Geosynthetics Engineering: In Theory and Practices
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Module - 3
Lecture - 13
Geosynthetics Properties and Test Methods

Welcome to lecture 13, my name is Professor J. N. Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India. The name of the course Geo synthetics Engineering in Theory and Practice. This is module number 3 lecture number 13 Geosynthetics Properties and Test Methods.

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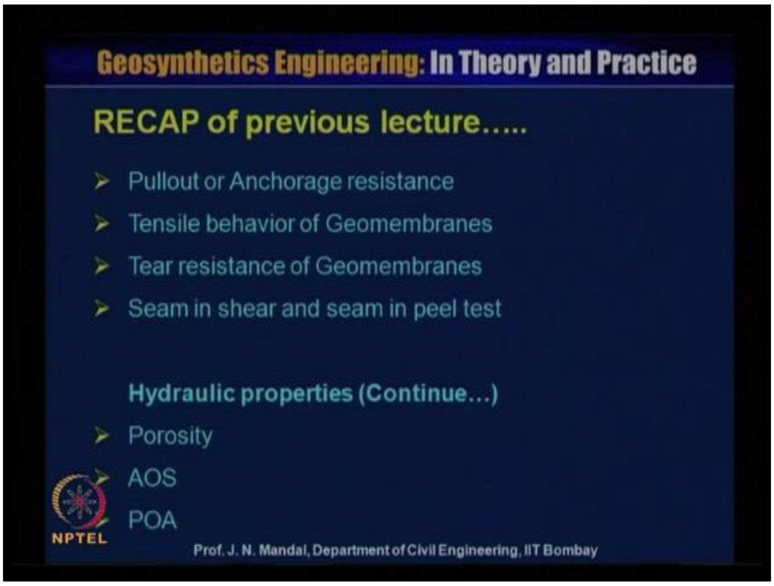

Recap of the previous lecture, we have completed pullout or anchorage resistance, tensile behavior of geomembrane, tear resistance of geomembrane, seam in shear and seam in peel test, and then we are continuing hydraulic properties that is porosity A O S Apparent Opening Size and P O A Percentage Opening.

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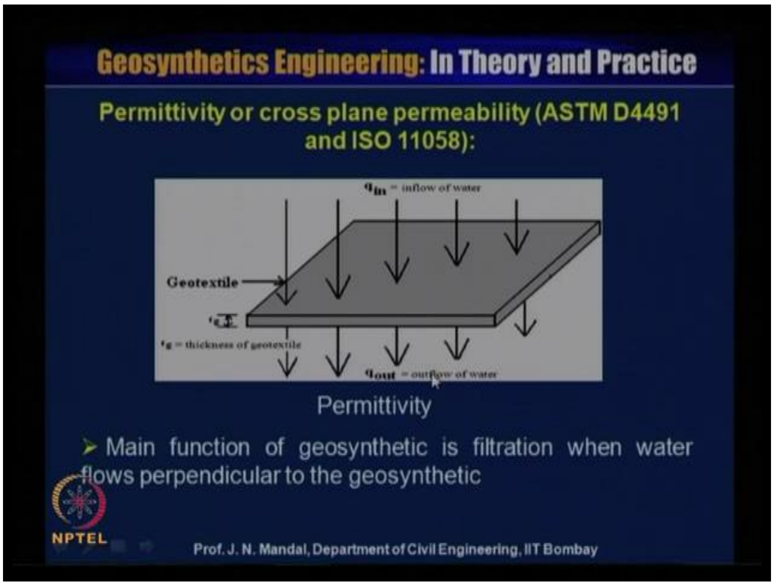

So, next we will address the permittivity or cross plain permeability as per ASTM D4491 and ISO 11058, this test is very important in hydraulic related structure. So, here you can see that this is the geosynthetics material and water flow into the geotextile material and water out from the geotextile material, so this is the flow q in and this is the flow q out and this is the thickness of the geotextile material is t g.

So, when the water or liquid passes across the geosynthetics material it is called permittivity. So, main function of the geosynthetics is the filtration, when the water flow perpendicular to the geosynthetic material.

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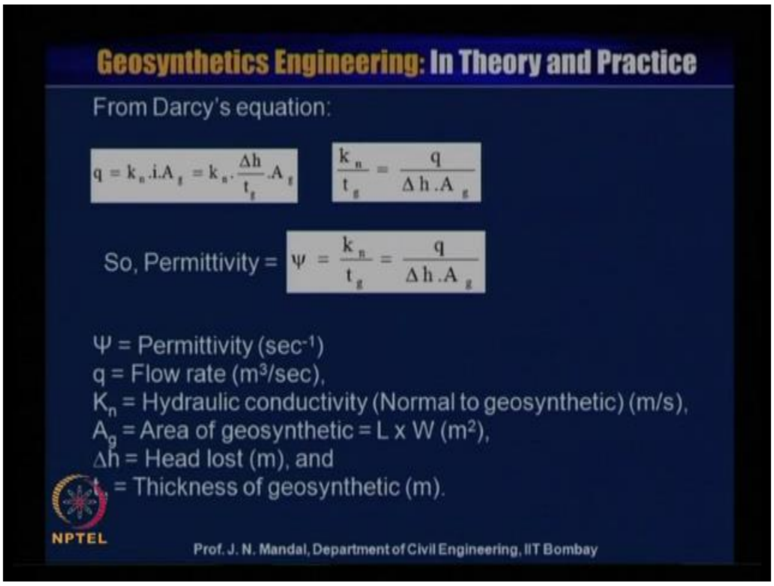

Now, that what are the theory from the Darcy's equation, we know q is equal to k into n into i into A g k n and i is delta h by t g, t g is the thickness of the geosynthetic material and delta h is equal to head lost and A g is equal to area of geosynthetics and area of geosynthetics is length into width.

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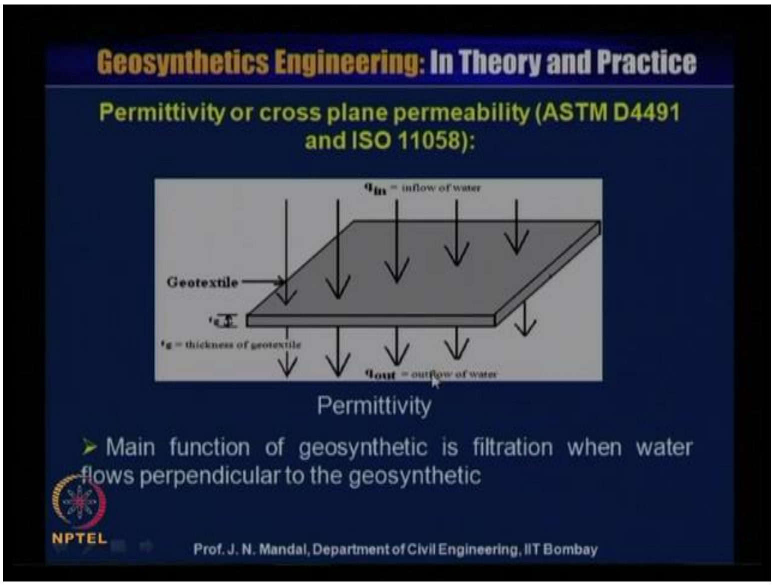

You can say this is the, if this is the length of the geotextile material and this is the width of the geotextile material, so area will be length into width.

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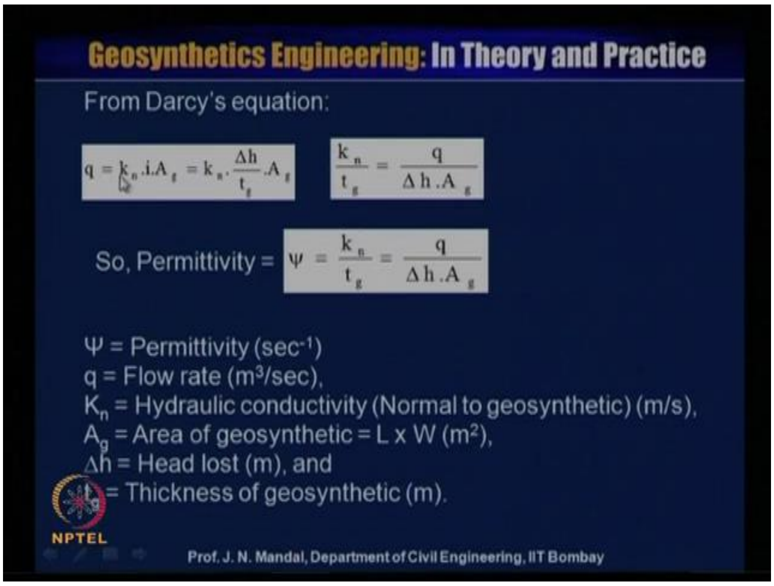

So, you can write this A g also length into width, so from this equation we can write k n by t g, this is t g is equal to k n by t g is equal to q by delta h into A g; that means, q by delta h into A g. So, this k n by t g which you call the permittivity or which is designated as a psi, so psi is equal to k n by t g is equal to q by delta h into A g, and unit of permittivity is per second and flow rate is meter cube per second, k n is the hydraulic conductivity normal to the geosynthetics meter per second. A g area of geosynthetic that is L into W length into width of the geosynthetics in meter square and delta h is equal to head lost in meter and t g is the thickness of the geosynthetic material in meter.

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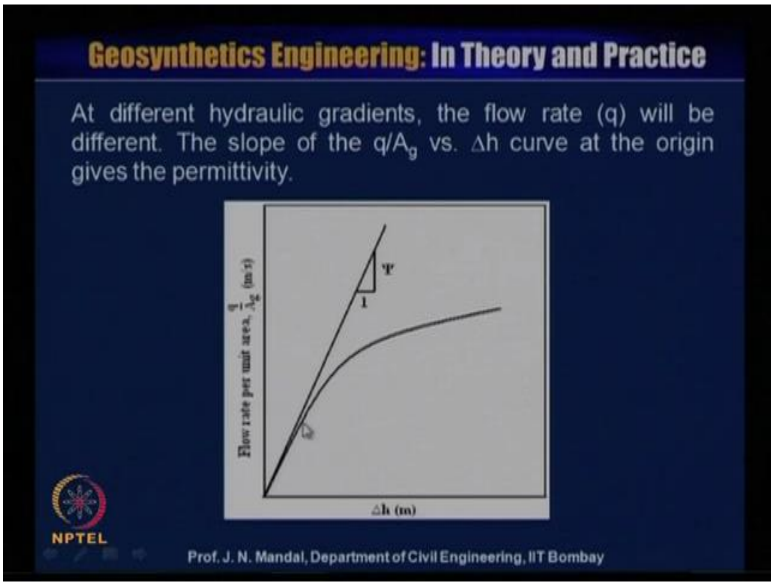

Now, you can also draw a correlation between the flow rate per unit time that is q by A g to the delta h; that means, this is q by A g to delta h, so if you can draw the relationship between the flow rate per unit area to the delta h and you can draw this tangent and this slope which will give you the value of permittivity. So, at different hydraulic gradient the flow rate q will be different, the slope of q by A g versus the delta h curve at the origin give the permittivity.

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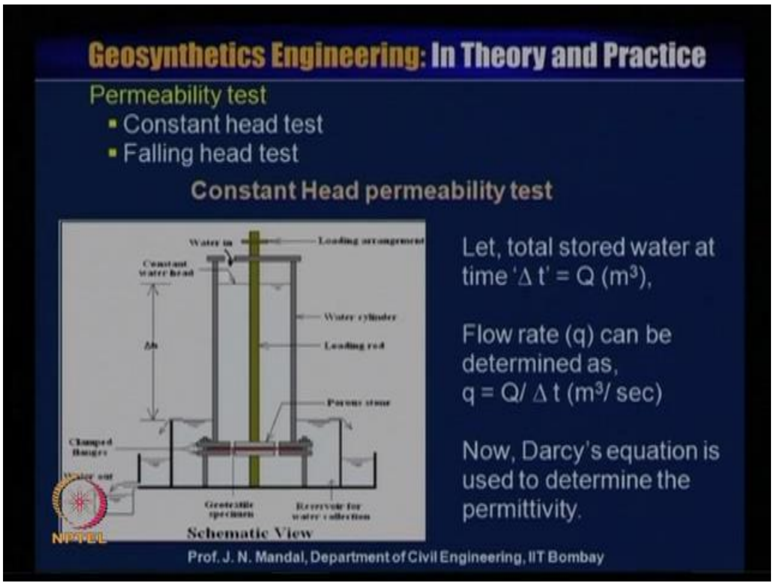

So, there are other method also you can determine the permeability test, one is constant head test another is falling head test, so constant head permeability test. So, this is the schematic view of the constant head, and let this what will be the total storage of water at the time that is delta of t. So, this is the geotextile material, and this is the porous stress at the top and the bottom, and this is the reservoir for the water collection and this is the loading arrangement, this is water is in and this has a constant water head and this is the clamped flange where geotextile is tightened.

And then ultimately water come out from here this is the water cylinder and this is the loading fed, so this is a kind of the loading arrangement and this is the reservoir of for water collection, so you can collect the water. So, let the total storage water at the time delta t is equal to Q meter cube, so flow rate q can be determined from this equation small q is equal to capital Q by delta t meter cube per second, now Darcy's equation is used determine the permittivity.

