Geotechnical Measurements and Explorations

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Lecture.No. # 34

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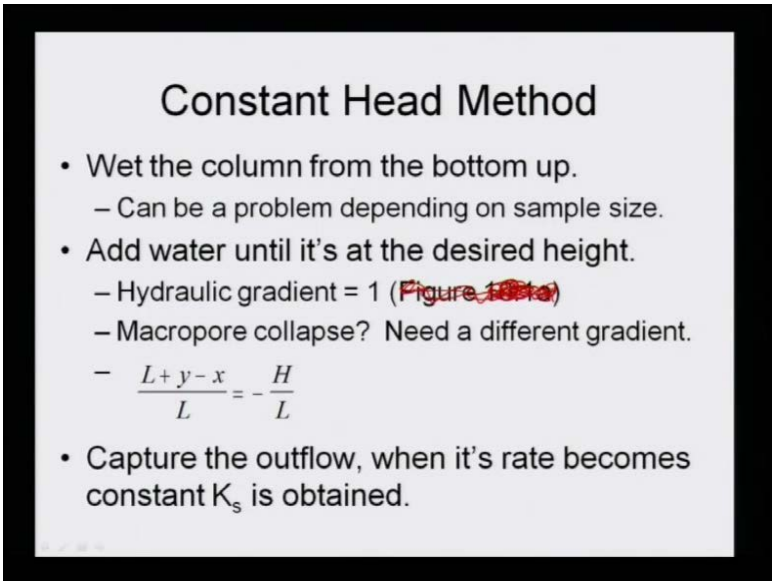

So, next part is your constant head method to determine coefficient of permeability as I said last class. So, there are two methods one is your constant head method other is your variable head method. In this method generally, you add water and collect at the outflow, when the rate becomes constant that means, how do you know that add water. Until, it is hydraulic gradient become one that means rate becomes constant that means you collect water in a stipulated time. So, same water you are getting a regular time interval, then you can say that the rate becomes constant.

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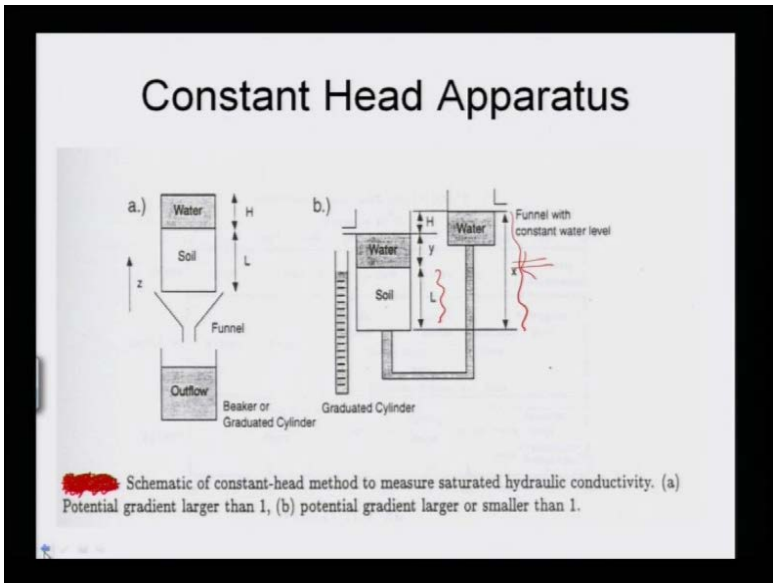

So, at that conditions you find it out, what is the difference means, coefficient of formability of soil, if you look at this constant head apparatus. Generally, what happen? There is a soil and water has been allowed to flow through the soil in a constant head that means, this head is fix this height of the water fixed from the soil. So, that the head is fixed so water allows to pass through the soil. So, then you will collect amount of water in the outflow, passing through the outflow water discharges for time based on the time. You can find it out your coefficient of permeability. So, L is the length through the soil, if you look at here means water passing through the soil from here to here this is called length.

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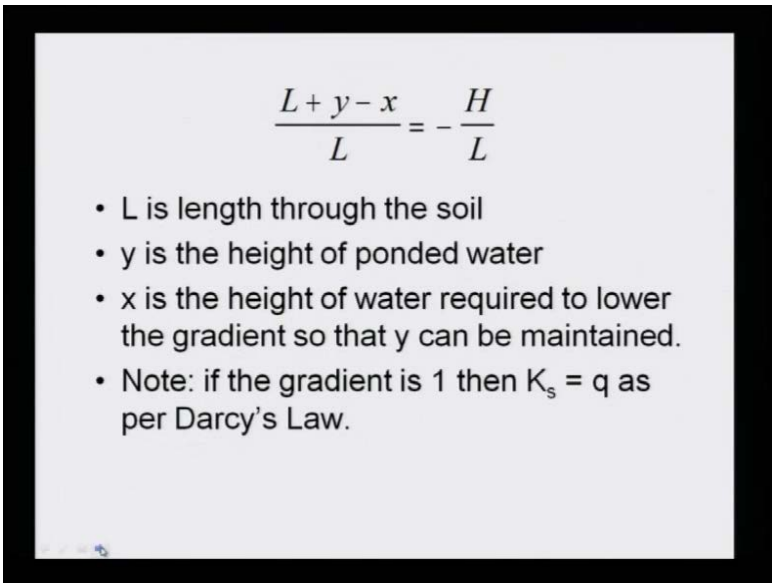

Y is the height of pounded water that means height of the water above the soil. x is the height of water required to lower the gradient so that y can be maintained. x is the height of the water required to be lower, so that y should be always maintained, if gradient is 1 then K s is equal to q as per Darcy's Law.

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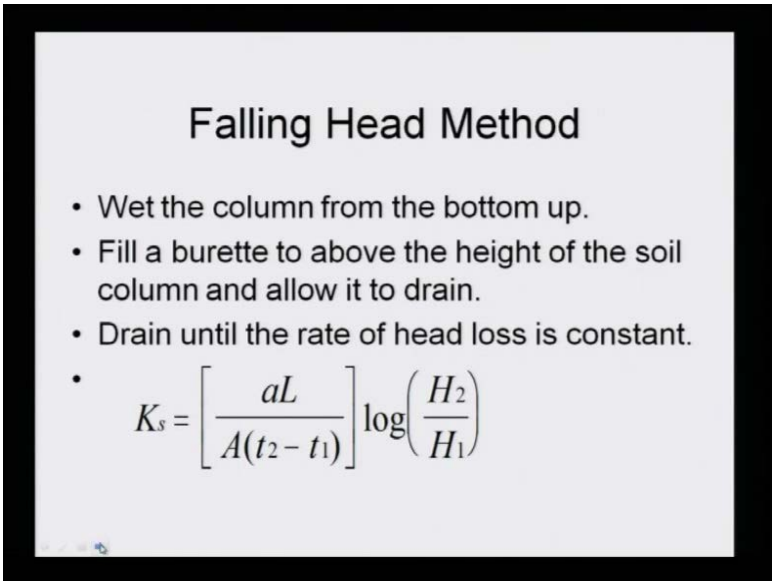

Now, come back to falling head method, in this falling head method wet the column from the bottom up fill a burette to above the height of the soil column and allow it to drain. Drain until rate of head loss is constant means rate of head loss is constant. So,

coefficient of permeability of soil you can find it out a l by A into t 2 minus t 1 log H 2 by H 1. It is called falling head that means the head has to vary, where this falling head has been used this falling head used for the soil of fine grained soil. Generally, for constant head method has been used to find it out coefficient of permeability of coarse grained soil.

