Geotechnical Measurements and Explorations

Prof. Nihar Ranjan Patra

Department of Civil Engineering

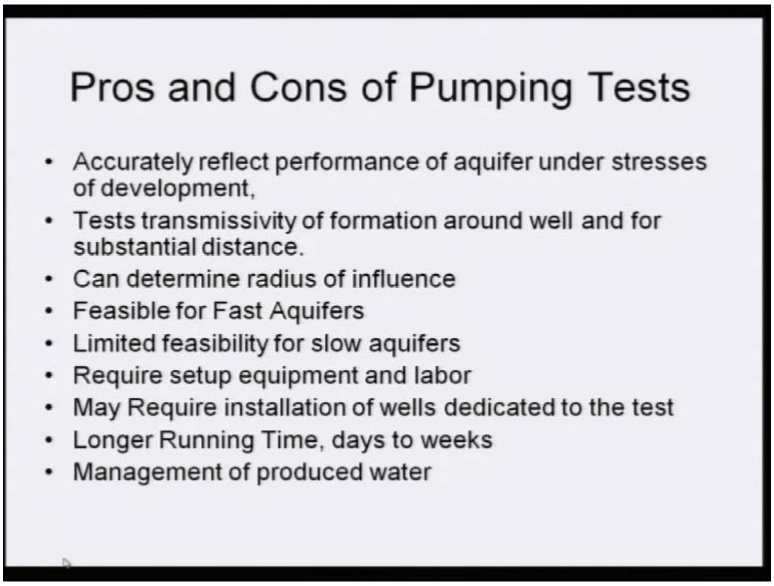
Indian Institute Of Technology, Kanpur

Module No. # 01

Lecture No. # 35

Last class we discussed two field test, that is your pumping test.

(Refer Slide Time: 00:23)

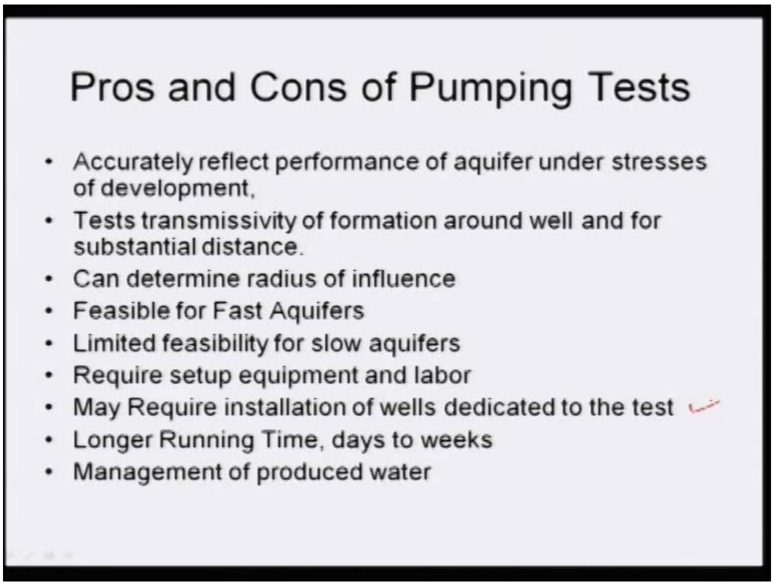


So, I discussed this pumping test, and slug test that means it is say, instantaneous insert of slug into observation wells, either it is a falling head test. Manual and electronic water level measurement before during and after slug insertion, and continued until water level has recovered; and now you come just go back to how this installation of monitoring wells, if you look at here this is a broad picture of how this wells have been installed.

And this is your aquifer where this, this is one well is your discharge well, other two wells are observed well; so at a constant rate, the water has been discharged from this discharge well (Refer Slide Time: 01.06). And at the same time in the observed well, how much water level has fall down, that can be measured by means of mechanically or by means of electronically; there are two measures, so as I said mechanically you can put a scale inside, and you can find it out how much water level in terms of depth has been decreased. This is another typical test of pumping test has been conducted in the field, in United States of America; so this this is a well, well has been made in this well, this pumping test is going on from this discharge, from this well has been conducted with this by means of pumping, pumping of water from the well (Refer Slide Time: 01:43). And these are the electronic monitoring of this observation wells.

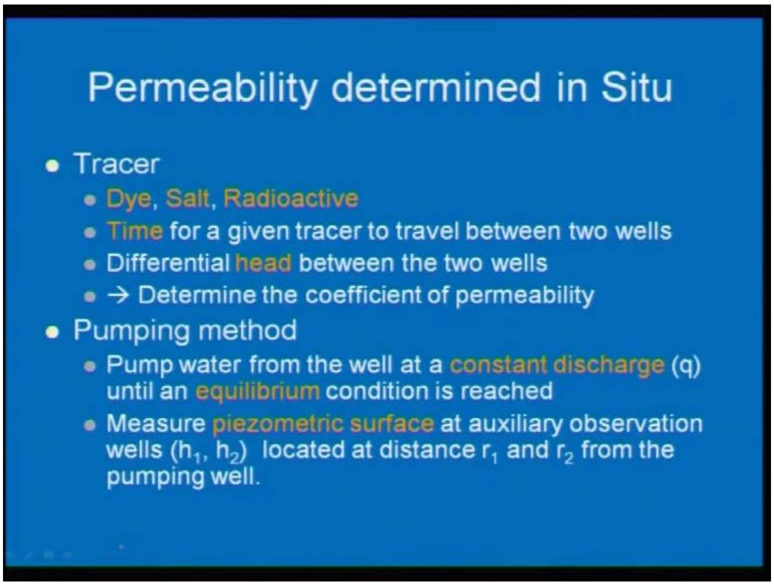
Now, another one is by means of pumping test, you can you can by help of tape, this is called measuring tape, with a prop this tape can be inserted, measuring tape can be with the prop it can be inserted inside this well, and depth of the water level by means falling down, you can measure by means of this measuring tapes (Refer Slide Time: 02:25). These are all, these arrangements for pumping test; this is one of the test which has been done in central America pumping test measurements.