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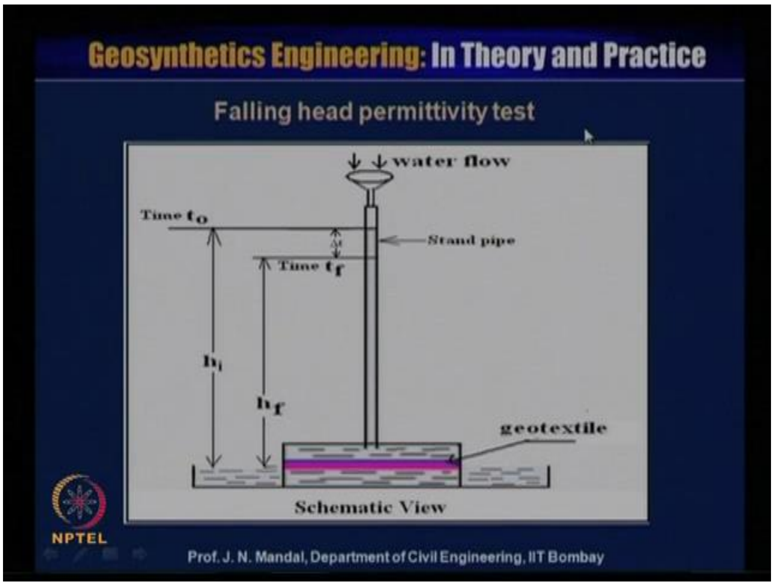

Similarly, falling head permittivity test, you can see this is the initial time t 0 and for a initial height h i this is the final time t f, and this is the final height h f and this is the stand pipe water is flowing to the stand pipe and geosynthetics material is here this red color geosynthetics material is here.

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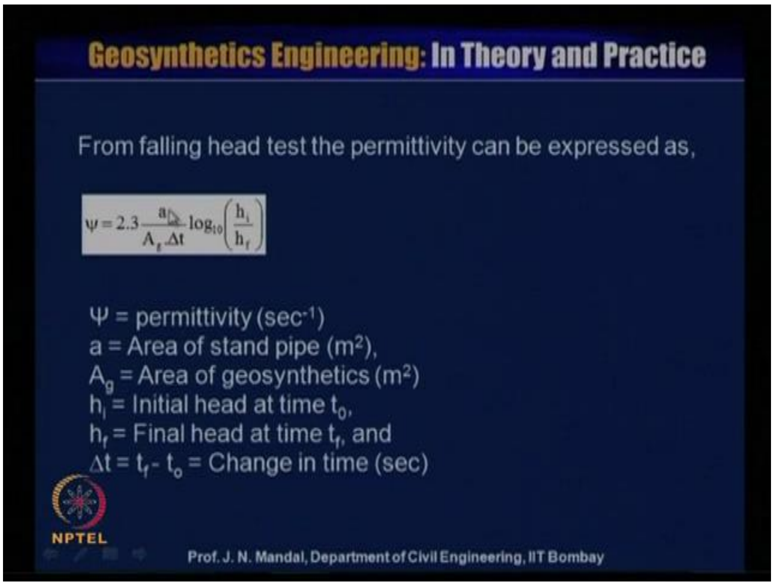

So, you know that falling head test, so this falling head permittivity test also you can determine, from the falling head test permittivity can be expressed psi is equal to 2.3 small a by A g into delta t log of h 1 by h f. And this psi which we call permittivity this expressed per second a is area of the stand pipe meter square, this is the a of this is the stand pipe and this area is small a, so small area of stand pipe A g is equal to area of geosynthetics. You know this is the geosynthetics material, you can calculate that what will be the area of geosynthetics material, and then delta of t, you know that is t f minus t 0 that is change in time this is t f t 0.

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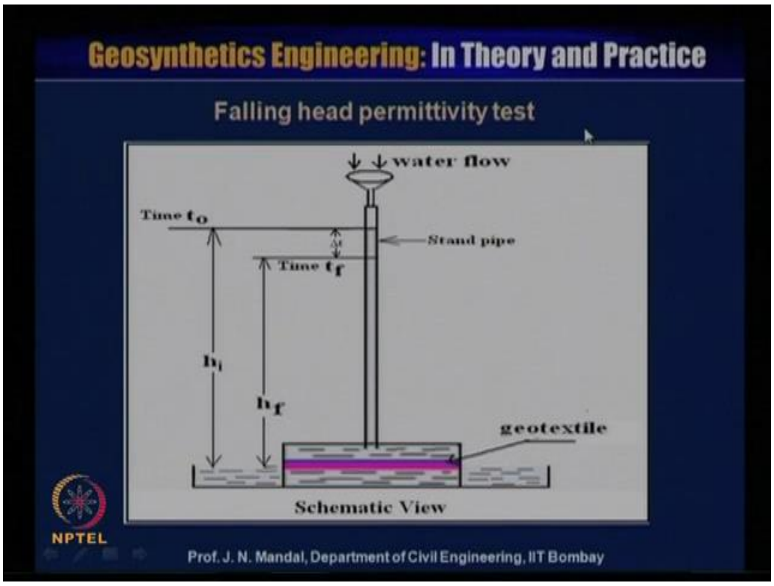

So, change in time this what is delta t and then h i and h 0 initial head at time 0, h f initial head at time t, t that is h i at the time t 0 h f at the time t f.

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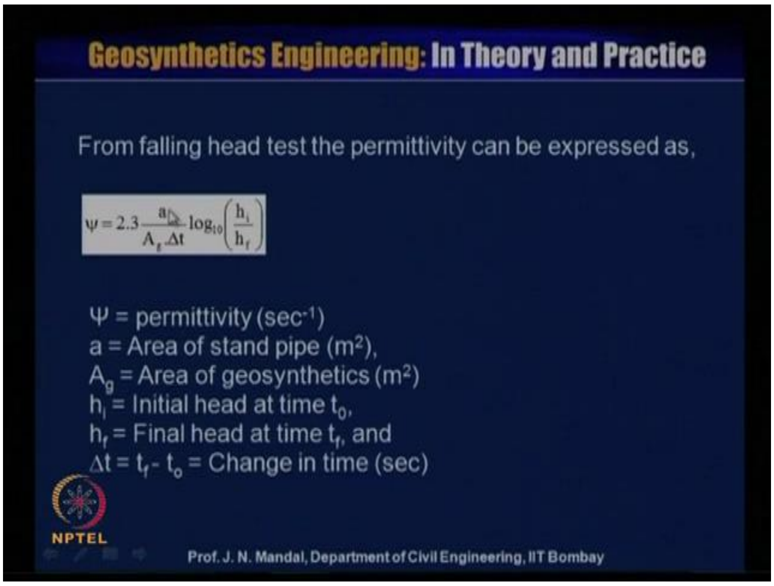

So, you can calculate this what should be the permittivity of the geosynthetics material by falling head permittivity test, so this test is very important permittivity test, similarly there is another term is very important that is transmissivity or in-plane permeability is as for A S T M D 4716 and I S O 12958.

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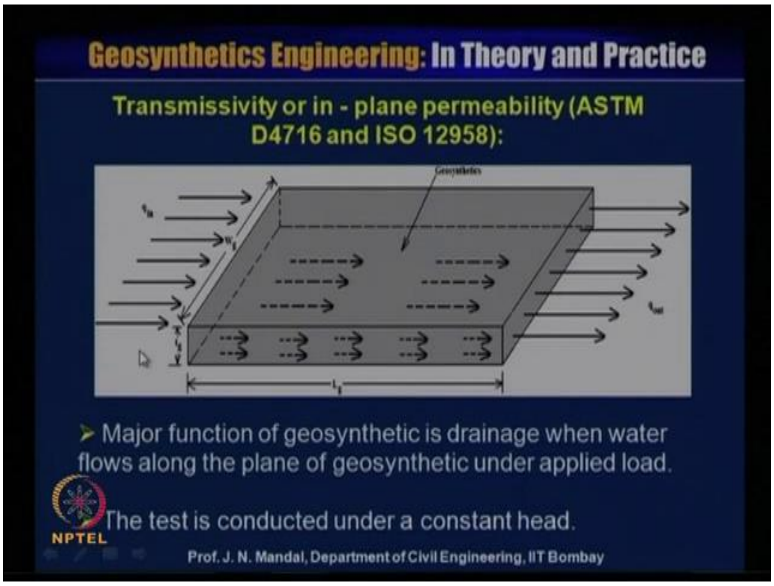

Here, you can see that this is the geosynthetics material and major function of geosynthetic is the drainage when the water flow along the plane of the geosynthetics material under some applied load, the test is conducted under a constant head like this.

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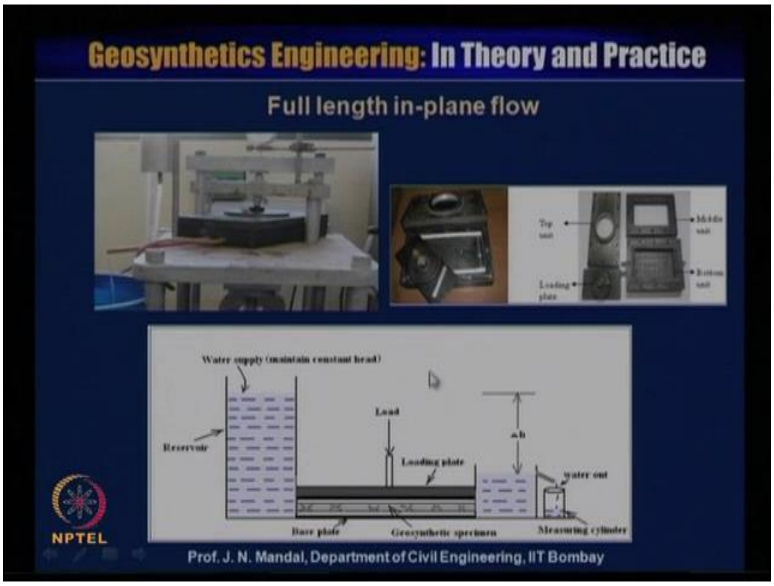

This is geosynthetics material and this is applied load I will tell you later on we are applying the load and this is geosynthetics material.

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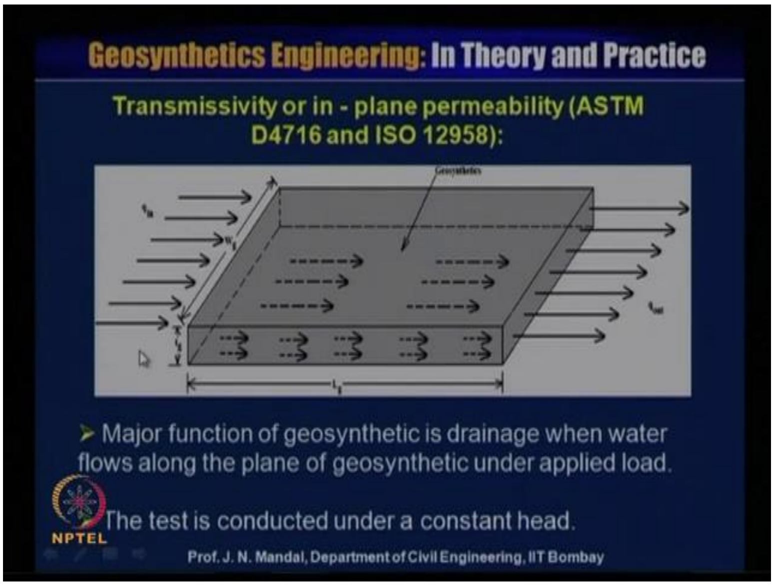

That means, that you have to test is to be conducted under a constant load, here you can see that this is the length of the geotextile L g, this is width of the geotextile W g, this is thickness of the geotextile t g and this flow in is q in and flow out is q out. So, this water or liquid flow along the plane of the geosynthetics material, that is why it is called transmissivity.