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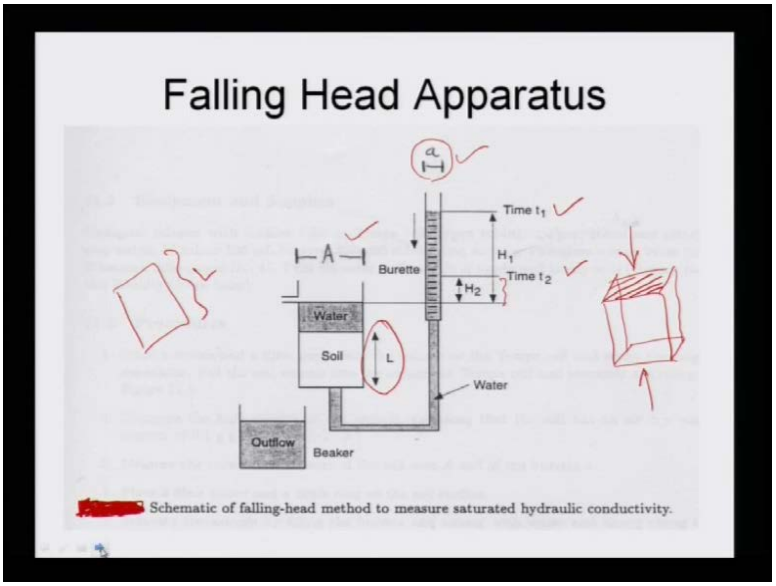

Now, if you look at this falling head apparatus this is soil so this is a burette water is there means initially you pour water inside the burette then A is your diameter of the burette. And find it out what is your time interval time t 1 then after certain height H 2 find it out time t 2, L is your length of the soil, where it is passing through. Now, area of cross section the moment I say area of the cross section. If this is my soil sample how water flow through this, water is flowing through this in this direction or in this directions that means, this is the area of cross section through which water passes.

So, a is your area of cross section, if you know the change in water collected with a time t 1 as well as t 2. And these are your fixed parameter that means a is your diameter of burette cross sectional area of soil you know, length of the soil you know in that mold what is that length of the soil? That you know then if you collect the out flow that means, discharge with respect to time t 1 and t 2. Then only you can find it out what is your coefficient of permeability for falling head apparatus that means for fine grained soil. If you look at a is your diameter of burette L is your length, length of the soil specimen a is

your area of cross section t 2 minus t 1 with this time t 2 and t 1 and H 2 by H 1 is nothing but your head or height. If you look at here H 1 with time t 1 with time t 2 with this, what is your head this is your H 2. From there you can find it out coefficient of permeability by means of falling head method this is I explained.

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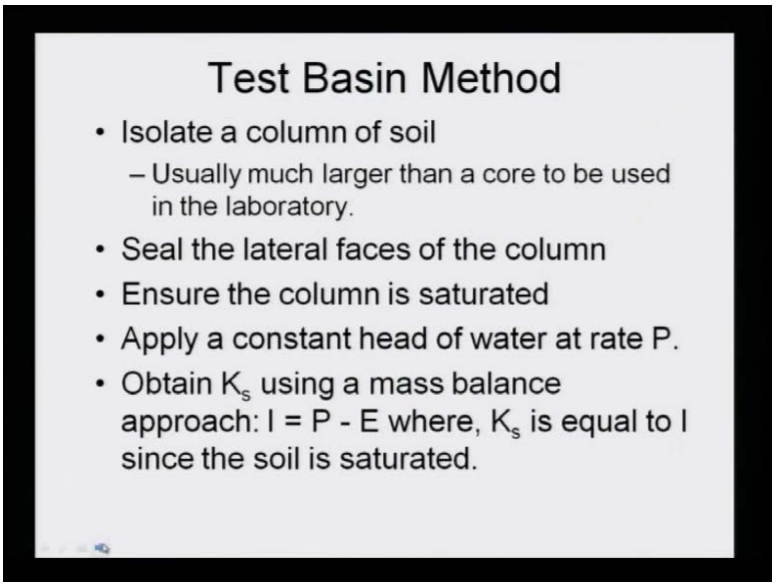

Now, another one is called test basin method that means isolate a column of soil. Usually much larger than a core to be used in the laboratory. Seal the lateral faces of the column. Ensure the column is saturated. Apply a constant head of water at rate p. Obtain K s using a mass balance approach that means, I is equal to P minus E where K s is equal to I since soil is saturated this is called test basin method.

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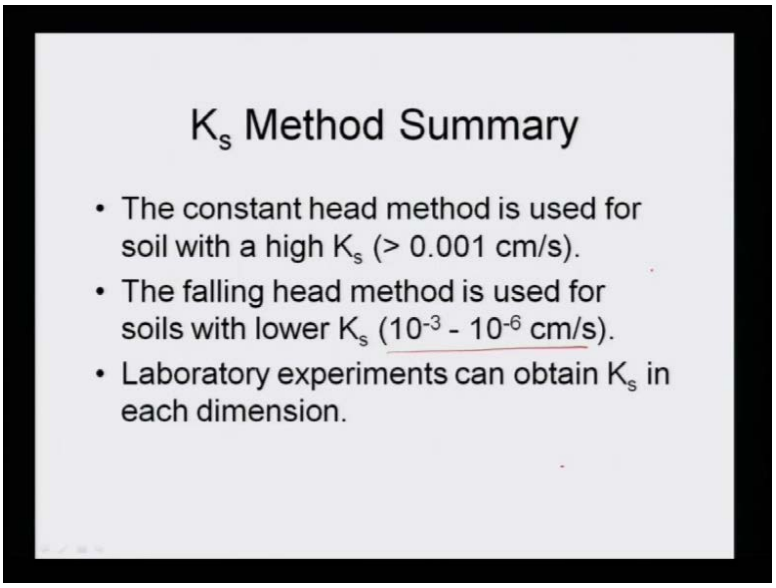

So, K s finding out coefficient of permeability of soil the constant head method is used for soil with a height with a with a high K s means high coefficient of permeability. That means the soil whose coefficient of permeability is greater than 0.001 c m per second. That means high coefficient of permeability from where you will get it? You will get it for cohesion less soil high coefficient of permeability. Because these, are a sandy soils, where you are going to or you are expecting high coefficient of permeability. The range is given if K s coefficient of permeability of soil is greater than 0.001 cm per second, then constant head method is to used. Somewhere else coefficient of permeability is written K s some people they write it K s some will write capital K.

So, it depends upon the notations how they are using the falling head method is used for soil with lower permeability that means, if coefficient of permeability is varying between 10 to the power minus 3 to 10 to the power minus 6 cm per second. That means this is for your fine grained soil, then the falling head method to be used. Falling head method indirectly it says that it is for fine grained soil. This is for coarse grained soil laboratory experiment can obtain K s in each dimension both the dimensions you can find it out means, a coefficient of permeability before I start this determining this unsaturated K.

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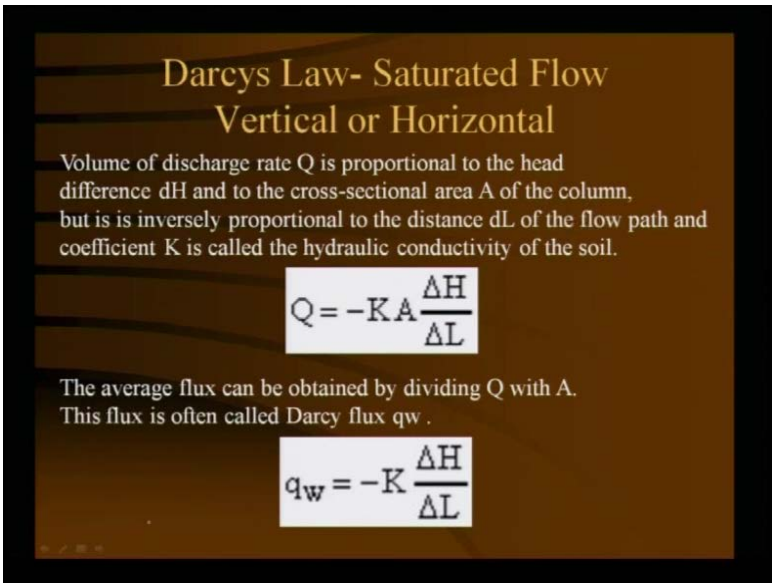

Now, if you look at here this Darcys law saturated flow vertical or horizontal, if I go back to theory volume of discharge rate Q is proportional to head difference d H. And to the cross sectional area a of the column but is inversely proportional to the distance d L or L. We say L or d L or H or d H of the flow path and coefficient of permeability K is called coefficient of permeability or coefficient of means conductivity sometimes hydraulic conductivity of soil. It say is Q is equal to minus K A delta H by L the average flux can be obtained by dividing Q with A the flux is often called Darcys flux q w Darcys flux q w.