(Refer Slide Time: 03:09)



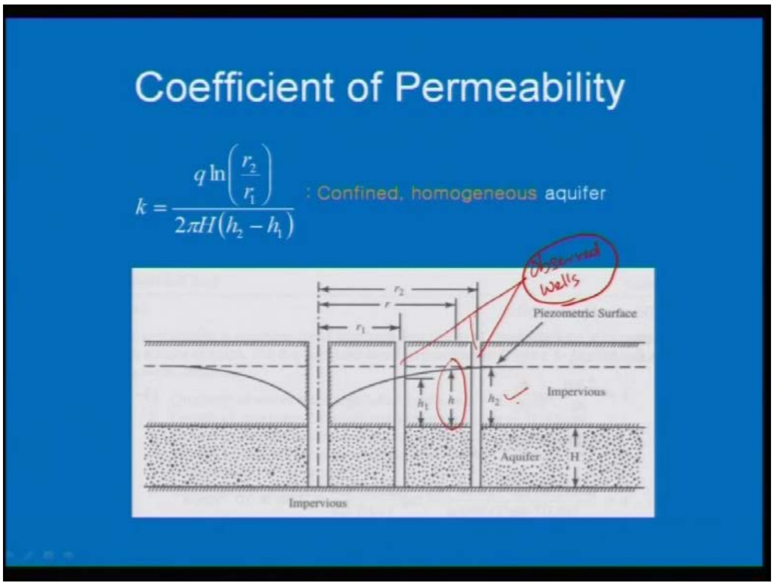
And what is what are the consequence of pumping test? Accurately it reflects performance of aquifer under stresses of development, and test transmissivity of formation around well, and for substantial distance, can determine radius of influence. How far it will influence, it can determine, feasible for fast aquifers, limited feasibility for slow aquifer, require setup equipment and labor, may require installation of wells dedicated to the test. And it requires lot of managements also, so this all about this aquifer. Now, come back to original one, where we are discussing about this permeability measurement by means of tracers or slug earlier, we discussed and I have shown that basic things.

(Refer Slide Time: 03:56)



So, tracer is dye or salt or may be a radioactive material, so this can be put inside the soil, inside this water; so that this flow inside the water by means of tracer. You can trace and you can find it out, by means of differential of head between the two wells, you can find it out what is the coefficient of permeability.

(Refer Slide Time: 04:16)

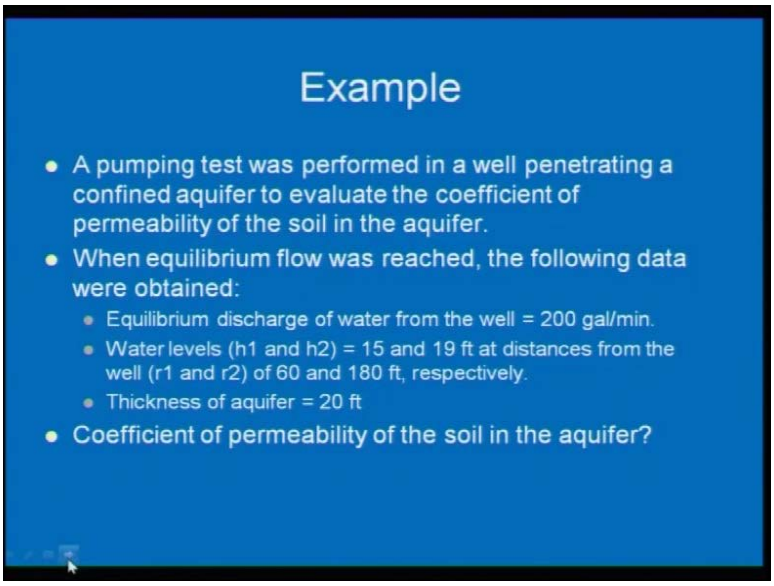


Now, this is the formula used to find it out coefficient of permeability from aquifer test, this is our discharge well this is our discharge well as I earlier shown, this is two measured well. Where this measurement has been made, means in this well, if you look at this, these are the piezometric surface, in first well ones this discharge or this pumping test has been conducted, what is the head of this, and what is the head of this h 2 minus h 1. So, coefficient of permeability k can be find it out q lon r 2 by r 1 2 pi h h 2 minus h 1, k is your coefficient of permeability.

And if you look at here, r is your distance of this discharge well, distance of this well from this, distance of the observed well r 1 is from your discharge well, this is your distance; it may be a radial distance, it is not a straight, it may be go in this direction, in this direction, in this direction, in radially you can place it. And r 2 is also radial distance of the observed well, this two are the observed wells two are the observed well, and r 2 is your radial distance of your second observed well, from this discharge well; this is your discharge well.

So, then r is nothing but, where there piezometric head is there, if you look at here this r is your radial distance, from where this head where this edge, at this level piezometric surface water level is there. And h 2 minus h 1 is nothing but, is your head difference compared to two observed wells, h 2 is head, in second well second observed well h 1 is your first observed well, from this you can find it out coefficient of permeability.