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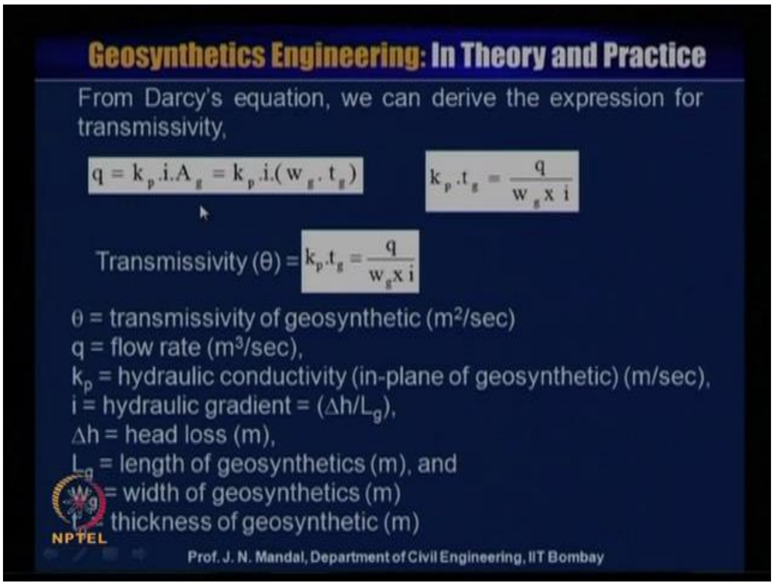

So, now again from the Darcy's equation we can derive the expression for transmissivity; that means, q is equal to k p into i into A g or k p into i into A g is the area,

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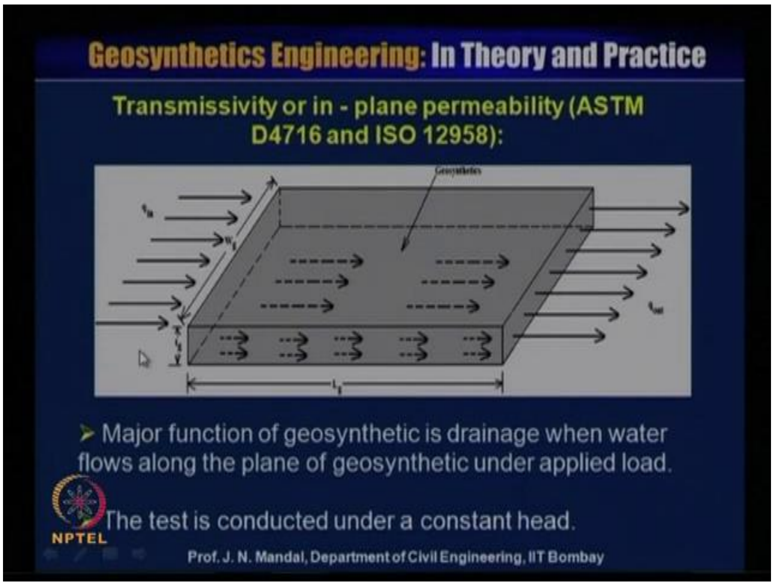

That means, this area will be this area; that means, this is the w g w g and this is the thickness t g, so this area will be w g into t g.

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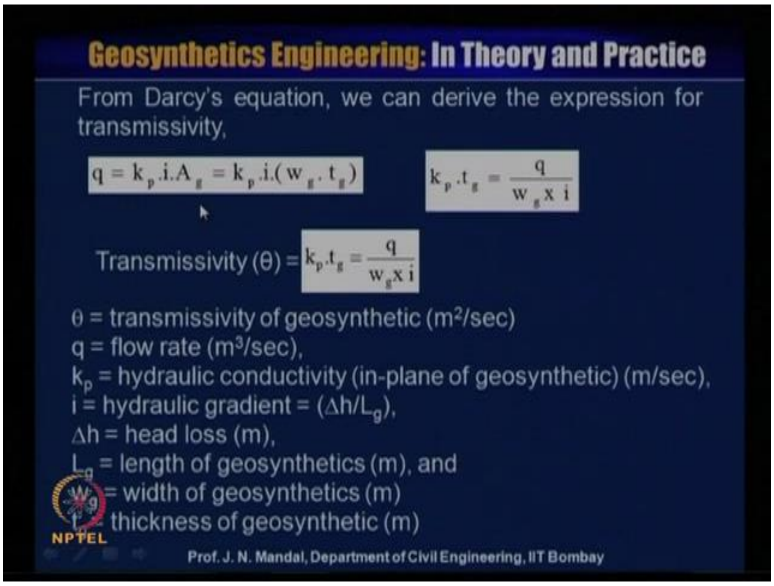

So, then k p into t g will be equal to q by w g into i, so transmissivity, which can be expressed as theta is equal to k p into t g is equal to q by w g into i, this theta is transmissivity of geosynthetics. And this unit of this transmissivity is meter square per second, and q is the flow rate meter cube per second k p is the hydraulic conductivity in plane geosynthetics meter per second, i is equal to hydraulic gradient that is delta h by l g.

And delta h is the head lost and l g is equal to length of the geosynthetic material w g is equal to width of the geosynthetics and t g is equal to thickness of the geosynthetics, so you remember this equation what is transmissivity that is theta is equal to t by w g into i.

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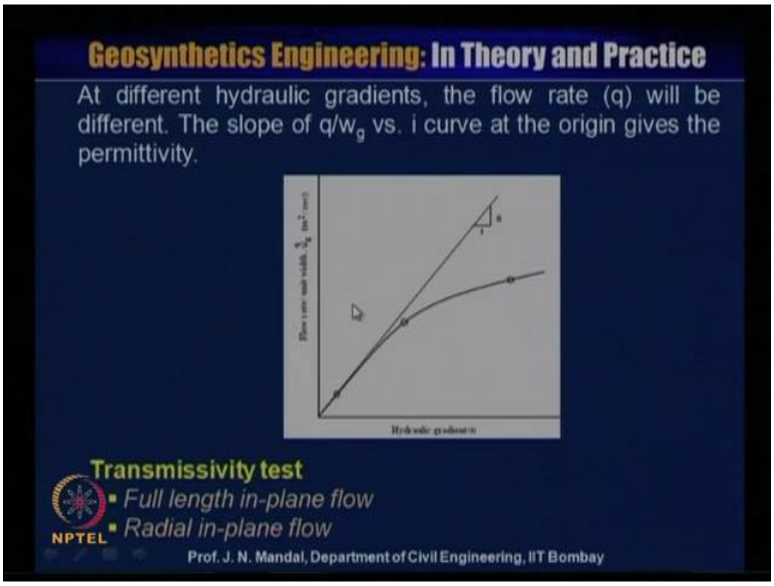

So, like permittivity you can also obtained that flow rate with width, that is q by this one q by, so this related with the hydraulic gradient i, so different hydraulic gradient flow rate q will be are different. So, you can see here the slope of q by w g versus i curve, so this will give you the slope this slope which you call that theta, so this theta value will give you the transmissivity value, so this transmissivity test also can be conducted by full length in-plane flow or radial in-plane flow.

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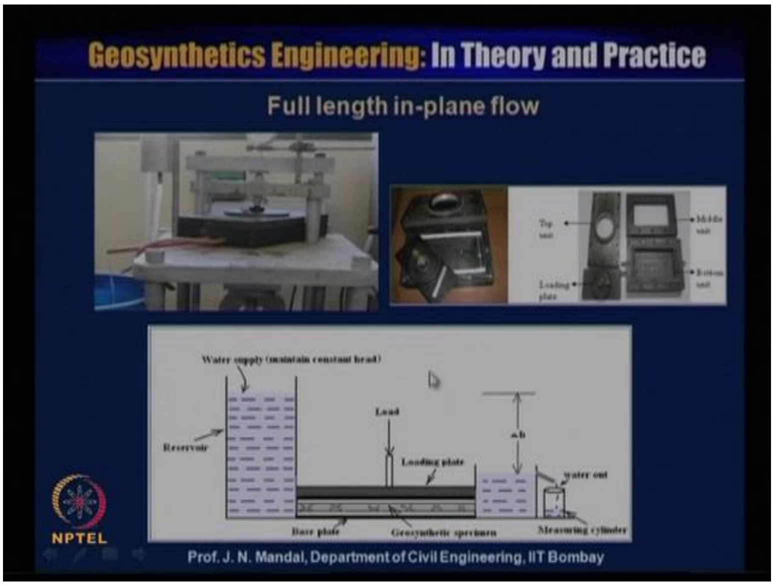

So, you can see full length in-plane flow, so here that sample size may be 200 meter length and this is 100 millimeter width and these geosynthetics material is placed between the 2 plate, and on the top and bottom of the geosynthetics there will be a impermeable material. And then this is the loading system here you can see these are all assembly for this for performing the transmissivity test and this is full length of the plane; that means, you can see here schematic diagram, this is a geosynthetics material.

And this is the base plate top also some base plate or it will be the impermeable material and this loading is applied from the top, and water is supplied and this at a constant head from this reservoir and this water can pass along the plane of the geosynthetics material, and then you’re collecting the water in a measuring cylinder, so water is out from here.

So, there will be a head that is delta of h, so for a particular load constant load, so you can measure what will be the quantity of water has been carried out at a particular time. And then you can apply the load let us say initially we applied 50 kilopascal then 100 250 350 450 550 like that continue and each and every time you have to give some constant load and measure what will be the quantity of water flow through the geosynthetics material under different loading.

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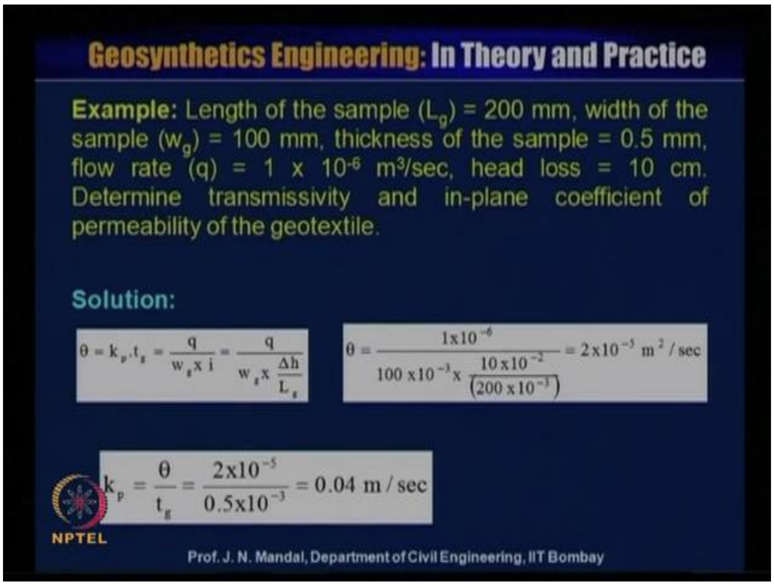

So, under different loading, you can calculate what will be the quantity of water, so I am giving one example, let us say the length of the sample L g is 200 millimeter, width of the sample w g is 100 millimeter thickness of the sample 0.5 millimeter flow rate q is equal to 1 into 10 to the power minus 6 meter cube per second, head loss is 10 centimeter. Determine the transmissivity and in-plane coefficient of permeability of the geotextile, so here is the solution, we know transmissivity theta is equal to k p into t g that is equal to q by w g into i.

So, q by w g is i is delta h by l g, so theta is equal to q is 1 into 10 to the power minus 6 this divided by w g and w g is the width of the sample is 100 millimeter, so this is in terms of the meter, so 100 into 10 to the power minus 3 into delta h delta h is the head loss is 10 centimeter. So, meter 10 into ten to the power minus 2, this divided by l g, l g is the length of the sample 200 millimeter, so 200 into 10 to the power minus 3, so you can have theta value 2 into 10 to the power minus 5 meter square per second.

Now, this you calculate what is the transmissivity and the unit is meter square per second, yet also to calculate what will be the coefficient of permeability of the geotextile. Then coefficient of permeability k p is equal to theta divided by t g, t g is the thickness of the geosynthetics material and theta is the transmissivity of the geotextile material. So, transmissivity you find out 2 into 10 to the power minus 5 this divided by t g; that means, thickness of the geosynthetics material is 0.5 millimeter, so theta divided by 0.5 into 10 to the power minus 3 in terms of meter, so you can have this g k p is equal to 0.04 meter per second, this is coefficient of permeability of the geotextile material.

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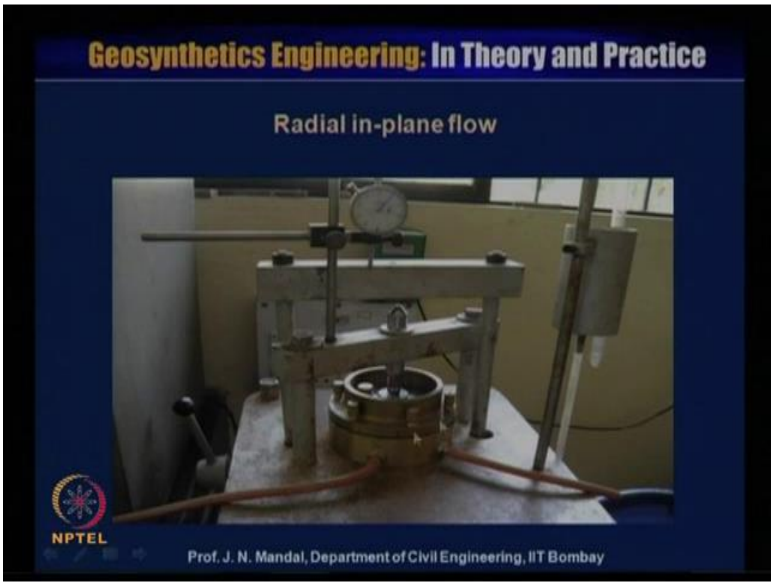

Now, this is another test for transmissivity this is call the radial in-plane flow, so you can see this equipment and this geotextile is placed somewhere here, and this there is a hole I will show you then water can just pass through radically through this; that means, along the plane of the geosynthetics material. And one side this water is in another side is water is out at a particular hydraulic gradient and this is the loading arrangement, so you have to apply the load.

