Testing of Functional & Technical Textiles
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Lecture - 19
Testing of Geotextiles (contd...)

Hello everyone, so we will continue with the Mechanical test of Geotextile. So, we will discuss now the trapezoidal tear strength test method.

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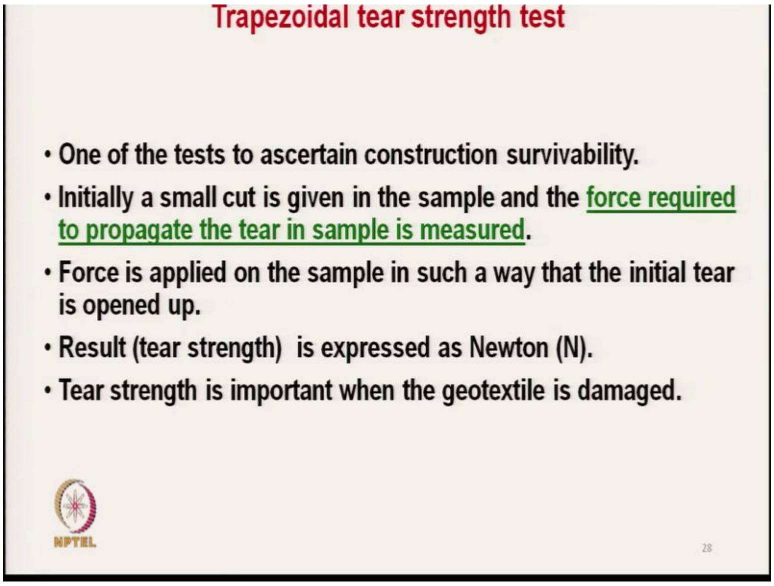

It is one of the test to ascertain construction survivability test. So, how the total structure will survive once the geotextile are got damaged, this we can assess by getting the data from tear strength test. So, here initially a small cut is given in the sample like to simulate that the geotextile is damaged by some sharp object or some stone. So, how is it going to survive so initially a small cut is given in the sample and the force required to propagate the tear in the sample and that is measured. So, the force is measured the force is applied in the sample in such a way that the initial tear is opened up.

So, direction of force is such that whatever initial tear was incorporated that will be opened up and that is why we have to form a shape like Trapezium. This trapezium will help in applying the force and the tear will start propagating, the tear strength result is expressed in terms of Newton and which is important when the geotextile is damaged. So, in normal condition the tear strength is not that important, but in case of damaged geotextile and if we have to use this geotextile we cannot replace the geotextiles, so for that how will it survive so, that will be assessed by Trapezoidal tear strength.

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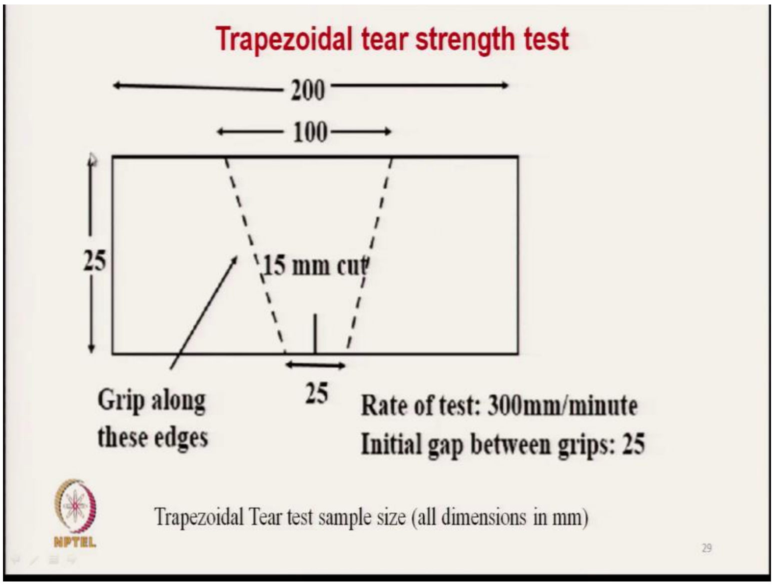

So, this is the specimen where length of the specimen is 200 millimetre by 25 millimetre and effective length is 25 millimetre and width is 200 millimetre, where at the midpoint a cut of 15 millimetre is imparted and this trapezium shape helps in propagation of the cut and the grip point is shown by the dotted line. Now I will show here this is the specimen, this is a specimen where I have incorporated one cut at the centre. Now Grip will be at this point and as this is the it is like in a tensile tester we will put this and then if we test the this tear will get propagated. So, due to this shape the trapezium shape this tear initial cut will start propagating and the rate of test is 300 millimetre per minute.

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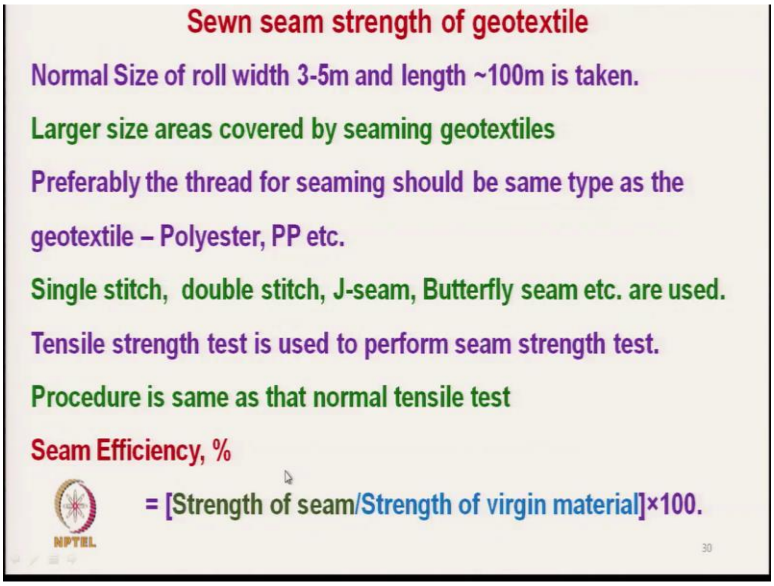

After that another important test is that seam strength of geotextile, normal size of roll is typically the width is 3 to 5 metre and length is 100 metre. But if we actually use in geotextile construction purpose where we like in road construction, the width is much more than this and length obviously is not enough we have to stitch and this seam strength is important, so larger size areas covered by the seaming of geotextiles.

So, we have to stitch the geotextiles and the thread while using the stitching the thread should be same as the base material for geotextile, like if it is polyester geotextile then we have to use polyester thread if it is Polypropylene then it should be Polypropylene thread. The stitches are of different types depending on the application, like single stitch, double stitch, J-seam, butterfly seam as per the specification we have to use and after forming the stitch after imparting the stitch we have to test the seam strength by testing the tensile strength at the stitched portion and then we have to compare with the strength of virgin material and the tensile strength is normal tensile strength. So, seam efficiency

The seam strength efficiency can be expressed as,

$SE = (T_{seam} / T_g) \times 100$ %

Where,

T_{seam} = wide width seam strength, and

T_g = wide width geosynthetic strength without seam

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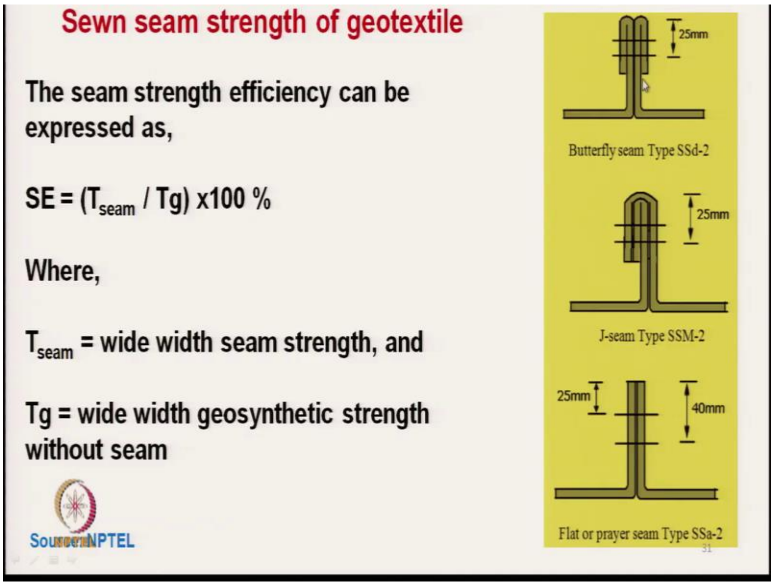

Now, these are the different types of seam this is butterfly seam, J-seam and flat or prayer seam type. So, these are the different types of seams and the seam efficiency is the strength at the seam portion and strength of the geotextile without seam portion normal tensile strength.

