Geology and Soil Mechanics
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Lecture - 16
Permeability - A

Welcome back. So, in the last lecture we just talked about the permeability in soil and we have seen what for this permeability and how this permeability is coming into the picture in soil mechanics right and then we stopped in the last lecture about the when we were discussing about the factors affecting hydraulic conductivity.

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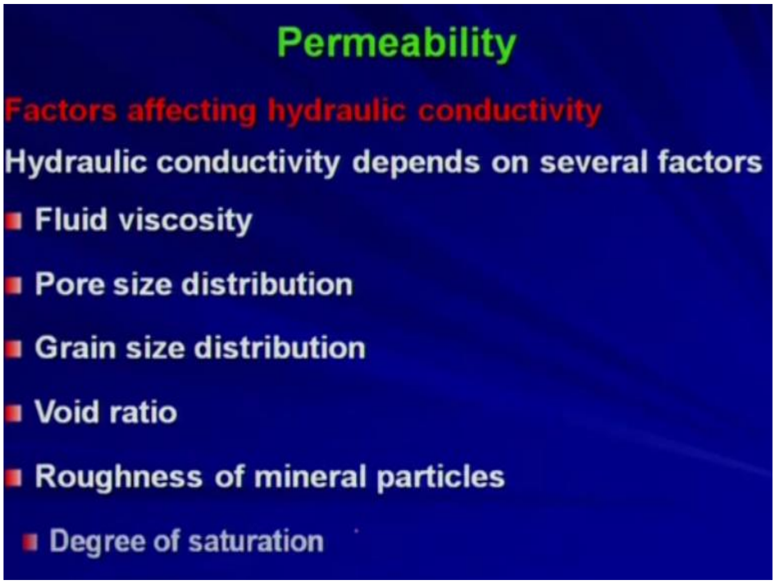

So, hydraulic conductivity depends on several factors as we discussed in the last lecture that is fluid viscosity because viscosity is dependent on temperature and of course the temperature will affect the permeability. So, pore size distribution because permeability depends on the interconnected pore space and therefore pore size distribution is very essential to determine the permeability. Now grain size distribution is another factor which will affect the permeability in a great extent. Then coming to the void ratio.

Of course, you know that as you increase the void ratio of course your pore space or the volume of voids will be increasing and therefore your permeability will increase. Then roughness of mineral particles because the mineral I mean the particles whatever is present in the soil deposit the roughness of the surface or the texture of the surface will greatly affect the permeability. Then finally degree of saturation.

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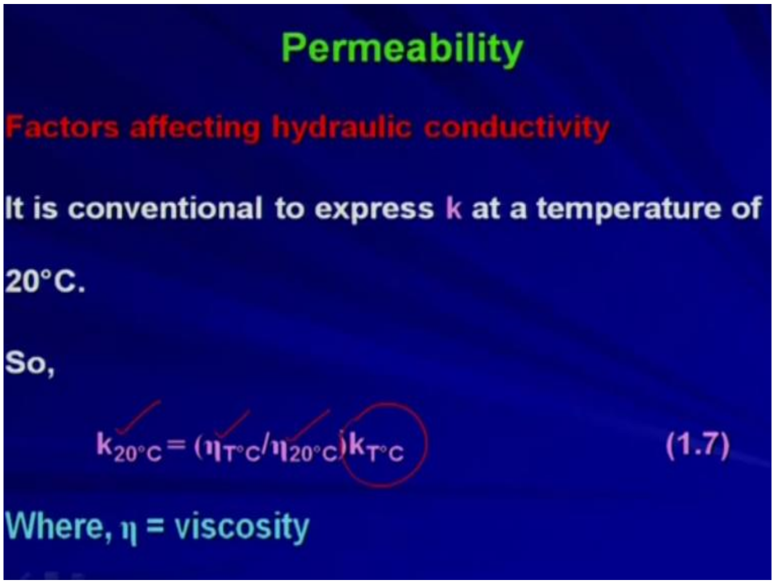

Now it is conventional to express the permeability, the coefficient of permeability k at a temperature of 20 degree centigrade. So, this is the conventional procedure or conventional method to express k; however, if you want to obtain k that is the hydraulic conductivity or the coefficient of permeability at different temperature then you have to use this expression. So, k 20 degree centigrade that is generally expressed in the literature which is equal to eta at T degree centigrade by eta 20 degree centigrade into k T degree centigrade.

