Geosynthetics and ReinForced Soil Structures
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Lecture - 7
Testing of Geosynthetics – II

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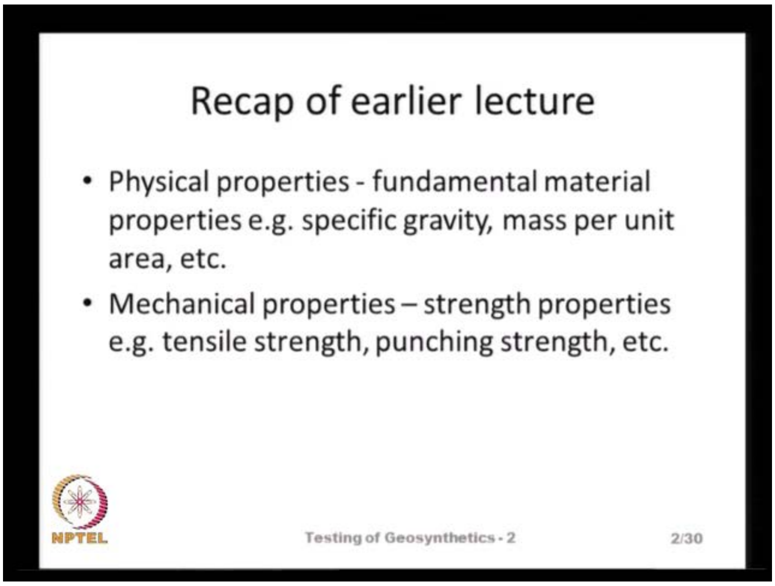

Let us continue the same topic in this class. Just to recap, we have studied about two different types of properties; one is the physical properties, and other is the mechanical properties. And the physical properties include all the fundamental properties like the specific gravity, mass per unit area and so on. And the mechanical properties are all related to the strength and the survivability aspects like the tensile strength or the shear strength or the punching strength and so on. And let us continue with some other properties in this class.

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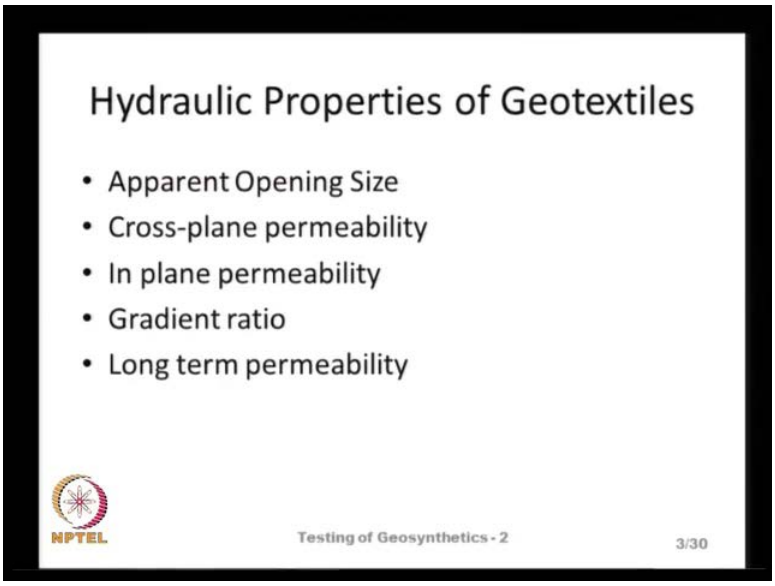

Let us look at the hydraulic properties of the geotextiles, these are very important for the geotextiles, because often we employ the geotextiles as drainage layers to drain the water or as a filter layer to prevent the piping of the soil. And some of the hydraulic properties of geotextiles they are listed here, the apparent opening size and the cross plain permeability in plane permeability. The apparent opening size is basically defines the opening size that is there in the geotextile and it is called as an apparent.

Because, most of these geotextiles, they may have several opening sizes, and it is not possible to actually quantify all the opening sizes. But, we are more interested in determining some of the opening sizes corresponding to 95 percent particles or 90 percent particles. And then the cross plane permeability is related to the flow of water across the plane of the geotextile and then the in plane permeability is related to the ability of the geotextile layer to act as a drainage layer, that can support the flow along the length of the geotextile. And then the gradient ratio is very important test that we perform to assist the compatibility between the given soil and a given geotextile. And then of course, the long term permeability properties of the flow through the geotextile is also very important, and let us see, how we can determine these properties.

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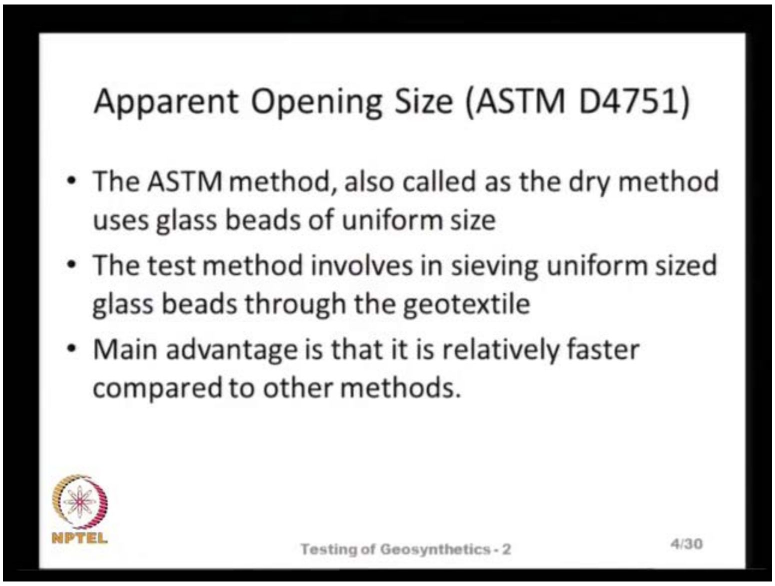

Let us look at the apparent opening size and the ASTM standard is ASTM D 4751, as noted and there are different methods for determining the opening sizes of the geotextile. The ASTM method, it recommends using glass beads of the uniform size for determining the apparent size and this is also called as the dry method basically because we do not use any water for performing this test.

And this basically, it involves in sieving uniform sized glass beads through the geotextile and when we sieve the glass beads, some particles which are finer than the openings, that are there in the geotextile will come through the geotextile. And then we collect the particles that are passing through and then analyze them for determining the opening size. And the main advantage of this test is that, it is relatively faster compared to the other methods of test, that we are also going to see bit later on.

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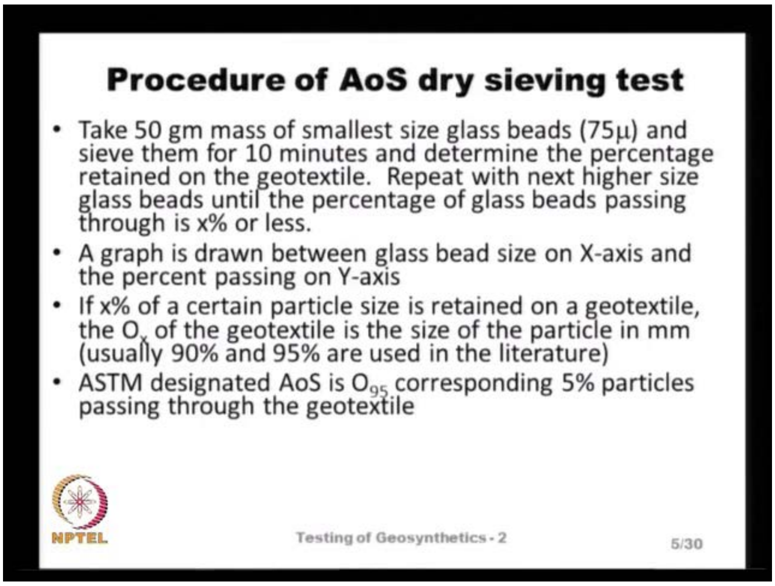

And the procedure for doing this test is very simple, just as how we perform the dry sieving test on the normal soils, we perform the same test on the geotextiles also. Instead of using the normal sieves, we use the geotextile itself as a sieve, we take 50 grams mass of the smallest size of glass beads, that is 75 micron size glass beads and sieve them through the geotextile for 10 minutes and determine the percentage of the glass beads retained on the geotextile or passing through the geotextile.

And we repeat this process with next higher size of glass beads on a same geotextile, we do not replace the geotextile. But, it is very important that we continue to use the same geotextile that was there earlier. And we continue with higher sized glass beads passing through the geotextile, until an x percentage or less is pass through the geotextile where, x is the particle size of our interest. And we draw a graph between the size of the glass beads on the X axis and the percentage passing on the Y axis.

And obviously, the x axis should be in the log scale, just as how we do it for the normal grain size distribution curves. And if x percentage of certain particle size is retained on the geotextile, the O x of the geotextile is the size of the particle in millimeters that is, we usually use 90 percent or 95 percent retained particle size in our design guidelines. And the ASTM, it designated the apparent opening size as the size of the particles corresponding to 5 percent passing through or 95 percent retained. And we call this particle size as O 95 that is, 95 percent of the particles are retained on the geotextile or 5 percent of the particle pass through the geotextile.

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And let us look at the equipment that we require, we require the glass beads of uniform size and here, we see different sized glass beads. And then we have the geotextile that is spread inside this pan and there is a mechanism to stretch the geotextile and lock it in. And when we do this starching, we should not stretch it too much because some geotextiles if they are starched too much, the opening size increases. And then we placed the glass beads, 50 grams of mass of glass beads on the geotextile and then fix it in a sieve shaker with a top cover and then a bottom pan.

So that, all the glass beads that come through are collected and then we keep it in a normal sieve shaker. And then sieve them for 10 minutes and then the mass of the glass beads that are retained on the geotextile are carefully collected in a container and then we determine the mass to the nearest 0.01 grams.