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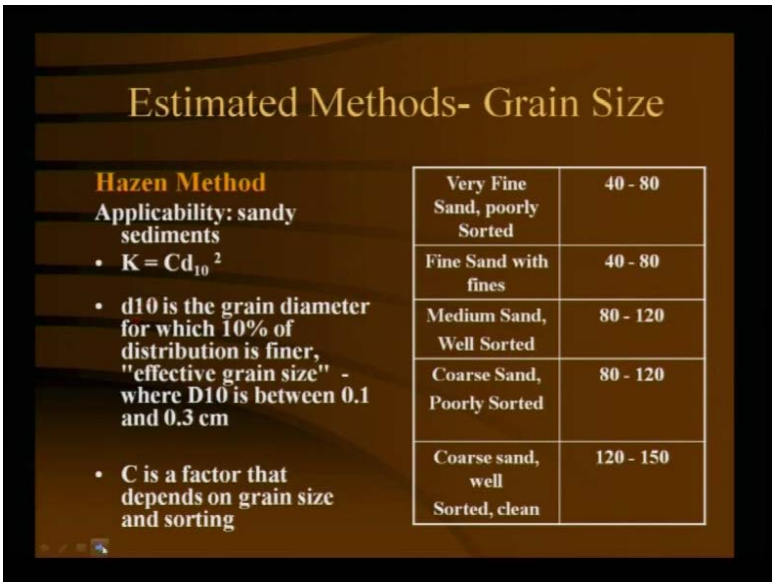

Now, if you look at this estimated methods grain size very fine, sand or poorly sorted means it will be 40 to 80 percent means applicability's sand sediments. So, K is equal to C into 10 d ten square d, 10 is your grain diameter for which 10 percent of distribution is finer that means effective grain size, where d 10 is between 0.1 and 0.3 centimeter C is a factor. That depends upon grain size and sorting C is a factor and medium sand well graded these are all turbulated form it is given.

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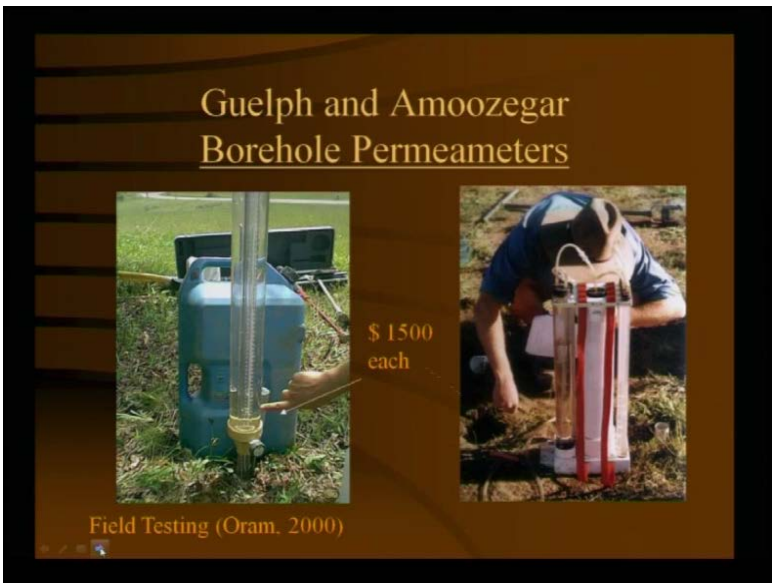

Field testing, if you look at this field testing this is called borehole permeameter one of the testing as I said earlier, in the field permeability how do you find it out. One is method is your pumping in, pumping out other is your by means of tracer third, is your by means of borehole method. And this is one of the felid test that is called borehole permeameter or permeability test, if you look at here these are all testing arrangements of the field testing for borehole.

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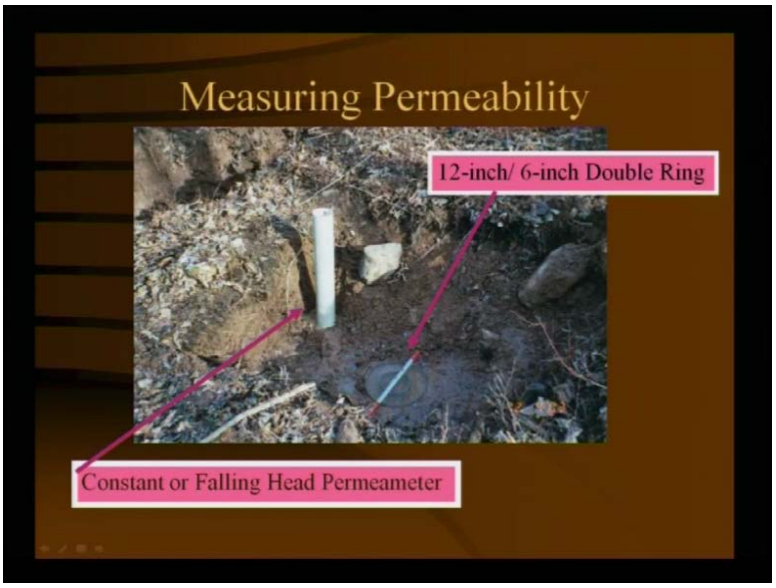

You see 12 inch to 6 inch double ring has to be provided here and by means of borehole constant or falling head permeameter. You can measure, if I go back to my this double ring.

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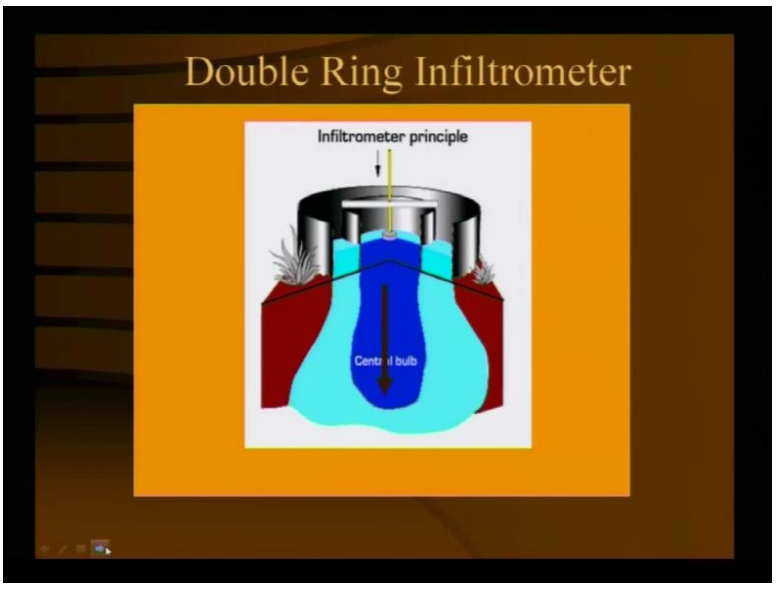

Double ring infiltrometer is a central bulb with this a infiltrometer principle is as far this.