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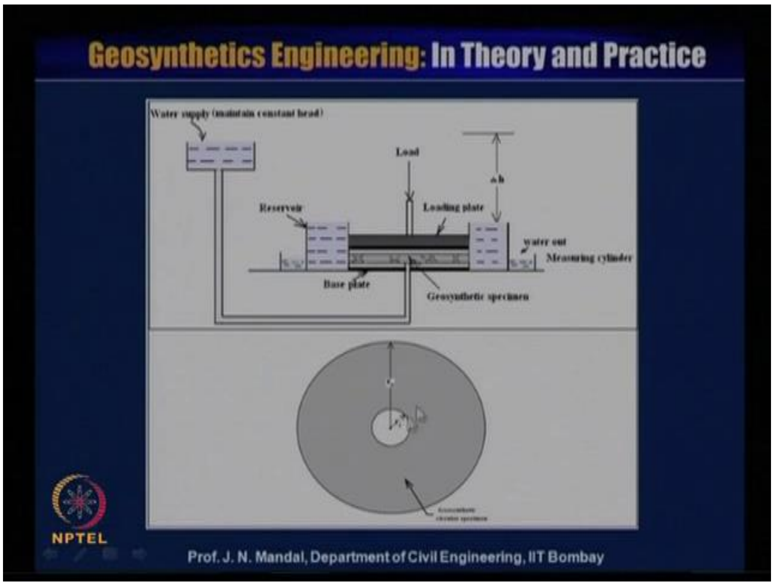

So, you can see here some schematic view, so here the geosynthetics material is placed this is the base plate, and there you can see this is the one diameter inner and this is the outer.

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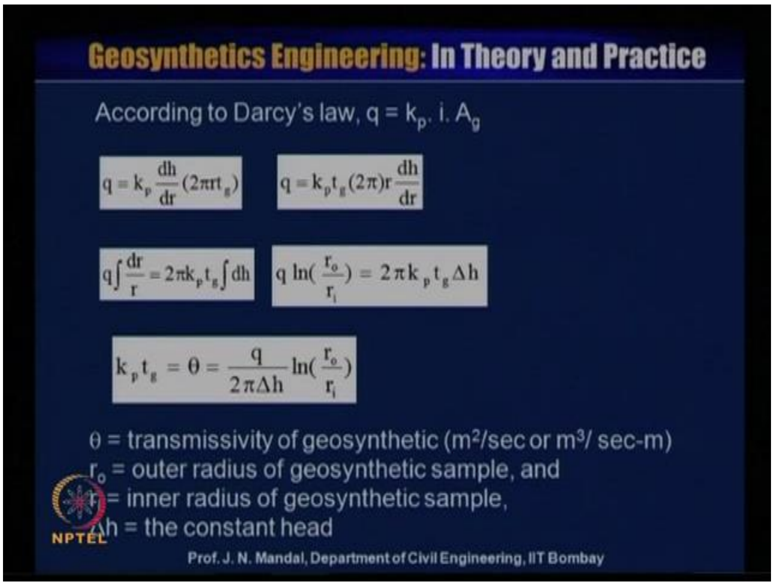

I can say that this is the inner radius of the geosynthetics sample.

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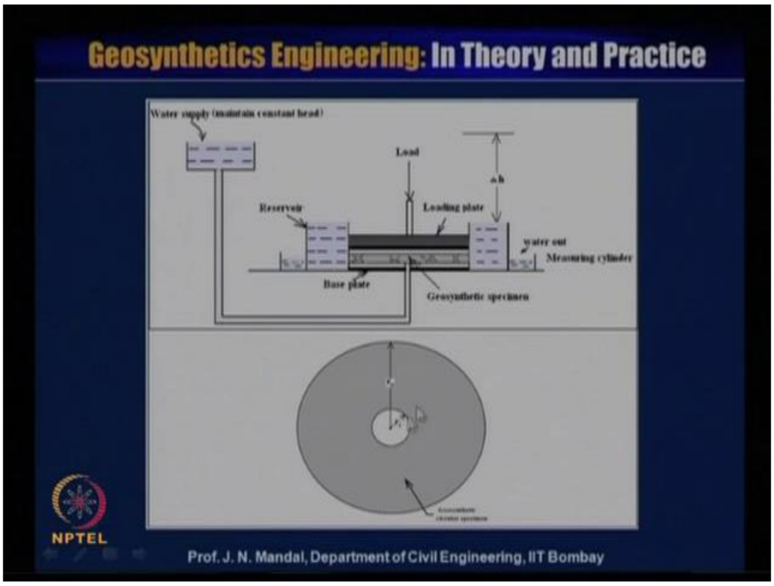

And this is inner radius of geosynthetics sample which is r i and this is outer radius of the geosynthetics sample r o, so here it is like a circular, so geosynthetic material place on the top of this, and then load is applied. So, you can see here the load is applied on this, so then water is supply it maintain constant, and then it pass through this geosynthetics material and passes radially along the plane of the geosynthetics material, it pass from this and this, this, this, this, this and then water is out from here and you are measuring in a cylinder, so this is the difference of delta of h.

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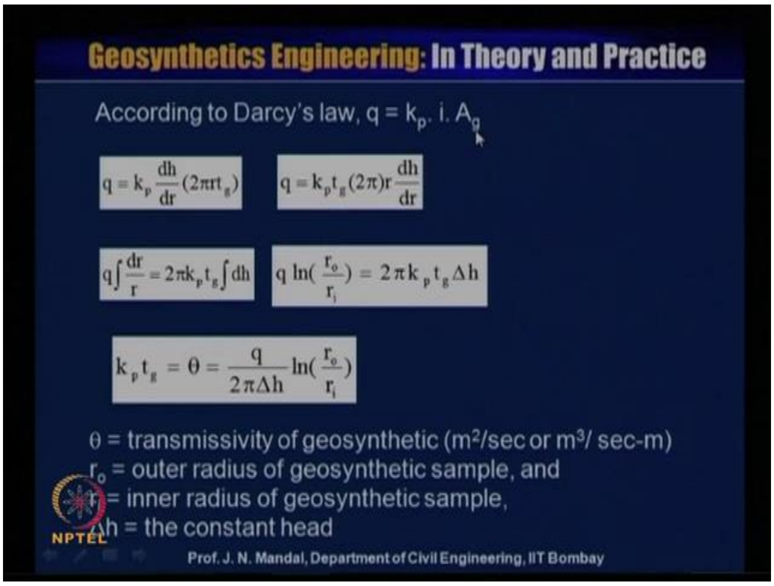

So, according to the Darcy's law we know q is equal to k p into i into A g, so you know the q into k p into d h by d r 2 pi r t g from here two pi r t g, so q is equal to k p into t g into 2 pi r d h by d r. So, this q will lies d r by d r is equal to two pi k p t g into d h, so it lies between the inner radius of the geosynthetics sample mean r 1 to r 0. So, you can write q of log in r 0 by r 1, r 0 is equal to outer radius of the geosynthetics sample, r i is equal to inner radius of the geosynthetics sample, this is outer radius this is inner radius.

So, you can write q into log in r 0 by r 1 is equal to 2 pi k p t g and this is delta of h, so k p into t g is equal to theta is equal to q by 2 pi delta h l n r 0 by r 1. So, if you know that what will be the quantity of water passed through this, if you known delta h if you know what is the outer radius of geosynthetics sample inner radius of geosynthetics sample, so you can calculate the transmissivity of the geosynthetics material that is in meter square per second.

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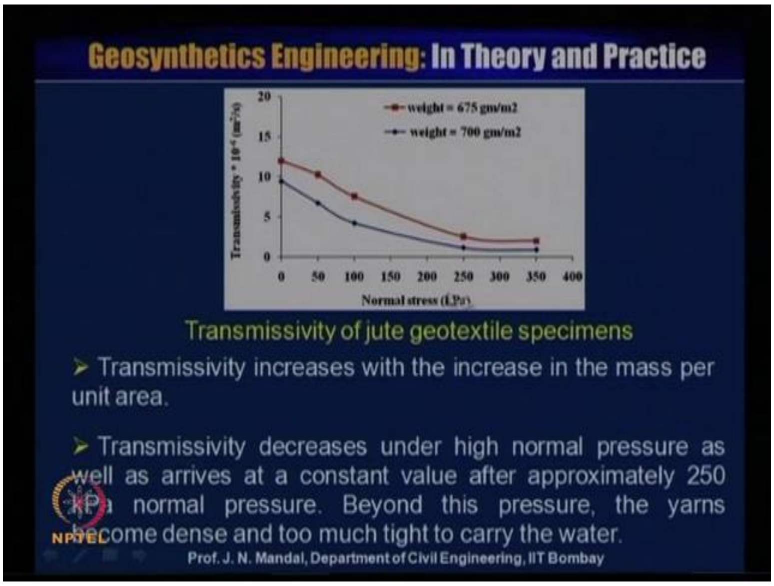

Now, as I mentioned that transmissivity of geosynthetics material are to be conducted under different normal stresses, you can see here we have performed some test under different weight and also under different normal stresses. So, this y axis is the transmissivity into 10 to the power minus 6 meter square per second, and this is all under the normal stress that is begin in the beginning, then you start with the 50 kilopascal.

Then you keep on reading what will be the quantity of water flow through, and then you determine transmissivity then again you increase the load to 100 kilopascal 150 kilopascal 200 250 300 350 like so on. And then you can obtain the transmissivity versus normal stress curve is like this, you can see that transmissivity increases with the increase of the mass per unit area, this is weight for 700 gram per meter square this red one is weight for 675 gram meter square.

So, you can observe that how the transmissivity increase with the increase in the mass per unit area, and at the same time transmissivity decreases under high normal pressure as well as arrived at a constant value, after approximately 250 kilopascal. Normal pressure beyond this pressure the yarn becomes dense and too much tight to carry the water, so you have to design for any flow related problem that what should be the normal stress and what should be the corresponding transmissivity which you will take into account for the design.

So, this is very, very important parameter we will use this kind of the transmissivity value for the design of the prefabricated vertical band drainage and other related problem.

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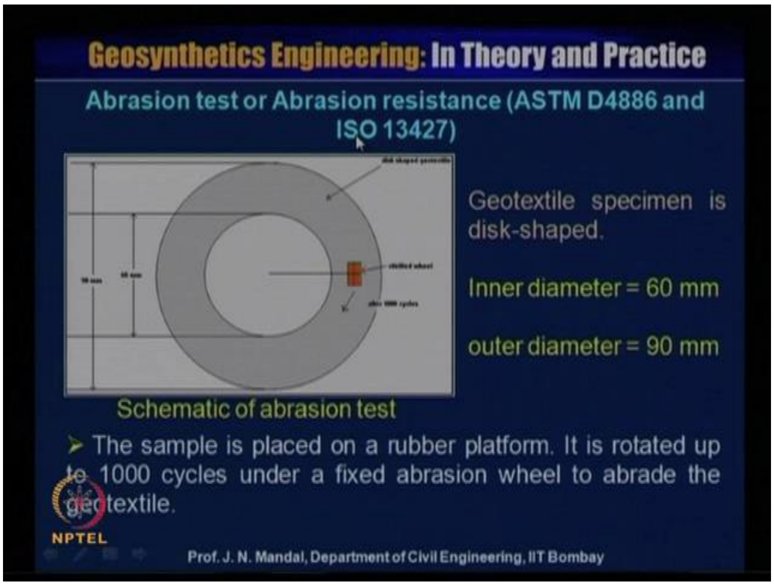

Next is endurance properties, so here abrasion test or abrasion resistance test as per A S T M D 4886 and I S O 13427, so this is the schematic of abrasion test and this has a inner diameter of about 60 millimeter and the outer diameter at about 90 millimeter. So, you can see this is 60 millimeter and outer diameter is 90 millimeter and geotextile specimen is disk shaped like this, and the sample is placed on the rubber platform and it is rotated it is rotated up to one thousand cycle under a fixed abrasion wheel to abrade the geotextile material.

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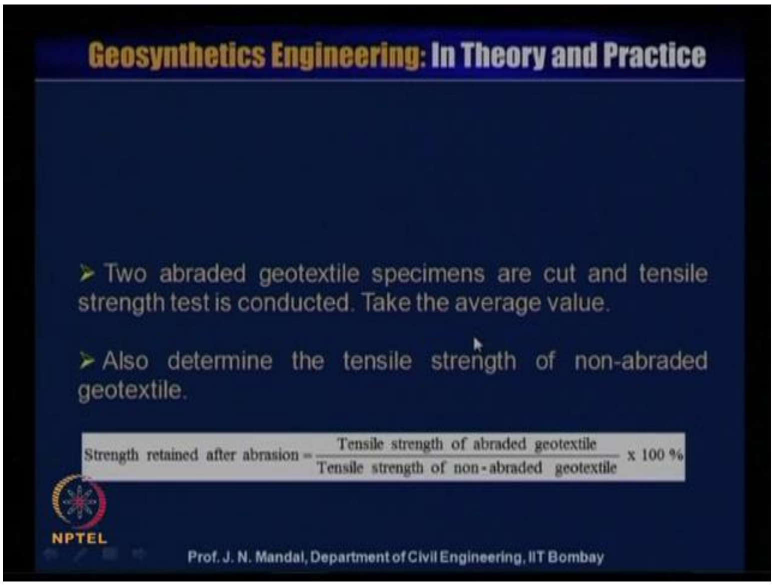

After this you take two abraded geotextile specimen are cut and tensile strength test is conducted take the average value and also you determine the tensile strength of the non-abraded geotextile material. So, strength retained after abrasion will be equal to the ratio of tensile strength of abraded geotextile and the tensile strength of non-abraded geotextile into hundred into percentage, so this way you can calculate what will be the strength retained after abrasion.

