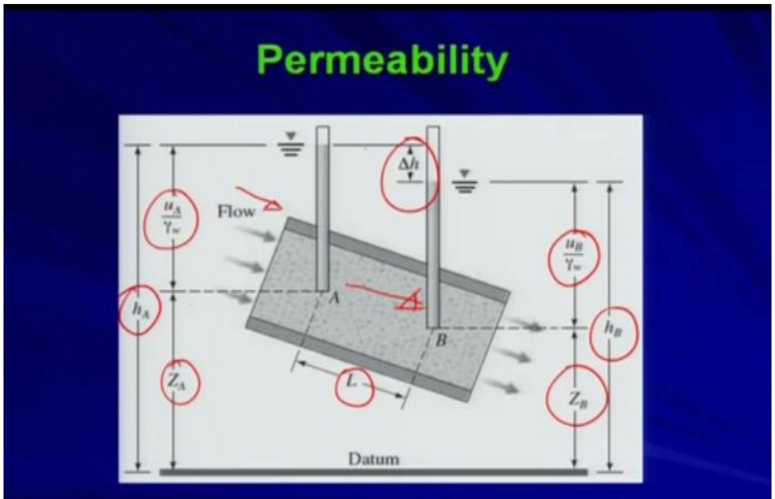

Fig. 19. Pressure, elevation, and total heads for flow of water through soil

So, if you see this figure, so basically flow is happening in this direction okay. So now at point A you have this is your datum head or the elevation head and this is your pressure head. So, total head is small h A. So that is the head at point A. Now at point B you have this is your datum head, this is your pressure head and the total head is h B.

So, h A must be greater than h B to cause the flow or to initiate the flow. So, flow is happening in this direction from A to B okay over the length say L Capital L and by exhausting the head delta h. So, delta h is the head loss. So, h A - h B is your head loss, which is coming as delta h which is causing the flow through the soil matrix.

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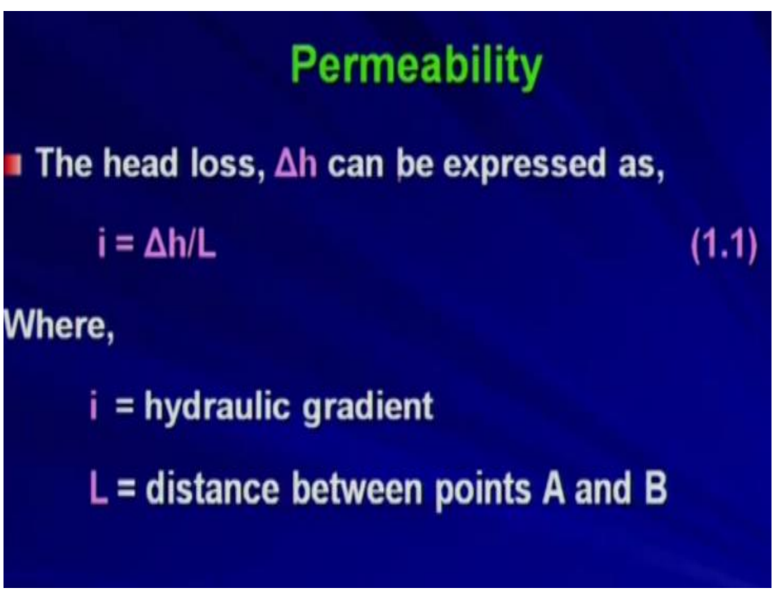

Now the head loss, already we have seen that is delta h can be expressed as i okay which is equal to delta h by L where i is the hydraulic gradient and L is the distance between points A and B. So, delta h is the head loss which is causing because of the flow from A to B and L is the length between these 2 points and your hydraulic gradient is given by this expression.