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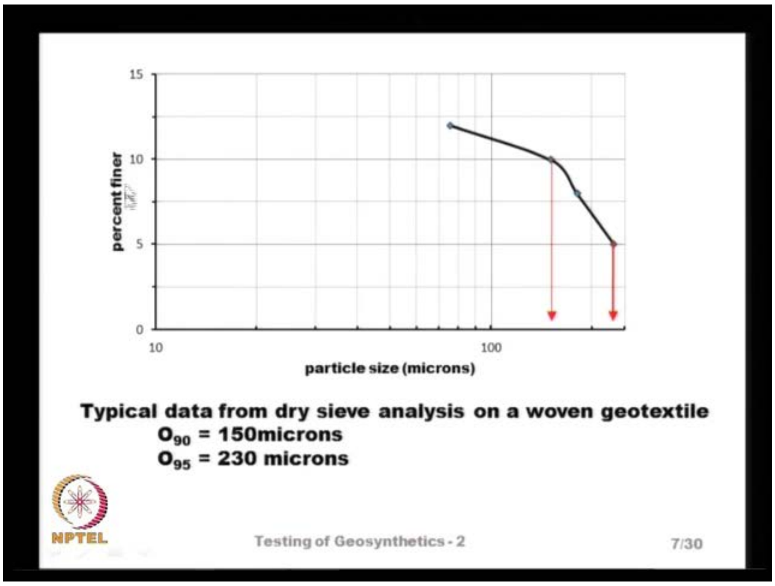

And then we draw a graph as I mentioned earlier, between the particle size or the glass beads size on the X axis in the log logarithmic scale and Y axis, the percentage finer. And here, we see a typical test performed on a woven geotextile and the test was repeated with the different sized glass beads starting with 75 micron particles and then 150, 180 micron and then 230 microns. And when 75 micron glass beads were used, nearly 12 percent of the glass beads are pass through and at 150 microns, nearly 10 percent are pass through.

And then the test was continued until the 5 percent of the glass beads pass through or 95 percent of the glass beads are retained. Then when we plot a graph, we can directly read off the particle sizes corresponding to 10 percent finer and 5 percent finer. The 10 percent finer is called as O 90, for this particular geotextile it is 150 microns and the 5 percent finer size is 230 microns and if you are interested, we can continue the test with other particle sizes.

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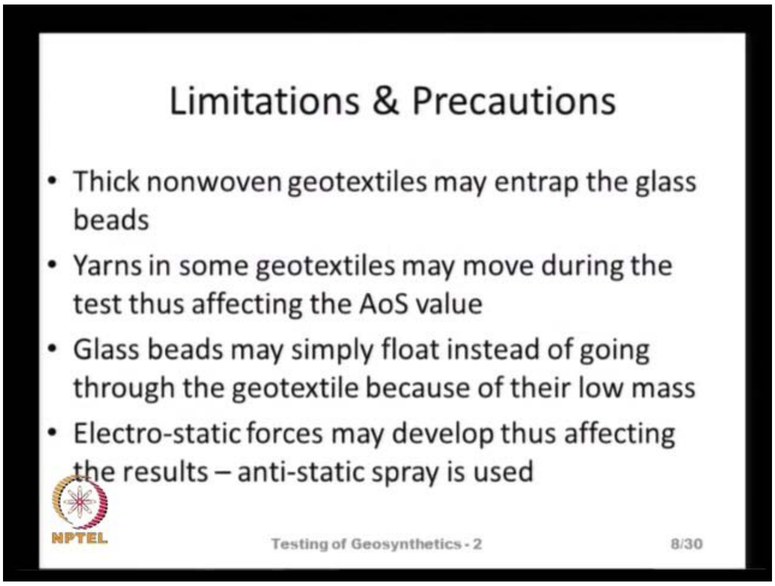

And this test is a very simple test and it does not take much time because for each size of the glass beads, it is only takes 10 minutes for this sieve shaking. And then we determine the mass of the glass beads, that are retained on the geotextile and passing through the geotextile. But, there are several limitations and we also need to take some precautions while doing the test so that, we do get consistent results.

When we deal with very thick non woven type geotextiles especially, of the needle punch type, the glass beads may get entrap especially, when we use the geotextiles, that are about say 5 or 6 millimeters thick. The glass beads may pass through the surface and then instead of coming out, they may gets stuck in between the on the geotextile. And then once they are stuck, they may remain there or they may come out when we repeat the test with higher sized glass beads.

Because, the higher sized glass beads may push them and then the finer particles may come out the next time when we repeat the test and sometimes, we may get mislead in results, because of this process. And in some type of geotextiles, the yarns may move during the test, because of this sieve shaking and then the glass particles that are there on the geotextile. And once the yarns move, the apparent opening size may get affected and because these glass beads are very light weight, they may just simply float when we do the sieve shaking and instead of coming through.

And especially, with very fine particle sizes this may happen, the 75 micron glass beads may not come through in some cases especially, when we have very fine opening sizes. And because of this polymeric nature of these geotextiles, the electrostatic forces may develop during the test, because of the friction that is taking place between the glass beads and the geotextile and we do have to use some antistatic spray. So that, this electrostatic forces do not develop, the reason why we do not want them to develop is, when they develop, the glass particles get attracted to the geotextile and they will not pass through and that can give us mislead in result.

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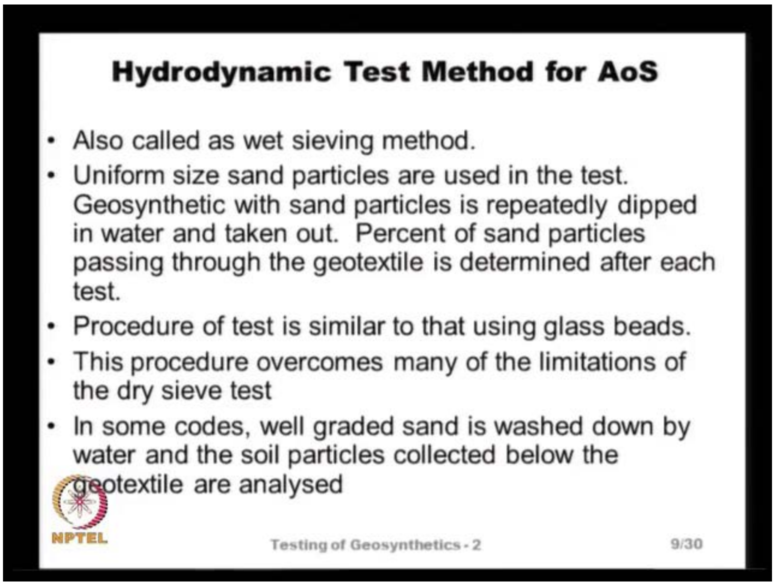

Another test method for determining he apparent size is the hydro dynamic test or the wet sieving method, just as how we do the wet sieving of the fine grain soils, we can use water and do this sieve test. And there are two methods once again, even in the hydro dynamic test, one is a procedure similar to the ASTM standard. Wherein, we use uniform sized particles and here, we sieve sand and collect uniform sized sand particles like 75 micron, 150 micron, 180 micron and then 225 micron and so on.

And then we can repeat the test just as the dry sieve method, starting with the lowest size sand particles that is, 75 micron. And then after we finish the test on the same geotextile, we can place the next larger size particles and repeat the test and this procedure overcomes many of the limitations that are there in the dry sieve test, because we are forcing the particles, the sand particles to pass through the geotextile, because of the use of water.

And there is no entrapment of the sand particles within the geotextile here especially, in the case of very thick geotextiles and this test takes a very long time. Because, every time we collect the sand particles, we cannot directly take their mass, we have to dry them in an woven and then determine their mass.

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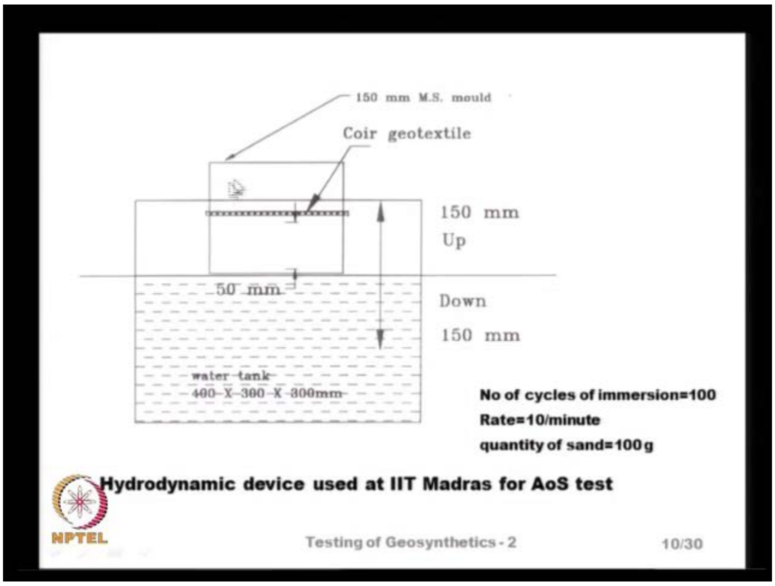

And the typical test is like this, there are different variations of performing the hydro dynamic test and this particular test operators, it was developed at IIT Madras especially, for testing the apparent opening size of the coir geotextiles. Here, we place the coir geotextile inside a CBR mold of 150 millimeters diameter and this mould is dipped in a bucket of water and taken out repeatedly. And we take 100 grams mass of soil, the sand or any soil, we place it on the geotextile and then immerse it in water, take them out, immerse in water, take it out.

And by trial and error procedure, we have found that, we do get consistent results if we do this dipping and taking them out at least repeatedly for 100 times, this was then only by trial and error and for some other type of geotextiles, it may be different. So, it is dipped in the water by 150 millimeters taken out by at least 150 millimeters so that, it completely comes out of the water.

Then, once again dip it in water for by 150 millimeters and take it out and the quantity of sand, the uniform size sand particles used was 100 grams. And then after the test is over, we can plot a graph similar to this and determine the different particle sizes O 90 and O 95 and so on.