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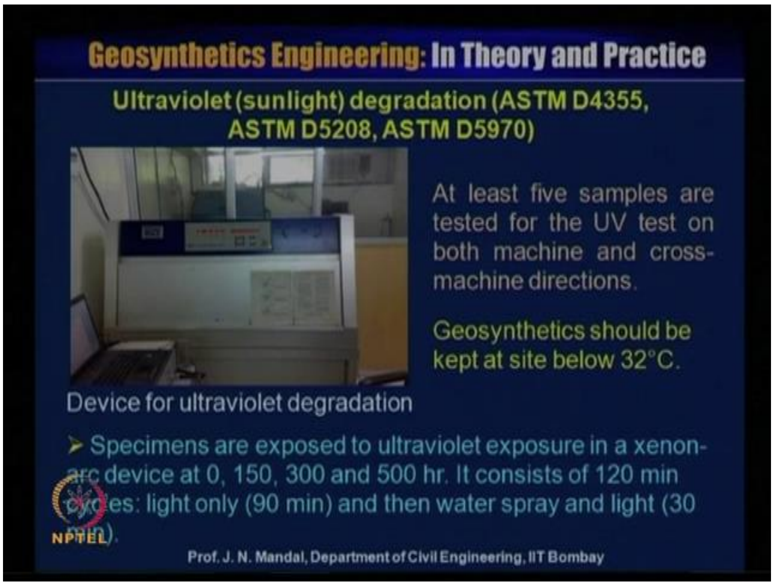

There is a ultraviolet or sunlight degradation test, this is as per A S T M D 4355or A S T M D 5208 or A S T M D 5970, this is also very important test you cannot keep open in the sunlight all kind of the geosynthetics material. So, this also very important, this is the devices for ultraviolet degradation, and at least you need the five sample are tested for the U V test on both machine and the cross machine direction, and geosynthetics should be kept at the site below the 32 degree centigrade. This specimen are exposed to ultraviolet exposure in a xenon arc device at 0 150 and 300 and 500 hour it consist of 120 minute cycle light only 90 minute and then water spray and light 30 minute.

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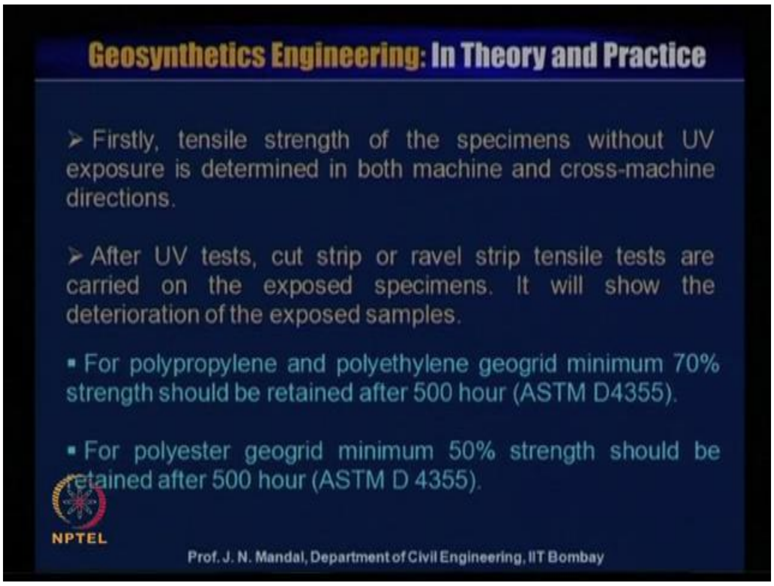

So, it is kind of very long term strength it continue up to the 500 hour and firstly, tensile strength of the specimen without ultraviolet exposure is determined in both in the machine and the cross machine direction, after the U V test cut the strip or the ravel strip tensile test are carried on exposed specimen. It will show the deterioration of the exposed sample for polypropylene or and polyethylene geogrid minimum 70 percentage strength should be retained after 500 hour as per A S T M D 4355 whereas, for polyester geogrid minimum 50 percent strength should be retained after 500 hour as per A S T M D 4355.

So, depending upon the different types of the geosynthetics material, so you will be knowing what will be the percentage of the strength required for this, and how after how many hours you have to continue the strength.

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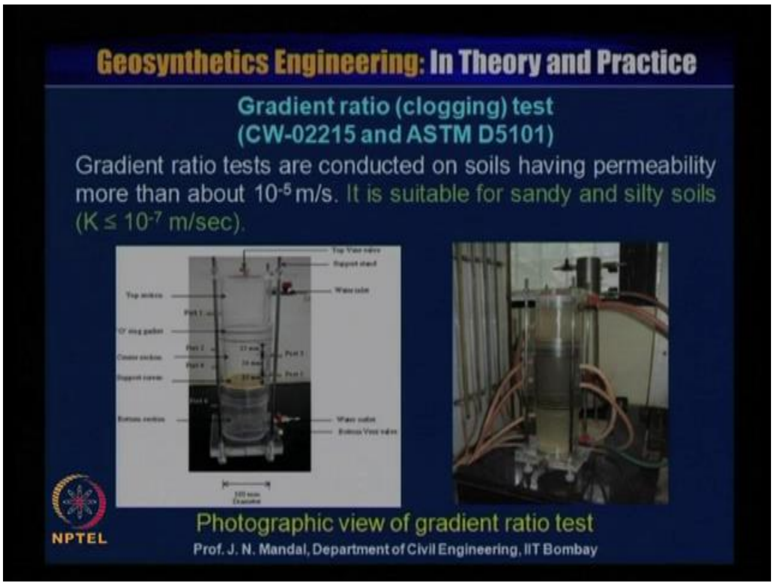

Now, gradient ratio or clogging test is U S army corps of engineers gradient ratio that is C W 02215 and A S T M D 5101, gradient ratio test are conducted on soil having permeability more than about 10 to the power minus 5 meter per second. It is suitable for sandy and silty soil for coefficient of permeability less than equal to 10 to the power minus 7 meter per second.

This is the photographic view of the gradient ratio test and here is the equipment in which you can measure the gradient ratio test, I am just showing in detail about this portion and how you can measure the head. Though most of the time we go for the determination of flow of water through the sample, but in this case of gradient ratio we are measuring the hydraulic head at the various location in the soil geotextile column. And head difference are then converted to the hydraulic gradient and that we calculate the what should be the gradient ratio.

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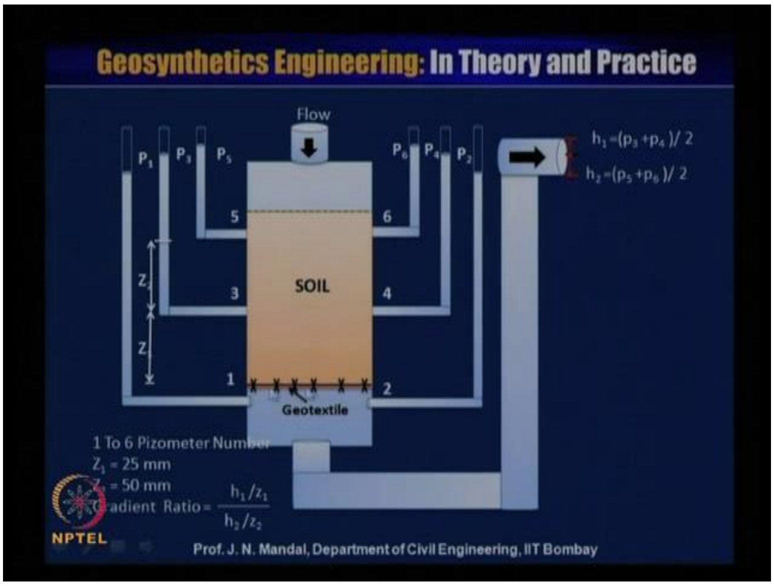

So, here you can see this is the geotextile material, this is the soil and this is the soil geotextile column and these are the piezometric number, this is 1, then this is 2, this is 3 this is 4, this is 5 and this is 6 at this point 1 2 3 4 5 and 6 and this distance is z 1 and the z 2. So, this z 1 and z 2 is fixed 25 millimeter and z 2 also 50 millimeter, so from this piezometer reading when the water will pass through the soil and to the geotextile, then you can measure that what will be the piezometer.

So, you know that what is that P 3 and also that p of four then you can calculate that h 1 is equal to P 3 plus P 4 divided by 2, similarly h 2 is equal to P 5 plus P 6 divided by 2. So, this is P 5 and this is P 6. So, you know that what will be the value of h 1 and h 2 and as I said that z 1 is 25 millimeter and z 2 is 50 millimeter and that is fixed, so from this you can calculate what will be the gradient ratio, so gradient ratio is equal to h 1 by z 1 divided by h 2 by z 2.

So, it is not measuring the flow rate the instead of measuring the flow rate you are measuring the hydraulic head at the various location in the soil geotextile column, and then you are measuring the head difference and from this head difference you are calculating the gradient ratio.

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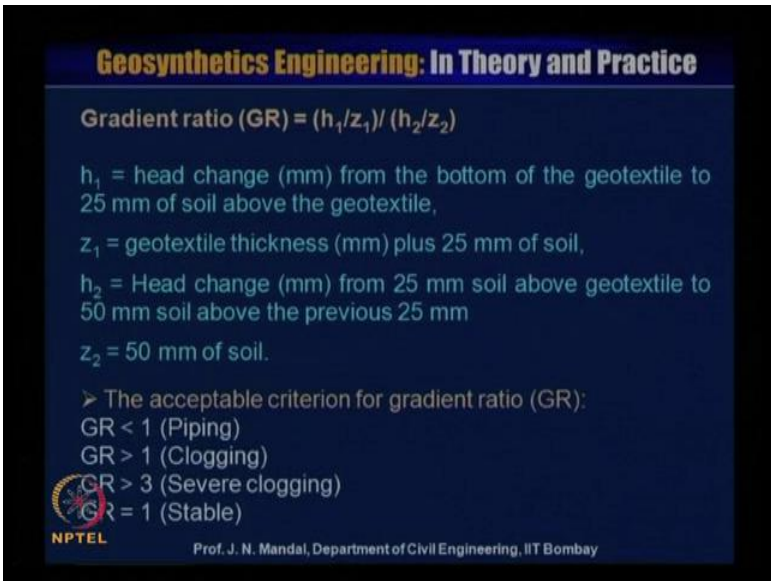

Now, this gradient ratio is designated as g r is equal to h 1 divided by z 1 divided by h 2 by z 2 and h 1 is the head change in millimeter from the bottom of the geotextile to 25 millimeter of the soil above the geotextile and z 1 is equal to geotextile thickness. That is millimeter plus 25 millimeter of soil and h 2 is the head change in millimeter from 25 millimeter soil above the geotextile to 50 millimeter soil above the previous 25 millimeter and z 2 is equal to 50 millimeter of the soil.

So, in general this acceptable criteria of the gradient ratio, now you know that what is head lost you can calculate that h 1 and h 2 and you know the z 1 and z 2, and then you can calculate the what is gradient ratio. Now, if the gradient ratio is less than 1, then it is piping if the gradient ratio greater than 1, it is a clogging if the gradient ratio greater than 3, then severe clogging. And if the gradient ratio is equal to 1, then you can say it is a stable, but these gradient ratio value also lots of engineer suggested that if the gradient ratio value is greater than three then not acceptable that kind of the geotextile material.

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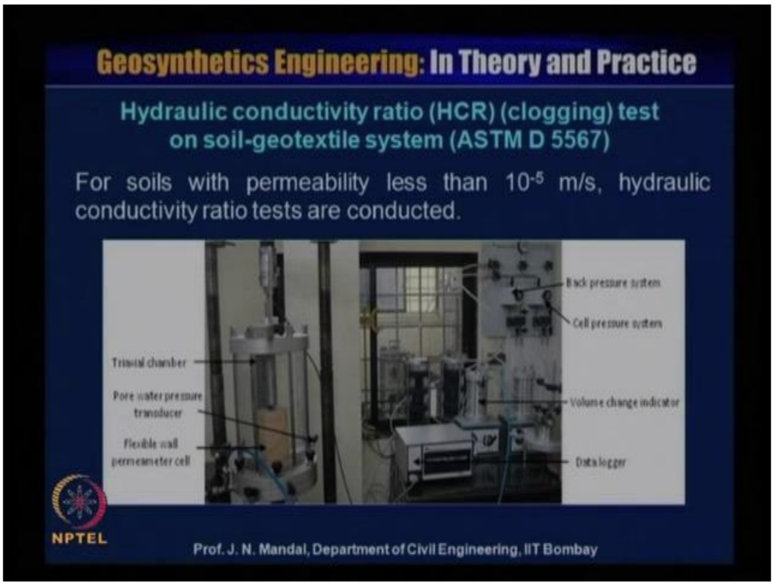

Next we will perform hydraulic conductivity ratio or H C R clogging test on soil geotextile system as far A S T M D 5567, so this is for long duration of test for soil with permeability less than 10 to the power minus 5 meter per second hydraulic conductivity ratio test are conducted. Here, is the equipment for the determination of the hydraulic conductivity and here is the back pressure system here is the cell pressure system here is the volume change indicator, and here is a data logger. So, it is nothing but a triaxial chamber, and you measure that what should be the pore water pressure transducer and flexible wall permeable cell here.