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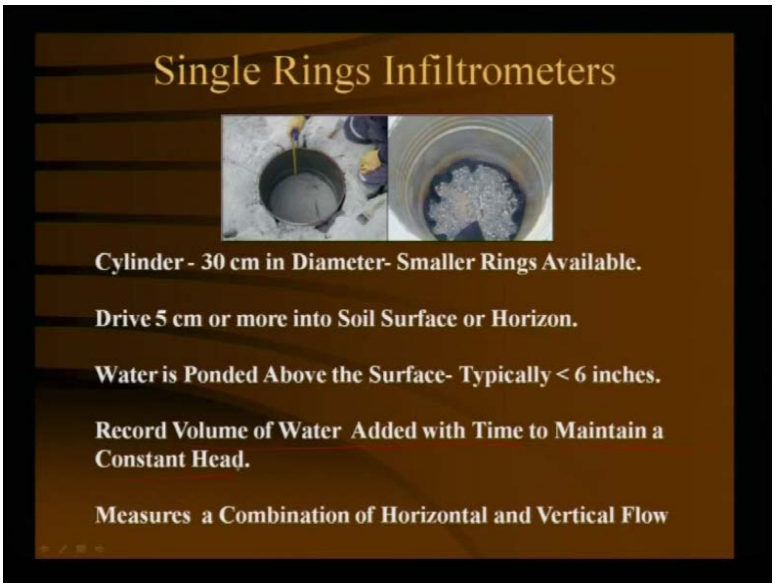

Cylinder of 30 centimeter in diameter smaller rings are available also, drive 5 centimeter or more into soil structure or horizon. Water is pounded above the surface typically less than 6 inches, record volume of water added with time to maintain a constant head how much of volume of water required to maintain a constant head. It can measures a combination of horizontal as well as vertical flow this is a single ring infiltrometer.

So, you in that infiltrometer allow water so, measure the volume of water with time to maintain the constant head. That means equal amount of water passes through this borehole with equal time difference at where, the it will achieve a constant head that means, how much volume of water require to achieve your constant head. That is in case, of this both single as well as, double ring infiltrometer. This advantage is this by borehole method you can measure both a combination of horizontal as well as, vertical flow in case, of infield testing method or insitu conditions.

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Now, A S T M double infiltrometer means, if you look at this A S T M double infiltrometer this is your infiltrometer. And outer ring are means, particularly this is your outer ring, this outer ring is about 6 to 24 inch in diameter. And A S T M recommend 12 to 24 inches and mariotte bottle can be used to maintain constant head, this is a bottle to be used to maintain constant head. And the rings driven 5 centimeter to 6 inch in the soil and if necessary to be (()) basically, in this ring what will happen, it should be inserted inside the soil and from here water should be added to the ring.

So, it allow to flow through this once it allow flow through this then you can find it, out how much water pass through the soil in equal interval of time. So that, a constant head has to be measured means maintained once a constant head has been maintained then you can find it out what is your coefficient of permeability. So, particularly very difficult to install and seal A S T M double rings single rings are easy to install and easy to seal particularly very difficult in double ring. Because this enter is has to go inside, because this five plain from where there but in case of single ring.

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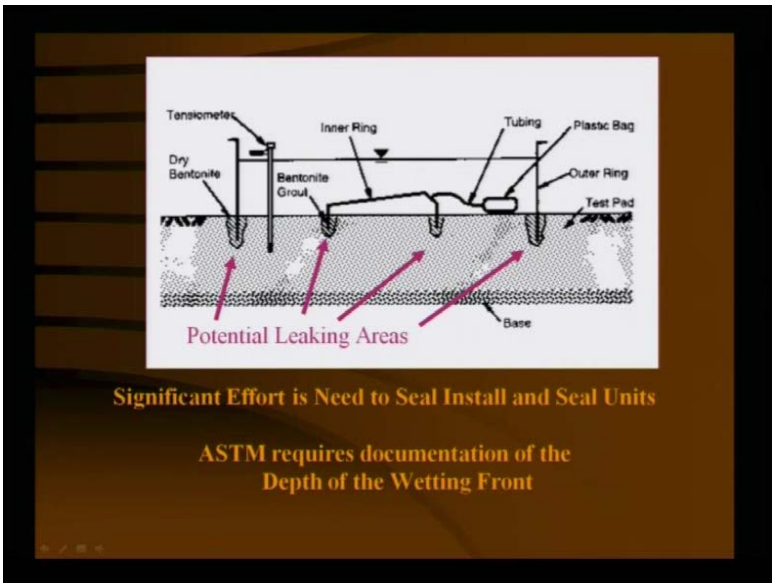

There is nothing, you can add water from the tub this is significant effort is needed to seal the seal install and seal units. That means A S T M requires documentation of depth of wetting front there might be a chance of leakage here potential leaking area here may be leaking it has to be sealed by means of bentonite slurry.

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Other double ring small diameter are easier to install or repeat the testing this is a 6 inch to 12 inch double ring 3 is to 5 inch double ring in 12 inch diameter look at this, how it has been install.

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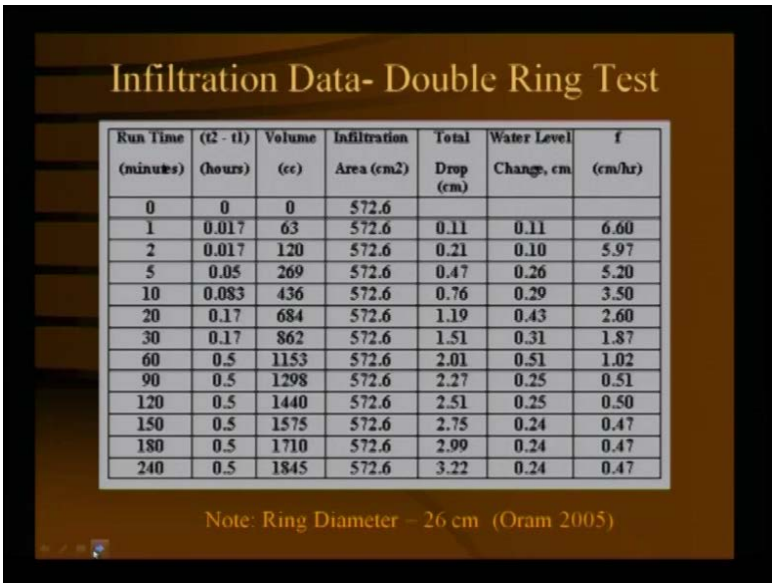

Run Time (minutes)	(t2 - t1) (hours)	Volume (cc)	Infiltration Area (cm2)	Total Drop (cm)	Water Level Change, cm	f (cm/hr)
0	0	0	572.6			
1	0.017	63	572.6	0.11	0.11	6.60
2	0.017	120	572.6	0.21	0.10	5.97
5	0.05	269	572.6	0.47	0.26	5.20
10	0.083	436	572.6	0.76	0.29	3.50
20	0.17	684	572.6	1.19	0.43	2.60
30	0.17	862	572.6	1.51	0.31	1.87
60	0.5	1153	572.6	2.01	0.51	1.02
90	0.5	1298	572.6	2.27	0.25	0.51
120	0.5	1440	572.6	2.51	0.25	0.50
150	0.5	1575	572.6	2.75	0.24	0.47
180	0.5	1710	572.6	2.99	0.24	0.47
240	0.5	1845	572.6	3.22	0.24	0.47

Means, these are all your infiltration data of this test has been made by Oram 2005.

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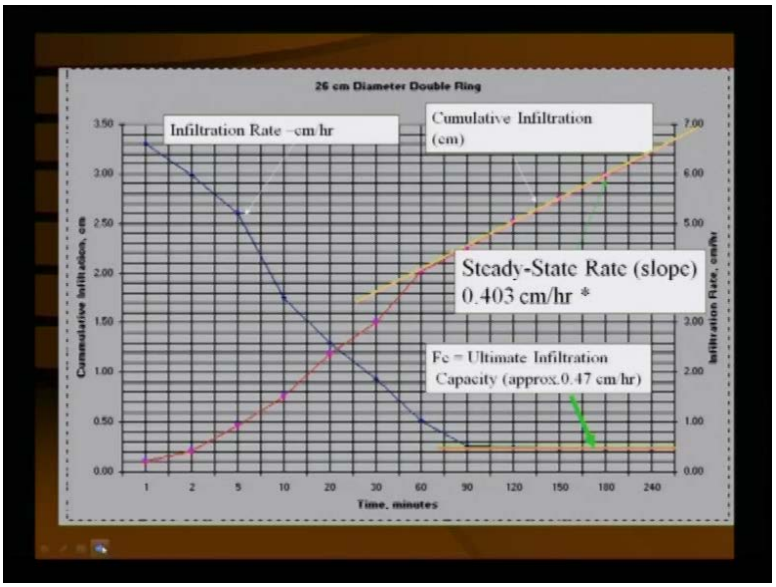

Now, come back to this field test look at this by means of boring insitu boring method means this is your borehole you made the borehole here. And boring pipe has been inserted here by means of single ring 12 inch to or 6 inch or single ring or double ring, you allow water to flow inside so that a constant head has to be achieved. Once a constant head has to be achieved that means delta H by delta L amount of soil, where you are considering inside this borehole.