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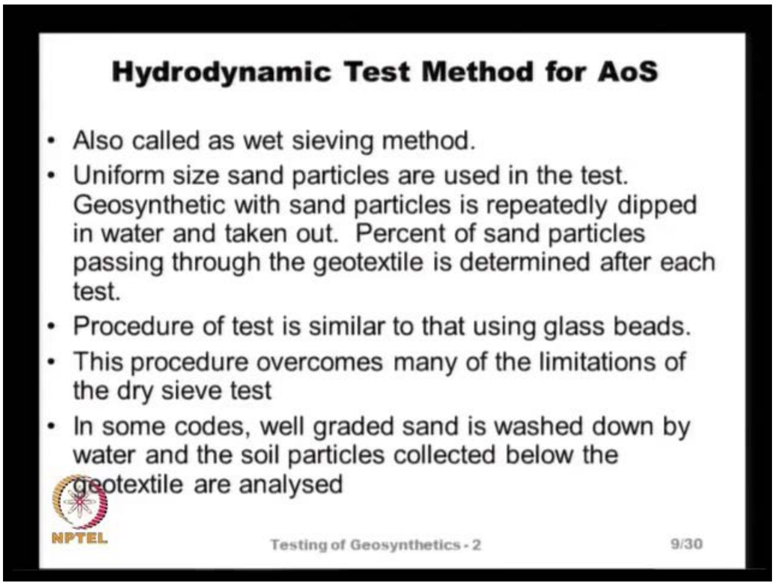

And in some codes especially, the ISO and the German codes, instead of using uniform size sand particles, they use a well graded sand, that is place on the geotextile.

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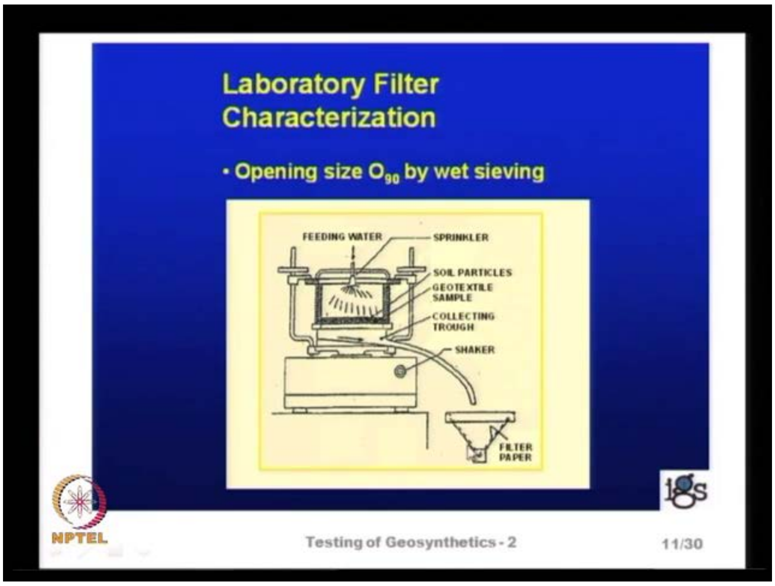

And we sprinkle water continuously for a very long time and then collect the water that comes through the geotextile and this water is allow to flow through a filter paper so that, all the soil particles are collected on the filter paper. And by analyzing the size of the particles that are collected in the filter paper, we can analyze the apparent opening size. And this test is also the wet sieve test method, but it slightly different from the earlier procedure of that is recommended by the ASTM.

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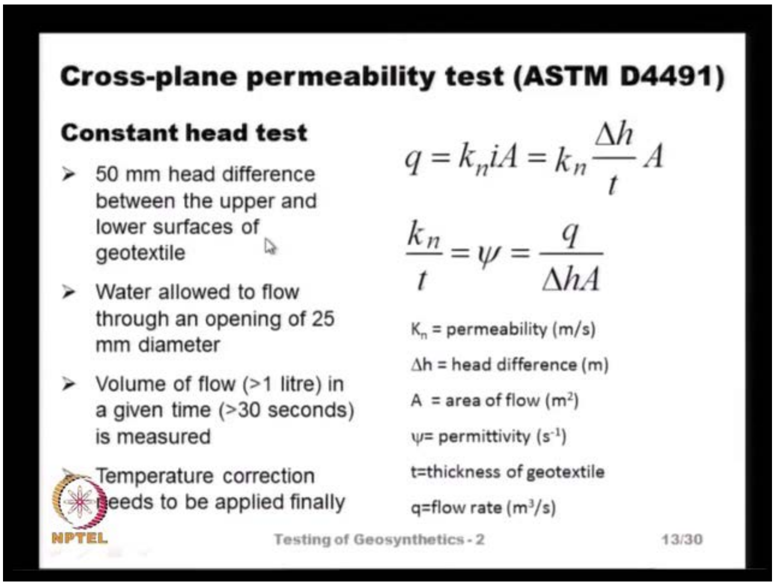

Let us now look at the permeability test and how to perform the permeability test on the geotextiles. The first one let us look at the cross plane permeability test and this is described by ASTM code D 4491 and the ASTM code recommends that, this test be done at either constant head or variable head. That is, the changing head of the flow and constant head test is performed at 50 mm head difference between the upper and a lower surface of the geotextile.

And water is allow to flow through an opening of 25 millimeters diameter on the geotextile and then the volume of flow is collected on a given time. And the duration and the quantity of flow should be, at least the duration should be greater than 30 seconds. Even if we collect very large amount of water within about 5 or 10 seconds, we have to continue the test for at least half a minute. So that, we do get representative result and the quantity of water that is collected should be greater than 1 liter.

And then we do some calculations and finally, we do have to apply temperature corrections, just as how we do for the permeability of the soils, let us first look at the operator itself.

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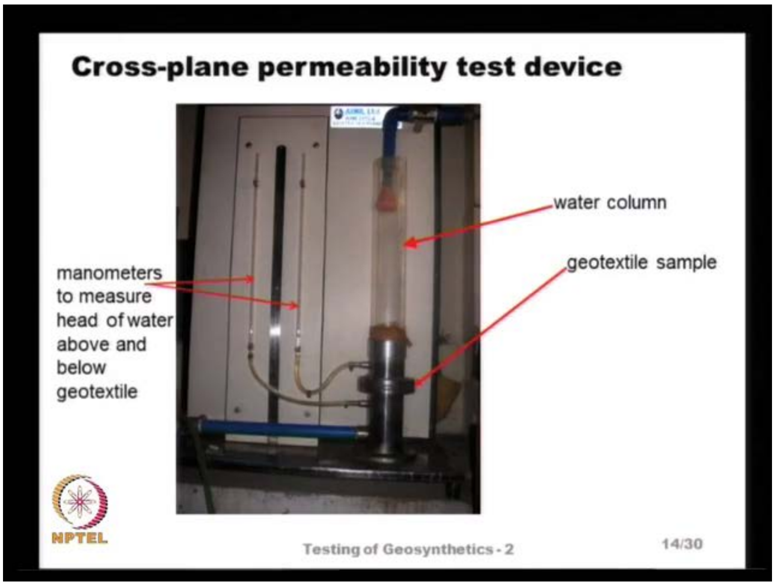

This is a an operators, that we can use for determining the cross plane permeability of the geotextiles. This instrument was developed by Emil in association with IIT Madras, we have recommended them about the size of the sand pipes and the other things. It is actually we have a long column of water, that flows through a geotextile and the water flows through. And as the water is flow is flowing through the geotextile, we measure the head of water slightly above the geotextile and also, at a locations slightly below the geotextile through these manometers.

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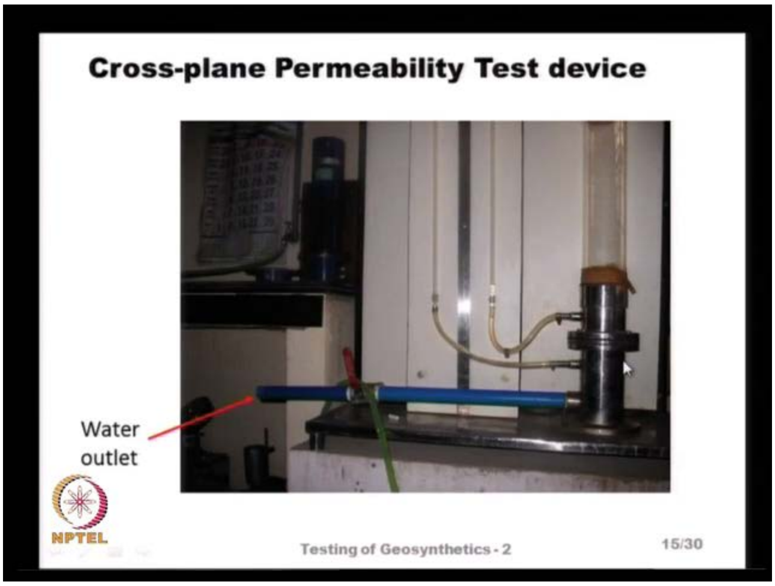

Another close up is here and the water is allow to flow out and we collect the quantity of water in a bucket in a given time and let us look, how to interpret the test result.

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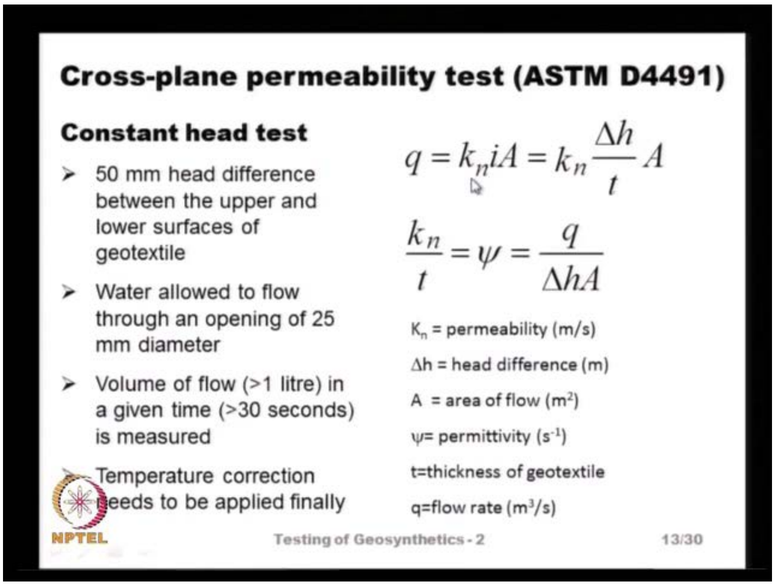

The q is the rate of flow in meter cube per second, it can be related to the permeability coefficient k n that is, the cross plane permeability coefficient multiplied by the hydraulic gradient i multiplied by the area of the flow. And the hydraulic gradient is nothing but the head difference divided by the thickness of the geotextile, because we are measuring the head of water above the geotextile and below the geotextile. And while flowing through a thickness of t, the head is lost by 50 millimeters in this particular test.