So, that means if you know so this is if it is known to you this k 20 degree centigrade that is provided or that is supplied in the literature then eta 20 degree centigrade that means you I mean if you are dealing with the pore fluid as water then of course the viscosity of water at 20 degree centigrade you need to find out.

Then the what are the temperature you would like to or you would wish to find out the coefficient permeability so for that you need to find out the viscosity or you need to obtain the viscosity at that temperature and if you know these 3 values finally you can get the k that is the coefficient permeability at that particular temperature whatever you want so where eta is the viscosity.

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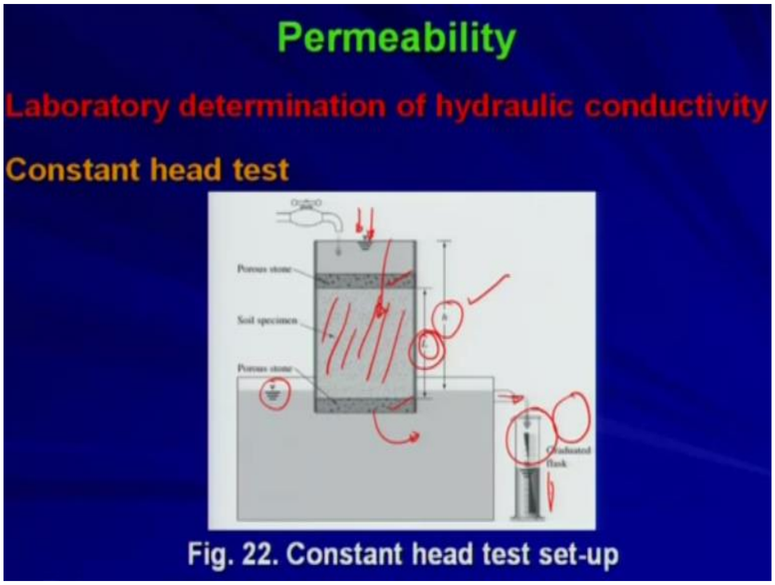

Now we are coming to how to obtain or how to find out this coefficient of permeability or the hydraulic conductivity. So, there are several procedure as well I mean in laboratory procedures as well as you have the field procedures. So, first we will discuss about the laboratory determination of hydraulic conductivity. So, you have got basically 2 different methods by which you can find out the hydraulic conductivity. First one is the constant head test. So, here basically what we do.

So, this is your soil sample. So, this is your soil sample okay and on top of the soil sample you have 1 porous stone and at the bottom of the soil sample you have got another porous stone. So, basically these porous stones will allow the water to flow through the soil body or the soil specimen but it will not allow the soil specimen to go out right along the flow. So, it will act as a screener okay. So, now what we do here, so we put the water on top of this. So, this is the water level and we try to maintain the constant water level at that surface. So, and this soil specimen will be resting on some say some tank and this is the water level of this tank.

So, therefore the this small h is the head difference between the entry level and the exit level okay and the L is the length of the soil specimen and you are basically measuring so you are putting the water on top of this so water will flow through the soil specimen, it will come out below the soil specimen and ultimately you have some outlet in this tank and this through this outlet basically you will be collecting the water in some graduated flask or some measuring flask okay.

So, that means you need to I mean what are the things you need to find out. So, this head basically you know what is the head difference between the entry level and the exit level, what is the length of the soil specimen, and how much water you are collecting okay in the measuring or the graduated flask, that means the quantity okay at some particular time. So, these are the things you need to observe in the laboratory.