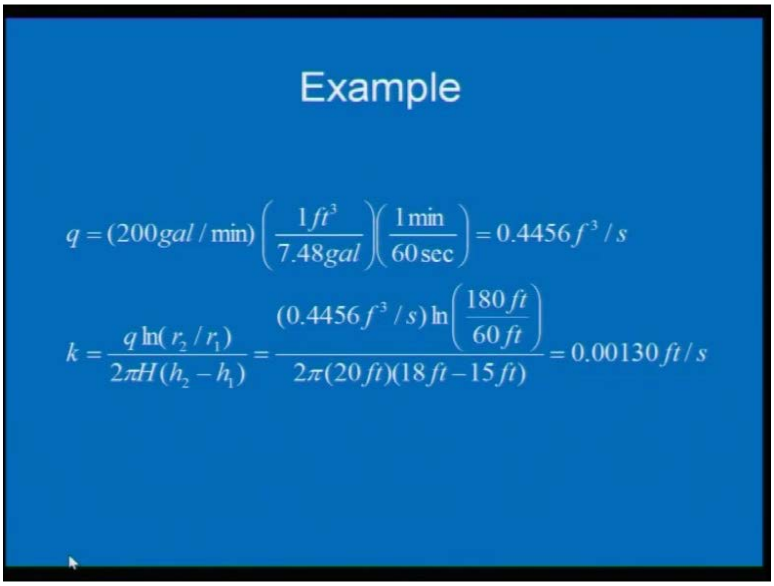
(Refer Slide Time: 06:29)



This is a typical example, a pumping test was performed in a well, penetrating a confined aquifer to evaluate the coefficient of permeability of this soil in aquifer; means this has been given data, from there you can find it out coefficient of permeability. So, it is said equilibrium discharge of water from the well is 200 gallon per minute, discharge is generally gallon per minute or c c per minute or c c per second c c per hour.

This your discharge q, water level h 1 and h 2, 15 and 19 feet at distance from well, r 1 and r 2 is 60 and 180 feet respectively. Thickness of aquifer is equal to 20 feet, so find it out coefficient of permeability of the soil in the aquifer (Refer Slide Time: 07:03). If you look at here h 1 and h 2, this is your h 1 this your h 1 h 2, it is about 15 and 19 feet, and discharge observed from the discharge well is 200 gallon per 200 gallon per minute. And thickness of the aquifer is equal to 20 feet thickness of the aquifer mean, this is your thickness of aquifer, this thickness of aquifer is your 20 feet, h is equal to 20 feet.

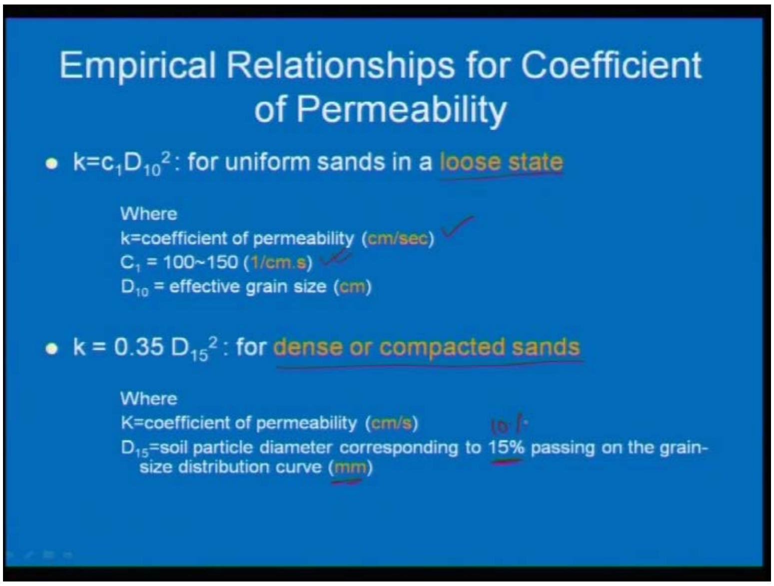
(Refer Slide Time: 07:04)



Now, putting this formula first you convert is your discharge gallon per minute to either, you can convert into feet cube per second or meter cube per second, discharge is meter cube per second or feet cube per second, so it has been converted to feet cube per second. So, it is 0.4456 feet cube per second, and coefficient of permeability, it can be found out from this formula, q lon r 2 by r 1, q is your is your discharge, which has been observed from here. And this is your r 2 distance of your observed well, two observed well one and 2 pi h, h is your thickness of your aquifer, this your 20 feet, and h 2 minus h 1 is 18 minus 15 feet, so this will be 0.00130 feet per second. Now, coefficient of permeability is 0.00130 feet per second. One is your confined aquifer, other is your unconfined aquifer; confined aquifer means the aquifer has been confined between this two layer, so another one is your unconfined aquifer.

In unconfined aquifer you can find it out, k is equal to q lon r 2 by r 1 pi h 2 square minus h 1 square; so same way in this aquifer unconfined aquifer, so one part is impervious, other is open. So, in this case h h 1 and h 2 as I defined earlier, r 1 and r 2 as I defined earlier also, q is the discharge obtained from your discharge well.

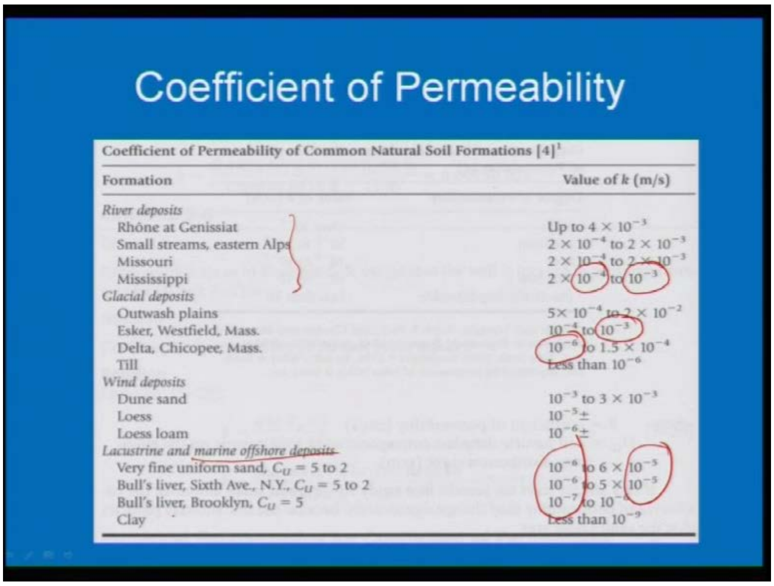
(Refer Slide Time: 09:50)



Now, empirical relationship for coefficient of permeability, how to find it out empirically, if you know D 10, D 10 is it is your size of the this means, 10 percent of the particle size finer than that particle, D 10 you can get from your sieve analysis. So, coefficient of permeability k is equal to C 1 into D 10 whole square for uniform sand in loose state; remember, it is in loose state, and this for we are discussing right now for sand.