So, the hydraulic gradient is defined as delta h by t then the area of flow is capital A and this k n divide by a thickness of the geotextile is called as the permittivity. So, the different quantities that are there in this equation are they shown here, the k n is the permeability coefficient that is expressed in meters per seconds in the SI units. And then the delta h is the head difference of water between the upper surface and the lower surface of the geotextile.

And in the ASTM standard, it is 50 millimeters and in the ISO standard, the head difference is 20 millimeters and some other codes, they also recommend 100 mm head difference. A is the area of the flow that is corresponding to 25 millimeters opening in the metal pipe and sie is the permittivity, t is the thickness of the geotextile in meters and the q is the flow rate cubic meters per second.

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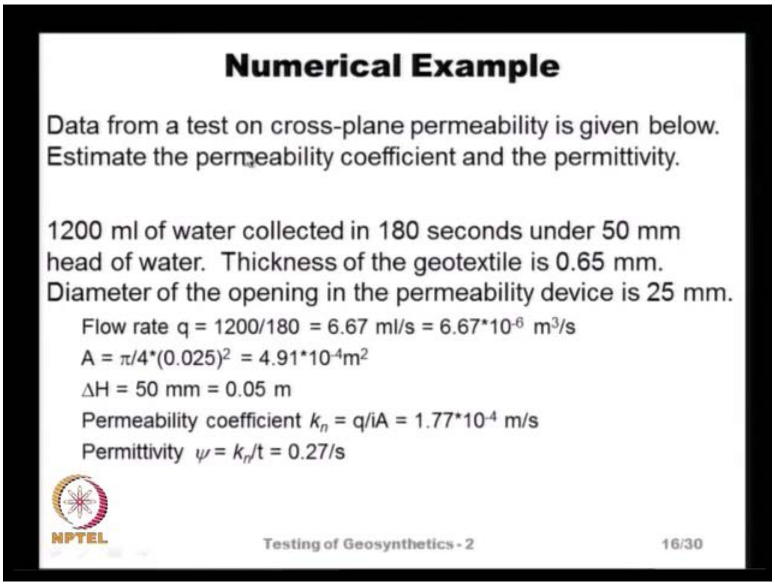

And just illustrate this procedure, let us look at numerical example on how to calculate the permeability coefficient and then the permittivity. The following is the data from a test on a cross plane permeability performed on a geotextile. Let us say that, in 180 seconds, we collected 1200 ml of water and the head difference is 50 mm and the thickness of geotextile at a standard pressure of 2 kp is 0.65 millimeters. And let us say that, the opening size is 25 millimeters in the geotextile let us see, how we can do the calculations.

The flow rate q is 1200 milliliters divide by 180 seconds that is, 6.67 milliliters per seconds or in terms of cubic meter per second, this is 6.67 times 10 to the power of minus 6. And the area of the flow is pi by 4 times 0.025 square that is, so many square meters and the head difference is 50 millimeters that is, 0.05 meters. And the permeability coefficient k n can be determined as q by i A, k n is simply q by i A and that works out to 1.77 times 10 to power of minus 4 meters per second and the permittivity sie is the k n divide by thickness t, that comes to 0.27 per second.

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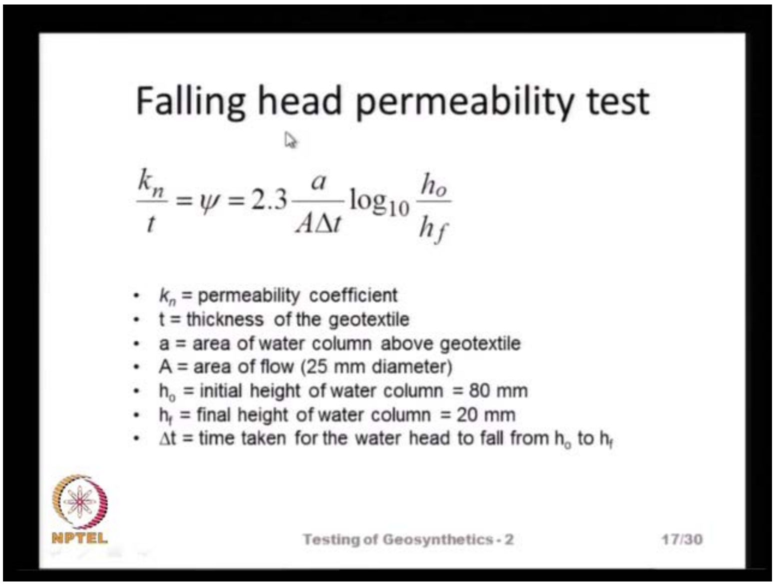

And similar to the constant head test, we can employ this AM operators for performing a falling head permeability test and just as, how we have the formula for the soils. The formula for the falling head test for the permeability of the geotextile are also given like this in terms of a log. And head difference h naught and h f and the ASTM recommends that, the head h naught and h f of 80 millimeters and 20 millimeters that is, these values are standardized, so that the values of the permeability that we get from different labs can be correlated.

So, because the permeability is also dependent on the some other factors like the turbulence and then other factors so we do have to maintain some standards. And let us look at all the terms that we have in this equation, the k n is once again the permeability coefficient so many meters per second in the SI unit and t is the thickness of the geotextile in meters, a is the area of water column above the geotextile.

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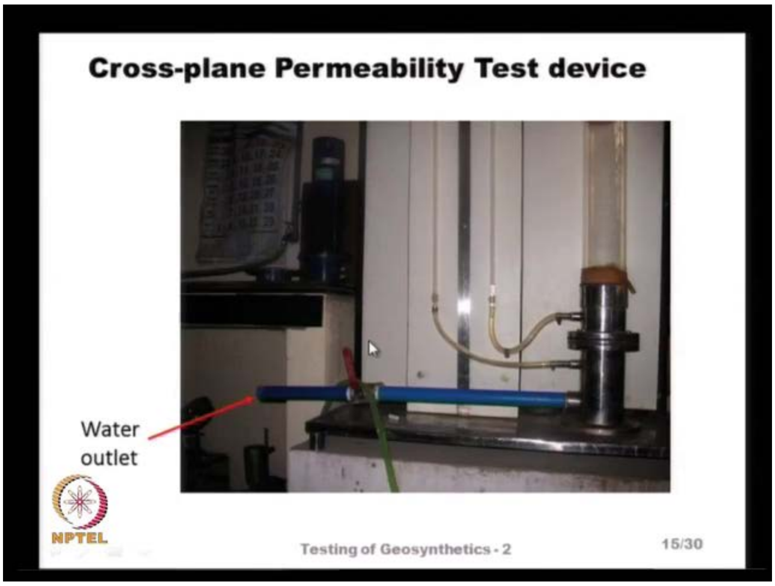

Water column is this, which is nearly depends on the design that we have whereas, the water column diameter is a and then the geotextile is actually this pipe. This tube that we have, it does not have the same diameter as this, it has a lesser diameter as recommended in the ASTM, it should be 25 millimeters.

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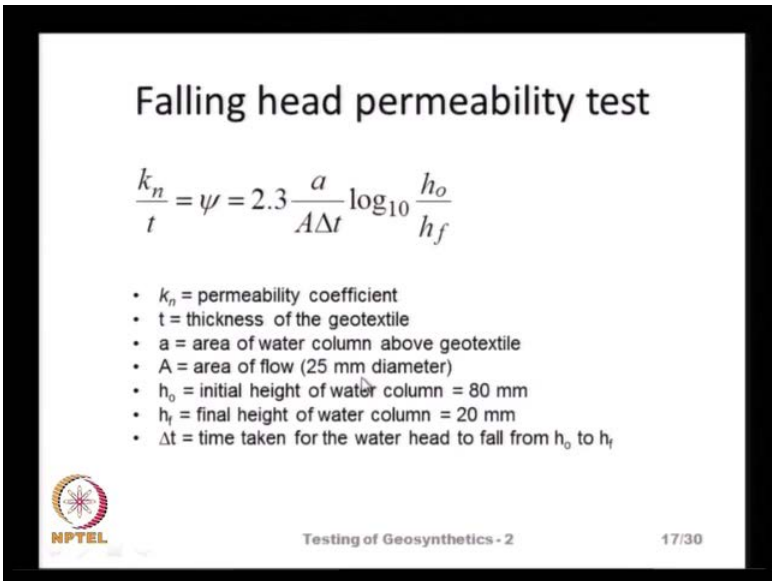

This capital A is the area of the flow that is, 25 millimeters that is corresponding to the internal diameter of the bottom shoe. And h naught is the initial height of water column that is, 80 millimeters and h f is the final height of water column that is, 20 millimeters and delta t is the time taken for the water head to fall from 80 millimeters to 20 millimeters. And based on all these values, we can determine the permeability coefficient or the permittivity site.