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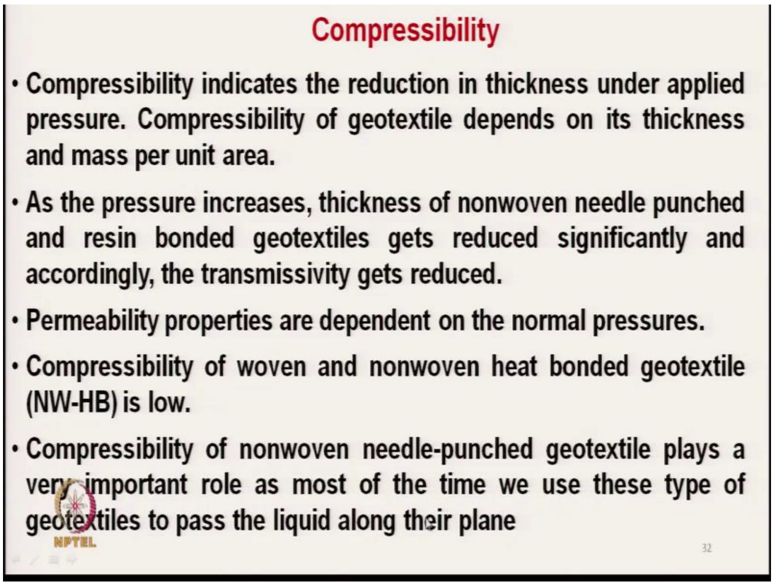

After that now we will discuss the Compressibility testing, compressibility indicates the reduction in thickness under applied pressure. So, it is a very important for geotextile as per as the water transmission is concerned, transmissivity or permeability is concerned.

If the geotextile is highly compressible once we apply load the pores of the geotextile will get compressed, so its transmission characteristics will be affected.

The compressibility of geotextile depends on the thickness and mass per unit area, as the pressure increases the thickness of nonwoven needle punched and resin bonded geotextile get reduced significantly and as I have already mentioned the transmissivity of this geotextiles gets affected. Permeability properties are dependent on the normal pressure, compressibility of woven and nonwoven heat bonded geotextiles are lower than that of needle punched geotextile.

Compressibility of nonwoven needle punched geotextile plays a very important role as most of the time we use this type of geotextiles to pass the liquid along their plane that is drainage characteristics, if the geotextile is highly compressible then the drainage characteristics will get affected.

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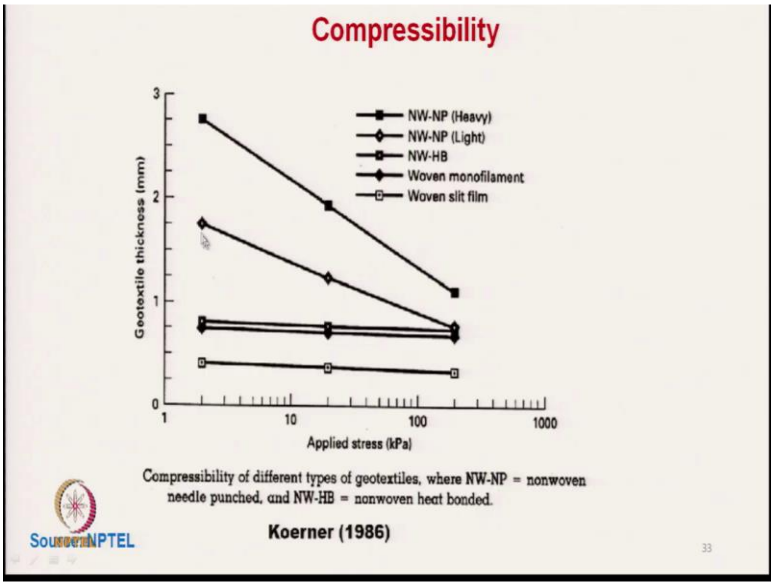

So, this is the typical graphs of applied pressure and geotextile thickness compression characteristics. So, this one top one is showing that nonwoven needle punched geotextiles which is heavier geotextile and nonwoven needle punched lighter geotextile. So, needle punched geotextile which we have seen here it is actually showing a very high compressibility.

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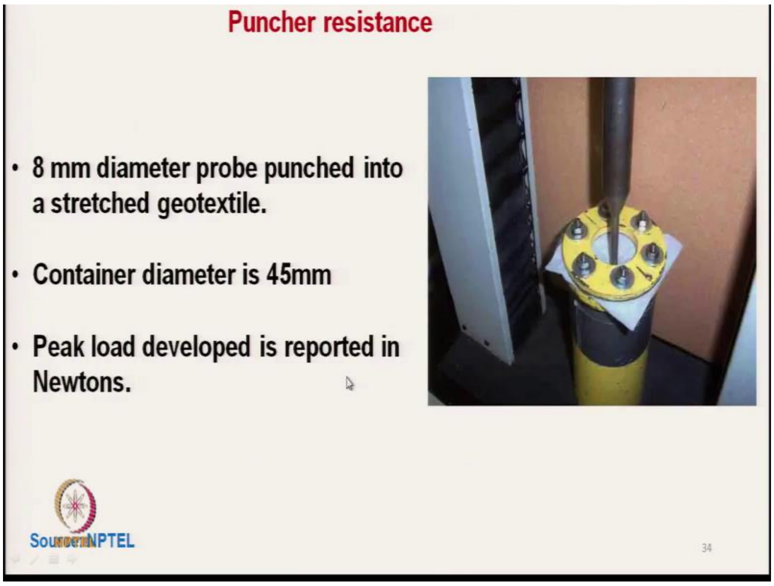

Next characteristics is that puncture resistance, this is extremely important because in application the geotextile material sometimes comes across the pointed stones or any other objects which will ultimately result punching of the geotextile and this initial damage will deteriorate the characteristics, it will gradually it may result larger holes and effectivity of the geotextile will be lost. So, here it is tested by 8 millimetre diameter probe this is 8 millimetre diameter probe, which is punched into a stretched geotextile material this is geotextile, stressed geotextile where this container diameter is 4.5 centimetre 45 millimetre diameter and here peak load is measured just before the puncturing is occurred.

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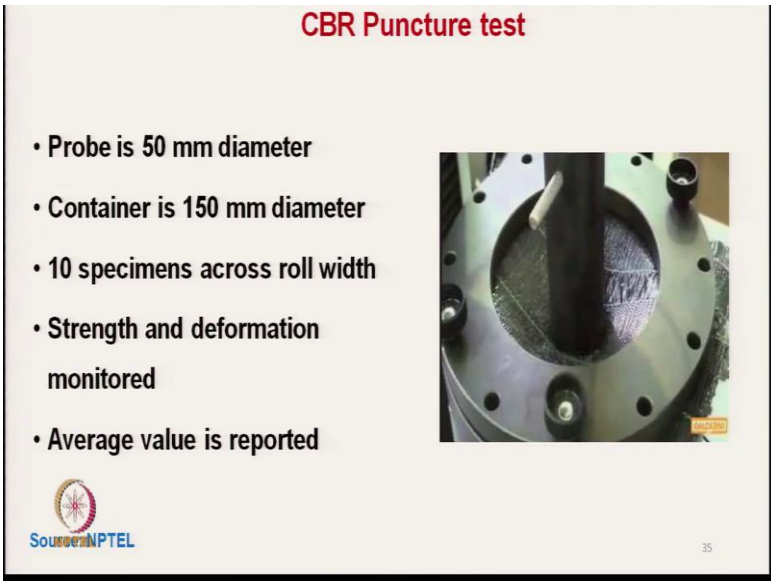

Another method of puncturing test is CBR puncture test, that is California Bearing Ratio Puncture test, this California Bearing Ratio test is basically it is used to test the compressibility of soil particle soil, but the same method we can use here; here the probe is of 50 millimetre diameter this is 50 millimetre diameter probe and the container is 150 millimetre diameter this container is 150 millimetre diameter.

Normally in this container we when we test the CBR test we feel this container with the soil, but here it is modified where we are holding the geotextile 10 specimen across the role width will be tested strength and deformation is monitored. So, both the strength and the deformation that is the penetration will be monitored and average value is reported. Now, let us see how this CBR test gives the idea about the elongation and the tensile strength of geotextiles.