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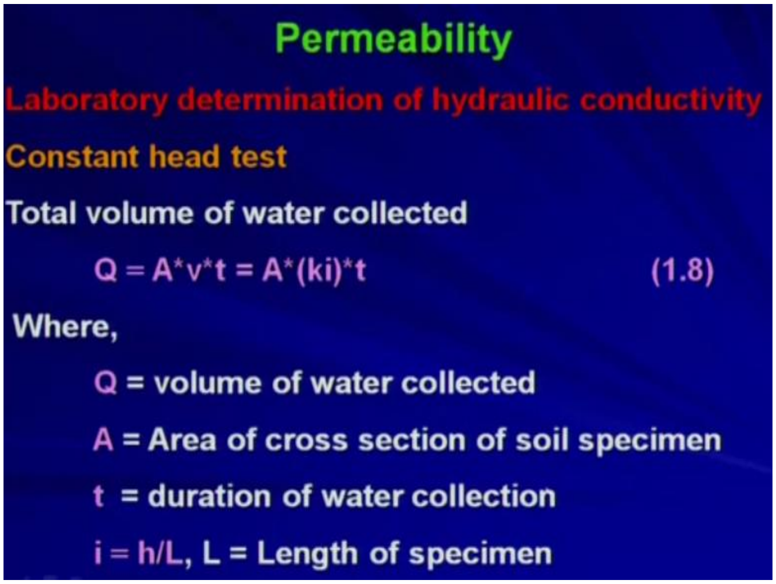

Now based on that the expressions can be derived like that. The volume of water collected at say time t is nothing but say capital Q which is nothing but the area that is A into v into t that is the area of the soil specimen into velocity okay the velocity of the flow and the time t. So, at time t whatever you are accumulating or you are collecting. So, where q is the volume of water collected. A is the area of cross section of the soil specimen.

Small t is the duration of water collection and i, i is nothing but hydraulic conductivity which is nothing but the head loss divided by the length through which the flow is occurring. So, head loss is h because that is the head difference between the entry level and the exit level. So, that is nothing but the head loss in this situation. So, h small h by L will give you the hydraulic gradient i and where L is the length of specimen.

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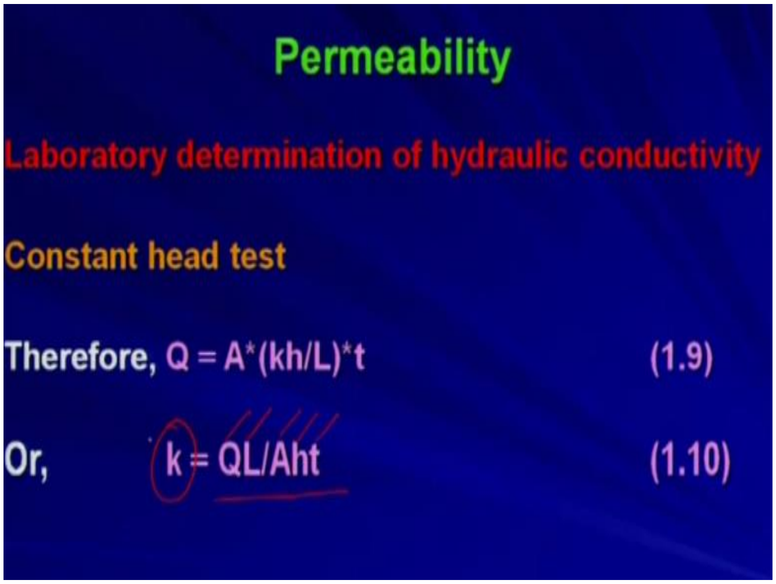

Now therefore Q can be written as A into instead of i you can write h by L so A into k into h by L into t or we can write k that is the coefficient of permeability or the hydraulic conductivity is equal to Q into L divided by A into h into t. Now you can measure this because you are observing that thing from the laboratory experiment. You can measure the soil specimen length. This is the cross-sectional area of the soil specimen.

That is also I mean very typical right, it is a standard one and small h that head actually you are maintaining that is the head difference between the entry level and the exit level and the time you are observing that at I mean that is time at which you are collecting the water in the graduating flask. So, if you know all these 5 parameters basically you can find out your desired parameter that is coefficient of permeability or the hydraulic conductivity.