So, K is equal to 0.35 D 15 whole square for dense or compacted sand, K is equal to coefficient of permeability, you can get it cm per second. And C 1 is equal to 100 to 150, this is a this is this is not constant, this is 1 by cm second, it has been found out from this this coefficient experimentally it has it got; so effective grain size D 10, this is in cm (Refer Slide Time: 10:43). So, similarly, D 15 is your soil particle diameter corresponding to 15 percent passing on the grain size distribution curve 15 percent passing on the grain size distribution curve in mm, is if it is D 10, then it will be 10 percent passing on the grain size distribution curve, it will be D 10.

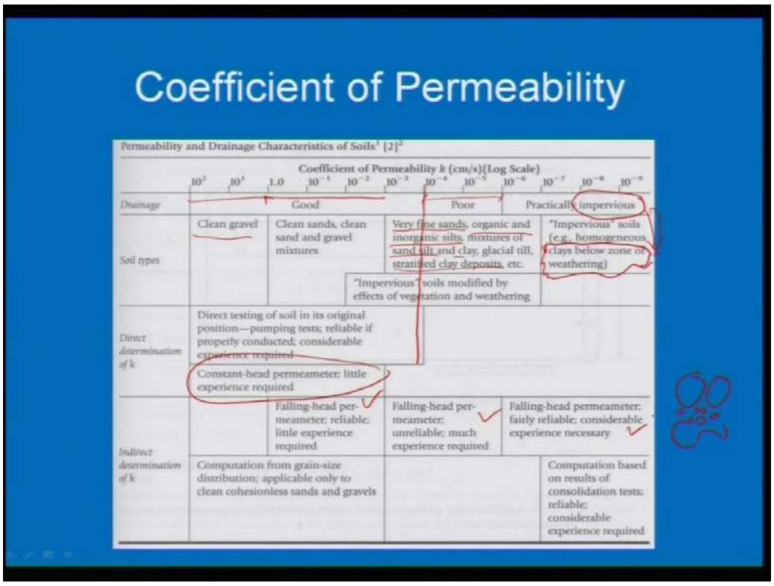
(Refer Slide Time: 11:22)



Now, coefficient of permeability for common natural soil formation, if you look at here this generally range has been given in terms of meter per second, river deposit these are the data, we have also data from Indian sand also. These are the data, I have taken from some of the reference, these are the data for US soil United States of America; so it generally, river soil is varying 10 to the power of minus 4 to 10 to the power of minus 4 to 10 to the power of minus 3.

And glacial deposits it is varying 10 to the power of minus 3 to 10 to the power of minus 6, and marine offshore deposits, it is varying again 10 to the power of minus 5 to 10 to the power of 6 or minus 6 7, even if for clay clay, it is less than 10 to the power minus 9.

(Refer Slide Time: 12:16)



Now, permeability and drainage characteristics of soil part two, if I classify this coefficient of permeability try to understand this chart, I am making it from bigger size to means, permeability cm per second 10 square to 10 to the power minus 9, I put in a scale 10 square to 10 to the power minus 9. So, coefficient of permeability, how it this scale is varying widely, if I start with the soil type, clean gravel, gravel means these are the all clean boulders, big sizes for this clean gravel generally, this is varying about 10 to the power 2 to 1.0.

Now, clean sands sand and gravel mixer, it may sand plus gravel mixer, that means these are my gravels with the sand particles, it is a mixer of sand and gravel it is varying between 10 to the power of minus 3 to 1. Look at the range, for clean gravel it is varying from here to here, for clean sand it is varying from 1 to 10 to the power of minus 3, very fine sand, means particularly this is the range we call as a good drainage (Refer Slide Time: 13:23).

That means, 10 to the power of 2 to 10 to the power minus 4, whatever the coefficient of permeability that we say it is a good drainage; that means in that soil water will pass very easily. Good drainage meaning, water will flow inside the soil, immediately water will come out from the soil means, its permeability capacity is very high. Now, between 10 to the power minus 4 to 10 to the power of minus 6 in soil mechanics, we say it is poor it is poor and 10 to the power minus 6 to 10 to the power minus 9, if the coefficient of permeability, we say impervious. Impervious means is absolutely, if water is there inside the soil, very difficult water to come out or to drainage will be (()), where drainage is not going to (()), that case it is called impervious. Now, very fine sand organic inorganic silts, mixer of sands silts, look at this soils, first part is your very fine sand, organic and inorganic silts, mixer of sand silts, clay, glacial till, stratified clay deposits; this range is lying between 10 to the power of minus 3 to 10 to the power of minus 7.

