Environmental Geotechnics
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Lecture - 33
Contaminant transport through porous media – 2

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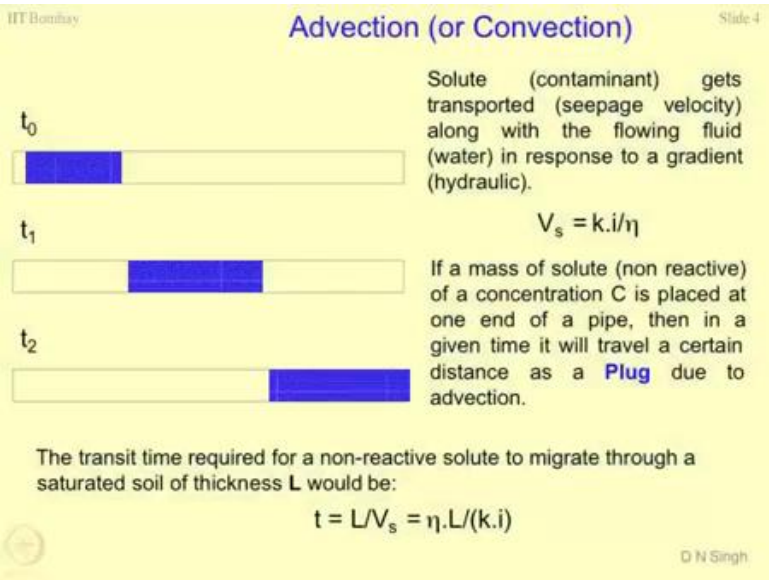

So, let us discuss now the first mechanism which is advection or sometime this is also known as convection. So, you consider a control volume at time t naught there is a solute which is available in the control volume. As time t_0 becomes t_1 and from t_1 to t_2, this whole control volume of the contaminants gets a place shift or it moves from one point to another point. So, this is how it shifts from one point to another point to another point now this is a phenomenon which is known as advection. That means, the solute or the contaminant gets transported because of what? Because of the seepage or the seepage velocity along with the flowing fluid which could be water in response to a gradient and this gradient is nothing, but hydraulic gradient.

So, if this is the case, you are talking about advection or convection, normally this type of mechanisms is defined by $V_s = k.i/\eta$. What is V_s here and what is η? Pore porosity. So, if you divide V/η, V is the discharge velocity divided by the porosity it becomes your seepage velocity. So, which velocity will be more discharge velocity or seepage velocity?

Seepage velocity.

So, seepage velocity is higher than discharge velocity. Now if a mass of solute and please note that this solute happens to be non reactive. What is the significance of non reactive? It has no affinity towards porous system clear it has no affinity towards porous system. So, it simply migrates through it without stopping anywhere.

Changing.

Without changing it is own form better word would be without changing it is own form. So, form includes concentration also clear. So, if a mass of solute which is nonreactive it is a passive contaminant of a concentration C is placed at one end of the pipe or the control volume then in a given time, it will travel a certain distance as a plug now this is what is known as a plug.

That means without losing its entity or identity or the control volume or the surfaces it simply keeps on migrating from one place to another place to another place due to advection process. So, these are the attributes of the advection mechanisms. Now the challenge is to find out the transit time, how much time it will take to move from one place to another place to another place; that means, how to obtain t_1 and t_2 and so on. So, the transit time required for a non reactive solute to migrate through a saturated soil of thickness L would be what? L/V_s.

So, if you know the distance, if you know the V_s, you can simply workout it is time is this part clear. Now suppose if I change the word the transit time required for a non reactive solute to migrate through an unsaturated soil.

Then, what is going to happen; that means in your logic the unsaturated hydraulic conductivity will be more or saturated hydraulic conductivity will be more.

Saturated hydraulic conductivity will be more.

Why it is so?

Because sir we are starting the third phase which is air ended up before it hampered.

That is right. So, you are correct for unsaturated soils that value of k would be much smaller. So, if value of k is much smaller what happens to the time, the time becomes

much more. What is the meaning of this, this is useful for engineers or not useful for engineers when you are dealing with unsaturated soils suppose a contaminant transmits itself from point A to point B when the aquifer happens to be saturated the time taken is less, when saturated when this system happens to be unsaturated time taken from one point to another point movement is much higher clear.

Now, this is where I had told you sometime back that if you are dealing with unsaturated soils you need not to go for barrier systems, provided you have characterized your soil mass very precisely and you know what is the hydraulic conductivity of unsaturated state of the soil mass and that is where most of us are trying to study unsaturated hydraulic conductivity of the soil mass ok. So, this is where the deviation is from classical geomechanics to unsaturated soil mechanics, because most of the deposits most of the aquifers in nature are unsaturated water tables are pretty deep.