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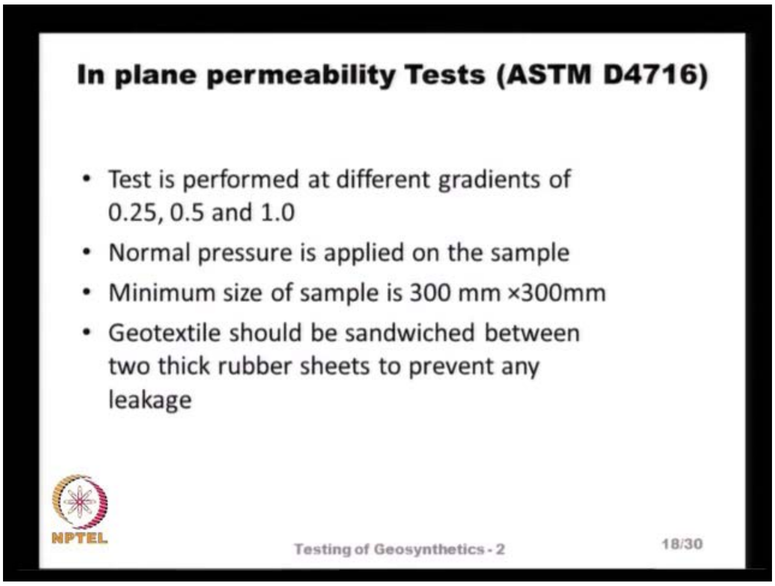

And another significant test, that we perform is the inplane permeability test and this is a very important test that we perform especially, on non woven thick geotextiles, that are employed as drainage layers in the land fields or below the pavement and so on. And the ASTM standard for performing this test is ASTM D 4716 and this test is performed at different gradients of 0.25, 0.5 and 1. And it is not necessary that, the flow rate is the same at different gradients, because of the turbulence and other factors, that are associated with the flow of water through the geotextiles or through the soil.

And we can also apply normal pressure, the difference between the previous test, the cross plane permeability and in plane permeability test is that, the cross plane permeability test is perform without applying any pressure. Whereas, the inplane permeability test is performed at different normal pressures and this normal pressure, the magnitude should correspond to the normal pressure, that we can expect in the field applications.

And the ASTM standards, they specifies a certain minimum size for this specimen that is, 300 millimeters by 300 millimeters and this. That means, the sample at the minimum should have these dimensions or it can be larger than this and in order to make sure that, the flow is only through the geotextile and not around any openings. The geotextile is normally sandwich between two thick rubber sheets, so that there is no leakage.

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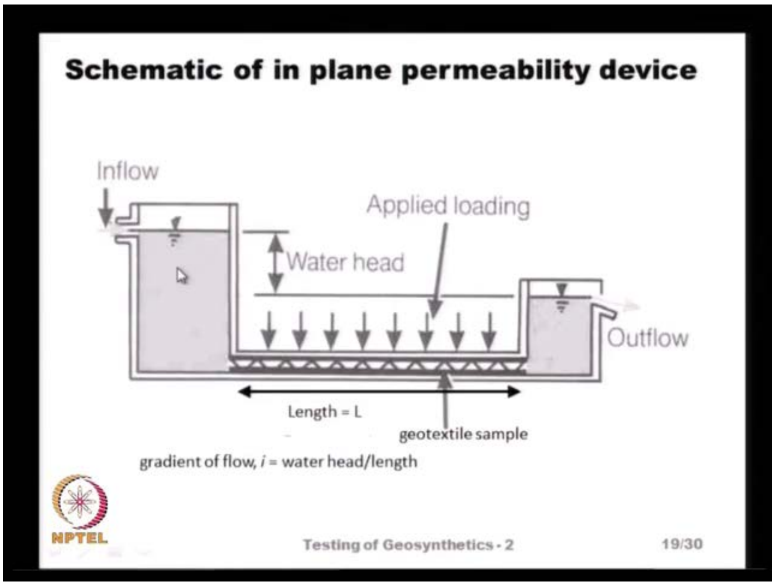

Let us look at this schematic, the schematic is like this, we maintain some head difference and we allow the water to flow through the geotextile. And here, in this we have two water tanks, one on the upstream side and other on the sown downstream side. And we have a water inlet here and an outlet here and so that, we can maintain on a constant head difference, this is the head difference and the length of the geotextile, that is shown here as L. And we can apply some desired pressure and the gradient of the water flow i, is the water head difference, head difference between the upstream and downstream side divide by the length of the geotextile.

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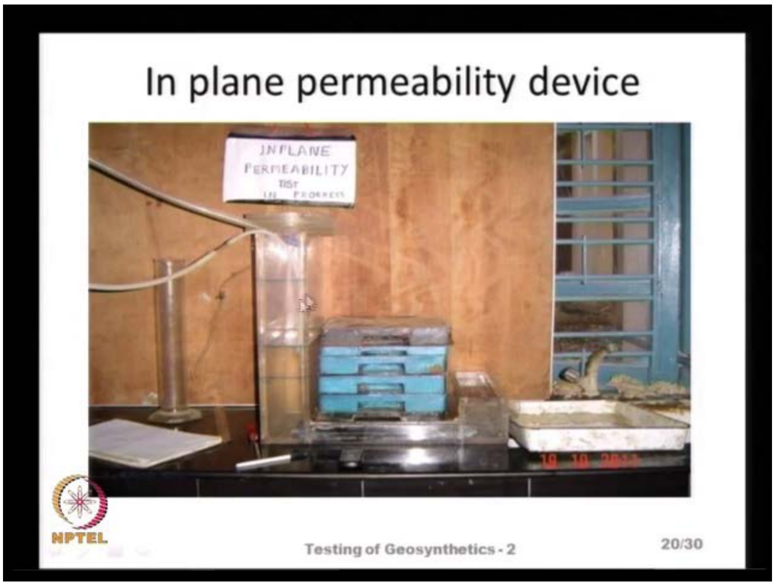

And natural operators is shown here, this is made of praspex , we have a column of water on the upstream side and then the column of water on the downstream side. And the water can freely flow out and the flowing water is collected in a pan. And we can apply the pressure on the geotextile, either through the dead white for very low normal pressures or through some other air or hydraulic actuator, in order to apply larger pressures.

And we can maintain a different heads of water and here, we can see three lines, the bottom most line is corresponding to a gradient of 0.25 and this middle line is corresponding to a gradient of 0.5 and this one is corresponding to a gradient of 1. And we can perform this test at different gradients, constant gradients and then we can determine the permeability in the plane of the flow.

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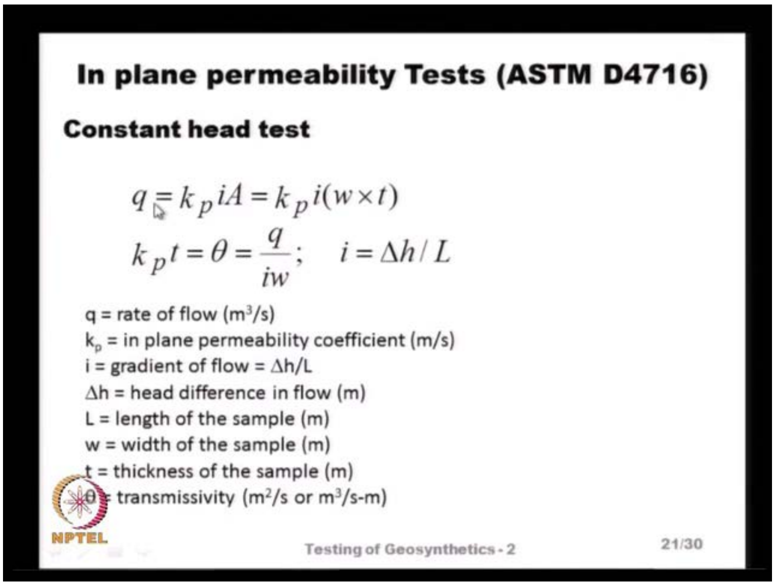

And is actually, this the flow rate q is given as k p that is, the permeability coefficient multiplied by the i, i is the hydraulic gradient and A is the area of flow. And here, the area of flow is the area of the geotextile itself that is, the width of the geotextile multiplied by the thickness. And when we use the thickness, the thickness of the geotextile should correspond to the applied pressure especially, for very thick needle punched geotextiles, the thickness is quite sensitive to the applied pressure.

So, if you apply a very high pressure like let us say, some 200 or 300 kPa, the thickness may be very small and if you apply very low pressure of say, 5 or 10 kPa, the thickness may be may be higher. So, the thickness that we have, it should correspond to the pressure that we apply on the geotextile. And then similar to the permittivity, we have one quantity called as transmissivity, that is related to the inplane flow theta, that is defined as k p times t that is, q by i w and where, i is the gradient of flow, delta h by L.

And the different quantities that we have in this formula are, the q is the rate of flow that is so many meter cube per second, the k p is the inplane permeability coefficient that is meters per second, i is the hydraulic gradient that is the delta h by L where, delta h is the head difference in the flow between the upstream and downstream side. And the w is the width of the sample and the thickness t is the thickness of the sample at the applied normal pressure and theta is the transmisivity that is, either expressed in a square meters per second or meter cube per second meter.

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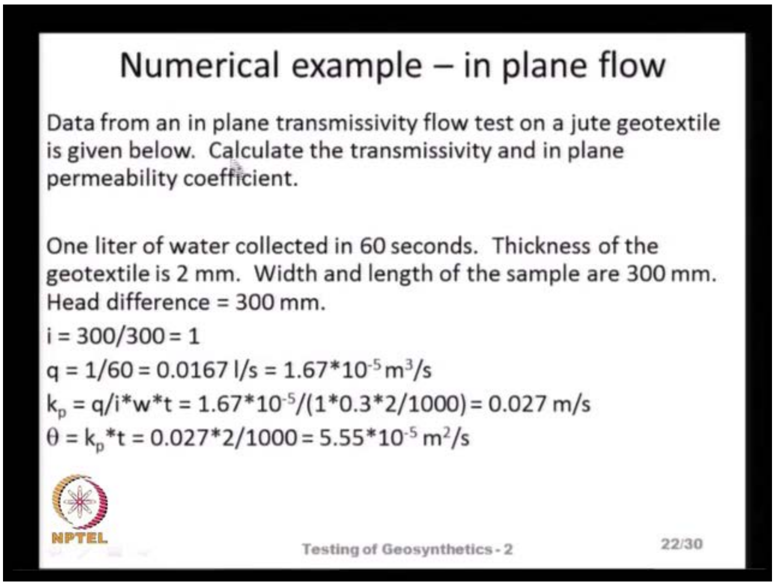

Let us look at numerical example, the data is given as 1 liter of water was collected in 60 seconds and the thickness of the geotextile is 2 millimeters at the applied normal pressure and the width and the length of the samples are 300 mm. And the head difference between the upstream and the downstream side is 300 mm and the hydraulic gradient i is the head difference 300 divided by length 300 that is, 1. And the quantity of flow is 1 liter per 60 seconds that is, 0.0167 liters per second or 1.67 times 10 to power of minus 5 cubic meters second.