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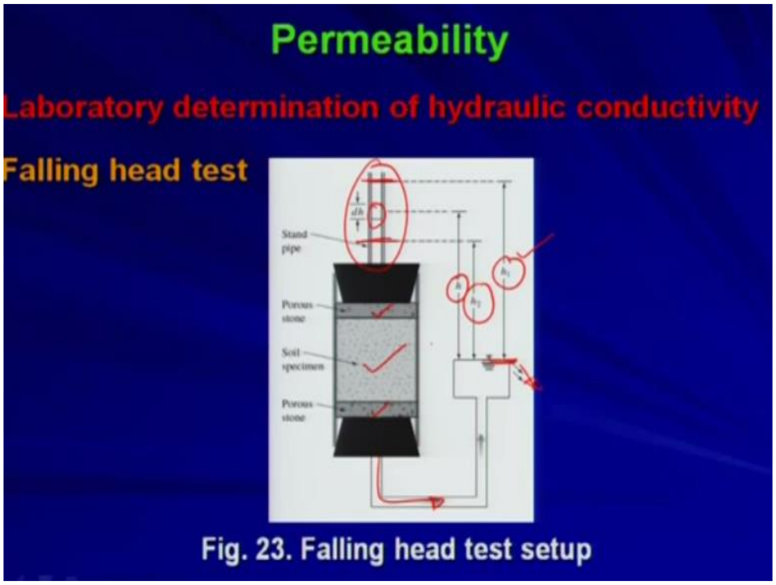

Now once we have seen the constant head test. Now another test is falling head test. So, there actually you are allowing the water head to fall from some height to some different height okay. So, we will see that. So, this is the test procedure. Basically, what we do. This is your stand pipe, this is your pipe.

You have the soil specimen here and again it is sandwiched between 2 porous stone, top porous stone and the bottom porous stone and you are collecting the water through this stand pipe at some measuring device okay some kind of tank and this tank I mean this is your constant head will be maintained at the tank. Otherwise, I mean if it is overflowing then the water will go out. Now basically you see so this is the water level at the exit level okay.

Now you are allowing, so before starting the test this was your water level and you are allowing the water level to fall down up to this level. So, h1 small h1 was the level difference between the entry level and the exit level during the starting of the test and during the finishing or the completion of the test you have h1, that is the head difference between the entry level and the exit level okay.

So, now at any depth or any level difference or the head difference small h and you can consider some incremental head difference that is dh okay. So, now these are the things you can I mean this h1 is known to you because you are starting the test so you must know what is your level at the initiation of the test okay and this h2 is your final level difference between the entry and exit level after completion of the test. So, you and you know the length of the specimen, you know I mean other details from the laboratory experiment details available with you.

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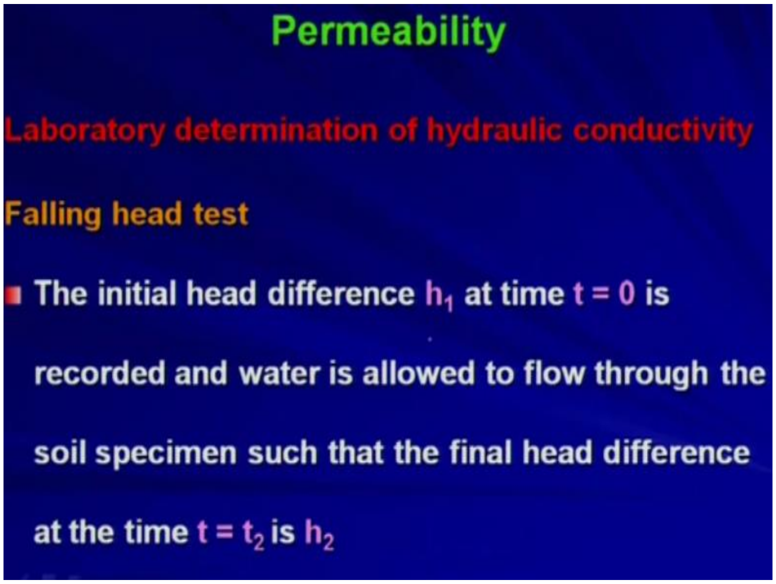

Now the initial head difference h1 is you are measuring at time t equal to zero say right. So, that is the initiation of the test, that is the starting point of the test. So, initial head difference is h1 at time t equal to zero is recorded and water is allowed to flow through the soil specimen such that the final head difference at the time t equal to t2 say at some time, at some time t2 the head difference, final head difference is h2 okay. So, basically at t equal to zero your head difference is h1 and at t equal to t2 your head difference is h2.