So, most of the contaminant transport is going to take place in unsaturated soils not in the saturated soils. Is this part clear? Exactly because hydraulic conductivity of unsaturated soils is much less. So that means, the contaminant transport from one place to another place would be very slow because hydraulic conductivity itself is very slow, but suppose if you are not using the correct hydraulic conductivity which is unsaturated hydraulic conductivity, what is going to happen you are going to over predict the phenomena which is not going to take place in nature ever. So, that is the reason people are now shifting from classical geomechanics to unsaturated soils, where they want to establish all the properties to most precise state of the material which happens to be unsaturated, clear.

Now a very loud thinking here would be if your waste has enough energy thermal energy and if this migration is taking place through the porous system, what is going to happen? A saturated porous media may get altered into unsaturated state of the material now this is what is known as a coupled phenomenon. That means, heat is migrating, moisture is migrating even vapors may also be there. So, lot of coupled mechanisms are going to take place simultaneously.

And I always like to give you an example of the people who are working in the field of petroleum engineering where they try to take out petroleum from the deposits clear. Now these deposits are mostly saturated in nature water saturated so; that means, you think of

a situation where the flow of gas is taking place and a fluid of different density is taking place through water saturated porous media till now you have been talking about only seepage through saturated soil mass consolidation through only saturated soil mass compressibility of saturated soils and so on. But then when you talk about the natural processes or more complicated processes where coupled mechanisms become essential for consideration.

Is this part clear did you follow or not? So, you think of doing a consolidation test where the gas permittivity should be obtained from saturated clays, how easily gas is going to migrate through the saturated clay deposit all right. Now my question to you is where you are going to this type of an equation in real life modeling, can you think of a situation where by simply obtaining V_s porosity of the material if you know the k value what wonders you can do for the society just by using this equation? Ultimately what is the whole idea of studying the transport mechanisms at a given distance L after certain time 't' how much contaminant is going to get migrated which happens to be nonreactive in nature.

So, by using simple equations I can give then answer that down the line in terms of time or in terms of distance, what type of environmental deterioration are going to take place because of some industrial activity. Now this is where what you have studied in undergraduate, can I model k layers of soil mass either in parallel series. So, I can find out k equivalent of the ground or the subsoil I can use this in this model and I can work out the time or distance regarding a given situation. Of course, the condition is that the contaminant is transport is taking place just because of advection flow of water and contaminants happen to be non reactive they are not going to lose their entity. So, the scope of even advection analysis is also quite big.

Now, this is what the real modeling is, what a hydrogeologist will be doing, is there any way of measuring V_s, how do you measure V_s under in situ conditions you cannot you cannot measure, why? Do not measure it then you do not require to measure it you can get the equivalent porosity you can get the equivalent permeability, you know what type of hydraulic gradients are acting and then you can find out the time for a solute to travel a distance L or vice versa is this part clear. So, you need not to talk about or determine V_s as such because V_s gets nullified. So, V_s is not a very important parameter there.

But suppose if somebody is after you and he says no you have to find out V_s, how would you obtain under in situ conditions under in situ condition how would you obtain V_s, can you obtain k under in situ condition yes or no, Sneha in-situ hydraulic conductivity how would you measure? How do you measure which tests to be done? Packers test packers yes. So, you perform a simple packers test and you can get the k value. Now if you know the k value, if you know the hydraulic gradient, you know the porosity, you can work out V_s that is right clear. So, either pumping in or pumping out test you can do to get the packers permeability good. So, though it seems to be very simple, but applications and implications are tremendous, is this part clear.

It is used for any deposit under in-situ conditions of course, then by go logging you should find out whether you have obtained the hydraulic conductivity or the discharge for a subsystem which contains soils or rocks. So, it depends upon if you can characterize this substratum the values which are going to get are nothing, but corresponding to that.

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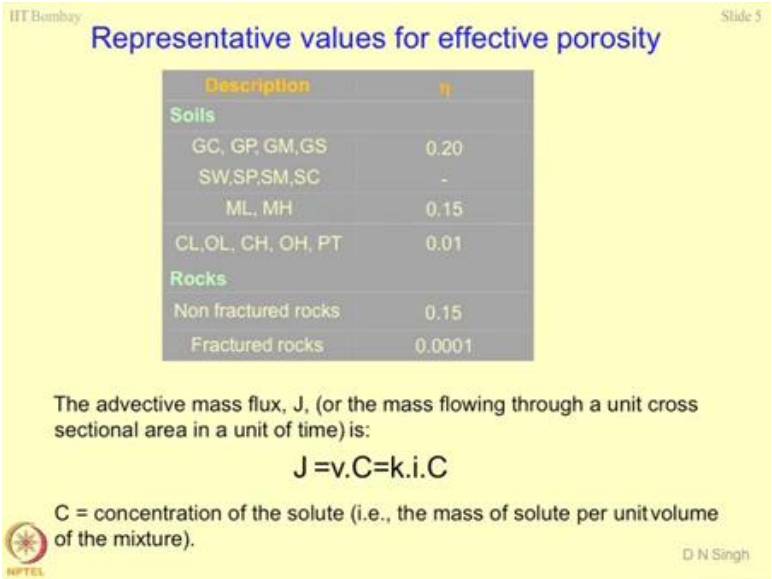