And the k p that is, the inplane permeability coefficient is the q by i w t that is, 1.67 divide by i is 1 and width of the geotextile is 300 millimeters. And then the thickness is 2 millimeters that is, 2 by 1000, so that this is converted to meter units, that works out to 0.027 meters per second. And then the permittivity theta is k p times t that is, 0.027 times 2 by 1000 that is 5.55 times 10 to power minus 5 meters square per second.

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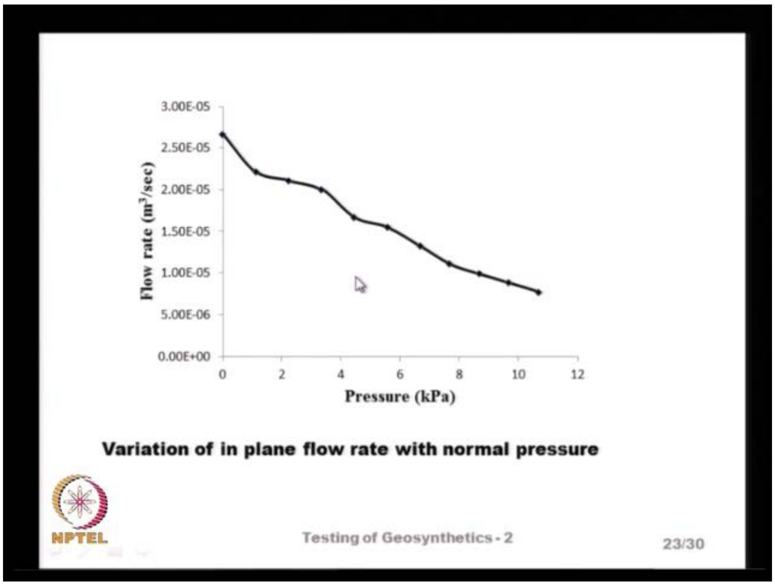

And for this particular geotextile that was used, this is how the inplane permeability coefficient changed with different pressures. When the test was repeated from 0 pressure to about 11 kPa pressure, continuously the permeability reduced and this particular one is for a jute geotextile. The Y axis, it has the flow rate and that can be converted to other properties like the k p or theta.

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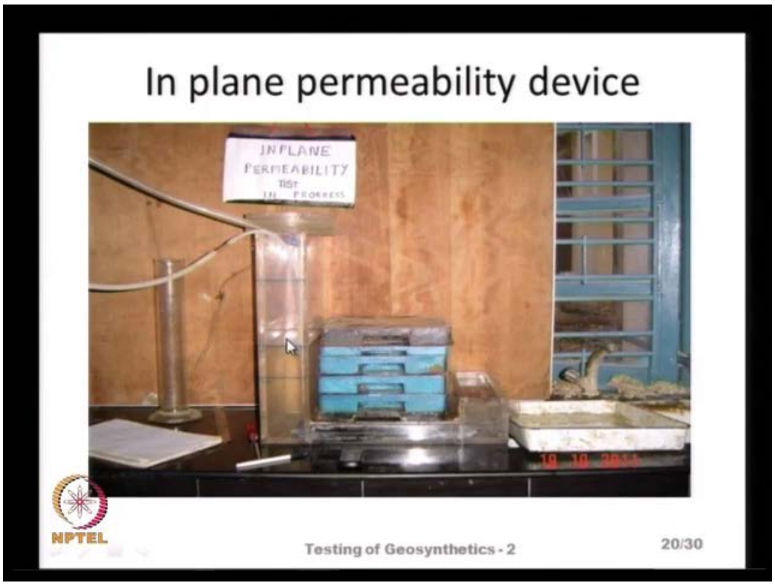

And this particular operators that we have here, it is called as the laminar flow operators because the flow is along the length. And some geotextiles like the needle punched geotextiles may be sensitive to the direction of the flow also.

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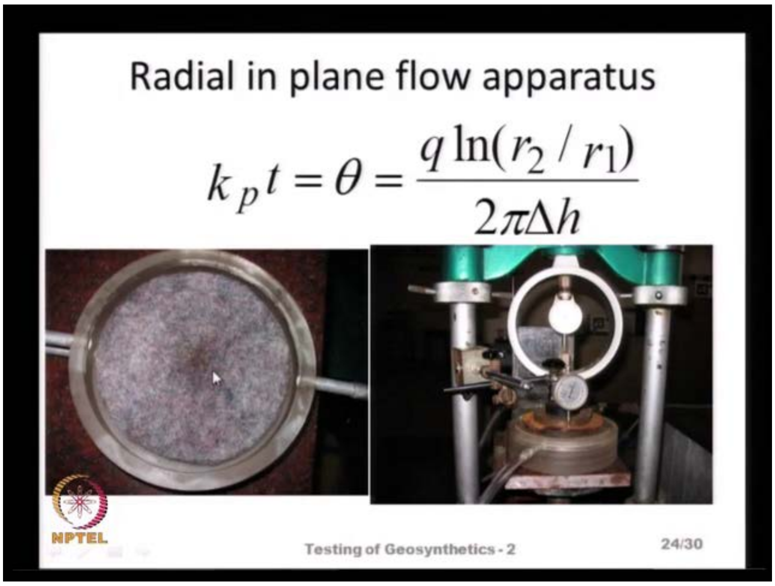

And so for that type of geotextile, we can also use a radial flow operators, here the radial flow operators is, the water is forced through an opening at the center of this circular plate of 300 millimeters. And the water enters the geotextile and flows along the geotextile into a opening at the collection trends around the periphery of the geotextile and it comes out. And we can do the test at different normal pressure by putting it in a load frame and apply the load and the formula for interpreting the result is given like this.

The lawn of r 2 by r 1 where, r 2 is the radius of the geotextile and r 1 is the radius of the opening, that is given in the in the operators and then the delta h is the head difference, t is the thickness at the applied pressure, the q is the flow rate. And once we have all these parameters, we can determine the permeability coefficient for the inplane flow. And some this particular radial flow operators is useful for analyzing the flow rate through the needle punched type of geotextiles.

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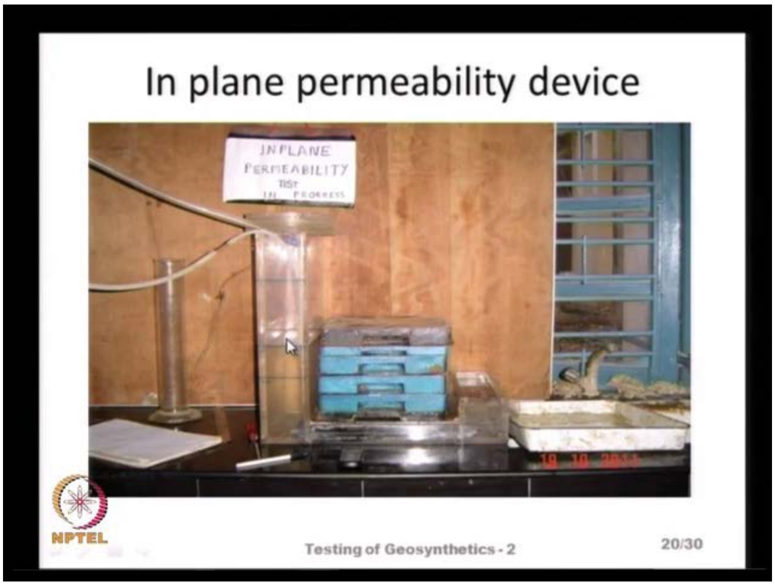

Whereas, this laminar flow operators is good for woven type geotextiles where, there is view pattern, which is continuous like there is a identifiable direction, that is the longitudinal and transverse strips and the flow is more or less along fixed paths, longitudinal and transverse.

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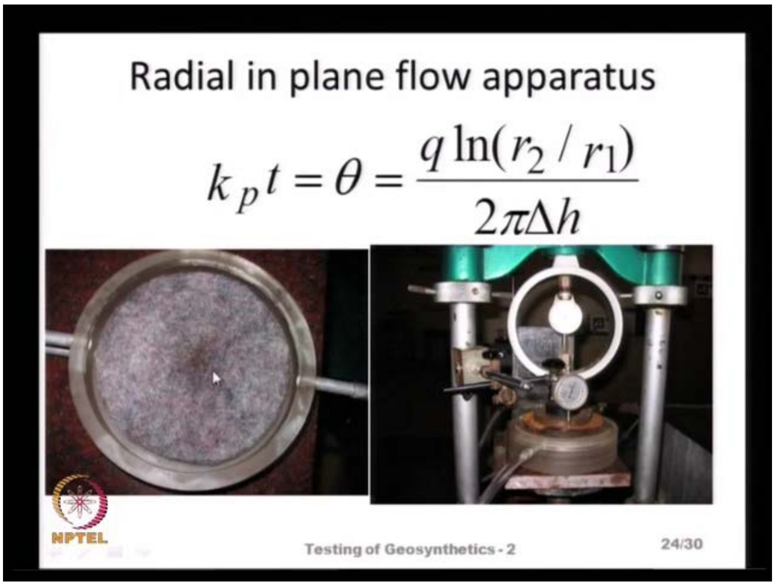

Whereas, in the case of very thick non woven geotextiles, like the one shown here, the flow could be more of radial type.