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Tensile strength from CBR Test data

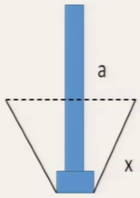
- Wide width tensile strength, $T_f = \frac{F_p}{2\pi r}$

T_f = force in kN/m
F_p = punching force, kN
r = radius of CBR plunger

Strain at failure, ε_f

$$\varepsilon_f = \frac{(x-a)}{a} * 100$$

x = diagonal distance at failure
a = horizontal distance between outer edge of plunger and inner edge of mould



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T_f = force in kN/m
F_p = punching force, kN
r = radius of CBR plunger

Strain at failure, ε_f

$$\varepsilon_f = \frac{(x - a)}{a} * 100$$

x = diagonal distance at failure
a = horizontal distance between outer edge of plunger and inner edge of mould

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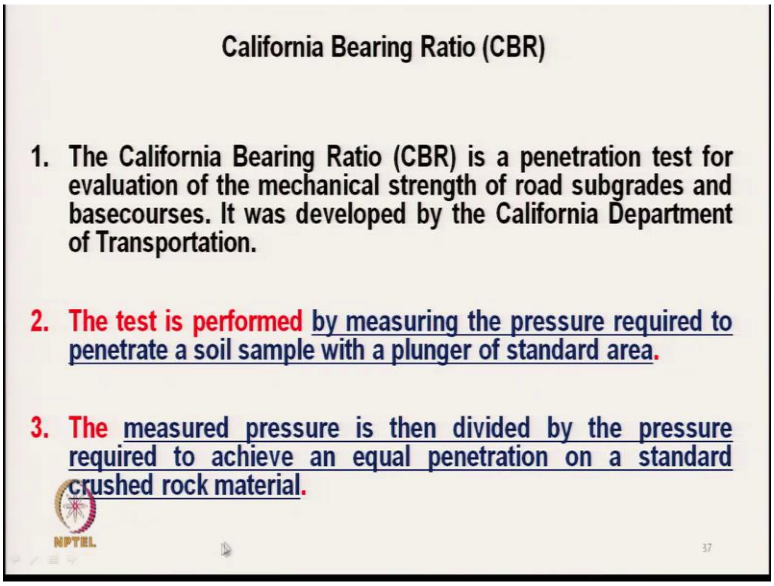

Now, let us see what is actual CBR test California bearing ratio test; in this test that CBR is a penetration test for evaluation of mechanical strength of road subgrade that is soil or any subgrade material and base course, so low road subgrade and base course we can measure the mechanical strength it was developed by California department of transportation that is why it is known as California bearing ratio test.

The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. So, the standard area plunger is there now pressure required to penetrate a specific distance. The measured pressure is divided by the pressure required to achieve an equal penetration on a standard crushed rock material that is a standard crushed rock material. So, we need to have a specified penetration and then we compare the pressure required for that penetration.

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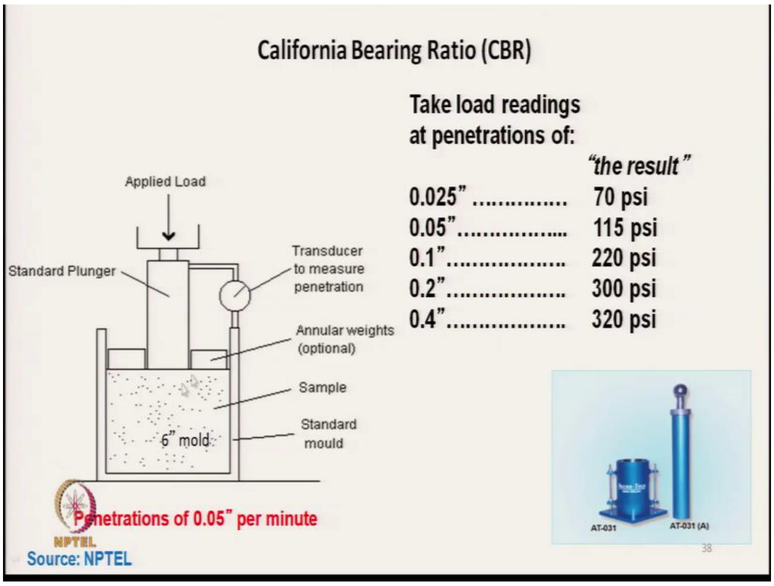

Now, here this is a soil sample and plunger is there, standard and applied pressure and here we can measure the penetration by transducer and we can have 2 types one is a cylindrical type plunger or we can alternatively we can have annular weight also, this annular weight we can use. This is sample standard mould the steps are the take load readings at penetration of all this values.

So, 0.025 inch 0.05 inch 0.1 inch 0.2 0.4 inch at all this penetration values we take the pressure requirement say 70 psi 115 psi 220 psi for 0.1 inch for 0.2 inch 300 psi 0.4 inch 320 psi. So, we record all this standard pressure value and for a particular penetration and this is the reading for a particular soil. Now we have to calculate the CBR value of this soil, to calculate the CBR value we need to know the force or pressure required for a particular penetration of standard sample. The standard specimen values are given these are the penetration versus load required or pressure required.

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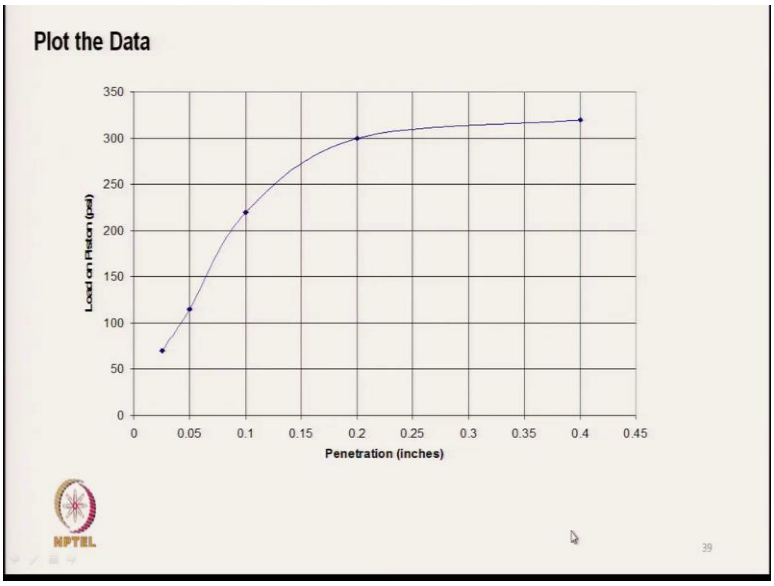

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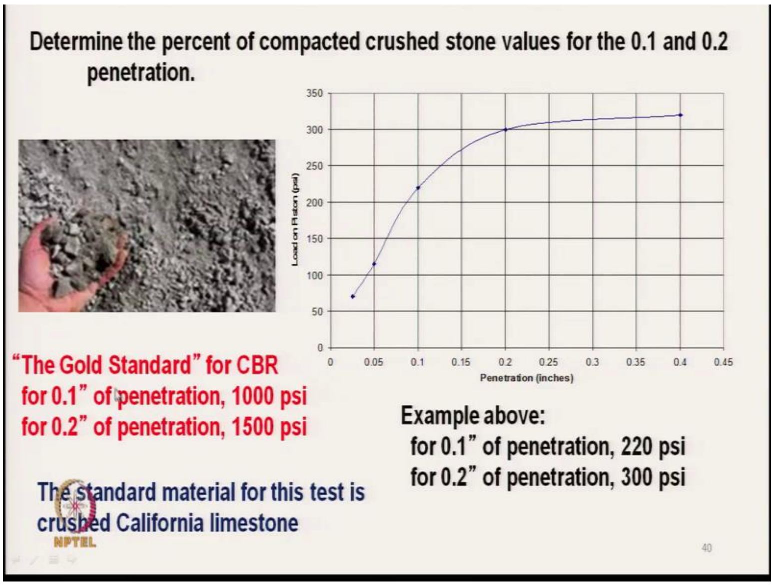

Now, the gold standard values of CBR, this are the standard value is for 0.1 inch of penetration the standard crushed California limestone has got 1000 psi value this is the standard value, for 0.2 inch penetration it is a 1500 psi and this we have to compare with the existing sample. For our present sample the value for 0.1 inch was 220 psi for 0.1 inch is 220 psi here for 0.2 inch it is a 300 psi. Now if we take the ratio that will be California bearing ratio, now here CBR value is the test example psi that whatever our specimen psi and standard psi that is a CBR value.

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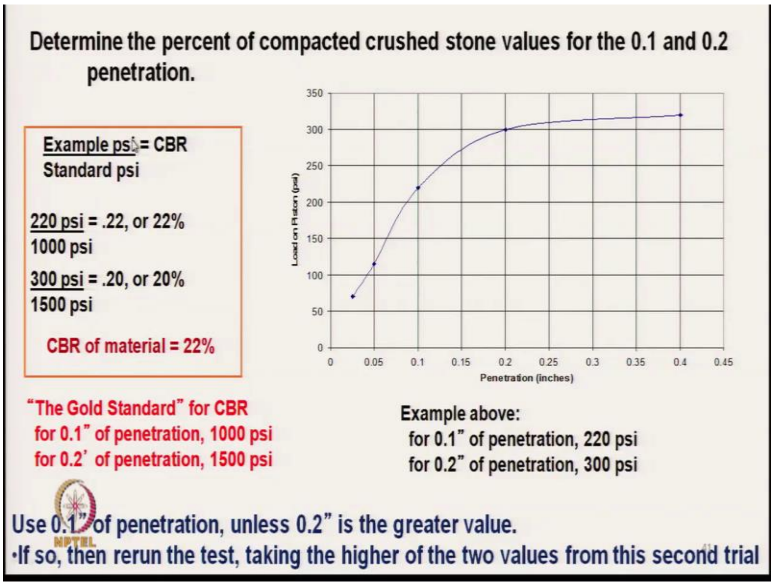

So, in our case for 0.1 inch penetration it was 220 if we divide it by 1000 which is standard, it is coming out coming out to be 0.22. So, it is 22 percent CBR value and 0.2 inch penetration it is 20 percent. Normally what we to do between 0.1 inch and 0.2 inch penetration the CBR value which is higher we used to take here. So, here for 0.1 inch it is 22 percent so effective CBR value for the soil is 22 percent.