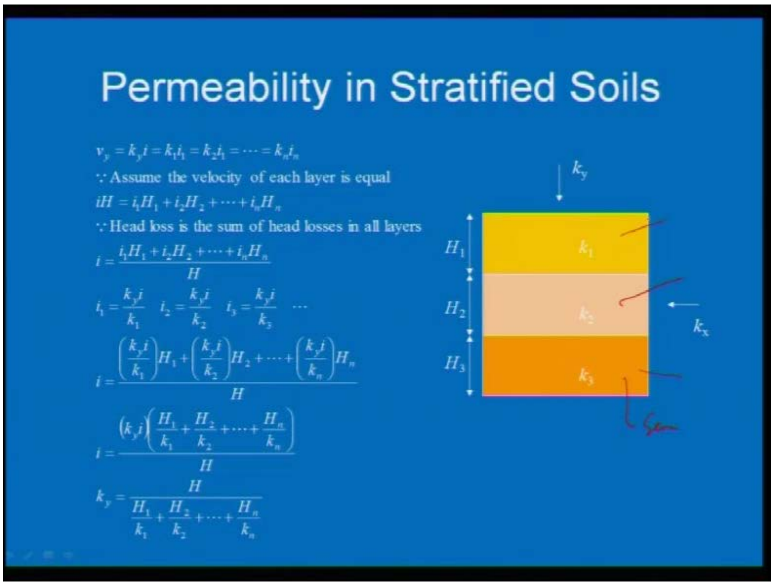
And impervious soils particularly, clay below the zone of weathering, if I can say clay soils below the zone of the weathering, this I can say that this is particularly impervious, that means permeability is not practically possible remember, impervious it is not necessary that permeability is not possible. Permeability is there, but looks at this 10 square and 10 to the power of minus 9, how far the permeability is varying, so that is why it is called impervious (Refer Slide Time: 15:24).

So, now how to find it out direct determination of coefficient of permeability K, so direst testing of soil in its original positions particularly, from between 10 to 10 10 square to 10 to the power minus 4, look at this range; either, you can find it out from the field, pumping test, if it has been properly conducted. This is a best test for insitu, pumping test where you can find it out K directly in the field, then in case of laboratory, laboratory you can find it out by means of constant permeability. Constant permeability means, the head will be head is constant as I explained earlier, by means of constant permeability you can find it out K.

Now, for other part of the soil other part of the soil how do you find it out, this for clean gravel, clean sand, you can find it out in the field by means of pumping test or by the means of constant head permeability test. Now, indirectly how do you find it out in the laboratory, for soils varying with your coefficient of permeability 1.0 to 10 to the power minus 9 falling head permeameter, though this is unreliable in the laboratory, you can find it out by means falling head permeameter test.

This three particularly very fine sand, organic soil, glacial till and stratified clay deposits, this three soils you can indirectly find it out K, by means of falling head permeameter in the laboratory. Then computation of grain size also you do for fine-grained soils, find it out grain size, and indirectly by empirical correlation also you can find it out.

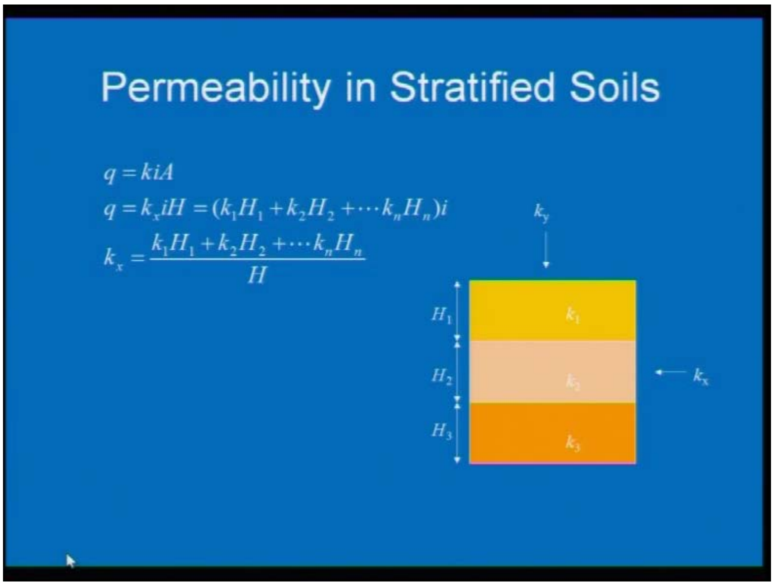
(Refer Slide Time: 17:33)



Then go to the next part, permeability in stratified soil in general, in the field it is not possible that soil is an only one component; if it is sand, it is not possible that throughout all will be sand. So, this is a different soil, this is a different soil, this is a different soil, this is called stratification; so k 1 is different, k 2 is different, k 3 is different, so stratification may be in y direction different, may be in x direction different, may be x as well as y direction it is different.

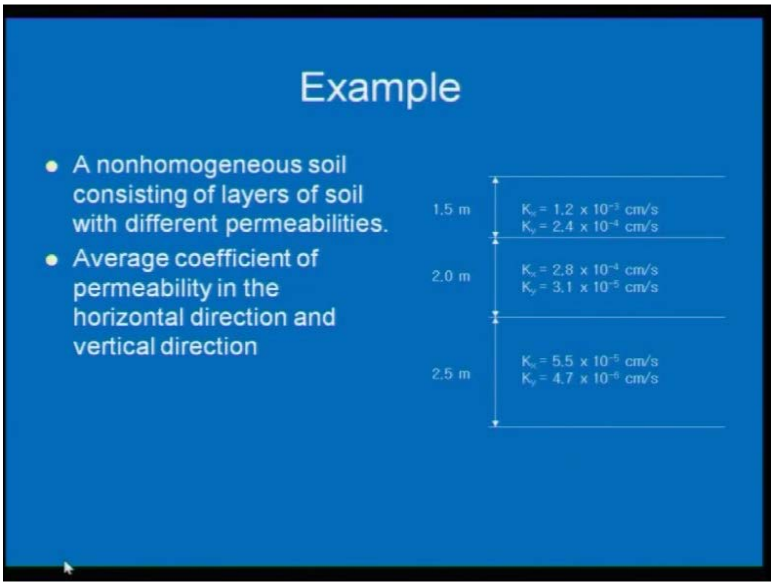
So, for this k y, you can get it this is this is your, how it has been derived k y, permeability in y direction for stratified soil deposit you can get it, H by H 1 by k 1 H 2 by k 2 H n by k n with this help, you can find it out permeability in y direction for stratified soil. Similarly, in x direction also you can find it out, because as I say it is stratification may be in x direction, as well as y direction; that means, you can find it out k 1 H 1 k 2 H 2 plus k n H n by H. If you look at this both this formula, one is your total height for y direction divided by H 1 k 1 H 2 k 2 h 3 k 3.