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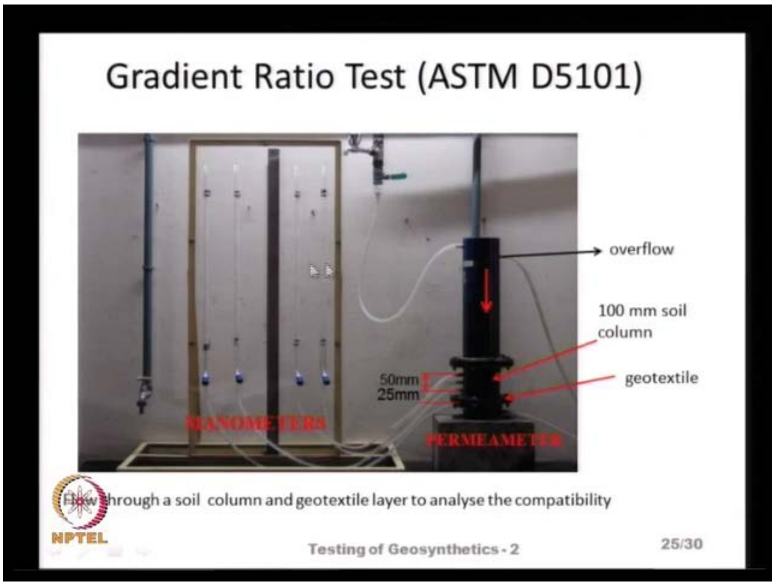

Then, another test that we perform a very important test is the gradient ratio test, originally this test was developed by the US army core of engineers. And later on, the ASTM has slightly modified and the ASTM code for performing this test is the ASTM D 5101. And the difference between the gradient ratio test and the other test is that, we employ the candidate soil where, we want to protect the, which are needs to be protected by use of geotextile in this test.

And here, we have the operators where, there is a column of water that flows down, it flows through 100 millimeters column of soil and then at the bottom, we have the geotextile and the water comes out and then flows out. And as the water is flowing through the soil and then the geotextile, it is possible that, any fine particles can flow along with the water and clog the geotextile. And if the flow is continued for a very long time, after sometime, all the pore openings in the geotextile may get clogged by the fine soil particles.

And so this the gradient ratio test is very important because it can assess the compatibility between a candidate geotextile and the particular soil, that we want to protect. Since there is no compatibility then we may either end up with too much loss of fine soil particles that results in piping. Or if the geotextile openings are too small then and if the fines content is very high, the fine soil particles may clog the geotextile and preventing the flow of water. And that can be assist by using these gradient flow operators and the flow of water is through a column of soil and a geotextile.

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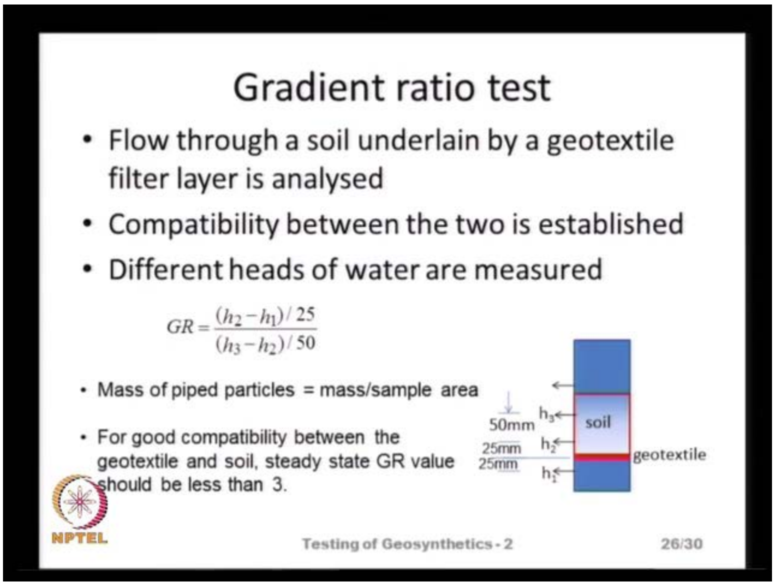

And this schematic is given here, we basically allow the water to flow through the soil underline by a geotextile and then analyze the quantity of water that is flowing through or the fine soil particles, that are washed through the geotextile. And we measure the head of water at a different places, one is just below the geotextile that is, h 1 that is, 25 millimeters below the geotextile. And one head of water is measured at 25 millimeters above the geotextile, that is designated as h 2 and then another head of water is measured at h 3 that is, at 50 mm above the h 2.

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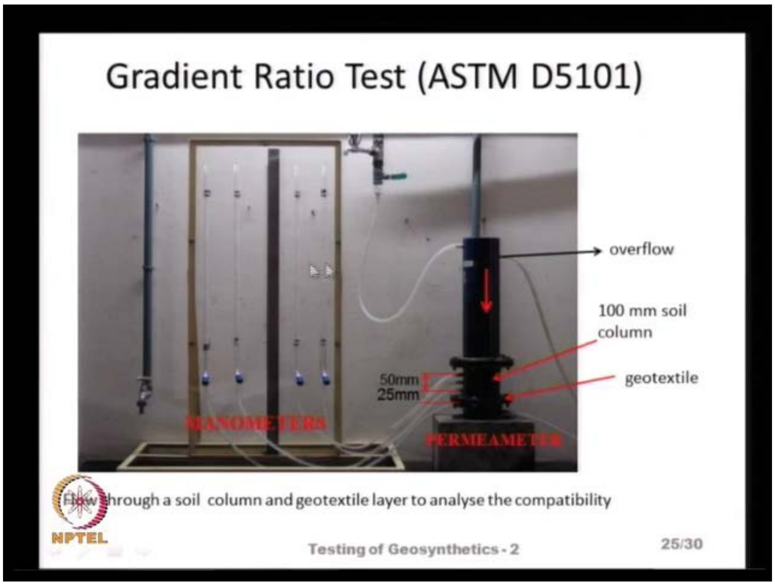

Using the manometers here, here we have different nanometers that are connected to different ports here at different locations.

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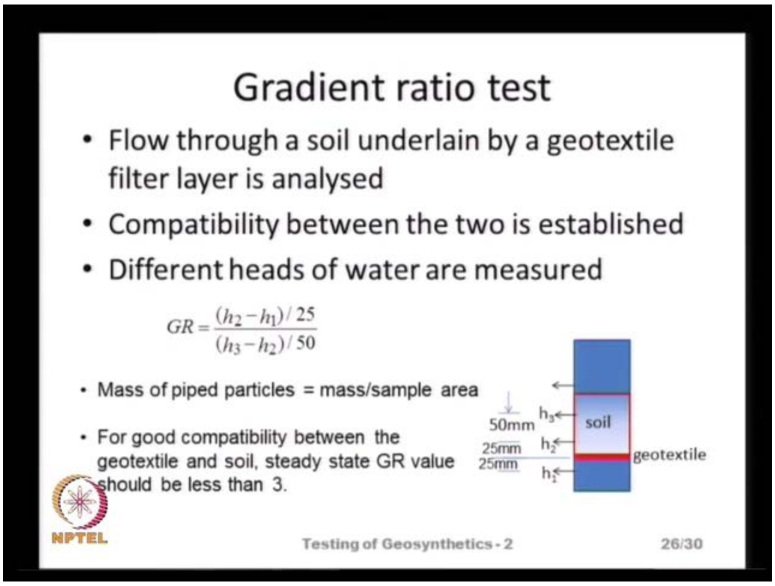

It is actually h 1, h 2, h 3 and so on and we can calculate the gradient ratio as the head difference between h 2 and h 1 divided by 25 millimeters, that is corresponding to the soil divided by h 3 minus h 2 that is, over a length of 50 millimeters in the soil and this particular formula is given assuming that, the geotextile thickness is very small. And if the geotextile thickness is very significant let us say, about 10 millimeters, we need to add the thickness of the geotextile to 25 millimeters and 50 millimeters.

Otherwise, the same formula can be used for both thin geotextiles and also thick geotextiles and we also collect all the particles that flow through the geotextile that is, the piped particles. And the US army core of engineers, they have recommended that, for a good compatibility between the candidate soil geotextile and the particular soil that needs to be protected, the long term gradient ratio value should be less than 3. That is, we can see it here, it is actually when there is clogging in the geotextile, both h 3 and h 2 become almost the same.

And the denominator tends to a very small value and that increases the GR value and then when there is clogging, h 1 may be very, very small, 0 and h 2 could be high and both h 3 and h 2 will approach almost the same values. So, the gradient ratio increases so when there is a good continues flow of water, the head difference, the h 3 and h 2 will be very large. And similarly, h 2 and h 1 also will be large and then the gradient ratio value will approach some constant value.

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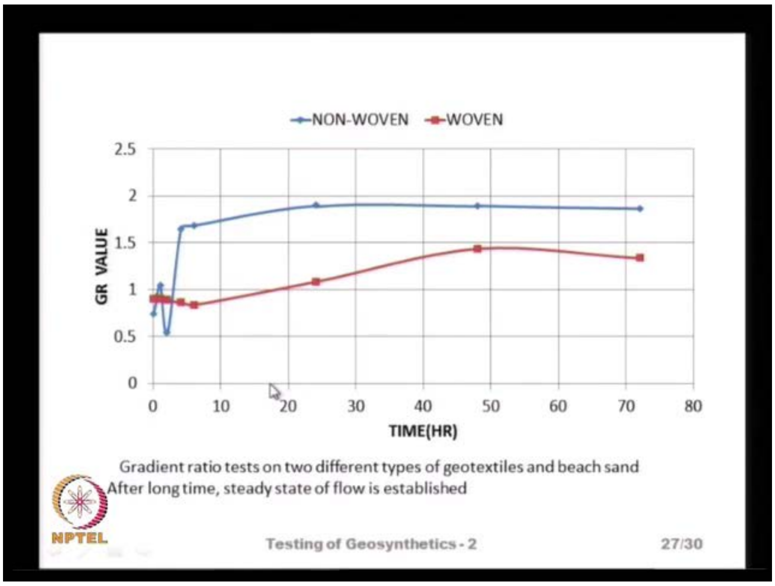

And here, we see the gradient ratio plotted against time for a particular geotextile, the test was performed with a beach sand that is, a sand collected from the beach. And the blue line is corresponding to a non woven geotextile and this red line is corresponding to a woven geotextile. And we see that, initially when the test was started within the about half an hour, there was some fluctuation in the gradient ratio.