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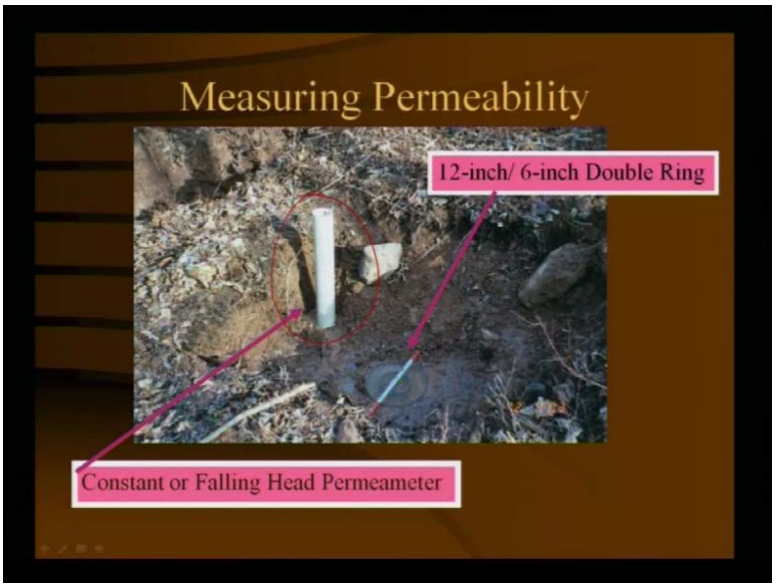

With the time you can find it out, your coefficient of permeability in insitu vertical as well as also laterally.

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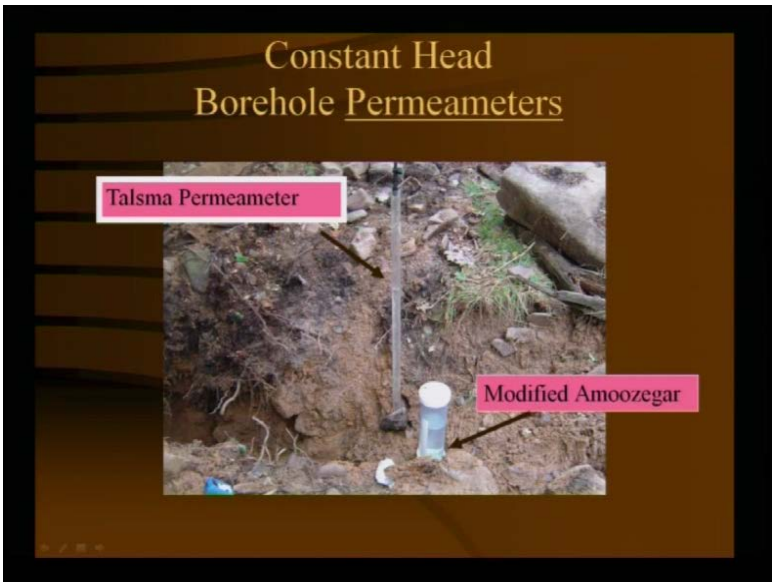

Another one is it has a different permeameter. You see sometimes it is given naming talsma permeameter, where you see here your modified amoozegar. So, here water you add it how much water passed through this you can find it out. So, this is a constant head borehole permeameter.

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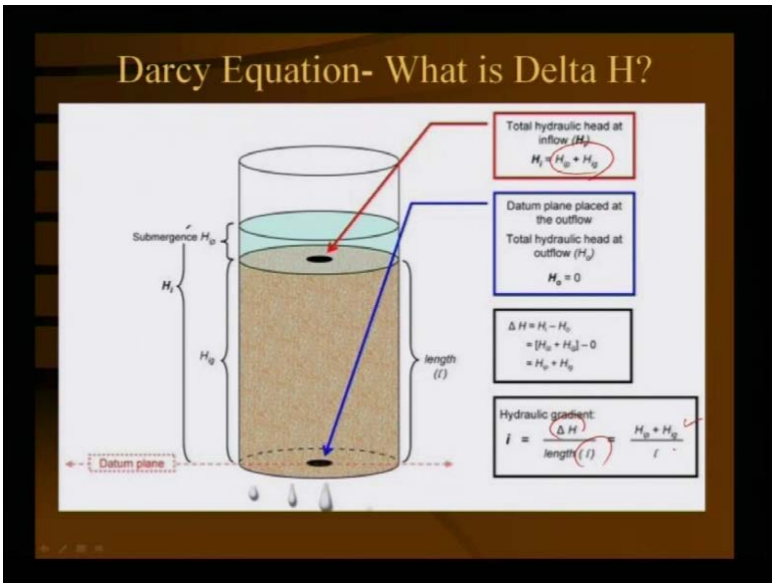

What is delta H, if you look at delta H each, if you look at the total hydraulic head at inflow at point of inflow total hydraulic head is your at this point. At this point total hydraulic head is if it is H i that means, H i rho plus H j p what is H i rho means, if you look at here this is your length of the soil plus this is your water. So, datum plane placed at the outflow that means, where this outflow will be there datum plane has to be place it this is my datum plane. So, total hydraulic head that outflow H 0 is equal to 0, because datum plane has been placed here. So, delta H change in hydraulic head is H i minus H 0, H i is nothing but your, it has come from here soil with water minus o. So, this will so hydraulic gradient i is equal to change in hydraulic head by length so, this is your change in hydraulic head and this is your length.

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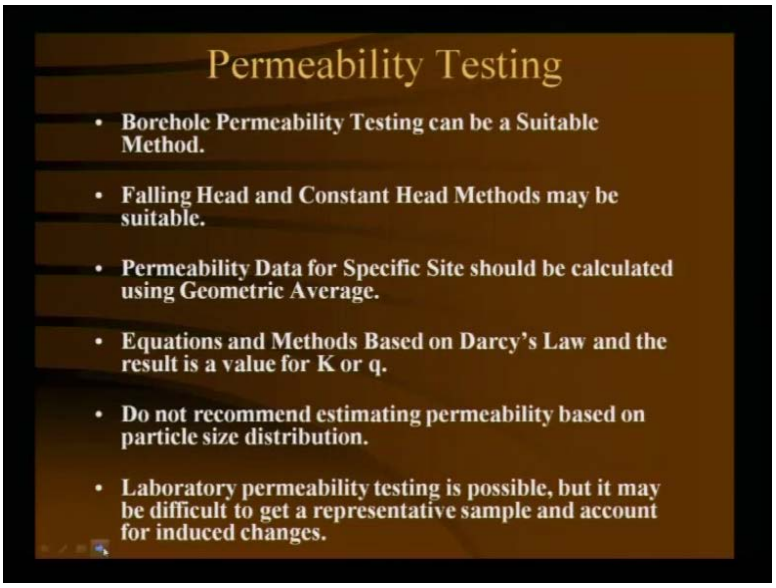

Borehole permeability testing can be a suitable method falling head and constant head method may be suitable permeability data for specific side should be calculated using geometric average. Means specific data specific side permeability data suppose, specific side is this side is there. So, how do you find it out in geometric average? You consider one borehole here find it out permeability, one borehole here find it out permeability, one borehole here find it out permeability, one borehole here find it out the permeability with these, once you find it out the permeability.