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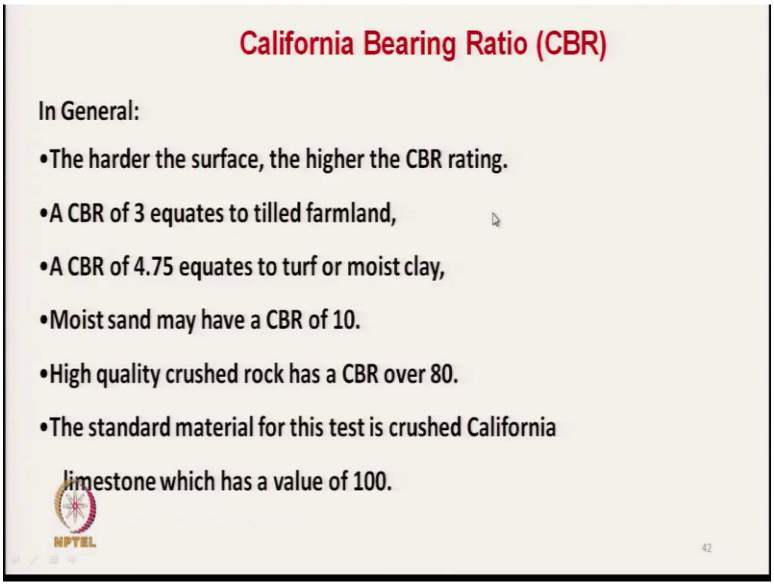

Now, the CBR is in general the harder the surface higher is the CBR value or CBR of 3 means it is a very low, it is a tilled farmland CBR 4.5, it is a moist clay moist send will have around 10 value CBR. High quality crushed rock it will have 80 and standard crushed California limestone will have 100, because it is a ratio with respect to that value. So, depending on this CBR value we have to select the geotextile.

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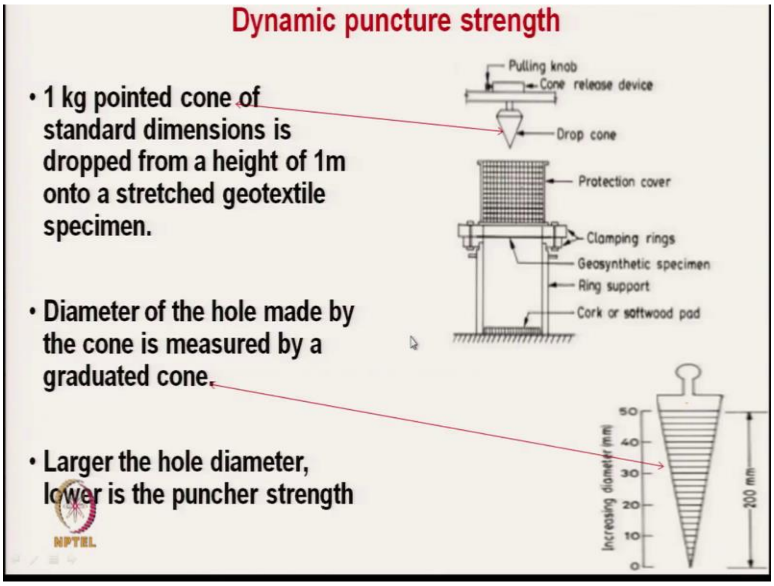

Next mechanical characteristics is that Dynamic puncture strength, we have discussed the punching strength for composite also. But for geotextiles the test method is little bit different, here 1 k g pointed cone of standard dimension is dropped from a height of 1 metre on to the stretched geotextile specimen. So, here it is a ring, the geotextile specimen is stretched and after dropping we calculate the diameter of hole made by the cone so this cone is graduated ok, here we can get the diameter value directly the larger the hole diameter lower is the puncture strength. So, this will give an idea about the effectivity of the geotextile during it is application.

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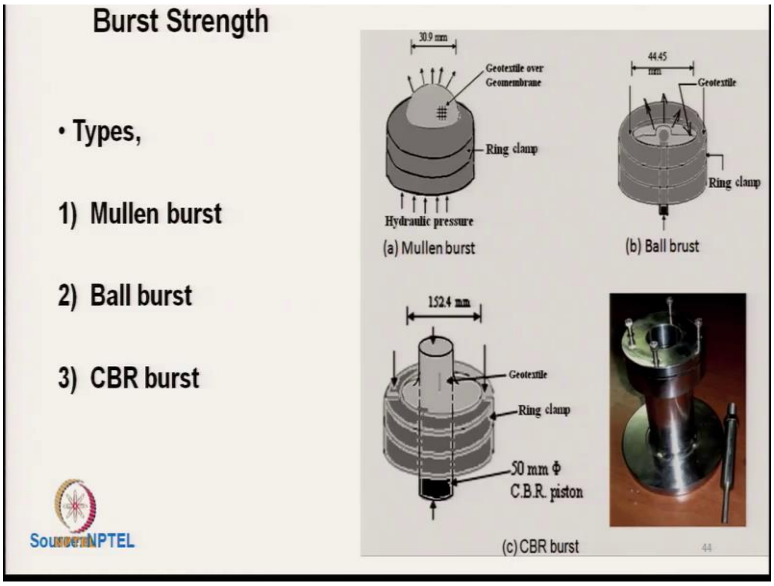

Next characteristics bursting strength, burst strength there are 3 different types of burst strength 1 is Mullen burst strength, where inflated rubber is used which is normally we use for textile material, Ball busting strength. We normally used for highly stretchable textile material and third method is again here we can use CBR burst strength.

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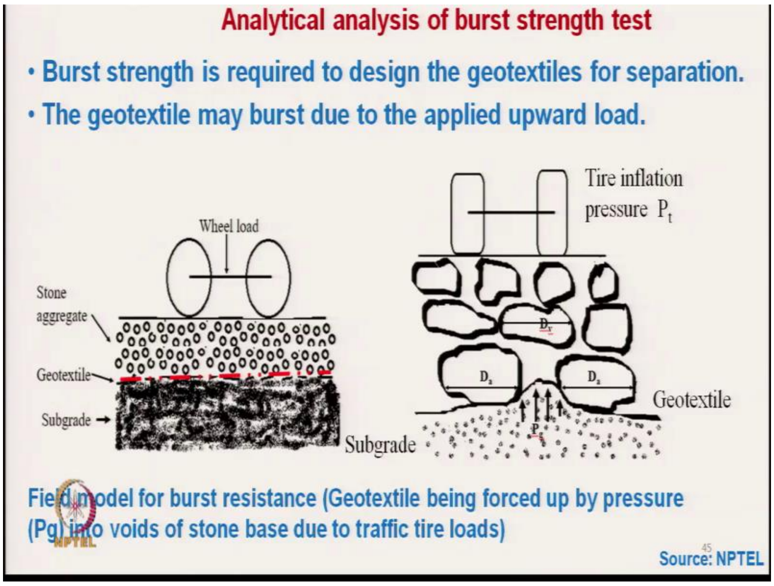

So, the analytical analysis of burst strength test is that the burst strength is required to design the geotextile for specific separation. So, here it is geotextile is used for separation purpose and when the soft soil is pumped inside the stones, when the stone is applying pressure downward this soft soil will try to pump up and it will simulate the bursting condition the geotextile may burst due to the applied upward load. So, the due to upward load this the field model for burst resistance test.

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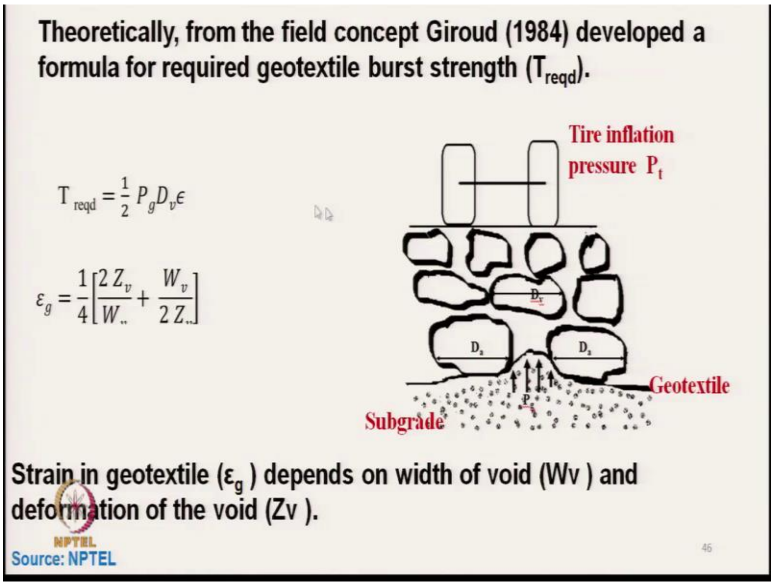

And the theoretically from the field concept the Giroud again developed empirical formula to calculate the required geotextile burst strength T required. So, what is T required, it is,

$$T_{reqd} = \frac{1}{2} P_g D_v \epsilon$$

So, what is P g? It is the pressure exerted upward and Dv is the diameter of the void and this is elongation, elongation can be calculated using this formula. So, elongation equal to

$$\varepsilon_g = \frac{1}{4}\left[\frac{2 Z_v}{W_v} + \frac{W_v}{2 Z_v}\right]$$

where Zv is the deformation of the void and Wv is the width of the void. So, from this formula we can calculate the elongation value strain of the geotextiles.