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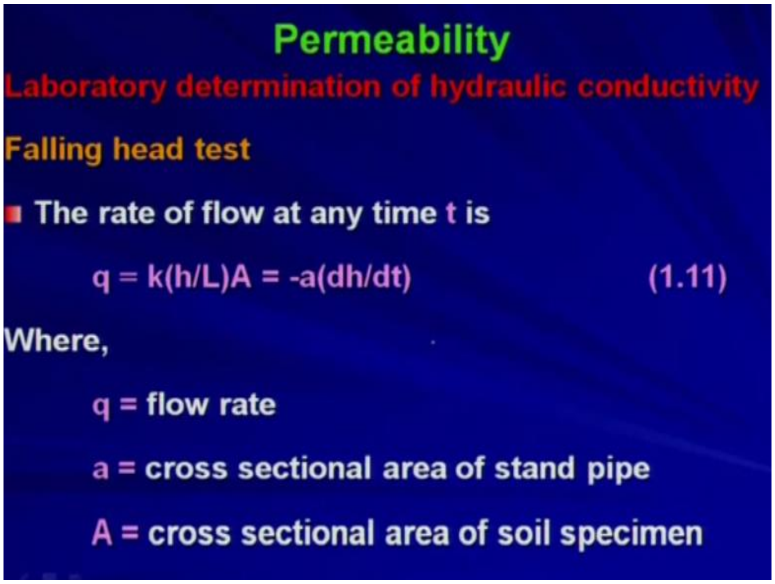

Therefore, the rate of flow at any time t is small q say equal to k into the hydraulic gradient that is h by L into A right, ki that is the velocity into A where i is nothing but h by L which is equal to minus A, minus A so I will come I will define all those parameters, minus A, A is the cross-sectional area of the stand pipe okay into dh dt okay.

So, dh is the incremental head difference of whatever we have just seen and dt is the incremental time where q is the flow rate fine, small a is the cross-sectional area of the stand pipe and capital A is the cross-sectional area of the soil specimen and the negative sign is coming because with time your head is decreasing right. So, because of that you have got negative sign before this expression okay.

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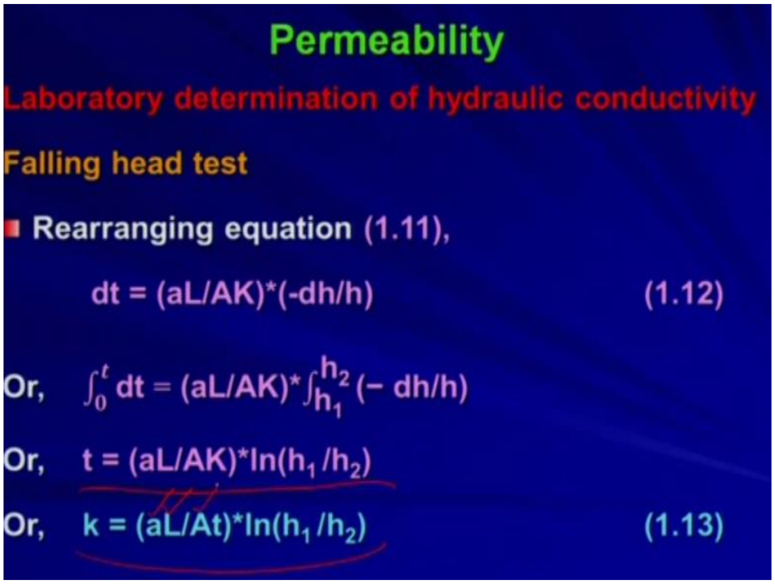

So, the rearranging the equation 1.11 basically we get dt is equal to small a into L divided by A capital A into K into minus dh by h. So, now we are integrating both the sides over the range 0 to t dt and over the range h1 to h2. So, from this basically we are getting t equal to this. So, t equal to small a into L divided by AK into log base e h1 by h2. So, now from this expression I can get, this is my final expression that is the expression which will give me the hydraulic conductivity small k where this is known to me because you know the cross-sectional area of the stand pipe, this is very standard.

So, if you go to the laboratory you will see the stand pipe, you can measure the stand pipe cross sectional area or the diameter of the stand pipe so you can find out the cross-sectional area of the stand pipe. So, L that is also very standard, so length of the soil specimen; A, cross sectional area of the soil specimen, that also you can measure; t basically you are observing at what time your head is falling from h1 to h2 and h1 the head difference at the starting level that you can record and of course h2 you can record at the finishing of the test or at the completion of the test. So, if you know all the parameters, you can find out the coefficient of permeability or the hydraulic conductivity.