Then you can take it is average equations and methods based on Darcy's law and the result is a value for K or q. Always do not recommend estimating permeability based on particle size distribution do not recommend it laboratory permeability testing is also possible. But it may be difficult to get representative sample and account for induced changes. So, best is you go for borehole permeability testing the field insitu condition, then you recurred it and that site recurred it three four places and take this average. This average value has to be reported to find it out means, particularly this geometric average value of this K has to be reported for your final value of coefficient of permeability of soil.

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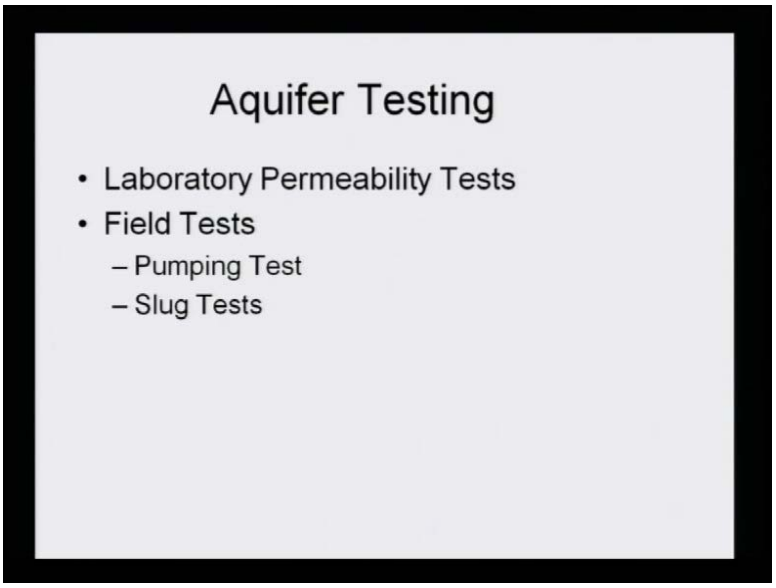

Let me, start with this aquifer testing laboratory permeability test and field test after this borehole test, field test also a pumping test also slug test also remaining. So, let me finish.

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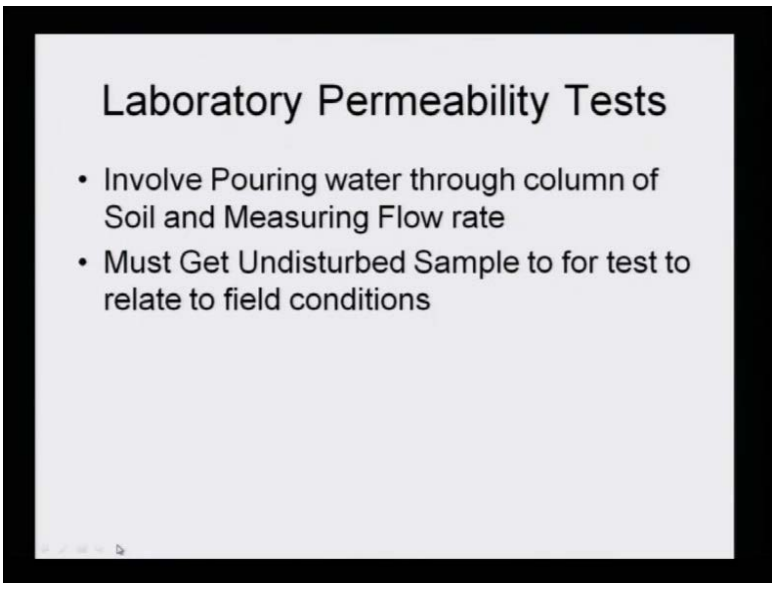

Then I will go to that means as I said, as I discussed last class in laboratory permeability test it involves pouring water through the column of soil and measuring flow rate. And you should get undisturbed sample for the test to relate the field condition undisturbed sample of the soil column, you have to collect from the field. So, that whatever

permeability in the laboratory you are going to get it has to be correlated to the field condition.

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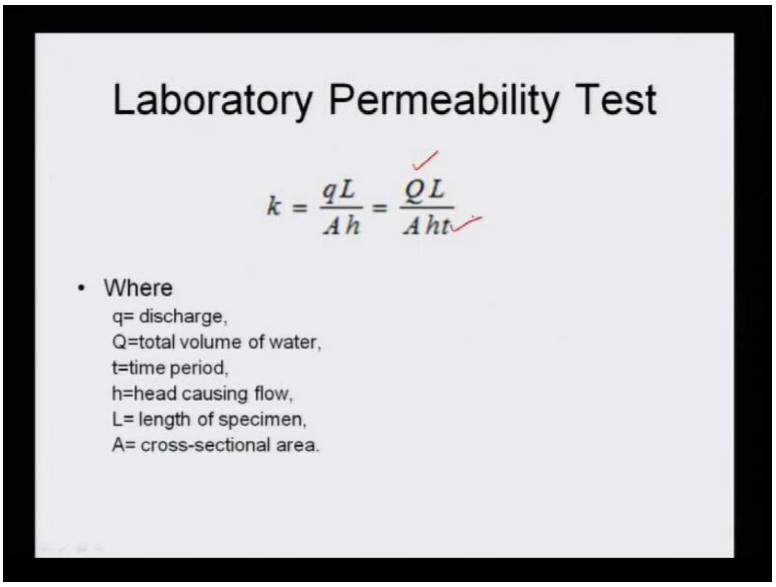

Laboratory permeability test as I said with your constant head k is equal to q L by A h. so, q is your discharge L is your length a is your area of cross section h is equal to head causing the flow, if I make it into Q total Q into L, A into h into t. So, Q is your total volume of water and t is the time period required to cause the head causing flow and L is your length of the soil specimen as I said A is your cross sectional area.

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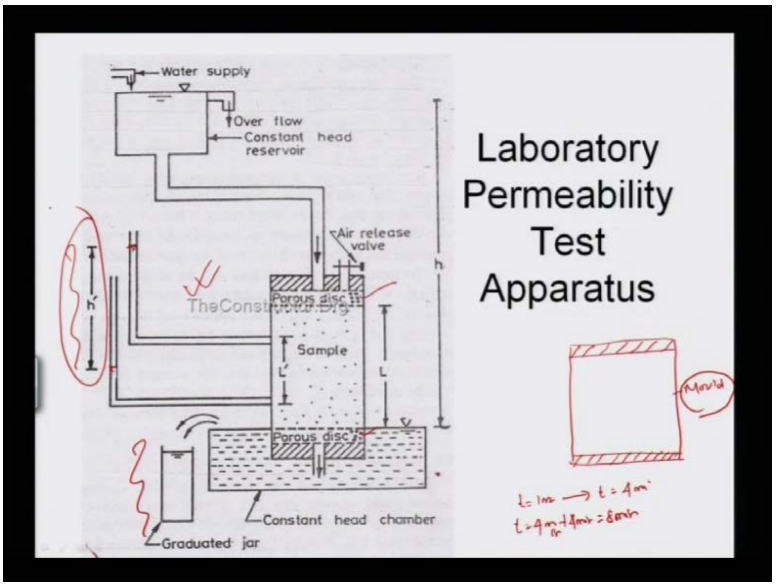

Now, constant head method just a bigger picture I want to show this. This water tank has been placed above the soil sample earlier just I show this means what is the principle, how it has been done this is that laboratory test equipment. Now, this soil sample has been put inside a mold it cannot stand inside a mold with this mold, if you look at this top part is connected with porous stone also bottom part is connected with this. You can connect means place your porous stone both has the top and bottom. And here it is your porous stone or porous disc why porous disc the moment, you allow water only porous stones are only allow water to pass that means the moment water is here. It passes through top of the soil sample.