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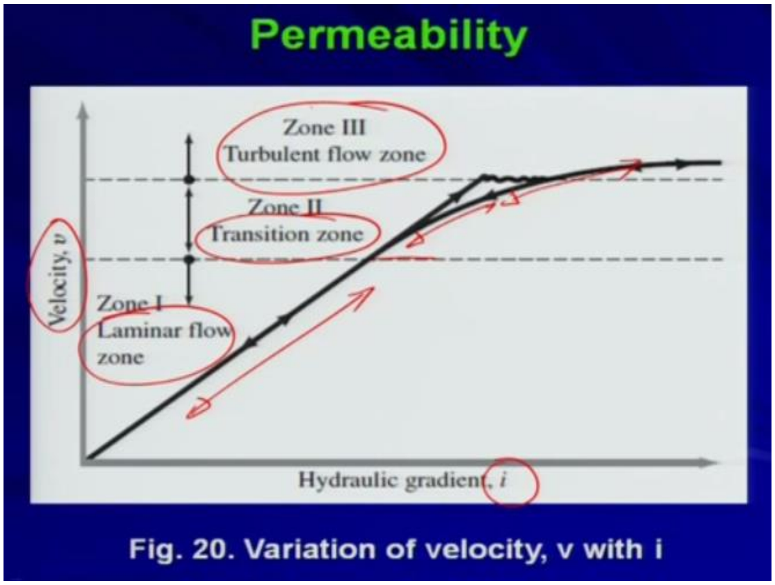

Now there is a very simple relation between velocity and the hydraulic gradient. As you can see when the flow is laminar okay, so during that zone that is zone 1 which is indicating the laminar flow, at that time velocity is increasing with hydraulic gradient, this is your velocity along the y axis, this is your hydraulic gradient along the x axis. So, velocity is increasing or hydraulic gradient is increasing with increase in velocity or reverse so in a straight-line relation or the linear relation.

So, between your velocity and hydraulic gradient the relation is linear as long as you are in the laminar flow zone okay. The velocity increases with increase in hydraulic gradient. Now in case of now once you cross the limit of laminar zone when you reach the transition zone that is your zone 2 basically then your non-linearity in the relation starts right and it will be continuing through the turbulent flow zone. So, this is your zone 3 when your velocity and hydraulic gradient relation is completely nonlinear okay.

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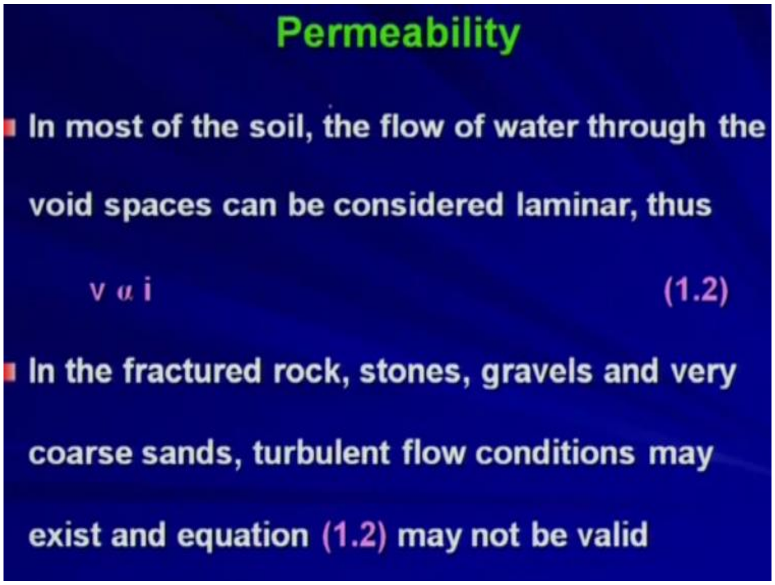

Now in most of the soil, the flow of water through the void spaces can be considered laminar okay because what you can say you are not considering some flow through the pipe right or some conduits which will be causing or some say river flow you are not considering that thing. You are considering a monotonous flow through the soil matrix which will be eventually or which will be reasonably a laminar flow right.

So, I mean you have some water storage on top of the soil matrix or soil deposit and the water will slowly or gradually flow through or sieve through the soil body and that flow obviously will be a kind of laminar flow. So, if that is the laminar flow then the relation between the velocity and your hydraulic gradient, already we have seen in the last figure that relation is linear. So, if the relation is linear then we can write v is proportional to i okay.