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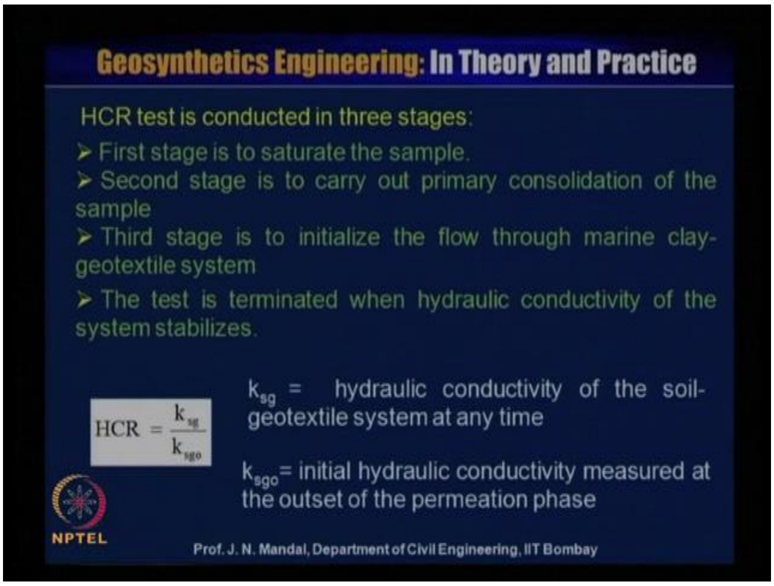

So, this H C R test is conducted in the three stages, first stage is to saturated the soil sample the second stage is to carry out the primary consolidation of the sample and third stage is to initialize the flow through marine clay geotextile system. The test is terminated when the hydraulic conductivity of the system stabilized, hydraulic conductivity ratio can be defined at k s g by k s g o k s g hydraulic conductivity of the soil geotextile system at any time and k s g o initial hydraulic conductivity measured at outside of the permeable phase.

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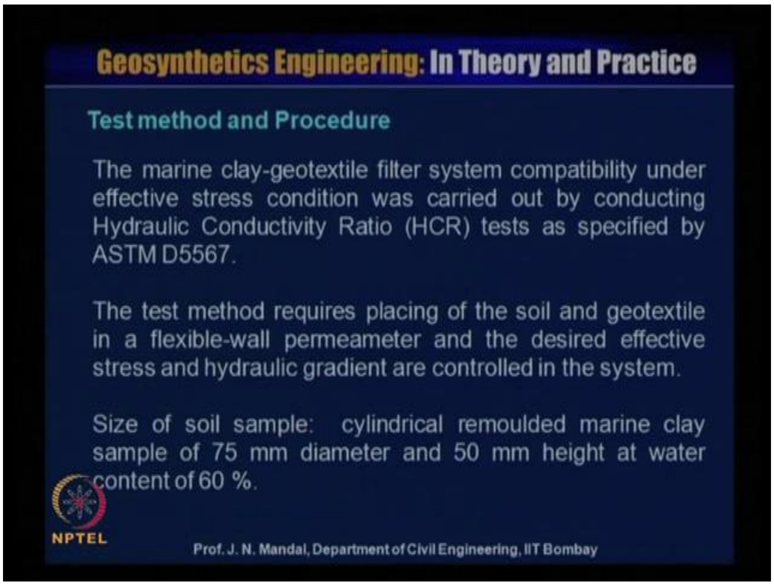

So, test method and the procedural like this, the marine clay geotextile filter system compatibility under effective stress condition was carried out by conducting hydraulic conductivity ratio test, as specified by A S T M D 5567. The test method require placing of the soil and the geotextile in a flexible wall, permeameter and the desired effective stress and the hydraulic gradients are controlled in the system. Size of the sample it will be cylindrical molded marine clay sample of 75 millimeter diameter and 50 millimeter height at water content of 60 percentage.

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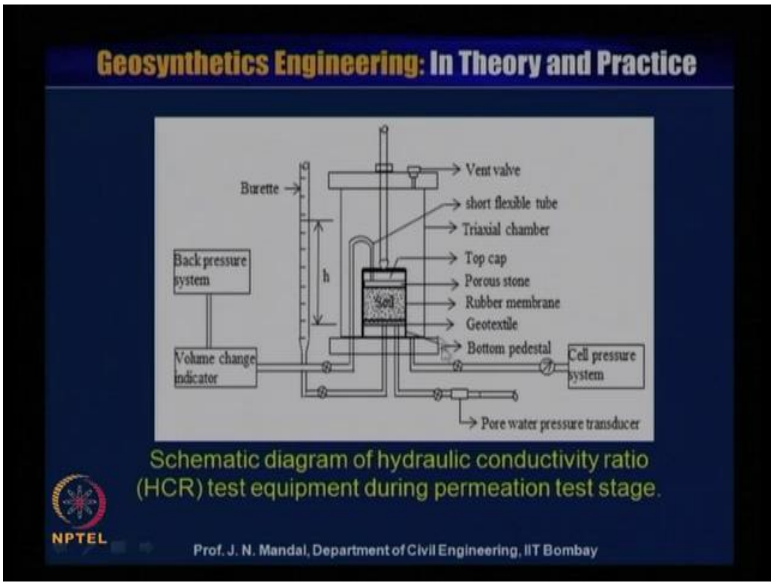

Now, here you can see that schematic diagram of hydraulic conductivity ratio test equipment during permeable test stage, here you can measure this is the soil sample this geotextile material is here this is the bottom pedestal. And this is the rubber membrane and porous stone is on the top, and then the top is the top cap, you can also from that back pressure system, so you can volume change indicator.

So, you can volume change also you can measure and this is the burette and this is the h this is the vent valve, this is the short flexible tube, and this is I say that this is a triaxial chamber, this is the top cap and this is the cell pressure system and the pore water pressure transducer, so with this equipment you can measure.

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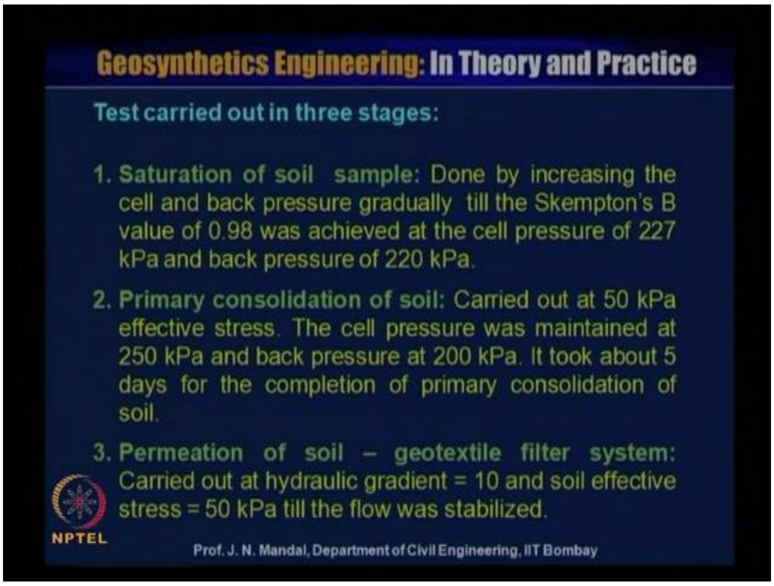

So, test carried out in the three stages as I said that saturation of the soil sample done by increasing the cell and the back pressure gradually, till the Skempton B value of 0.98 was achieved at the cell pressure of 227 kilopascal, and back pressure of 220 kilopascal. Then secondly primary consolidation of the soil carried out at 50 kilopascal effective stress the cell pressure was maintained at 250 kilopascal and back pressure at 200 kilopascal. It took about 5 days for the completion of the primary consolidation of soil, and thirdly permeation of the soil geotextile filter system and carried out at a hydraulic gradient is equal to 10 and soil effective stress is equal to 50 kilopascal till the flow was stabilized.

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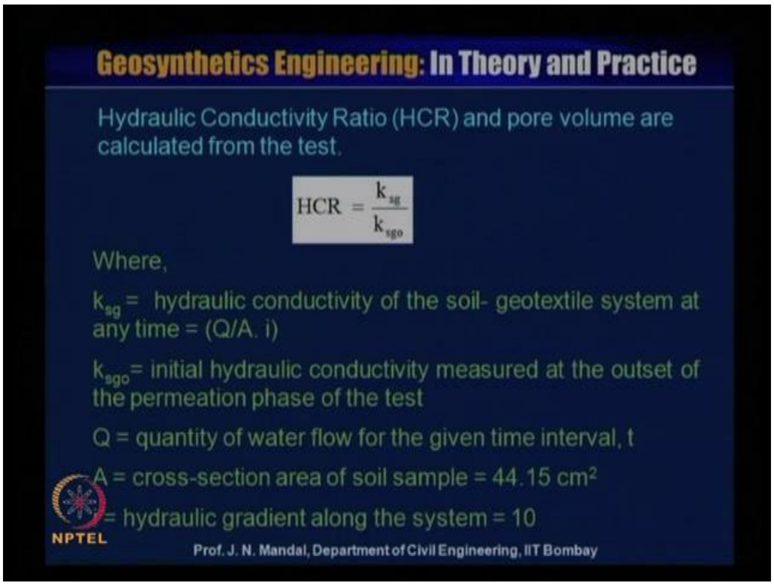

So, then hydraulic conductivity ratio and pore volume are calculated from the test, so we know H C R is equal to k s g by k s g o. So, where k s g is equal to hydraulic conductivity of the soil geotextile system at any time and that is Q by A into i where Q is equal to quantity of water flow, for the given time interval t. A is cross sectional area of soil sample that is 44.15 centimeter square and i is equal to hydraulic gradient along the system that is 10. So, we know everything, so we can calculate what is k s g or what is hydraulic conductivity of the soil geotextile system at any time.

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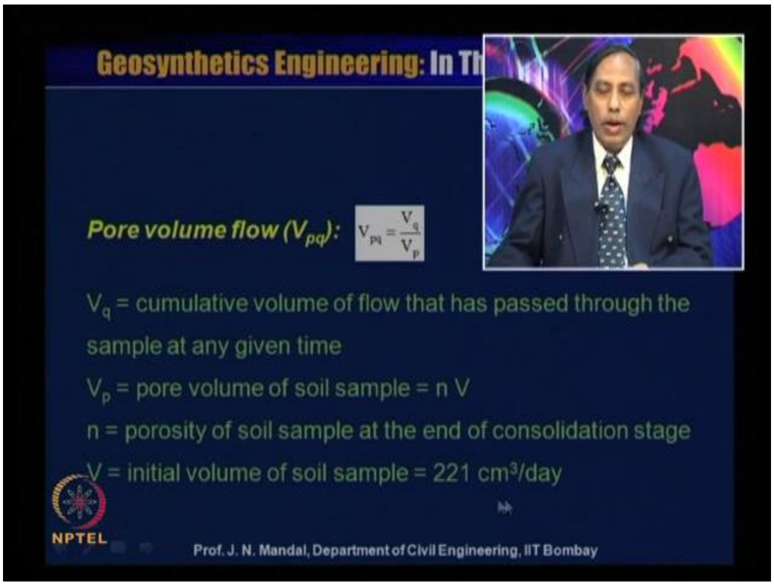

Now, pore volume flow or V p q, V p q is defined as the ratio of V q by V p, V q cumulative volume of flow that has passed through the sample at any given time and V p is the pore volume of soil sample is equal to n into V. So, n is equal to the porosity of the soil sample at the end of consolidation test and V is initial volume of the soil sample that is 221 centimeter cube per day.

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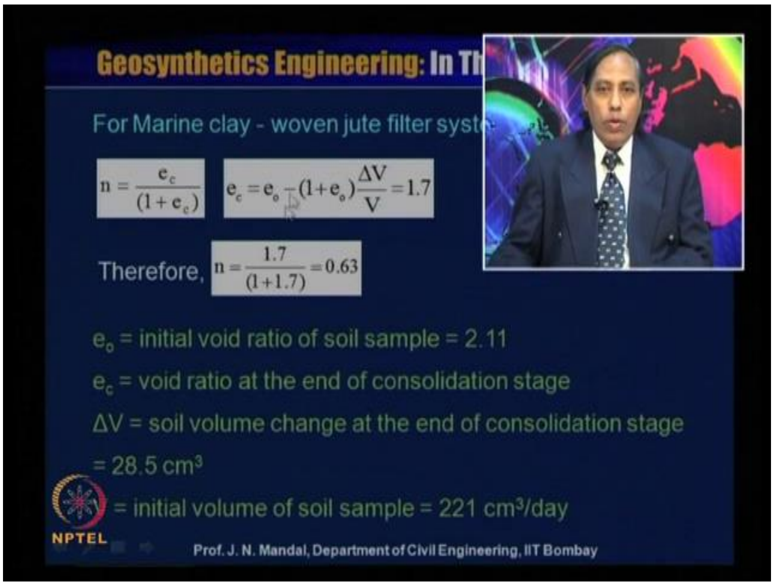

So, for the marine clay and woven jute geotextile filter have been used, so you can calculate n is equal to e c divided by 1 plus e c e c is equal to e 0 minus 1 plus e 0 delta V by V is equal to 1.7. So, therefore, n is equal to 1.7 divided by 1 plus 1.7 is equal to 0.63, where e 0 is equal to initial void ratio of the soil sample, that is 2.11 and e c is the void ratio at the end of consolidation stage. And delta of V is the soil volume change at the end of consolidation stage that is 28.5 centimeter cube and V is the initial volume of the soil sample that is 221 centimeter cube per day. So, from this you can calculate what is the n?