(Refer Slide Time: 18:14)



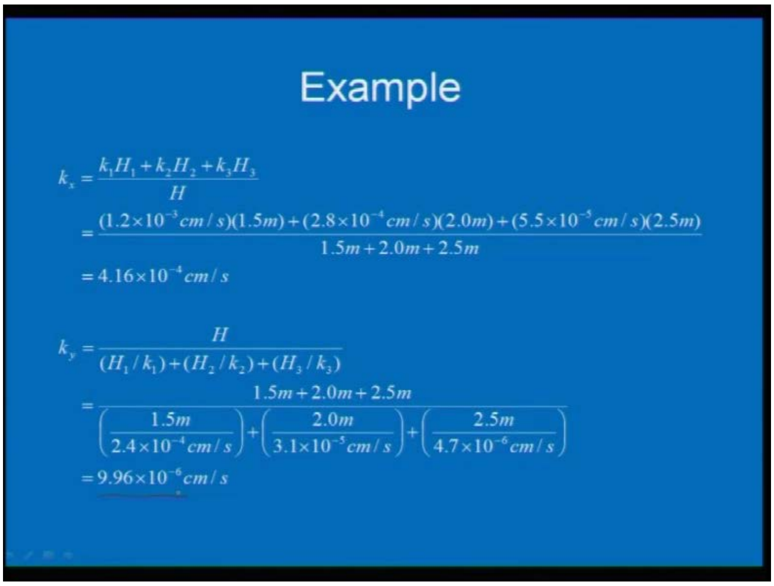
So, other is you are in x direction, k 1 H 1 plus k 2 H 2 k n H n divided by your total height.

(Refer Slide Time: 19:12)



Now, one of the examples, another example a non-homogeneous soil consisting of layers of soil with different permeability, average coefficient of permeability in horizontal, and vertical direction, it has been asked to find it out. So, each layer by means of laboratory test k x and k y you got it, it is 10 to the power minus 3 and 10 to the power minus 4 cm per second for layer 1, it is height is 1.5 meter. Similarly, four layer 2 its height is 2.0 meter, layer 3 it is 2.5 meter with help of layer 1, layer 2, layer 3.

(Refer Slide Time: 19:50)

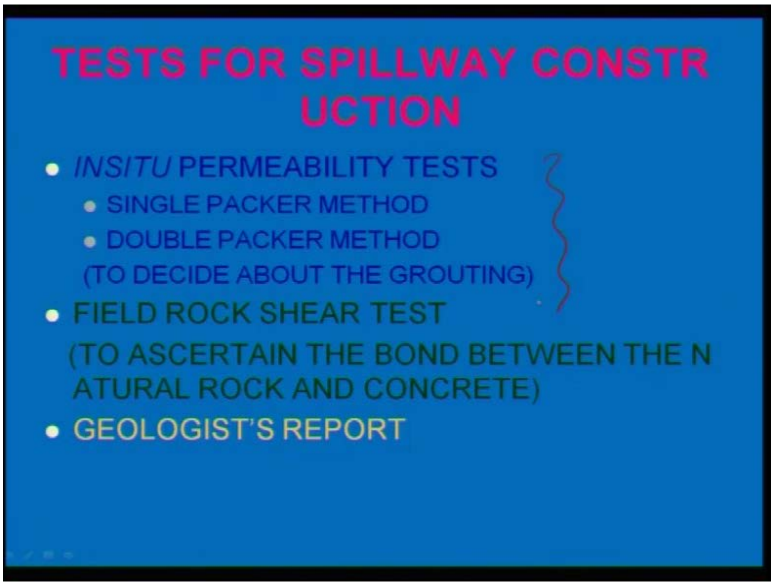


You can find it out, by means of using this formula you can find it out, k x and k y average permeability in horizontal direction, it is 4.16 into 10 to the power minus 4 cm per second. Average permeability in vertical direction, it is 9.96 into 10 the power minus 6 cm per second.

(Refer Slide Time: 20:13)

Another one is your related to permeability particularly, irrigation projects, what are the different test of soil required that means, irrigation projects means particularly, cannels in the irrigation projects; it required preconstruction, during construction also post construction. The soil test required, during pre construction means, before construction, during construction, when the construction work is going on.

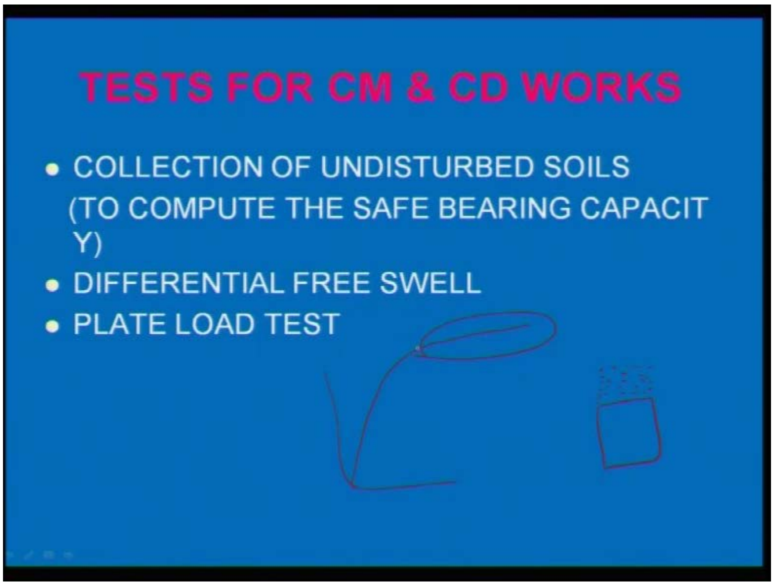
(Refer Slide Time: 20:47)



then after construction is over, after few years you can do also post construction, so test for spillway constructions like, you can for irrigation projects you can do because, this is a continues flow of water particularly in irrigation projects. In the soil insitu permeability test you can you will have to determine, because it is related to permeability that is what I am discussing by means of single packer method or double packer method to decide about this grouting.