Now in the fractured rock, now when you will get the laminar turbulent flow. Now in the fractured rock when you have some high drainage or high flow okay which is happening through the fractures so in the fractured rock, stones, gravels, and very coarse sands, turbulent flow conditions may exist and equation 1.2 whatever we have seen just now may not be valid. So, we are not considering any turbulence in the flow or we are rather we are considering the laminar flow in the soil matrix so that this equation 1.2 is valid and based on that we will try to establish the expressions for permeability.

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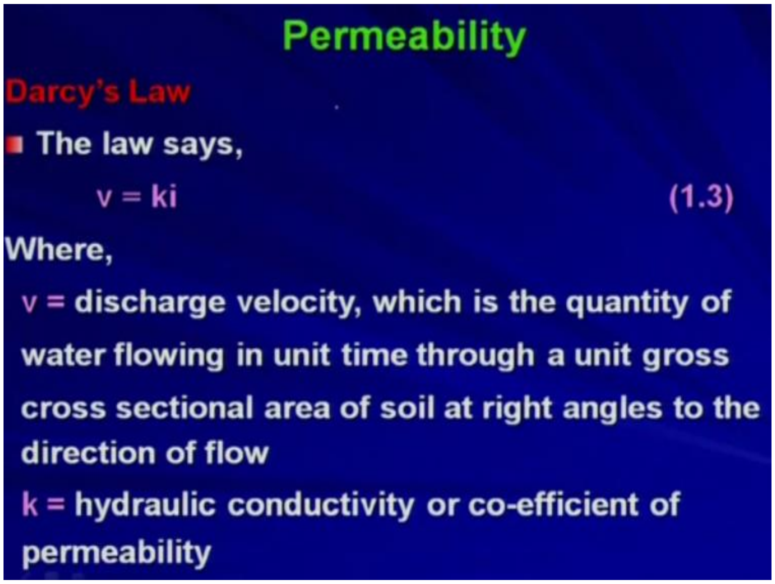

Now as per Darcy's law, the law says the v is equal to ki some constant k multiplied by the hydraulic gradient i where v is the discharge velocity, which is the quantity of water flowing in unit time through a unit gross cross sectional area of soil at right angles to the direction of flow. That means this is the discharge velocity and that velocity is happening we are considering the gross area that means if you have some soil deposit the whole gross cross-sectional area we are considering which is participating in the flow okay and where k is the hydraulic conductivity or the coefficient of permeability.

This is very important term in soil mechanics. So, whenever you try to design some water retention structure or say some kind of structure which is associated with some flow so they are actually this parameter is very important and you need to find out that thing from the from some experiments or from some empirical relations.

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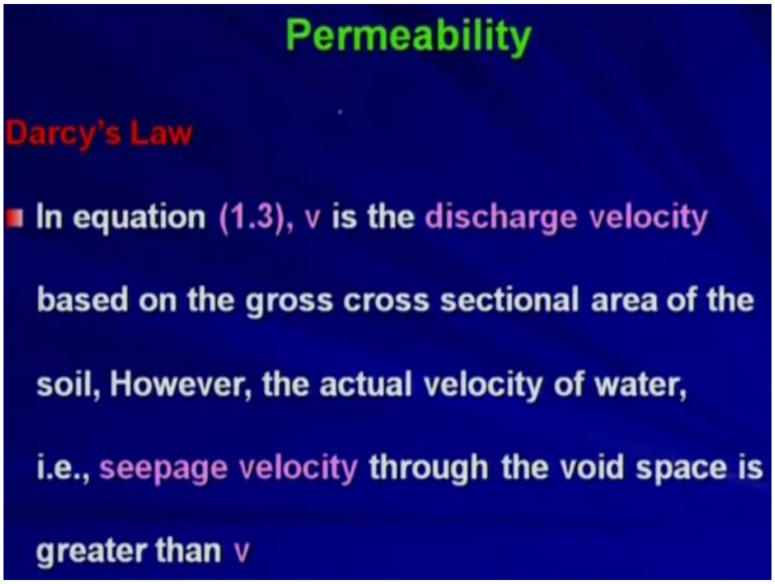

Now in equation 1.3 already we have seen v is the discharge velocity, already we have discussed that is the discharge velocity based on the gross cross-sectional area of the soil. Now already we know, however, the actual velocity of water that is the seepage velocity through the void space is greater than v. Now what happens. So, we are considering the discharge velocity which is happening along the whole cross section of the soil deposit or the soil body.