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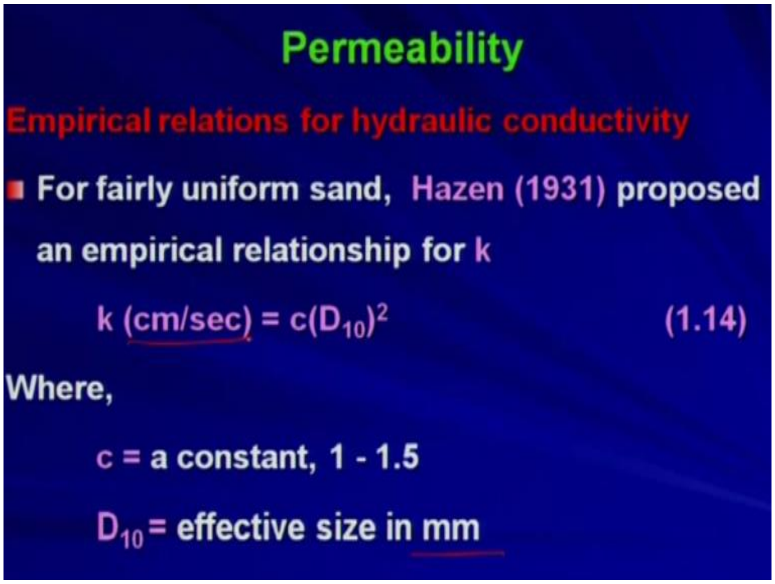

Now there are several empirical relations available in the literature to find out hydraulic conductivity. I will go one by one. So, for fairly uniform sand, Hazen in 1931 proposed an empirical relationship for k which is given by k in cm/sec is equal to c some constant multiplied by D 10 to the power 2.

That means c D 10 square where c is a constant which will vary from 1 to 1.5 and D10 is nothing but as you know from our earlier discussion that effective size in millimeter. So, please remember the unit because this is the empirical equation. D10 is expressed in millimeter where k is expressed in centimeter per second and c is a constant.

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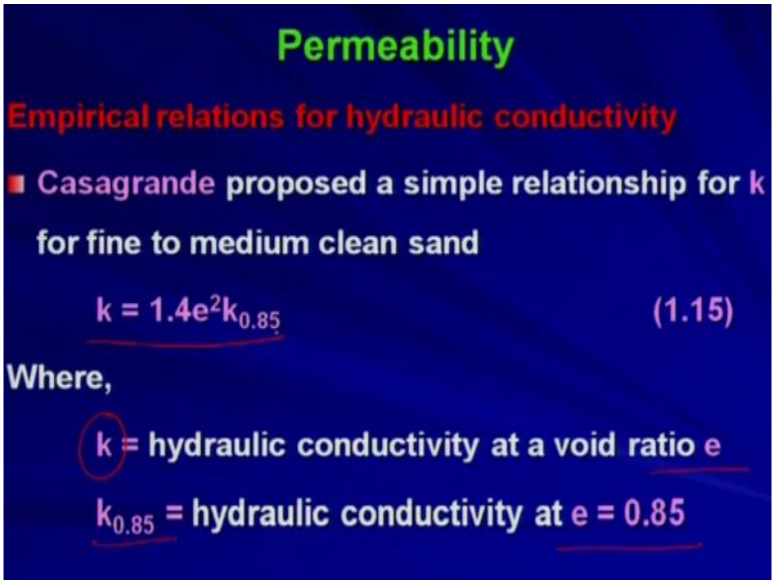

So, Casagrande proposed another say empirical equation, proposed a simple relationship for k for fine to medium clean sand okay so this I mean empirical relations are suitable for I mean sandy particles or the granular material. Now k as per Casagrande k is given by 1.4 into e square into k 0.85. Now what is k 0.85? Now let us see. Where k is the hydraulic conductivity at a void ratio e. So, now suppose you have got some sand so you can find out the void ratio.

So, at that void ratio basically you need to obtain or you wish to obtain the hydraulic conductivity. So, at that e or the corresponding to that e basically you need you want to find out k. Now you have to find out k 0.85 which is nothing but the hydraulic conductivity or the coefficient of permeability at void ratio equal to 0.85. So, at the same sand basically you obtain the hydraulic conductivity from some laboratory experiment at this void ratio e 0.85 and the whatever void ratio is available with you, so corresponding (()) (15:34) at void ratio you can find out k from this expression okay.