Because, the flow takes sometime to establish itself and after that, the flow is continuous and then the head of water may become constant. And here, you see after about 20 or 30 hours of test, the non woven geotextile, it has reached a steady state value whereas, after about 50 hours, the woven geotextile ahs reached more or less steady state value. It is actually, this test has to be continued for at least 1 or 2 weeks, so that we can establish the long term flow characteristic. And in this particular case, the gradient ratio for both the nonwoven and the woven geotextile are less than 3. That means that for this particular beach sand, both the tested nonwoven and woven geotextiles, they are suitable.

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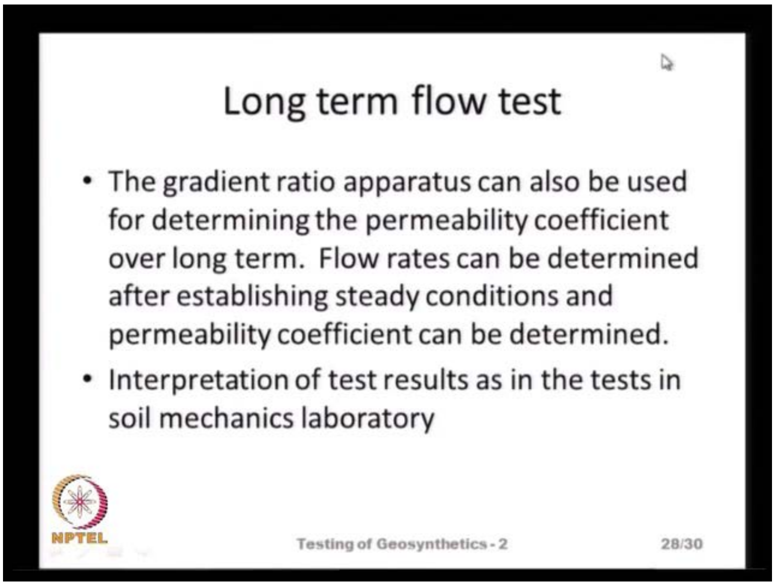

And a slight variation of the gradient ratio test is the long term flow test, it is actually here.

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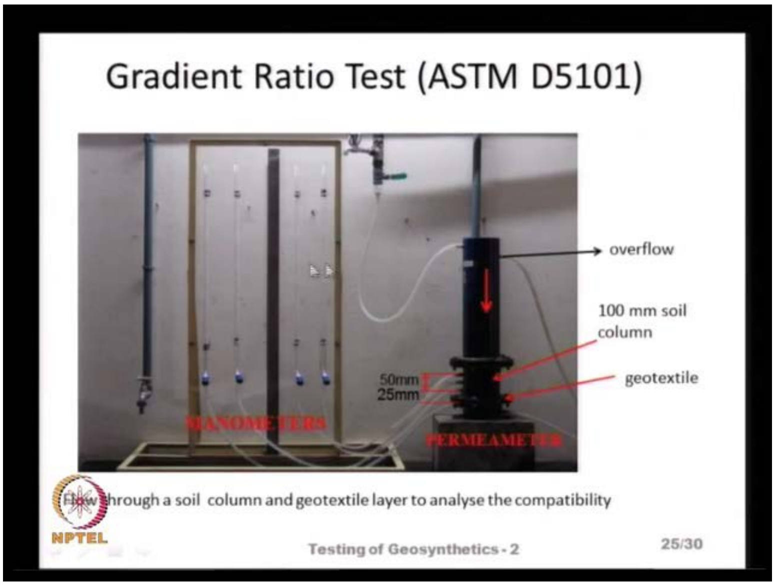

In the long term flow test, we use the same operators except that we do not measure he head of water at different times or different locations. We just simply allow the water to flow through and just like in the normal test on the soils.

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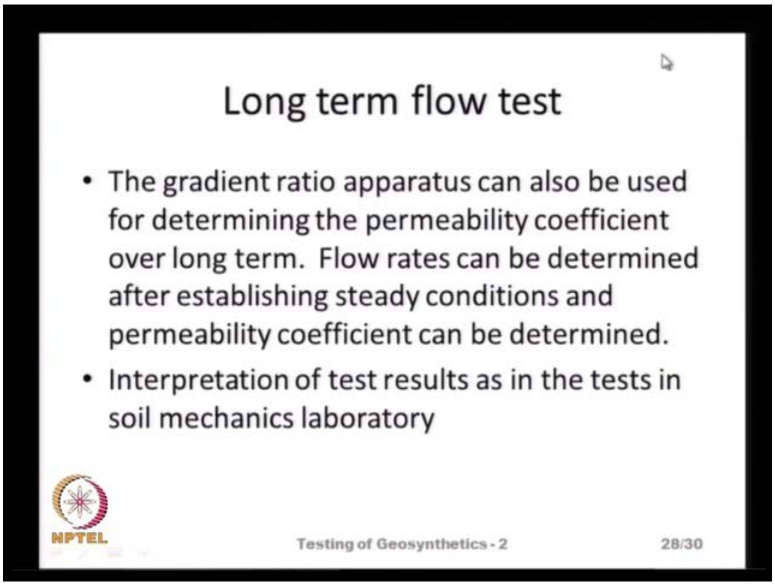

We allow the water to flow through and then we determine the rate of flow after a very long time, after the flow starts typically say, after 1 hour or 1 day or 7 days or so on. And then say, if we do the test for a very long time and if steady state conditions are established, the permeability constant that we calculate will reach a constant value. And then at the same time, what we do is, we also collect the fine soil particles that are flowing through the geotextile to make sure that, the piping does not take place. And the interpretation for permeability of the system that is here, I am calling it as system, because the water flow is through the soil plus the geotextile, not just through the soil alone. And the interpretation of the test result for permeability coefficient is just as how we do it on the soil samples.

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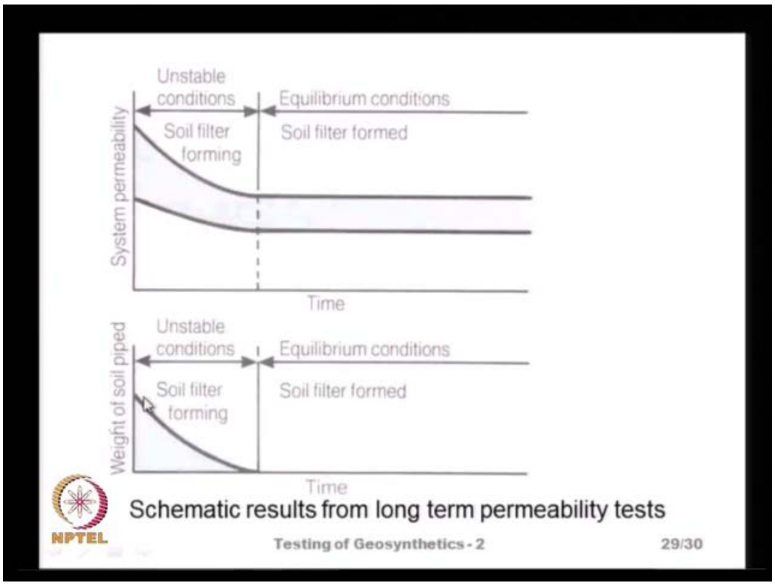

And if you plot a graph between the time and the system permeability or the weight or mass of the soil particle, piped soil particles, it is like this. Say, initially the permeability may decrease, because of the clogging of the geotextile with fine soil particles and after some time, once the steady state conditions are established. That is, when the soil filter cake is formed, the permeability remains constant or the flow rate remains constant.

And this particular constant flow rate should be more than, what we require in the field then if you look at the other graph, after sometime, the piped soil particles may become 0 once the soil filter is formed. And this equilibrium time should be reasonable like it should not happen after very, very long amount of time. Because, by that time, the loss of fines may be so much that, we may end up with problems of the piping.

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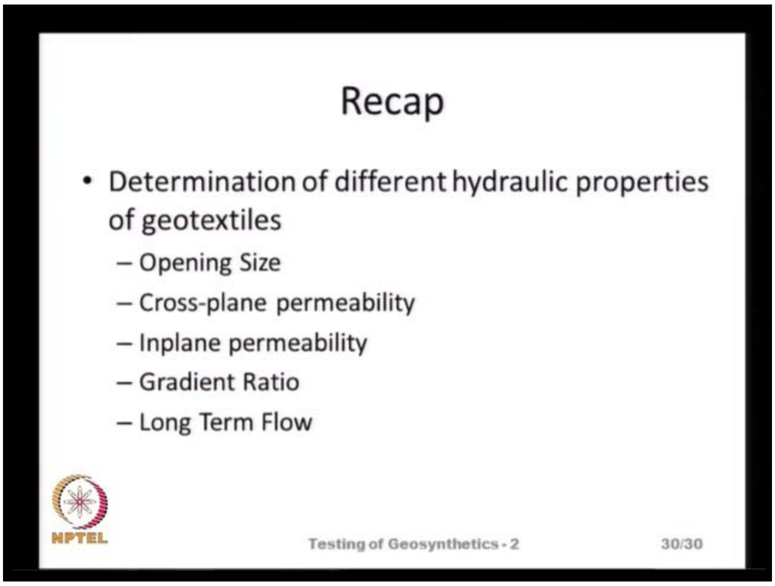

Just conclude, in this lecture we have discussed about the determination of different hydraulic properties of the geotextiles. That is, the opening size, the cross plane permeability, in plane permeability, the gradient ratio and an adaptation of this gradient ratio of long term flow. And once we have all these properties, we can properly select a geotextile for drainage and filtration applications.

Thank you.