Now frankly speaking or truly speaking the actual velocity or actual flow is happening through the interconnected void space. So only the void space okay the interconnected void space that is I mean participating in the flow, not the soil solids. So, you have in the soil matrix you have the soil solids and you have the voids. Now the flow will be happening only through the voids because that is only the space which will allow the flow. Soil solids will not will rather obstruct the flow right. So, you are getting 2 different kind of velocity components.

One is the discharge velocity if you consider the gross cross-sectional area that means you consider the cross-sectional area which is formed by the soil solids as well as the void space whereas the actual velocity that is known as seepage velocity that is only happening through the void space which is really true in that sense but most of the analysis or most of the say calculations we consider the discharge velocity for our own benefit or the for our convenience. Now there is a relation between the discharge velocity and the seepage velocity. Now we are going to establish that relation.

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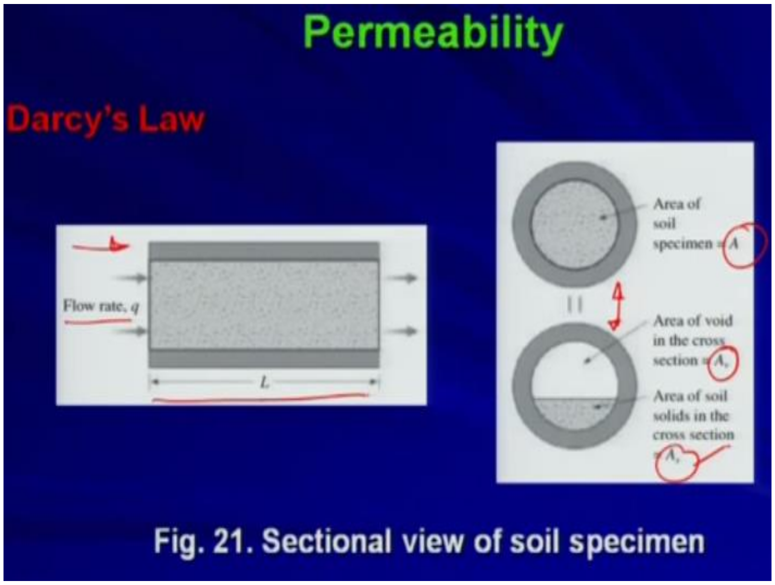

So, let us see this flow. So, flow is this is your flow rate say q which is the flow is happening from left to right over the length L and this is the area of soil specimen that is the gross cross-sectional area whereas we are separating the area of voids and area of say soil solids like this so in this figure so in this figure basically this is equivalent to this figure. So, this is equivalent to this figure but in this figure basically we are separating the void area that is the area of void in the cross section that is A v and area of soil solids in the cross section that is A s okay. So, these 2 are the areas which will be making the total area A okay.

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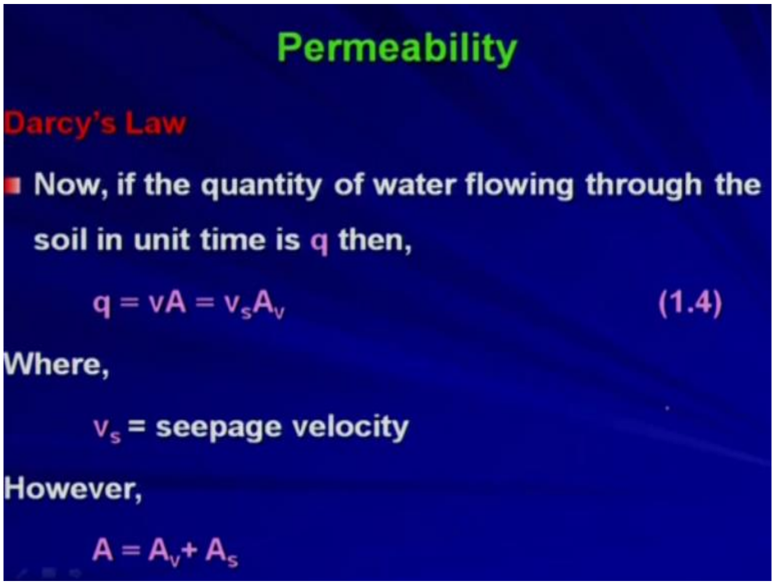