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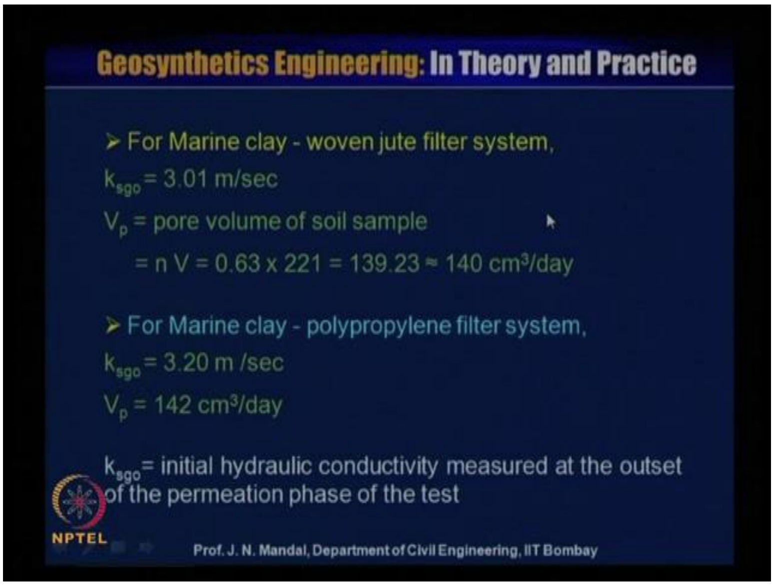

Let us say for the marine clay and woven jute geotextile filter system, so you can calculate k s g o 3.1 meter per second V p pore volume of soil sample that is n into V, and n we have calculated earlier that is n is equal to 0.63. This n is equal to 0.63 and this V is 221, this is V initial volume of the soil sample 221 centimeter cube, so V p will be equal to 0.63 into 221; that means, 139.23 this is approximately one 40 centimeter cube per day.

Similarly, also you can calculate for marine clay and polypropylene filter system for k s g o is 3.20 meter per second and V p is 142 centimeter cube per day, here k s g o is initial hydraulic conductivity measured at the outset of the permeation phase of the test.

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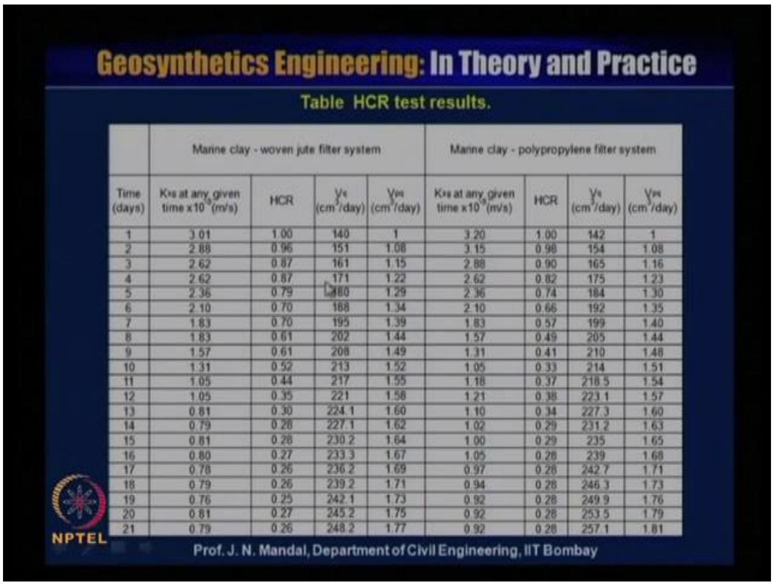

	Marine clay - woven jute filter system				Marine clay - polypropylene filter system			
Time (days)	K_{sg} at any given time x10^{-9} (m/s)	HCR	V_s (cm^3/day)	V_{pv} (cm^3/day)	K_{sg} at any given time x10^{-9} (m/s)	HCR	V_s (cm^3/day)	V_{pv} (cm^3/day)
1	3.01	1.00	140	1	3.20	1.00	142	1
2	2.88	0.96	151	1.08	3.15	0.98	154	1.08
3	2.62	0.87	161	1.15	2.88	0.90	165	1.16
4	2.62	0.87	171	1.22	2.62	0.82	175	1.23
5	2.36	0.79	180	1.29	2.36	0.74	184	1.30
6	2.10	0.70	188	1.34	2.10	0.66	192	1.35
7	1.83	0.70	195	1.39	1.83	0.57	199	1.40
8	1.83	0.61	202	1.44	1.57	0.49	205	1.44
9	1.57	0.61	208	1.49	1.31	0.41	210	1.48
10	1.31	0.52	213	1.52	1.05	0.33	214	1.51
11	1.05	0.44	217	1.55	1.18	0.37	218.5	1.54
12	1.05	0.35	221	1.58	1.21	0.38	223.1	1.57
13	0.81	0.30	224.1	1.60	1.10	0.34	227.3	1.60
14	0.79	0.28	227.1	1.62	1.02	0.29	231.2	1.63
15	0.81	0.28	230.2	1.64	1.00	0.29	235	1.65
16	0.80	0.27	233.3	1.67	1.05	0.28	239	1.68
17	0.78	0.26	236.2	1.69	0.97	0.28	242.7	1.71
18	0.79	0.26	239.2	1.71	0.94	0.28	246.3	1.73
19	0.76	0.25	242.1	1.73	0.92	0.28	249.9	1.76
20	0.81	0.27	245.2	1.75	0.92	0.28	253.5	1.79
21	0.79	0.26	248.2	1.77	0.92	0.28	257.1	1.81

So, from this test we have tabulated in this figure, there are two type of the geotextile material have been used that is marine clay with the woven jute geotextile and marine clay with polypropylene filter system. This is the time days 1 to 21 days and this is k s g at any given time 10 to the power minus 9 is 3.01, this is hydraulic conductivity ratio H C R.

So, H C R in the beginning this is that you know the ratio, so that is 3.01 by 3.01 that is 1, and next 1 will be 2.86 divided by 3.01 this is 0.96, then next again 2.62 divided by 3.01 will give that 0.87, like that you can calculate that what will be the H C R value and V s value is centimeter cube per day is calculated 140 like that 158 depend upon days.

Then V p q centimeter cube per day this is 140 by 141 and then next is 151 by 141.08, then 161 by 140 this is 1.15, 171 by 141.22 like that you can calculate that what is V p q for the different value of V q, and similarly we can calculate for the marine clay polypropylene geotextile filter system also.

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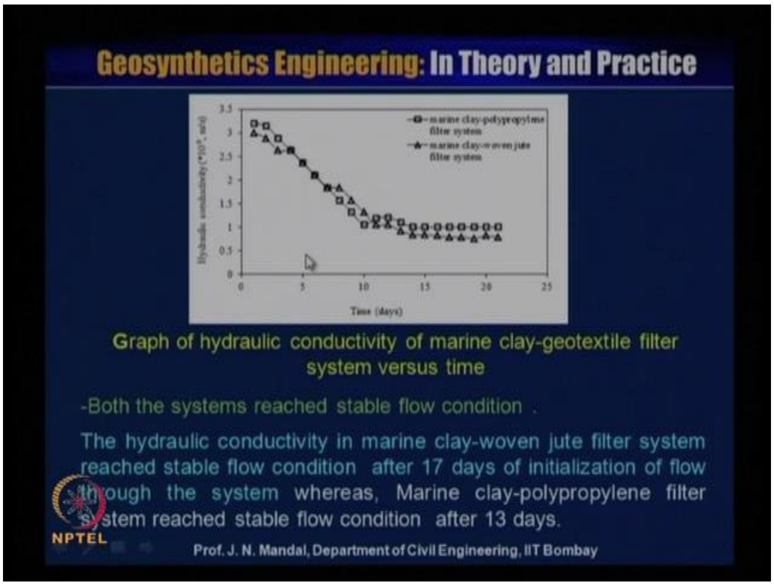

Now, from this chart we will show some variation, what is happening, so this figure shows that graph of hydraulic conductivity of marine clay and geotextile filter system versus time.

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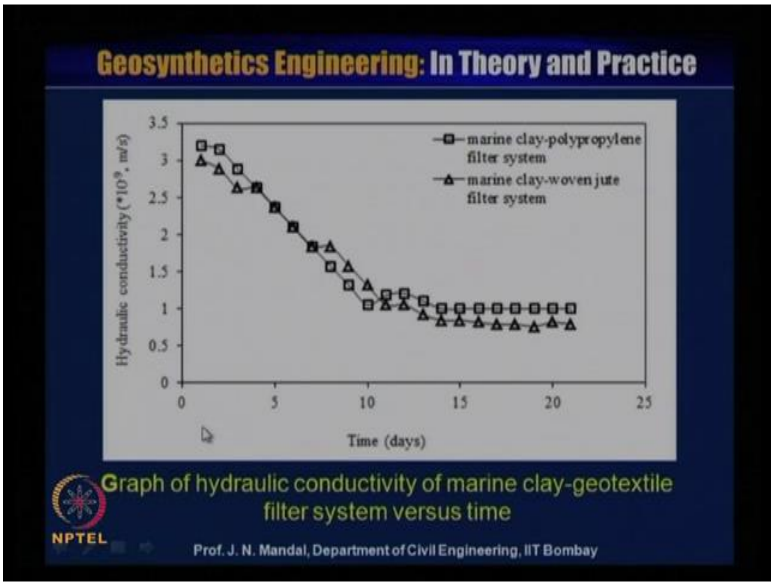

I am showing in a larger scale here, this is the graph of hydraulic conductivity here this is 100 can tend to the minus 9 meter per second and this is time days, so this is for the marine clay geotextile filter system value. There are two marine clay polypropylene filter system marine clay woven jute filter system, you can see that what will be the nature of the curve; that means, how what is happening the hydraulic conductivity with respect to the time.

So, both the system reached stable flow condition the hydraulic conductivity in marine clay woven jute filter system reach a stable flow condition, after 17 days of the initialization of the flow through the system you can see that in the case of woven geotextile material. This is almost after 17 days then it is in equilibrium stage, here then after that it is almost constant, but in case of the marine clay polypropylene system these filter system reached stable flow condition, after 13 days you can see here that it is after 13 days in it is in stable condition.

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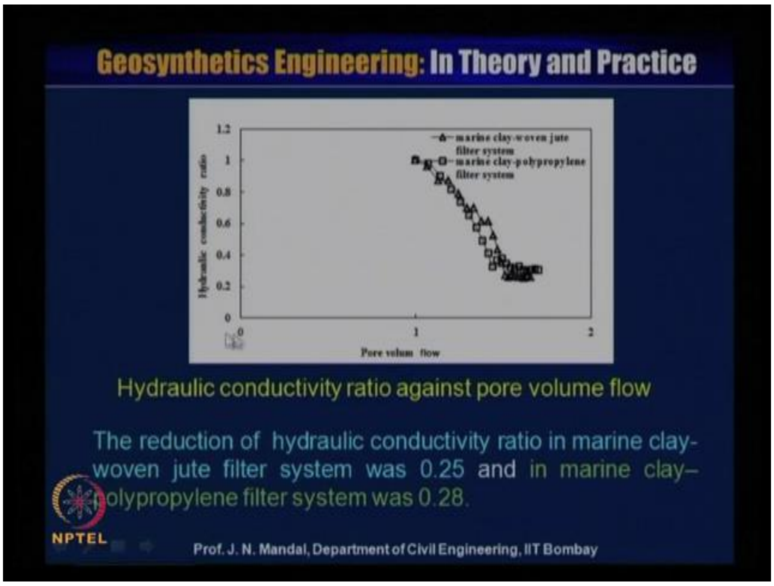

So, it depend upon that what will be the type of the material you are using, what type of the soil and after how many days it is stabilized, this figure show the relationship between the hydraulic conductivity ratio that is H C R and pore volume flow that is V p q from 0 to 2 and the hydraulic conductivity ratio from 0 to 1.2. This is hydraulic conductivity ratio against pore volume flow, so hydraulic conductivity ratio pore volume flow for both cases this is marine clay woven jute filter system marine clay polypropylene filter system.

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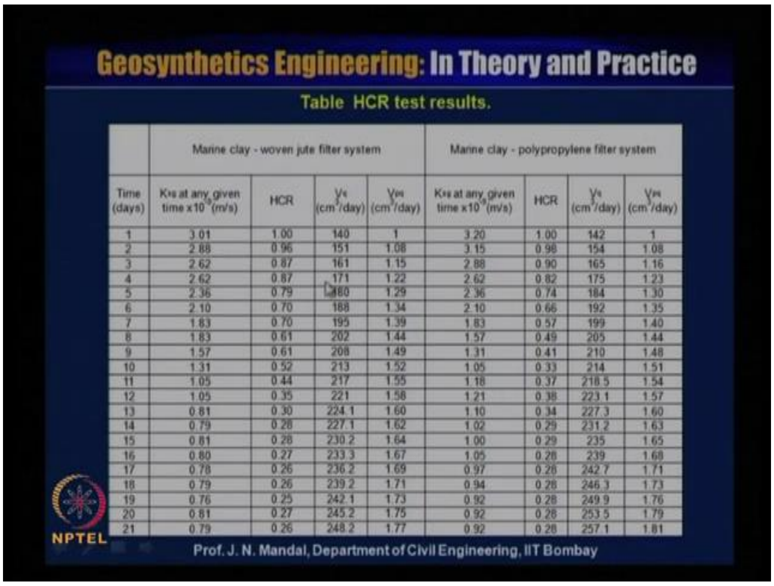
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Table HCR test results.