No just to give you an idea about the representative values for effective porosities, all soils clear would show you a very wide range of porosity 0.2 to 0.01 that is 1 percent to 20 percent approximately, do you agree with this data or you thing that this is not very correct soils I think you can understand what is GC, GP, GM, GS, SW, SP, SM and SC,

ML, MH, what about this CL, OL, CH, OH, PT, what is PT peat, OH organic soils of high plasticity index.

So, as you transform from this to this state of the material what happens to the porosity Sneha this answers your point that there could be some dead ends and all in the materials which are fine grained. So, what is the meaning of this it indicate that for this type of soils definitely you have to do microstructure analysis, otherwise your porosities and the permeabilities may not be very correct, because you have already studied that there will be meso, micro and macro pores, micro macro and meso pores in the fine grain material yeah.

Now for rocks if you talk about the nonfractured rocks and the fractured rocks, there could be a situation where you can find out this type of range the fractured rocks minus fractures highly fractured material. However non fractured materials can also give you 15 percent of porosity what is the porosity of basalt, approximately granite would be of the order of 8 to 10 percent, basalt can be 15 to 20 percent, chalks would be 15 to 30 percent, sedimentary rocks will show you high porosities 25 to 40 percent and so on. So, this is a sort of a very rough indication of the state of the material and the corresponding porosity yes please.

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I told you minus fractures.

Minus (Refer Time: 13:55).

Minus fracture; that means, though it is very fractured rock mass, but when you talk about see that is what actually I am been trying to tell you all the time ah, when you talk about the porosity if you include the fracture that becomes fracture porosity you are not talking about fracture porosity as at all. Most of the fractured rock masses will be very less pervious their porosities will be very less because of the weathering process all right. So, because of the weathering process what you will find is there will be fractures in the system which may attribute to over all porosity, but not at the micro level. So, this is the chart which is normally used for obtaining the effective porosities of the materials.

Now the question is, how would you obtain the advective flux. So, it is very easy advective flux would be J which is the mass of a fluid which is flowing through unit cross sectional area in a unit time. And this is nothing, but the discharge velocity multiplied by the concentration, where else you use this type of equation apart from geomechanics. Have you ever used this mass balance equation for determining something apart from geotechnical engineering $V_1C_1 = V_2C_2$

sorry?

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Fluid mechanics.

Fluid mechanics exactly that is right, but $V_1C_1 = V_2C_2$ you have used fluid mechanics.

Concentration

For determining what for finding out the discharge through open channels. So, if you want to find out the discharge in a open channel what do you do you take some salt put it here and down the stream at a distance you must measure the concentration, if you know the concentration you know the V_1 V_2 and you can work out the discharge. So, that is the utility and you know beauty of this equation symbol equation. So, it is nothing, but the mass balance. So, velocity multiplied by concentration will give you.

Now in geomechanics how we can extend this further we can use V= KiC is nothing, but your total mass flux. So, from one point to another point if your mass flux is moving, what is the significance of this. You think of a situation where your falling head test is replaced by a solution of sodium chloride which is permeating through the soil mass, is this clear.

Now what I want to ask you is after certain time at the middle of the sample what is the concentration of sodium chloride, it is not less or more what I am saying is if I want to ask if I want to determine how would I point find it out. So, you have k.i.C you know what is the hydraulic gradient acting between the first half and the second half of the sample is this clear.

What is unknown is C. So, till now you have been plotting I variation with the samples you agree or no delta h upon l the variation is linear. Similarly, you can plot the variation of concentration within the soil sample the one end is exposed to 100 percent concentration of sodium chloride which is permeating into the soil sample. So, my question to you was what is the concentration, variation of sodium chloride within the soil sample of length L is this clear. You know hydraulic conductivity the same test which we have been doing to obtain k can be done just by replacing ordinary water with sodium chloride solution.

You can take out the sample of the soil mass or the porous media you can slice it and find out the concentration of chloride ions at different depths. And then you can do the profiling you need not to do this even, if you use mass balance k.i.C. At first point equal to second point equal to third point you know the variation of hydraulic conductivity, you know the variation of i, you know the C values from the boundary conditions and you can draw the variation of concentration. Is this part clear? Most of the problems which are encountered in day to day life are being modeled by using this simple equation impact analysis of certain in activity on the environment.