Now if the quantity of water flowing through the soil in unit time is q, then q is given by v into A that is v is the discharge velocity multiplied by the gross cross-sectional area okay. So that is giving me the I mean the quantity of water per unit time which is equal to v s that is the seepage velocity multiplied by the area of voids, both are equal because ultimately you are considering the flow so that is our convention what we are considering but whether we are considering the area of void space only which is participating in the flow or the gross cross-sectional area which is participating in the flow.

Depending on that you are getting 2 different velocity components, that is the discharge velocity v or seepage velocity v s, but the total flow will be constant say q okay. So, q is equal to v A which is equal to v s into A v where v s is the seepage velocity as we have discussed. However, from the earlier figure if you recall, the total gross cross-sectional area A is composed of 2 components. One is the area of voids that is A v plus area of soil solids that is A s.

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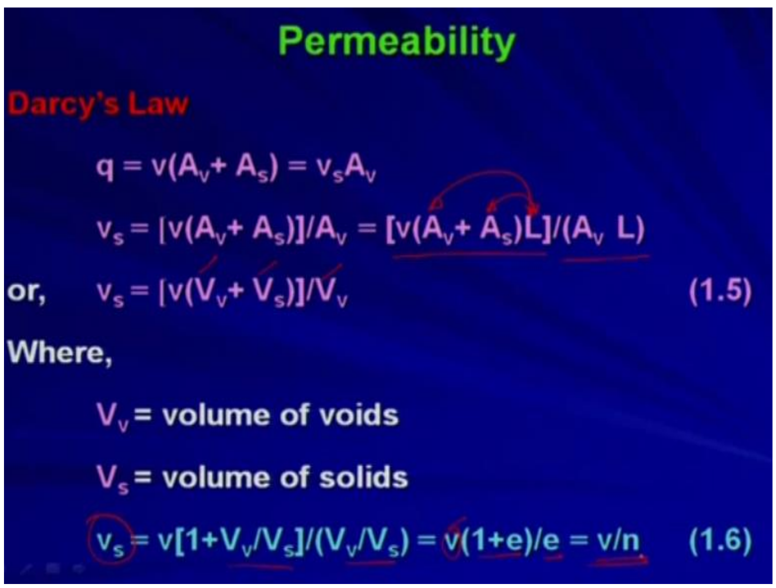

So, we can write q equal to v into instead of A we can write A v plus A s which is again equal to v s into A v. So, we can write v s equal to v into A v plus A s divided by A v okay which is equal to v into I mean we can multiply L that is the length over which the I mean flow is happening length both where we can multiply L to the numerator as well as denominator both. So, we can see we are multiplying L with the numerator so v into A v plus A s into L divided by A v into L we are multiplying L to the denominator as well.

So, from this now what I am getting. So, if A v into L what is A v into L, A v is the area of voids, please try to understand, this is very conceptual okay and fundamental. So, what is A v, A v is the area of voids and if you multiply it with the length then that will give me the volume of voids okay. Similarly, A s into L if you multiply, what it will give me, it will give me volume of solids. Similarly, volume of voids okay. So V s is equal to small v that is the discharge velocity multiplied by V v that is the volume of voids plus V s that is the volume solids divided by volume of voids.

Where this is given V v is your volume of voids and V s is your volume of solids. So, we can write v s equal to v into 1 plus V v by V s okay divided by V v by V s. So, I am taking V v V s as outside and we are getting this. Now what is this? Can you recognize this parameter? This is nothing but your void ratio okay. So, your v multiplied by 1 plus e by e okay. So, this is the relation between your discharge velocity and seepage velocity.