Time (days)	Marine clay - woven jute filter system				Marine clay - polypropylene filter system			
	K_{rs} at any given time x10^{-9} (m/s)	HCR	V_s (cm^3/day)	V_{pq} (cm^3/day)	K_{rs} at any given time x10^{-9} (m/s)	HCR	V_s (cm^3/day)	V_{pq} (cm^3/day)
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5	2.36	0.79	180	1.29	2.36	0.74	184	1.30
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10	1.31	0.52	213	1.52	1.05	0.33	214	1.51
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15	0.81	0.28	230.2	1.64	1.00	0.29	235	1.65
16	0.80	0.27	233.3	1.67	1.05	0.28	239	1.68
17	0.78	0.26	236.2	1.69	0.97	0.28	242.7	1.71
18	0.79	0.26	239.2	1.71	0.94	0.28	246.3	1.73
19	0.76	0.25	242.1	1.73	0.92	0.28	249.9	1.76
20	0.81	0.27	245.2	1.75	0.92	0.28	253.5	1.79
21	0.79	0.26	248.2	1.77	0.92	0.28	257.1	1.81

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So, you can determine what will be the pore volume flow, so pore volume flow is this V p q, this is pore volume flow, you can see 1 to 1.7 and in this polypropylene filter system it is 1 to 1.81 and this is the H C R value 0.26 give you 1 and here H C R value 0.26 to 1.

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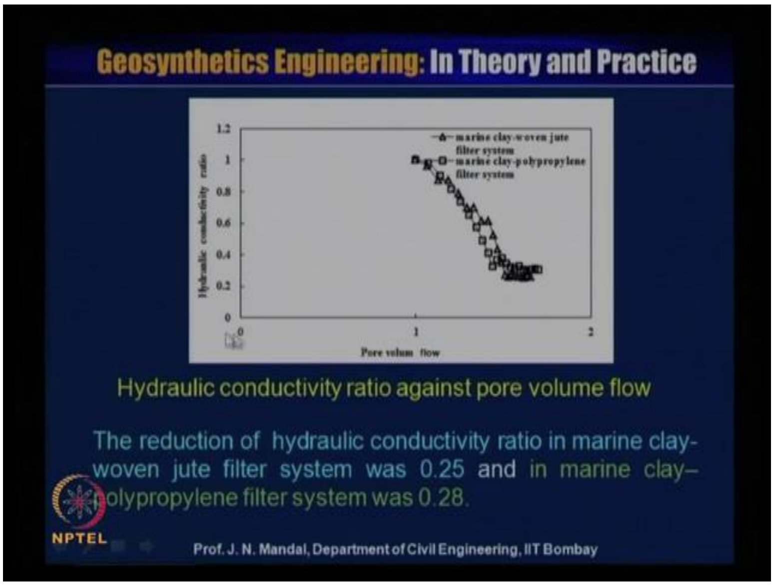

So, from this data you can you can draw this diagram pore value volume because for the different hydraulic conductivity ratio, what will be the pore volume flow. So, the reduction of the hydraulic conductivity ratio in the marine clay woven jute geotextile system was 0.25, and in marine clay polypropylene filter system is 0.28.

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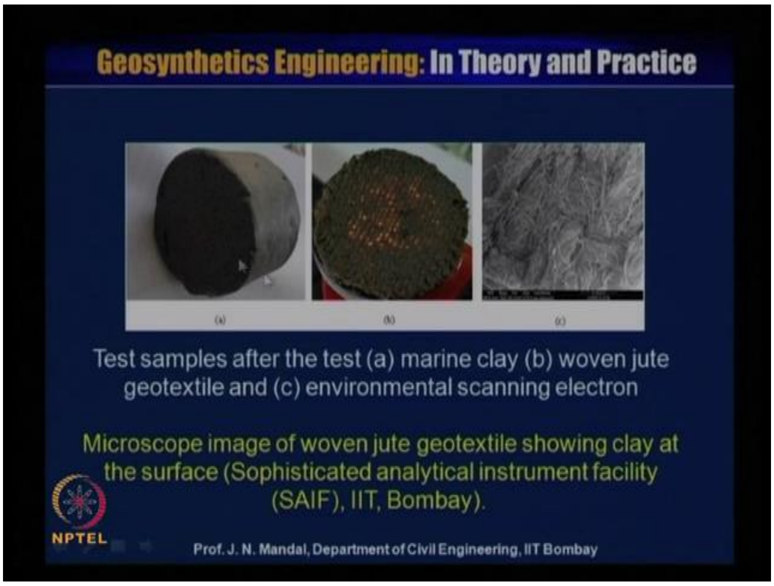

So, this is the some microscopic image of the woven jute geotextile showing clay at the interface, this is has done in sophisticated analytical instrumental facility SAIF in IIT, Bombay. And test sample after the test a is the marine clay and B is the woven jute geotextile material, and see you can see how environmental scanning electrons, so what is happening just to see their structure and their behavior.

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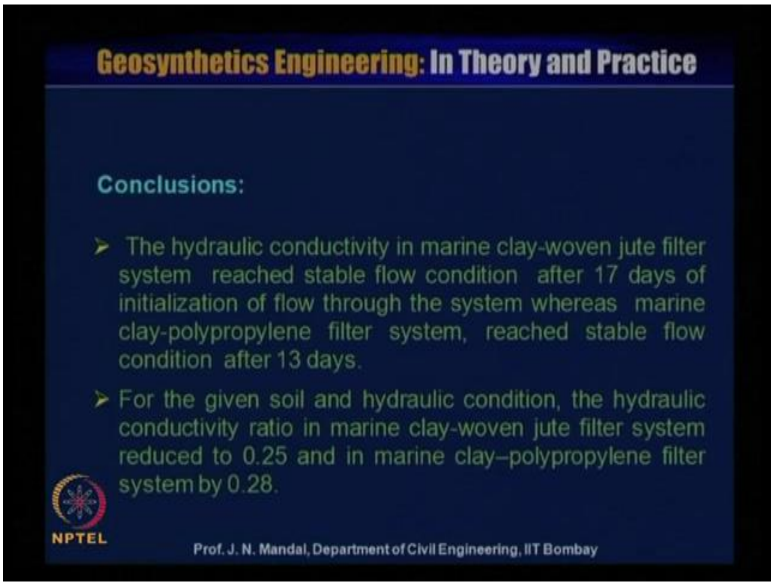

So, we I am drawing some conclusion that hydraulic conductivity in marine clay woven jute filter system reached stable flow condition after 17 days of initialization of flow through the system whereas, marine clay polypropylene filter system reached stable flow condition after 13 days.

For the given soil and hydraulic condition, the hydraulic conductivity ratio in marine clay woven jute filter system reduced to 0.25 and in marine clay polypropylene filter system by 0.28.

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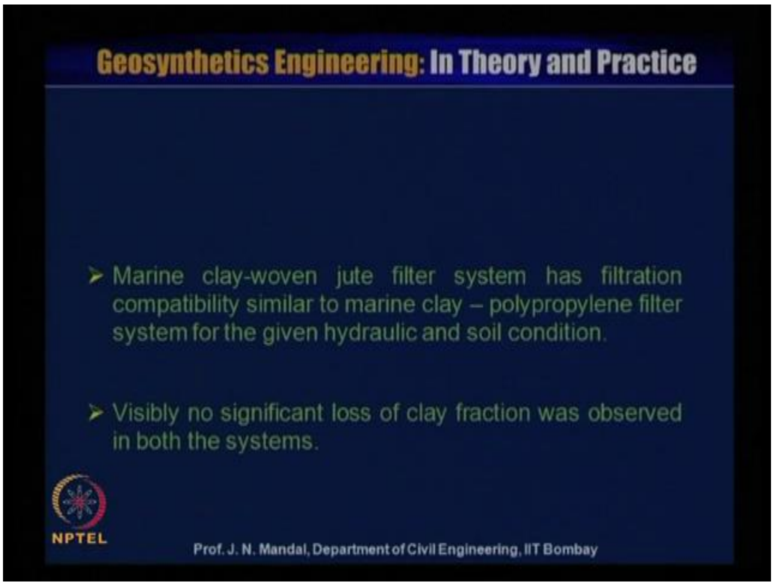

Marine clay woven jute filter system has filtration compatibility similar to marine clay polypropylene filter system for the given hydraulics, and soil condition visibly no significant loss of clay fraction was observed in both the system.

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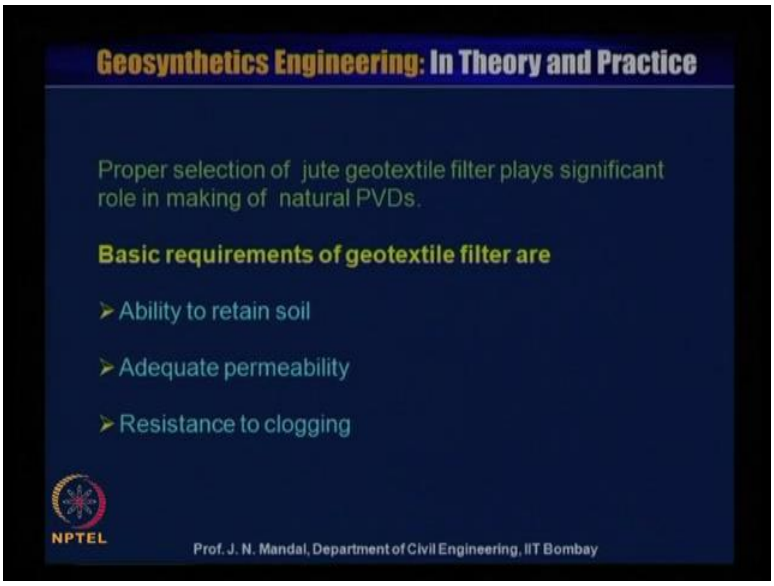

So, we are tried with both the system with the natural material and also the polymer material, and we observed the nature of the curve is the similar and the stabilization also is vary depending upon the time, also it depend upon what should be the pore of the geotextile material. So, we have shown some variation of the hydraulic conductivity ratio and pore volume ratio, we have also shown that what will be the value of hydraulic conductivity ratio.

So, in the I just mentioned here that lieu ti chi and the William they have reported that if the hydraulic conductivity ratio value, you can say it is high, then it is a soil loss and is the hydraulic conductivity ratio or H C R is low; that means, it is a excessive clogging. And if the intermediate value for example, that H C R value is lies between 0.4 to 0.8, then you can say it is the equilibrium.

So, for the assess of excessive geotextile clogging and soil retention criteria, so this manages the very important test whether it is a gradient ratio test and these long term hydraulic conductivity ratio or clogging test, because most of the cases when there will be the drainage and the filtration problem. And there is a possibility for the clogging or the choking, so how you can select the proper kind of the geotextile material whether it is a woven geotextile material whether it is a nonwoven geotextile material.

So, one must perform the gradient ratio test and as well as the H C R test and then you can judge whether that material is suitable for that particular soil or not. If it satisfied this gradient ratio value as well as the hydraulic conductivity ratio value, then we can recommended for this material, so this is very, very important because most of the structure that fell, because for the clogging and because this is the choked. So, one has to be take care for the proper kind of the material, and they should select the proper kind of the geosynthetics material for the specific project.

Proper selection of jute geotextile filter play significant role making of the natural prefabricated vertical drain though, one hand you know that that what is the natural geotextile material and this natural geotextile material also can be made from the jute and the coir. So, this also very useful for the ground improvement for we exclusively use the natural P V D material and for this also you require the filter criteria. So, you require that 3 most important criteria, one to ability to retain the soil and then you require what is adequate permeability, and lastly you required resistance to clogging, so this three criteria should satisfy.

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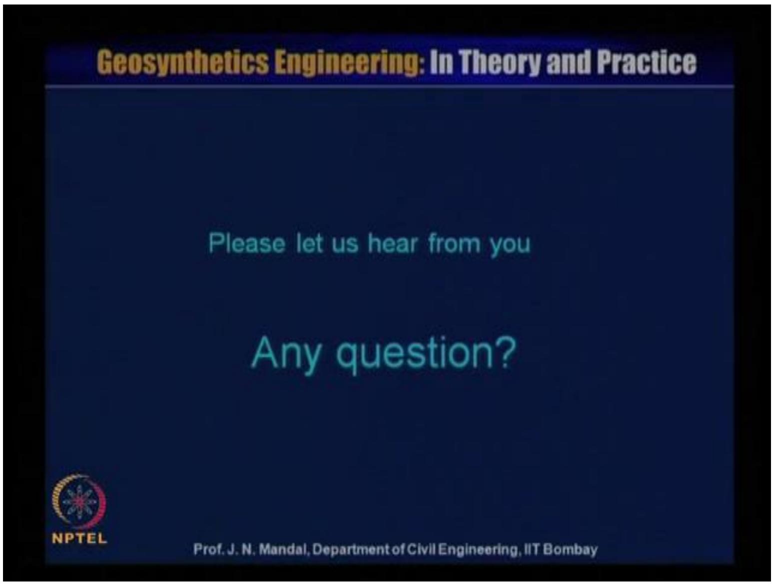

So, with this I ended up this lecture please let us hear from you, any question.

Thanks for listening.