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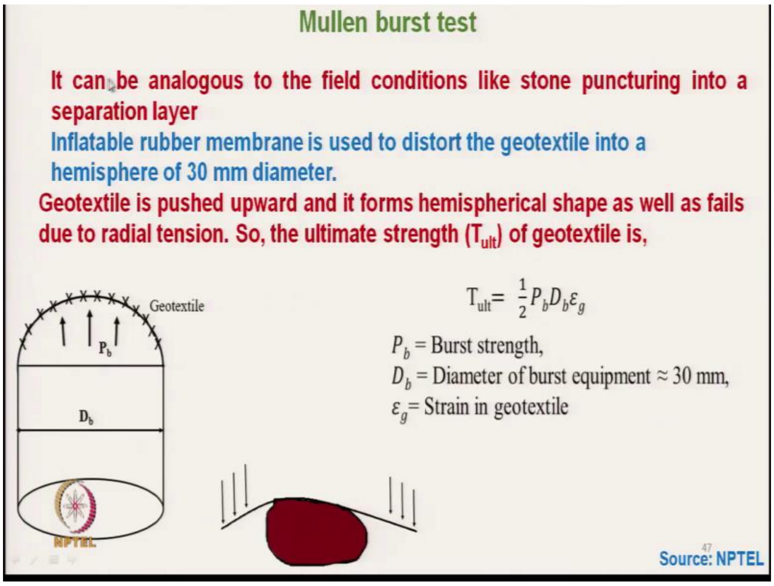

So, it can be analogous to the field condition like stone punching into the separation layer. So, can also be the condition, not only the soft soil is pumping up this can also be the condition. So, inflatable rubber membrane is used to distort the geotextile into a hemispherical shape of diameter 30 millimetres.

This is a 30 millimetre and this shape is hemispherical shape, geotextile is pushed upward and it forms hemispherical shape as well as the fail is due to radial tension, this fail of the geotextile state that it fails due to the radial tension. So, ultimate tensile strength, ultimate strength of geotextile you can calculate by

$$T_{ult} = \frac{1}{2} P_b D_b \varepsilon_g$$

P_b = Burst strength,
D_b = Diameter of burst equipment ≈ 30 mm,
ε_g = Strain in geotextile

If we know the strain diameter of burst equipment and pressure required to burst we can calculate the tensile strength of the geotextile.

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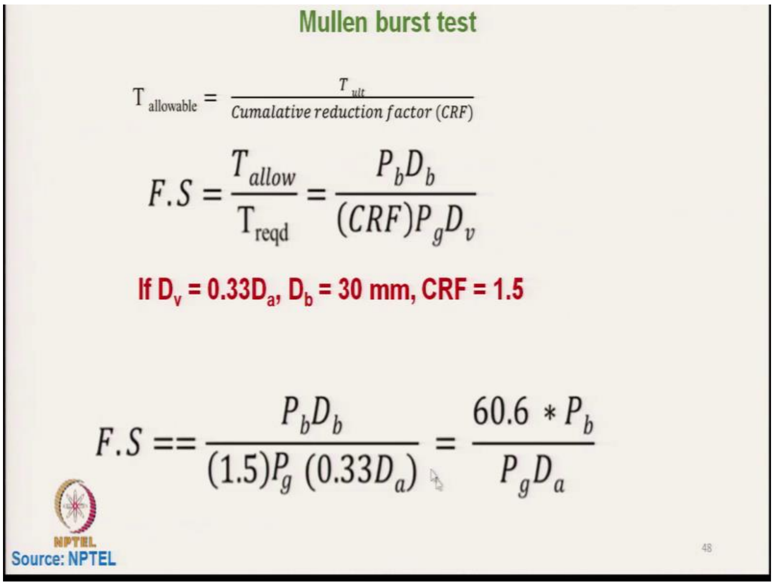

So, using this formula we can calculate the Factor of safety also.

$$T_{\text{allowable}} = \frac{T_{ult}}{Cumalative\ reduction\ factor\ (CRF)}$$

So, this ultimate tensile strength as we have seen here we can if we replace we will get the factor of safety

$$F.S = \frac{T_{allow}}{T_{\text{reqd}}} = \frac{P_b D_b}{(CRF) P_g D_v}$$

So **If $D_v = 0.33D_a$, $D_b = 30$ mm, CRF = 1.5**

$$F.S == \frac{P_b D_b}{(1.5)P_g\ (0.33D_a)} = \frac{60.6\ * P_b}{P_g D_a}$$

The next characteristic is that the properties which influence the soil geotextile interaction.

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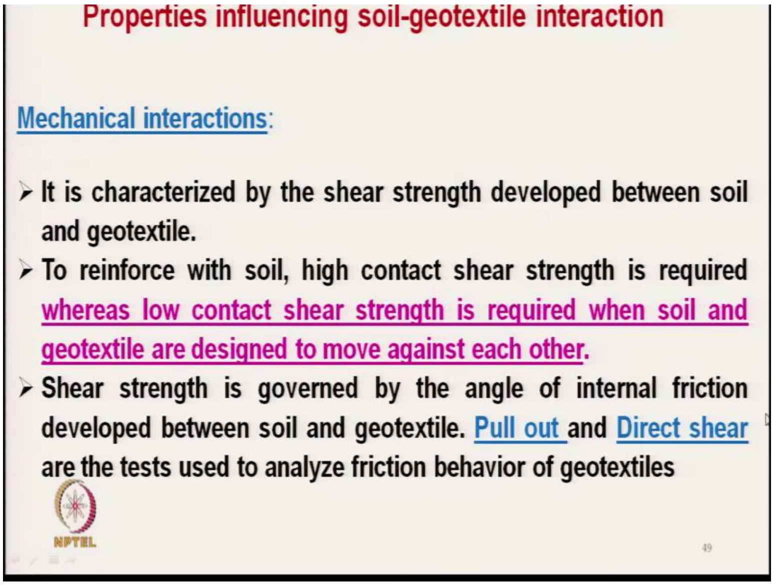

So, mainly it is a mechanical interaction the here we will discuss the frictional characteristics between soil and geotextile. So, it is characterized by the shear strength developed between soil and geotextile suppose a soil structure is trying to slide or geotextile is trying to slide over the soil structure. So, how much friction is there between the soil and geotextile? So we can assess by this methods to reinforce with soil high contacts shear strength is required. So, for reinforcing purpose we do not expect that there will be sliding between soil surface and the geotextile surface.

Whereas low contact shear strength is required when soil and geotextiles are designed to move against each other. So, depending on the requirement we can select the particular geotextile for particular soil, shear strength is governed by the angle of interaction that is angle of friction developed between soil and geotextile and this interaction we can evaluate by two methods, one is pull out test another is direct shear test.

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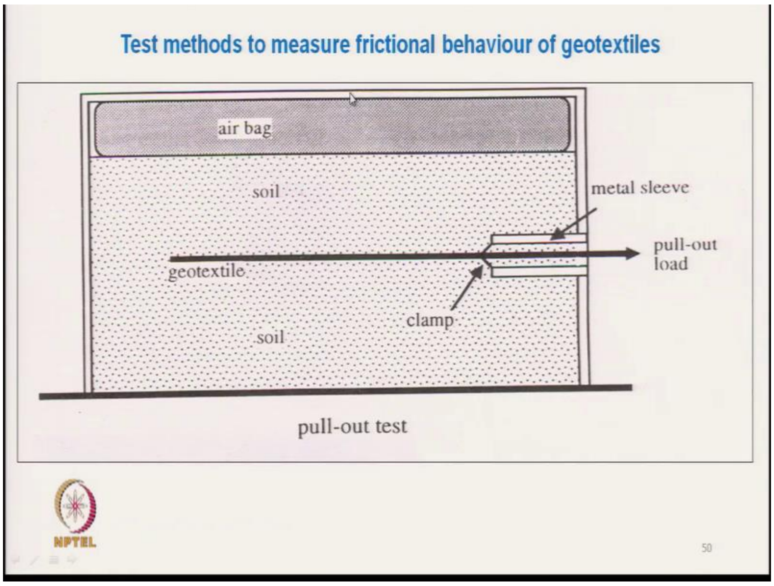

Here it is a pull out test, this is same as that we have discussed in composite the single fibre pull out test. The concept is same here, here the geotextile sample the specimen is confined between the soil surface and the at the end the geotextile is clamped and then it is pulled out and the pulling force is recorded higher the pulling force means higher will be the interaction and we apply the normal load which is constant.