Then field rock shear test also, some geological report you need, so basically geotechnical engineering as far as geotechnical engineering is concerned, so you have to do this insitu permeability test particularly, irrigation projects like cannel.

(Refer Slide Time: 21:39)



Then test for CD or CM works means collect undisturbed soils, and differential free swell test and plate load test; free swell test means particularly, irrigation projects the soil sample is there, the soil sample what will happen during summer season, it will try to shrink. During winter season as the water added, it will try to the soil will try swell against loading, it is sometimes we say free swell or swell against the discharge; that means with application of water, it will try to swell, this is most important particularly irrigation projects.

So, generally in the lab, we do this swell test by taking the soil sample putting in oedometer test, oedometer equipment, then apply certain loading, then apply water, then we allow this soil to swell, say for a day 2 2 days, 3 days, 4 days months together. So, we record how much swell pressure we get it or swell swelling we get it over the period of time, that means swelling is going on, going on, going on somewhere else, it remains constant that means no more further swelling, at that point will stop this test (Refer Slide Time: 22:55).

(Refer Slide Time: 23:07)

So, mechanical analysis, now it is called test on CNS material or CNS soil, what is CNS? CNS is Cohesive Non-Swelling remember, CNS is nothing but, cohesive non-swelling soil, C for cohesive, N for non, S for swelling, that means we will do test cohesive non-swelling soils generally, it has been used for irrigation projects. So, mechanical analysis we do sieve analysis, and hydrometer analysis, atterberg limits and liquid limits and plastic limits, it has been discussed and swell pressure test.

(Refer Slide Time: 23:49)

Now, requirement to use as CNS soil, what are the different requirement means, CNS material, if I say CNS cohesive non-swelling soil, if I say how this profile is varying, what kind of material we can say cohesive non non-swelling soil, for this the gradation curve it says gravel should be 0 to 10 percent. How do you decide gravel, in 2 mm, sieve percentage of soil particle retain is about 0 to 10 percent, then we can say that that gravel is about 0 to 10 percent.

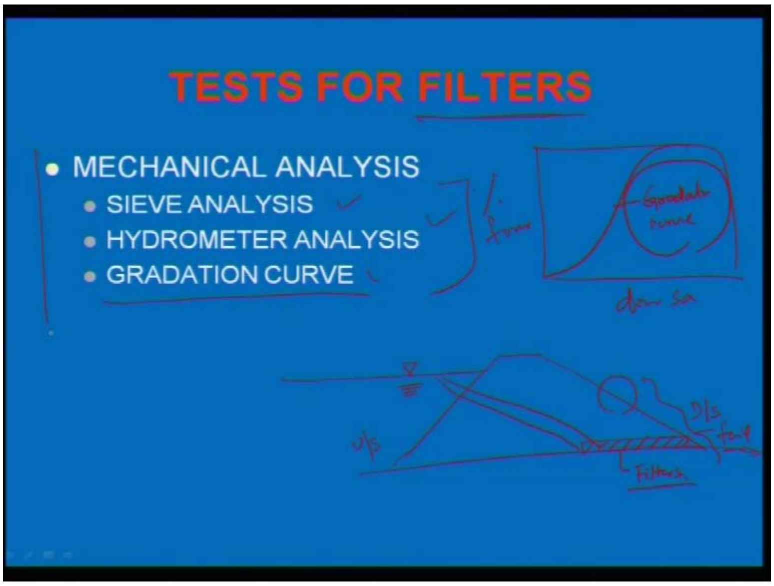
Similarly sand, this sand is varying from 2 mm to 0.06 mm, if it is 30 to 40 percent, then silt also 30 to 40 percent, clay clay is your which is less than 0.002 mm, it is generally 15 to 20 percent, and liquid limits should be between the range of 30 to 50 percent1 plastic limit in the range of 20 to 25 percent, and swelling pressure is your less than 0.10 K g per square centimeter. These criteria are best for your CNS soil, cohesive non-swelling soils to be used in irrigation projects, example in cannel.

Generally in village areas long cannel has been constructed, over which water has been allowed through the canal, so that people can utilize water, for land purpose. So, over the period of time what will happen, this soils we are getting kind of a cohesive soil, to make it not to be not to be swell more, will have to add CNS material, cohesive non-swell soil, with these cohesive soil, these are the material to be added so that complete soil if I take it in to 100 percent complete soil, gravel will be 0 to 10 percent, sand 30 to 40 percent, silt 30 to 40 percent, clay is your 15 to 20 percent.

So, liquid limit is 30 to 50 percent, and plastic limit is your 20 to 25 percent, this has been given by Indian standard, Bureau of Indian Standards or we can we generally say BIS, on in terms of it is Indian Standard. It is a codal provision 9451.1994, what should be your rang of CNS material in terms of particle size, in terms of liquid limit, in terms of plastic, limit in terms of swelling pressure.

If you look at here these are the three things required, for your cohesive non-swell soils mechanical analysis that means hydrometer as well as sieve, atterberg limits, liquid limit and plastic limit, and your swell pressure test. If you look at here, this is your mechanical analysis that means, this your sieve analysis and your hydrometer analysis analysis and this liquid limit and plastic limit is nothing but, is your atterberg limits; atterberg limits is your liquid limit, plastic limit and shrinkage, as I discussed earlier. And swelling pressure test you can do it in the laboratory by taking this material mixing with the soil, so that the pressure should be less than 0.10 Kg per square centimeter.