So, this is very simple expression. Only thing is that you need to find out say k 0.85 from the laboratory experiment. Now one thing I would like to mention as we are discussing about this sand and all, now from the laboratory experiment you have seen 2 kinds of laboratory experiment right, one is your constant head another one is your falling head test. Now as you know from your own experience that if you put water on top of sand then it will sieve through or it will percolate through the sand body immediately right. Whereas if you put water on top of clay it will take some time okay to percolate through or sieve through the soil body.

Now basically these are 2 things which will govern or which will tell you that what type of test will be suitable for what type of soil. Now if you think about the constant head test, basically you are maintaining the constant head. Now if your flow through the soil is not good enough, if your flow flowability or the permeability of the soil body is not good enough then you will not be able to maintain the constant head. So, that means you need to have some higher magnitude of coefficient of permeability so that you can maintain the constant head.

So, therefore the constant head will be always suitable for sandy type of soil or the granular type of soil because the water percolation rate will be very high and you will be able to maintain the constant head whereas in case of cohesive soil that is I should not say cohesive soil at this moment because you are not familiar to this term cohesion, anyway but clayey type of soil if you consider or fine grained soil where the permeability is very less because as you know from the grain size distribution the granular material will allow you more drainage or more seepage whereas the fine particles or the fine grained soil will allow will give you very less amount of permeability.

So, now what exactly you are thinking of? So, if you choose the clayey soil and if you want to find out the hydraulic conductivity in the clayey soil then basically you are putting water and that water that seeping of this water through the soil body will take some time right. So, you will not be able to maintain the constant head for that because the permeability is very low.

So, you are putting some initial head and you are allowing the water to seep through and then you are observing some final head. So, therefore for I mean this fine-grained soil particularly clayey type of soil you should use the falling head test to determine the hydraulic conductivity. So, for granular material you will be using constant head and for fine grained soil you will be using falling head.

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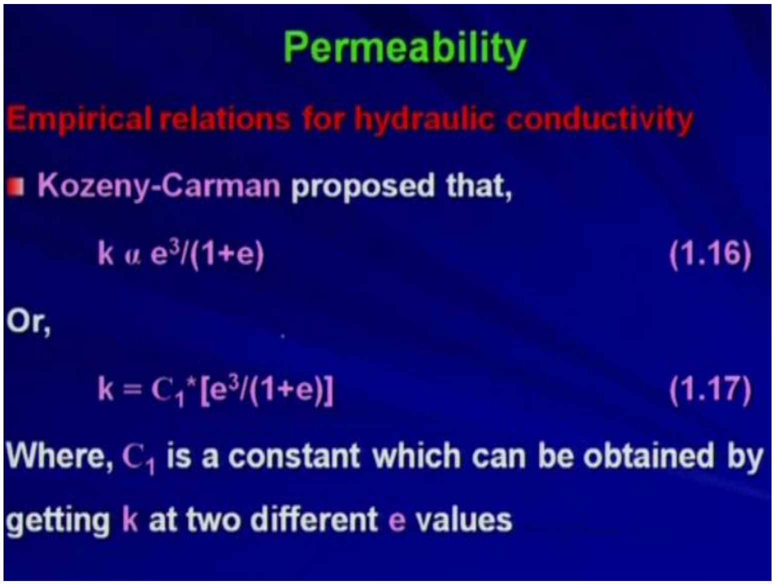

Now coming back to the empirical equation once again that Kozeny and Carman proposed that k is proportional to e cube by 1 plus e where e is the void ratio or k is equal to C1 that is some constant multiplied by e cube by 1 plus e where C1 is a constant which can be obtained by getting k at 2 different e values. So, at 2 different e values you choose so any soil you take and then for different e values you find out the permeability and then based on that you find out C1. So, once C1 is obtained then you can find out k for any other void ratio okay.

So, I will stop here today. So, in the next lecture we will continue with this permeability and we will try to find out how to find out the permeability in the field and other different factors like if you have the stratified soil how the permeability or the equivalent permeability can be calculated, all those things we will be seeing in the next class. Thank you.