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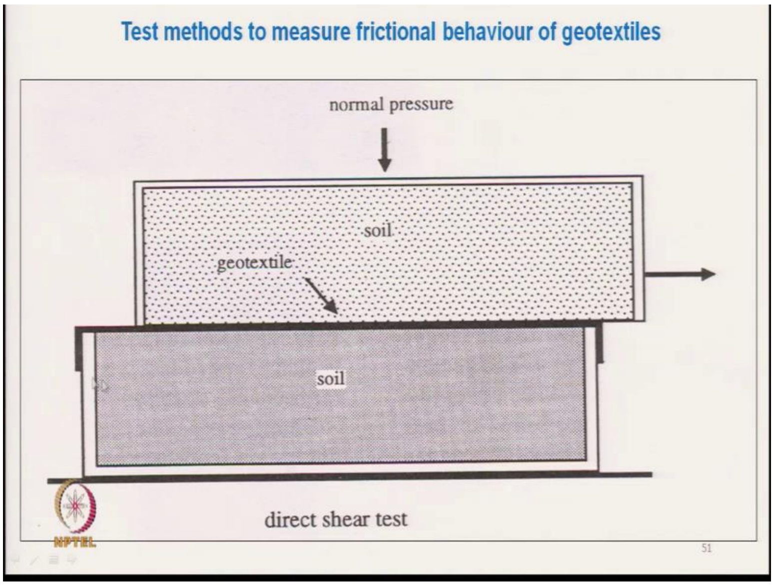

Another method is that here this is one soil surface which is covered with geotextile specimen and at the top box which is filled with soil and normal pressure is applied and then this top box is actually pulled it sheared against geotextiles and this pulling force is measured and depending on the frictional interaction between the soil and the geotextile this pulling force will change and we can evaluate the interaction force.

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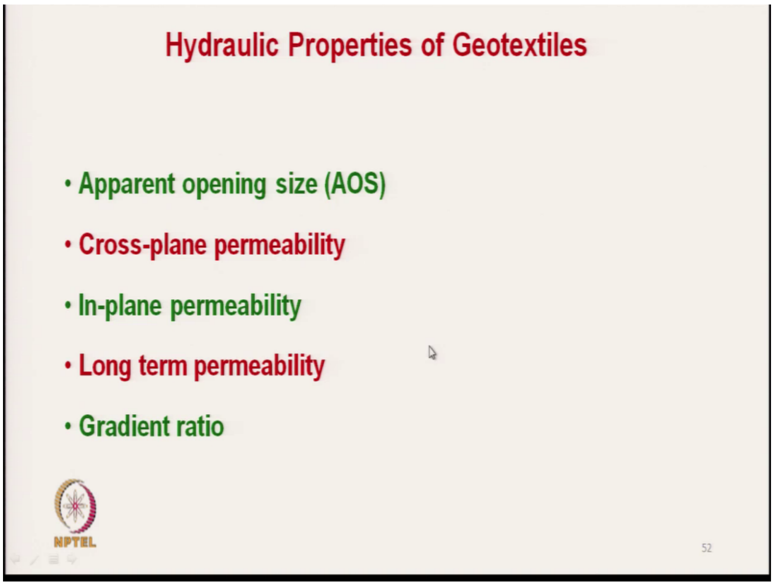

Now, will start discussing the Hydraulic Properties of Geotextiles, first we will discuss that apparent opening size. For any hydraulic characteristics means the flow characteristics of water mainly through geotextile depends on the pore structure of geotextile and the combination of pore structure and soil particle size it is important for proper designing of geotextile for their particular hydraulic characteristics.

So, for to get effective hydraulic properties we have to select geotextiles we have to understand we have to know the opening size of geotextile and the relation between the opening size and the soil diameter is extremely important. So, in hydraulic properties we will discuss how to measure the apparent opening size, then we will discuss cross plane permeability in plane permeability long term permeability and then finally we will discuss gradient ratio.

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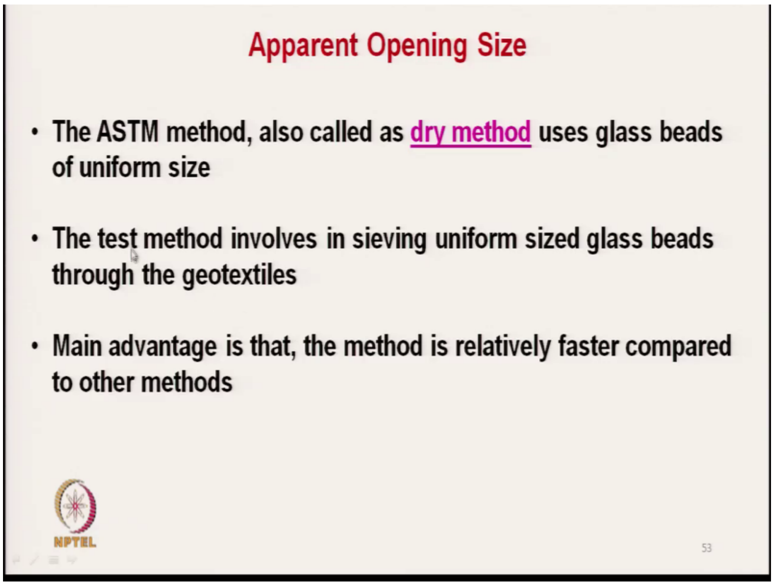

First apparent opening size as per ASTM method which is called dry sieving method, where the glass beads are used and this class beads are uniform in size. So, the test method involves in sieving uniform size glass beads through the geotextiles and main advantage is that the method is relatively faster compared to any other method, so faster and simple method.

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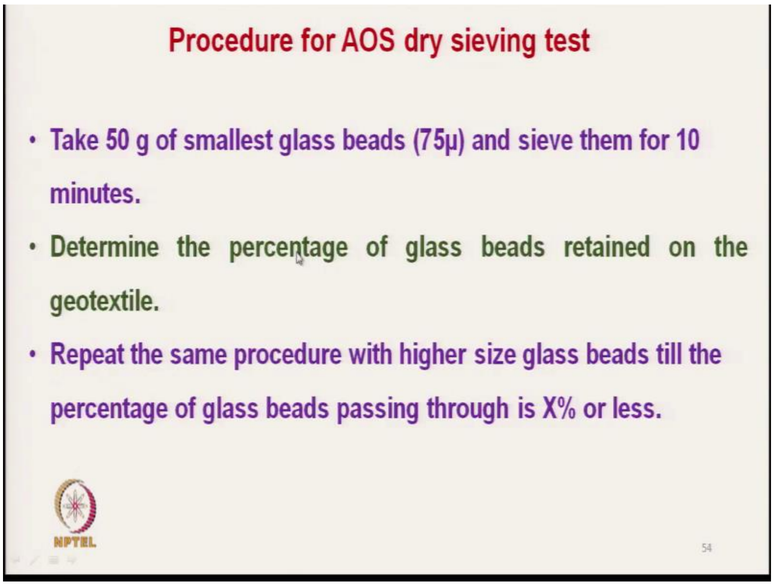

Now, here we take 50 gram of smallest beads available. So, typically a 75 micron beads and which is sieved then for 10 minutes. So, sieving is there for 10 minutes and then we have to determine the percent of glass beads retained on the geotextiles and this same process is repeated with higher size of the glass bead till the required percent of glass beads passing through which is X percent is achieved.

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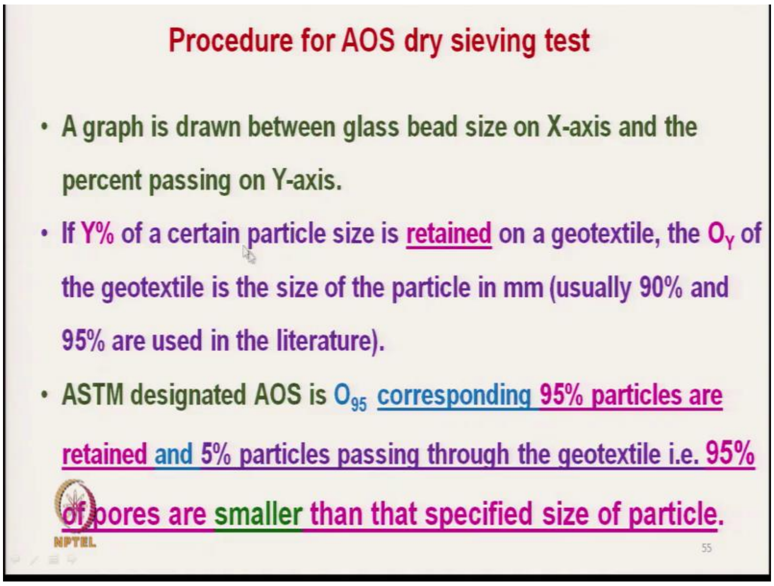

Now, graph is drawn between the glass bead size on X axis and percent passing in Y axis, and how do we express the result? If we know the percent passing then we can calculate the percent retained. So, let us see if y percent of the certain particle is retained on geotextile then O_Y of the geotextile is the size of the particle in millimetre using usually 90 percent and 95 are used.