(Refer Slide Time: 27:38)



Now, what kind of filter you are going to provide, what are the test for filter, this is also coming in geotechnical exploration, and measurement, you should know what why this filter has been provided. Generally, in a dam also, if I look at the example, simple example you might have seen this arch dam, so dam has been provided to storage purpose this water. So, what will happen, this dam there is a steady state seepage flow of this dam initially, if you look at here, instead of allowing water to pass, if if this is my upstream, and this my downstream, US is your U U for up S is stream, D for down, S for stream water.

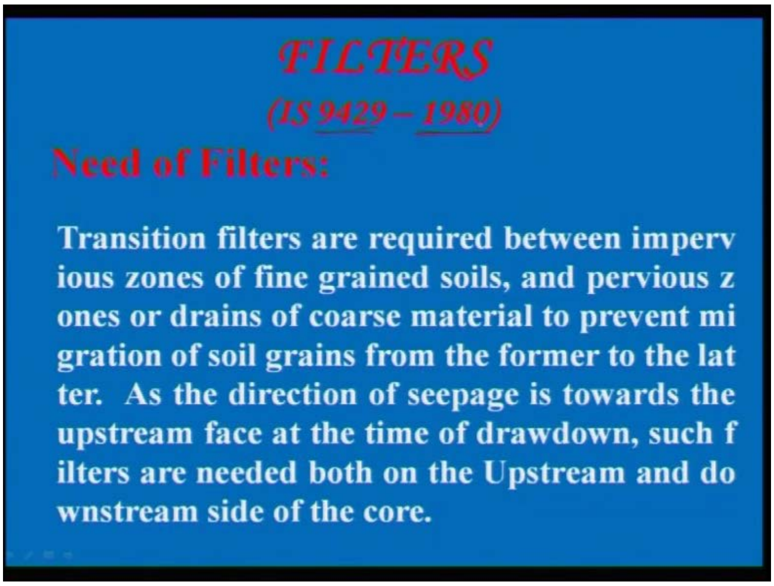
Generally, we allow water to pass though to the dam from upstream to downstream, if we do not provide the filter what will happen, water will flow from upstream and it will cut somewhere else, in the downstream; over the period of time what will happen, this downstream will get fail. Because, of water is passing through, we do not want the dam should be failed, because of this high passage of water through inside the body of the dam to prevent this.

Generally, filters has been provided at the base of the dam, it may be a sand filter or it may be geo-synthetic filter, it may be sometime earlier days, they called as a sand blanket also; what will happen, this seepage line has been changed, and it will it will pass through your filter. So, this filter will collect water from upstream, and pass through here, and by means of filter because, filter is a property, it will allow water to discharge, immediately pass inside. So, what will collect from upstream, and allow to flow inside this dam and collected in the filter, and safely discharge here; so that means, we are not allowing water to flow inside this dam, it is allowing water to flow and collected by means of filters. So, these filters are required for geotechnical testing purpose also, it is related to your coefficient of permeability, these are the material related for your coefficient of permeability.

Because, the movement you say filter that means, you want what is its permeability how much discharge it allow per per second or per minute or per hour, what is the quantity of water should pass inside this filter that means, gallon or CC centimeter cube, per hour or per minute or per second, that you will decide. So, what are the test for your filters, mechanical analysis generally, sieve analysis, hydrometer analysis, and gradation curves.

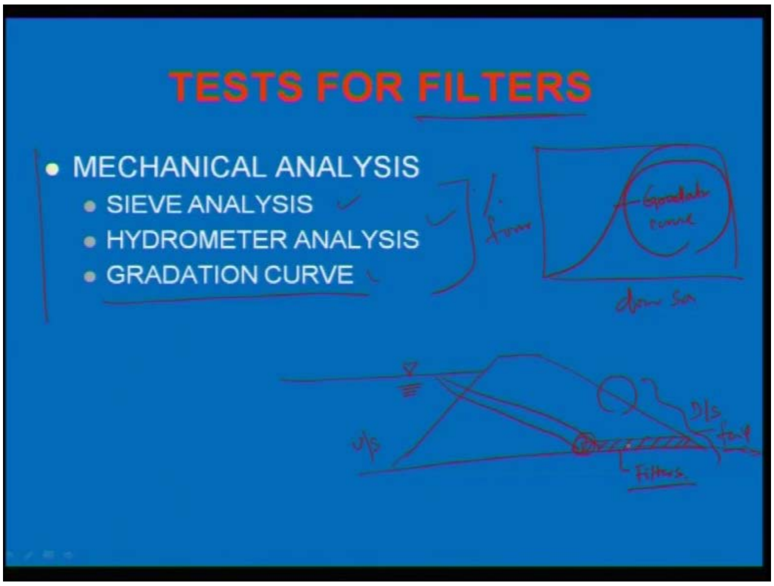
As usual it is complete sieve analysis and hydrometer, and you will have to find it out how your gradation curve, if I as I explained earlier if this is my percentage finer versus this is the diameter soil, how the gradation curve is varying, this is called nothing but, is your gradation curve. How the gradation curve is varying means, this gradation curve is required for your filter design for this filter; so for filter, these are the test mechanical analysis we need, sieve analysis hydrometer analysis as well as gradation curve.

(Refer Slide Time: 31:46)



Now, what is as per IS standard, Bureau of Indian Standard, 9429 this is the number, and this is the year 1980, need for filters look at this paragraph. Transition filters are required, between impervious zone of fine grained soil, and pervious zones or drained of coarse material to prevent migration of soil grains from the former to later. As the direction of the seepage is towards the upstream face, at the time of drawdown, such filters are needed both on the upstream and downstream side.

(Refer Slide Time: 32:50)



Look at the meaning, it preserve the movement filter has been applied it only allow water to pass remember, it only allow water to pass, it does not allow soil along with the water should pass; the movement the soil flow means water flow starts, inside this body of the dam what will happen, soil plus water it will flow inside. So, here soil will be filter and water will pass inside, so next class will discuss about this complete design of this filter material, what are the test requirement.