So, water is allowed to pass through the porous stone along the soil sample then at the bottom what will happen porous stone will only allow water to flow not allow soil sample to flow through here. So, this is a mold inside this mold here soil sample is there and with this soil sample connect it by means, of piezometer. So, you can find it out, how much is your hydraulic head developed H prime how much is your hydraulic head developed then here, at this here there is a graduated jar is there from there you collect your water. Basically, if a constant head permeability this is your constant head permeability method what will happen water first you allow from the tank it should be placed over the soil so that the head has to be maintain.

So, water will pass inside so, how water will pass water will flow from higher head to lower head. So, head loss or head with a difference at head you will observe by means of piezometer. This piezometer will be at the top so, how much water will be here. You can find it out, this is your water this is piezometer at the bottom of the soil sample you will find it out water level. Here with this water level top and bottom, then you can find it out H prime what is your head loss and with this help of head loss. You will find it out constant head permeability you can find it out what is your coefficient of permeability. You see sometimes we write K s sometimes some people write K.

So, K earlier slides are K s, here it is K it is nothing but coefficient of permeability. Now, this total volume of water can you measure it how much volume passing through this yes. I can measure how you will measure look at here, the moment you allow water to pass through this here and collected in a graduated jar. That means, you take a stop watch allow, for suppose, say time t is equal to 1 minute, initially you start time t is equal

to 1 minute then with this stop watch take time t is equal to 4 minute, with 4 minute time t interval collect the water how much water you are collecting.

Then second step with time you start t is equal to 4 minute then allow another time interval say 4 minute that means, next step of 4 minute plus 4 minute at 8 minute time. Then you collect your water and stop the collection of water means at regular interval of time. How much water collected? That, you can measure from there, you can find it out your discharge or total volume of water, where it has been collected in this graduated or measuring jar. How much amount of volume of water you can collect? You can find it out then head causing the flow you can find it out from here by means of measuring the piezometer, you can find it.

Head causing the flow then time period how much time period as I said initial time sort t, t 1 is equal to says 0, t 2 is equal to 2 minute how much time period with this 2 minute of time period of time. You have collected discharge of this m l sustain m l with two minute time interval you get the discharge say Q is equal to 10 m l and time interval t is equal to with 2 minutes. That means you will get Q, you will get t h you will find it out as I said h you will get it from here what is your hydraulic head from there you can find it out h. So, h you also you get you know length of the soil sample from the mold you can you know, what is that pre decided length means, this is your fixed length what is your length, you know it.

So, once you know the length then what else remaining area of cross section that you can very easily find it out. From there you can find it out coefficient of permeability by means of constant head permeability, you can find it out. So, this is meant earlier slides are how it has been done what is the physics behind it, and this slide is showing coefficient of permeability by constant head method laboratory equipment. And how, this laboratory equipment has been placed for this coefficient of permeability by means of constant head method.

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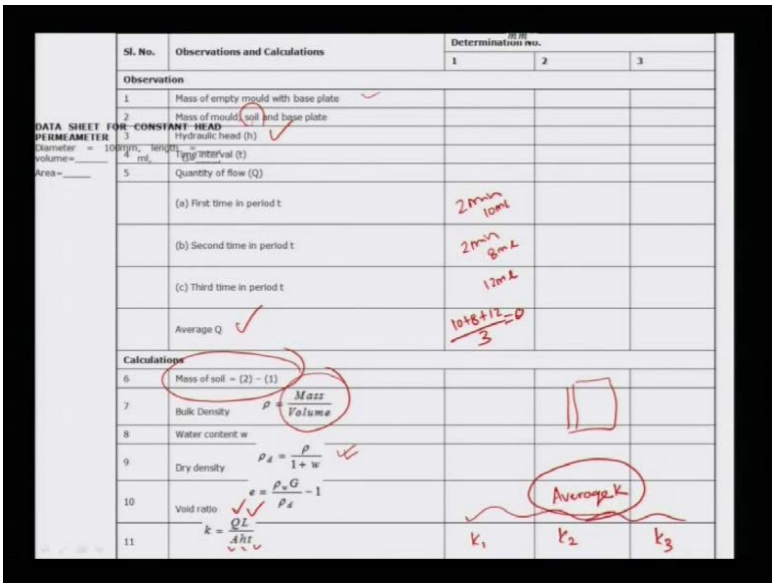

Now, come to next what are the measurement you are going to do this is your calculation sheet that means, mass of empty mold with base plate you measure you have to take at least three molds. So, that average value as I said one coefficient of permeability may not be correct at least two to three. At least three mold you will take it or three soil sample you will take it find it coefficient of permeability and take the average. So, initially mass of empty mold with base plate you measure mass of mold with soil and base plate, you can find it out. Third is your hydraulic head you can get it then time interval quantity of flow you can get it. So, first time in period t, second time in period t, third time period in t what is mean by, first time period in t suppose, if first time period of 2 minute.

What is your flow, what is your q means, how much water you collected in the measuring jar. Second time period suppose, say another 2 minute, how much volume of water you collected how much m l you are collected suppose first 2 minute you collected ten m l, second 2 minute you collected 8 m l, third you collected suppose say 12 m l that means, average value of 10 plus 8 plus 12 by 3 this q l has to be reported. This average volume has to be reported do not go by only one value of q only one time interval whatever you are getting the q that is not to be true. Because inside the soil to get this achieve, this constant head it takes time. So, what will happen you take any two three interval of time and take the average and report it for your calculations.

So, from this from two and one mass of mold soil and base plate, if I deduct mass of a empty mold with base plate I can find it out, what is my mass of the soil. So, mass of the soil you can get it two minus one so bulb density you can finds it out mass for volume. Because mold volume is fixed one meter by one meter by one meter means, what is the dimension is there it is fixed. Now, water content you can measure it from this bulb density you can find it out, dry density then you can find it out also vold ratio, what is the vold ratio it is also required. Then from all this value of Q average value of Q report it length of the sample length of the mold if no area of cross section hydraulic head and time interval.

From there you find it out this is your k 1, this is your k 2, this is your k 3 for three soil samples with help of k 1 k 2 and k 3 then three permeability you are getting theoretical they are suppose, to be same, but it is not true. So, the vary will be means the value will be vary slightly then you consider report it average value of the k 1 k 2 k 3. This you have to report means while reporting this, because this is a laboratory test. This is a laboratory test more the number of samples you are going to test, it more accurate data you will get it more average value you can interpret it.

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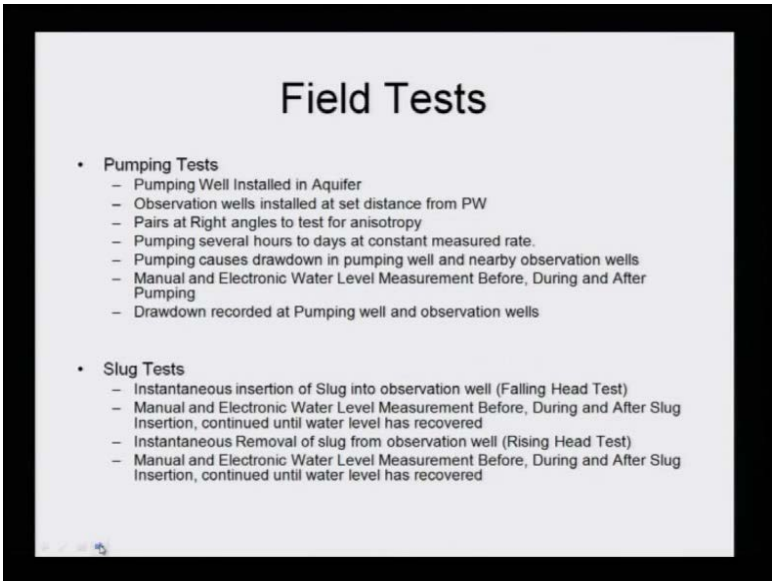

This is the same thing the coefficient of permeability is the dimension is either centimeter per second or m l per second. If you look at this it is a centimeter per second or m m per second in depend upon that how you are representing this sample. Now, there

are two test as I said, I have shown you thus one detail data sheet about the laboratory test data sheet, what are the measurement you are going to do one two three, how many samples what detail data sheets what you are going to get. Same data sheet can be used for variable head in this variable head this hydraulic head to be to h 1 and h 2 with time t 1 and t 2 these two things will come here.