So, O Y means Y percent of that particle size is retained; what does it mean? As per ASTM that is AOS Apparent Opening Size is expressed in either O_{95} or O_{90}. So, as per ASTM it is O_{95} corresponding that 95 of particles are retained. That means, 5 percent particles are passing through the geotextiles which means 95 percent of pores are smaller than that specified size of particle. So, 95 percent O_{95} means that 95 percent of the pores are smaller than that size.

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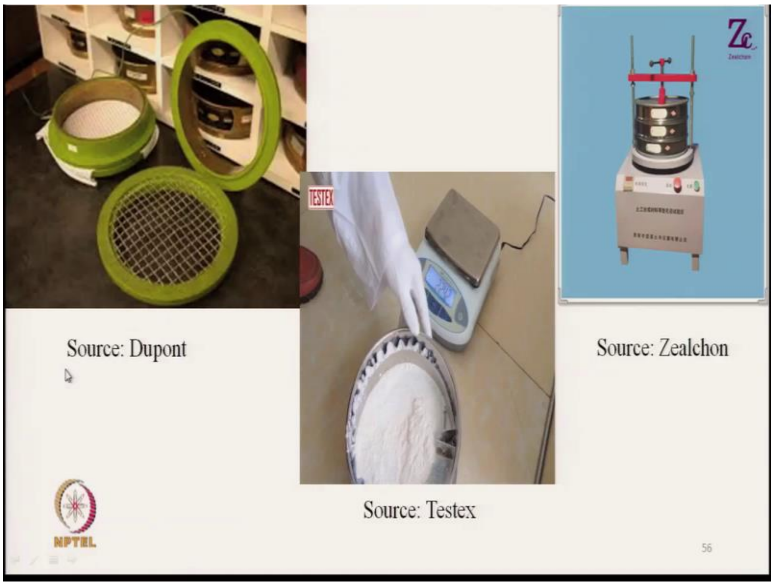

Now, let us see how to measure, these are the sieves available now this is the instrument here.

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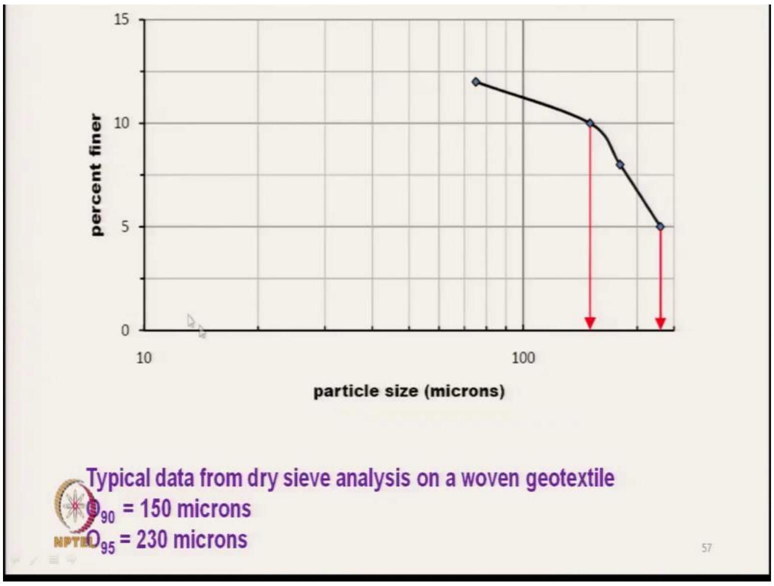

And this curve shows we start with the smallest particle size, this is the smallest particle size say 75 micron and we start sieving and when you have observed here that typically around say 12 percent particles are this is finer particle these are 12 percent particles are passing through. Here 10 percent particles are passing through. that means, 90 percent particles are retained here with this size and at this point it is showing that 5 percent particles are passing through that means 95 percent particles are retained if the particle size is this one.

That means, here it is 150 micron 150 micron mean, that means 10 percent of the particles will be passing through the geotextiles, 90 percent of the particle will be retained here. So, the apparent opening size of the geotextile O_{95} equal to 150 micron; what does it mean? O_{90} 150 micron means the 90 percent of the pores are less than 150 micron similarly O_{95} 230 micron means 95 percent of the pores are less than 230 micron, that is the significance of apparent opening size.

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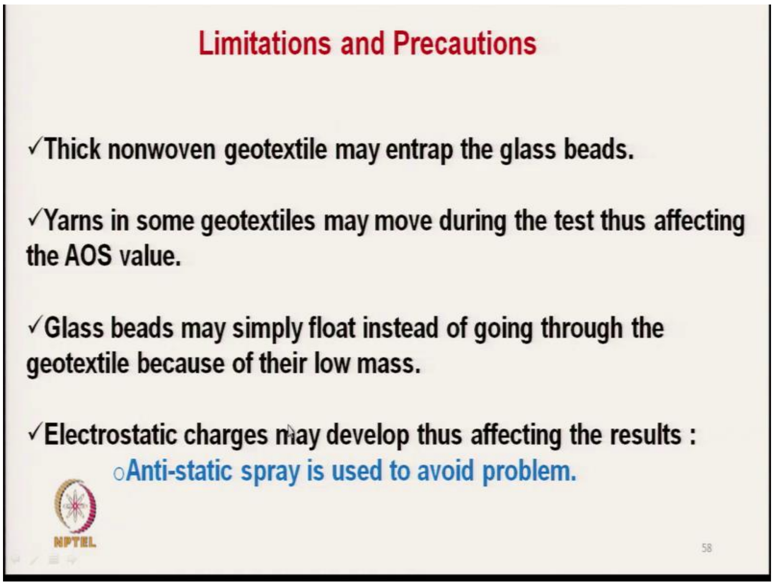

So, what are the limitations of this method? The method is actually cannot be used for very thick nonwoven, because that may entrap the glass beads within the structure for geotextile of woven structures, Yarn in some geotextiles like woven geotextile may move during testing during sieving that may affect the apparent opening size method.

Glass beads may simply float instead of going through the geotextile, because of their low mass because lighter glass beads while sieving they may simply float on the geotextile. And most important drawback is that the electrostatic charge may be developed, it may generate and which will affect the free flow of the particles through the pores, so in that case to avoid this problem anti static spray can be applied. Another method which is similar to dry sieving method which is called hydrodynamic test method for AOS apparent opening size which is called as wet sieving method.

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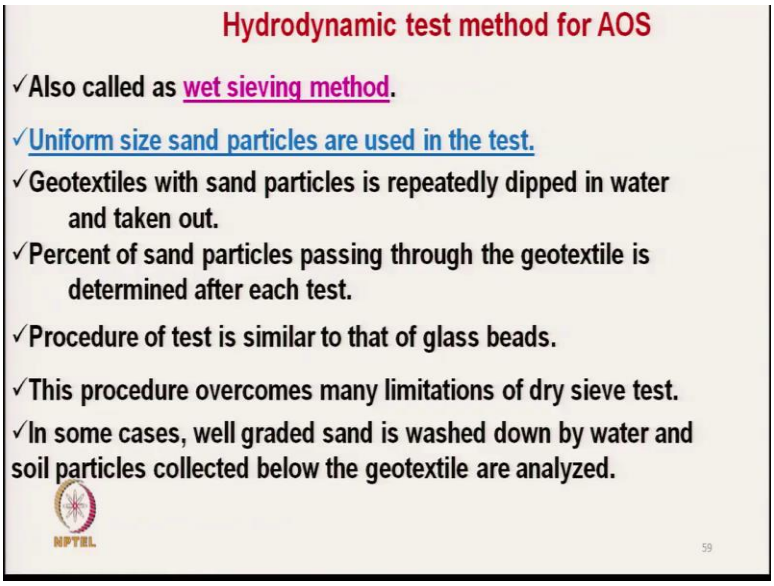

The test methods are exactly same to that of dry sieving method uniform size sand particles are used here instead of glass beads geotextile with sand particles is repeatedly dipped into the water and taken off instead of normal hydro sieving here. We test the repeated dipping and taking out percent of sand particles passing through the geotextile is determined after each test, procedure of test is similar to the dry sieving as we have seen using glass beads.

This process overcome many limitations of dry sieving like generation of static electricity or floating of glass beads, in some cases well graded sand is washed down by water and soil particle is collected below the geotextile are also analysed. So, that will show the piping characteristics of geotextiles. So, how the soil particle is lost, what is the quantity, what type of soil that also we analysed in addition to the apparent opening size measurement this is the method here.