So ultimately 1 plus e by e is nothing by v by n, what is n, n is the porosity. So now basically if you see this relation you will obviously you will appreciate that your v V s that your seepage velocity is always greater than your discharge velocity because this relation can be established by this porosity because if you know the range of porosity you can say that V s is always greater than your discharge velocity v.

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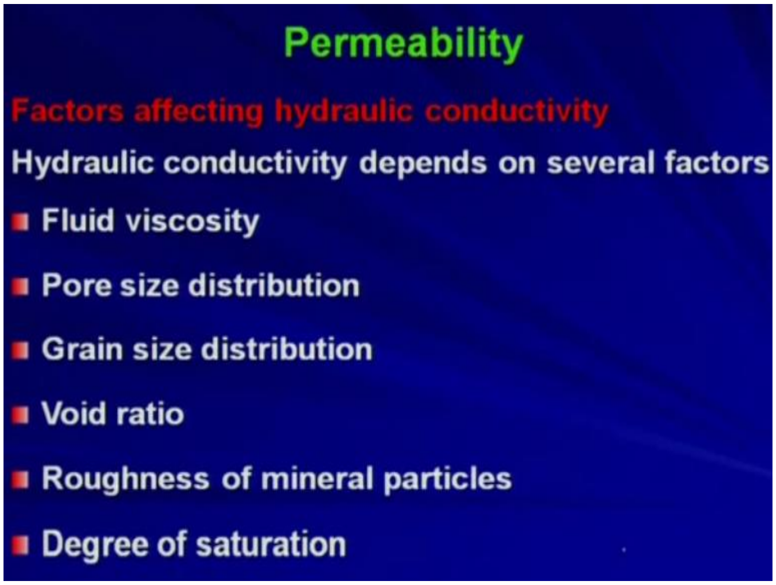

Now what are the different factors which are affecting the hydraulic conductivity what is that is nothing but your permeability. So, hydraulic conductivity depends on several factors. First one is the fluid viscosity. Of course, if you consider if you put water on top of some soil and if you put some very viscous fluid like oil on top of water the permeability or the draining of these 2 kind of fluids will not be same.

Or even the temperature at I mean if you use water at different temperature and you know based on the temperature you will be getting different viscosity of the material of the fluid. So, at different temperature you will be getting different permeability okay. So, the fluid viscosity plays an important role to estimate the permeability. Similarly, pore size distribution.

As you appreciate from the earlier discussion that the pores, interconnected pore space will cause the flow. So of course, the pore size I mean depending on the pore size whether it is very large pore space or very narrow pore space depending on that basically the large diameter pipe or small diameter pipe that will cause the or that will affect the permeability in a greater extent.

Now grain size distribution. Of course, grain size distribution plays an important role because if you have a very well graded sample or poorly I mean poorly graded sample, based on that you will be getting different permeability because grain size distribution is having the direct effect on the pore space or the pore size or the pore I mean the orientation of the soil particles right.

Then the void ration. Of course, if void ratio increases as you have seen, void ratio increases, your permeability increases. Roughness of the mineral particles. Now this can be discussed in this phenomena or this can be interpreted like that. So, if you have very rough surface inner surface is very rough for a pipe and if you have a very smooth surface, smooth walled pipe then I mean you can see or you can think of the flow happening in 2 different types rough interface or the rough face of wall I mean pipe and the smooth face of wall, pipe. So, these 2 things when it is considering when the flow is happening through these 2 types of pipe you can think of which one will be giving you the better permeability or the better flow right.

So similarly, the roughness of the mineral particles of course will cause some effect okay on the permeability. Then coming to the degree of saturation. So of course, the degree of saturation will have the direct impact on the permeability. So, as you have more saturation so that means you have already the void space is occupied by the water. So, if you have less saturation that means the more void space is occupied by the air. So, based on that you will be getting different permeability in the same soil right.

So, I will stop here today. So, in the next lecture we will continue this permeability and we will understand the different concept and how to obtain the coefficient of permeability from the laboratory experiments as well as some empirical equations and several other issues. Okay thank you very much.