Then calculation as for the formula you can find it out, what is the value of q. And then you can find it out what is the value of k from this formula once you are getting.Now, this field test this is your pumping test pumping well installed in aquifer observation wells installed at set distance from pumping well. Look at this there are two test I left earlier at borehole method I said one is called, another method is called pumping in or pumping out test. So, pumping wells that means pumping wells should be installed in a aquifer, there are two pumping wells, one pumping well has two installed in aquifer, other pumping well is called observation well.

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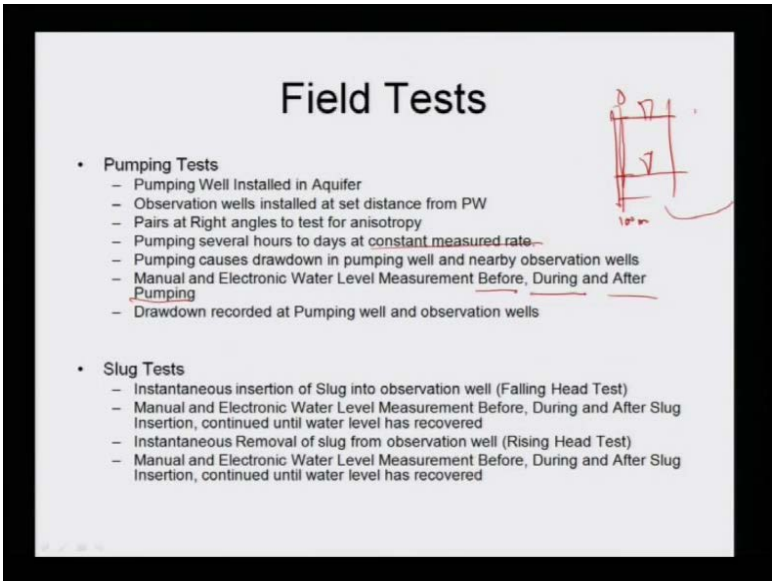

It should be installed at a certain distance away from your pumping well, pairs at right angle to test for anisotropy, if this is my pumping well means pairs at right angle. So, one pumping well will be here one will be here so that it should be right angle to each other. So, that I can find it out anisotropy, anisotropy means isotropy anisotropy, anisotropy means, the property of permeability in x and y direction, it should not be same. Isotropy means k x is equal to k y is equal to k z, x y and z direction the permeability is same.

Pumping several hours to days at a constant measure rate that means pumping means you pump it constant rate that means several hours to days it maybe 4 hours it maybe 8 hours it maybe 1 day it may be it maybe continuous 2 to 3 days.

At a constant measure rate it means, you decide how much amount of water to be pumped out, how much water says suppose, say 100 m l of water so maybe 1000 m l of water that is called constant measure rate. That measure rate should be constant pumping causes, drawdown in pumping well the moment you start pumping water outside this pumping well, if this is a pumping well the water level is here, then you are pump out so sudden drawdown the water level will be fall down. And manual and electronic water level measurements, before during and after pumping that means both manually you can measure it, manually how you can measure it you place a scale from top to bottom you place a scale. Suppose, this is started with 0 this is your 100 m m.

So, how much height water you have pumped that you can measure by manually or by electronics device electronics device you can place it, it can directly give once the dimension is fixed you know the how much volume of water is there. So, how much has been pumping out that you can electronically, you can measure it you place it so meticulously. So, that you can measure before what is the height and during also what is the height and after the pumping, how much the height has to be achieved. Drawdown recorder at pumping well and observation well both these wells you measure how much drawdown has been achieved.

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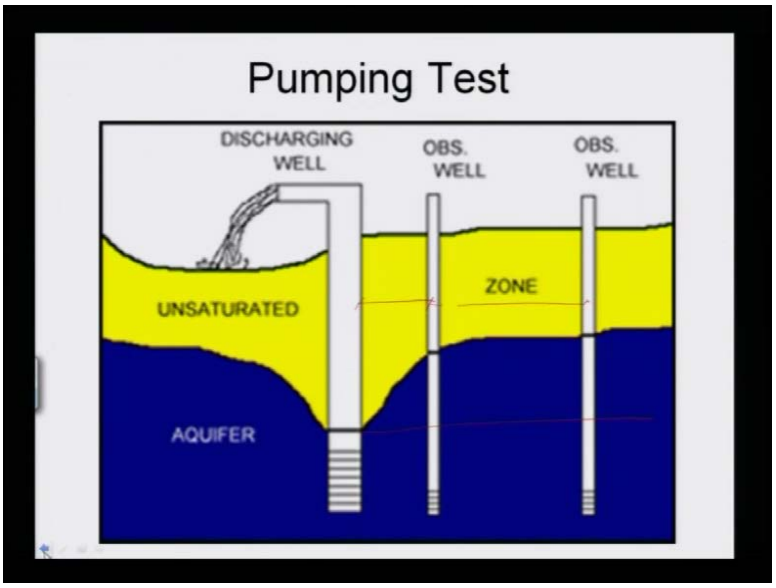

So, another test is your this I am going to show you also, in details these are all infield I am going to show you in details, if you look at here, this is your aquifer means water table is there water level is there aquifer in that aquifer means, this is constant aquifer in that case, you just a discharge well, this is your discharge well and nearby at certain distance. You know this distance with this distance this is your observed well either one well or two wells you can put it.

So, what will happen at a constant rate this discharge you pump, at a constant rate you take out this water from this aquifer so, what will happen? There will be a sudden drawdown, sudden drawdown of water so, how much if water from the soil it is a sudden drawdown with this observed well and as well as here you can measure it. This is how this physics, how it looks, if I summarize, how it looks outside, if I draw a schematic diagram how it looks.

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But in the field it is different you see, how this pumping in, pumping out pumping test has been done. If I take it here pumping test monitoring this observation well these are my observation well one, observation well two it has been electronically pushed so that you can find it out, what is your observation wells also. Then you see this by means of tape also you allow the tape should go inside you can measure the how much, if height of fall how what is the distance the water drawdown is there. You see how much pumping means, by means of constant rate you are taking out the water from the aquifer. These, are pumping test heavy equipments used in the field means, sometimes some people use heavy equipment sometimes some people are using portable equipment.

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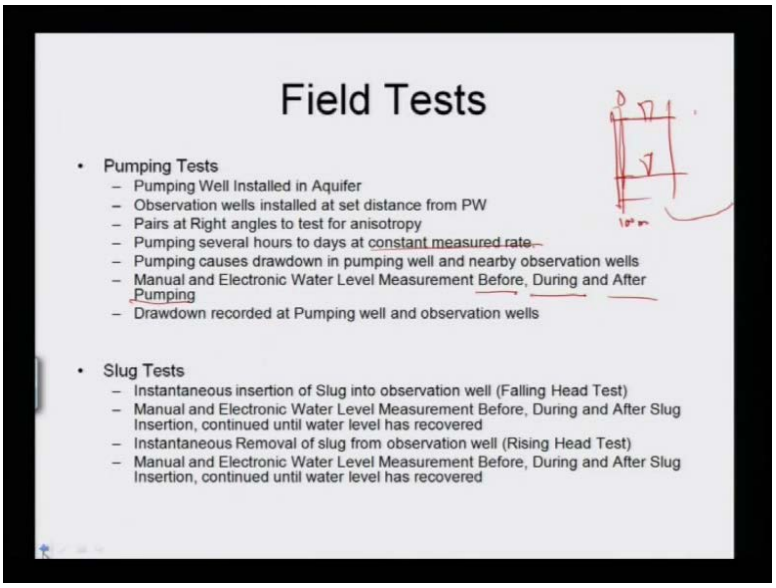

So, then we will go back to our next part of this slug test that we have I will discuss, in the next class.