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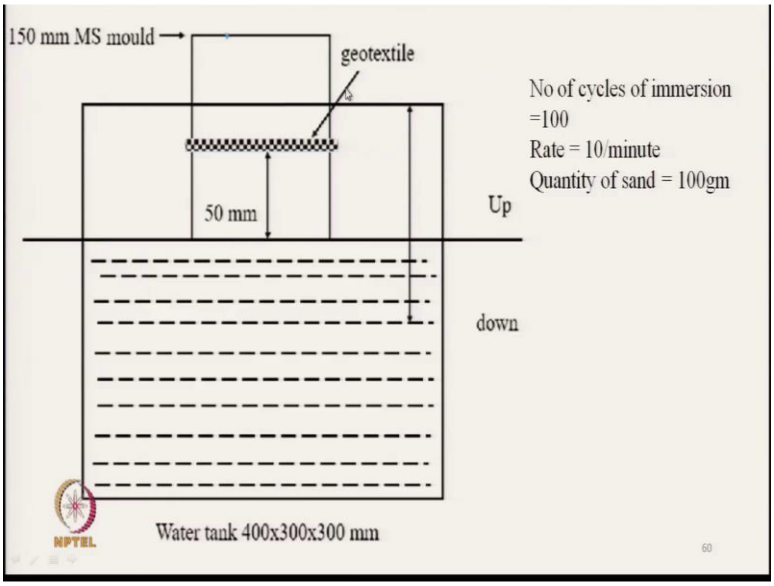

And here it is a geotextile sample and we place some sand particle here and the total mould is dipped and taken out and the amount of sand particle retained is measured. Based on the apparent opening size and the size of the particle we can design the filter, there are different filter criteria. So, fine soil particles should not be lost that is the first criteria of geotextiles, although the pore sizes are more than the finest particle.

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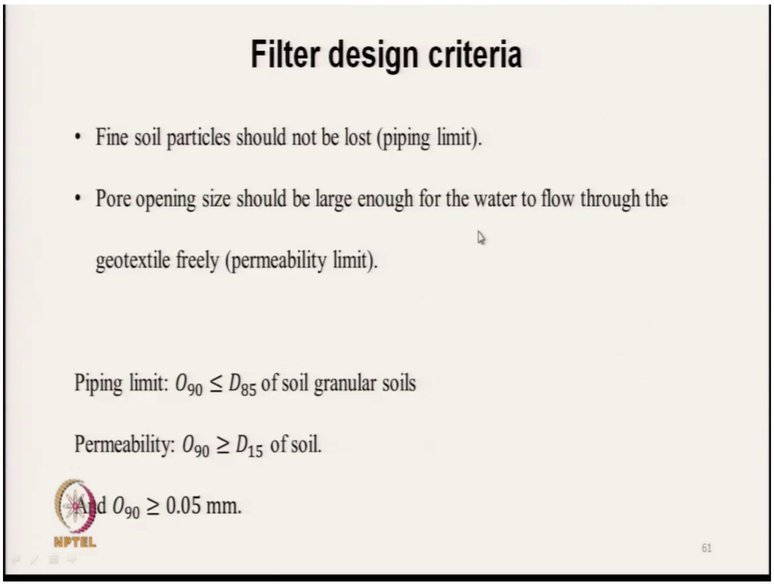

Pore opening should be large enough for the proper water flow, so there should be proper flow of water for that pore size should be large enough. So, there are 2 criteria's one is piping limit, that means the soil loss should not be there through geotextile, for that have O_{90} should be less than equal to D_{85}, O_{90} is the apparent opening size of 90 percent. That means, 90 percent of the particles 90 percent of the pore sizes or less than that size.

The D_{85} means; 85 percent of the particles are of diameter less than that particular size. So, for piping limit this is the condition and for permeability limit the condition is this O_{90} should be more than equal to D_{15} of soil O_{90} means the characteristics of geotextiles D_{15} is the characteristics of soil particle. So, for permeability we should have minimum opening size and for piping we should have minimum diameter of soil.

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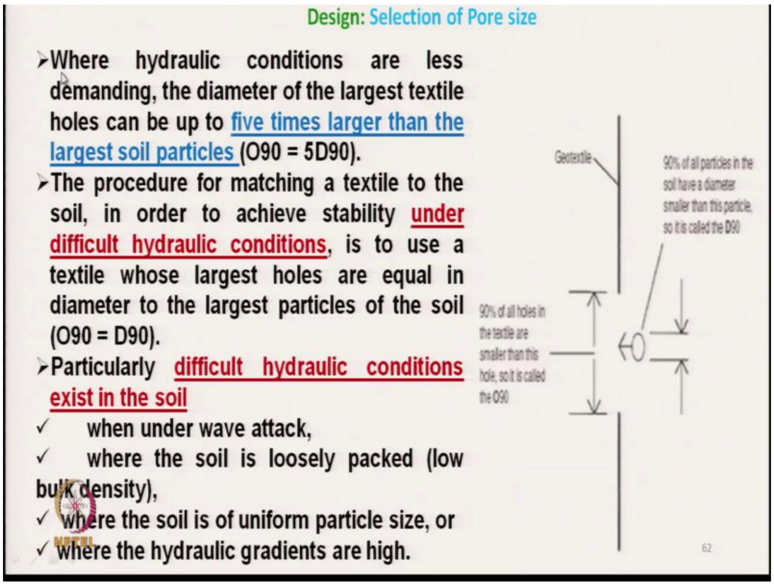

Now, here for selection of pore size where hydraulic conditions are less demanding, that means the waves are not there the pressure is not very high there is no turbulence the flow of water is streamline, so not demanding condition. The diameter of largest textile holes; that means, largest diameter that can be up to 5 times larger than that of largest soil particle which is very important, let us try to see understand.

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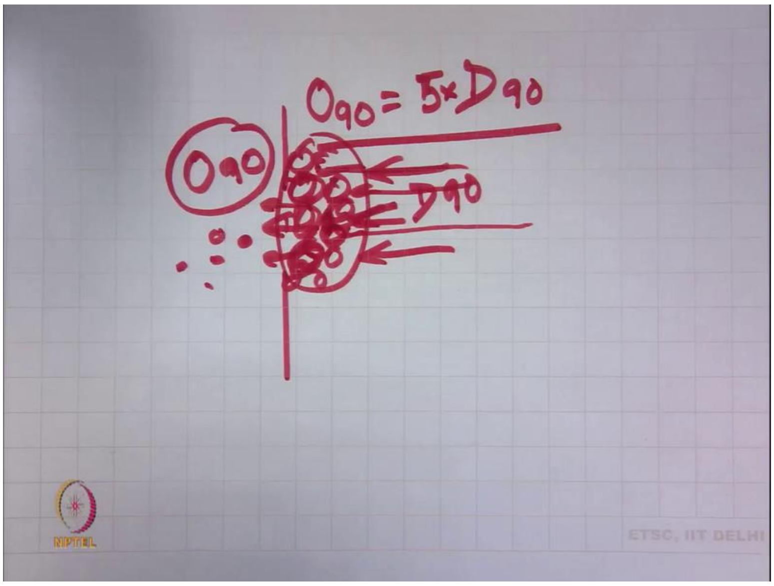

So, apparently it looks, this is the largest size that means O_{90}; O_{90} and here the diameter is the D_{90}, as per this condition D_{90} is 5 times to that of O_{90}. So that means, opening size is larger than the particle size which means the particle will simply flow through this pores, but it is not the actual case. Initially there will be definitely little bit piping, but after certain time this particles will form a structure and initially there will be larger size particles and gradually it will form a permanent structure. And as the hydraulic condition is not demanding so, the water will flow through this pores created by the soil itself without losing the soil.

So, this is the stabilized condition and under difficult hydraulic condition where there is a turbulence, the waves are there in that case O_{90} equal to D_{90} particularly difficult hydraulic conditions exist in soil when under wave attack is there, where the soil is loosely packed low bulk density, where the soil is of uniform particle size or where the hydraulic gradients are high. So, in all this conditions we have to select the criteria O_{90} equal to D_{90}. Now we will discuss the test method for cross plane permeability so there are different types of tests, one is constant head test there are other test like falling head test.

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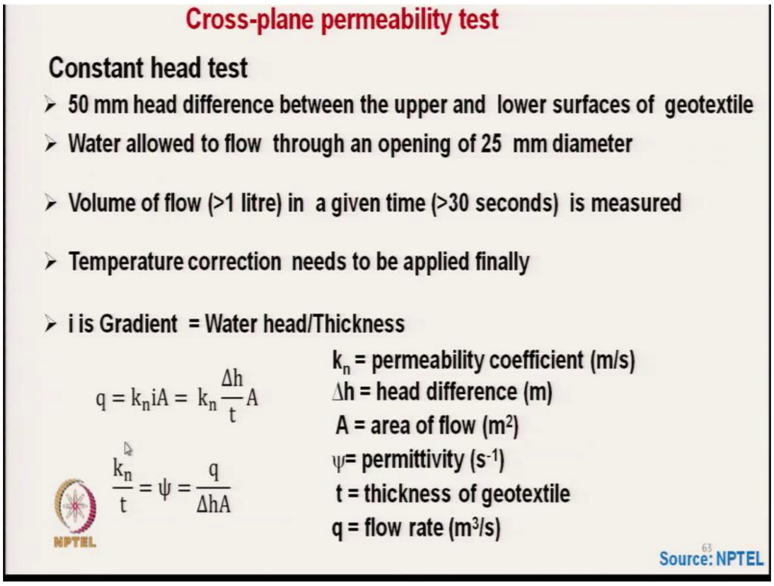

In constant head test 50 millimetre constant head difference between upper and lower surface of geotextiles are maintained, water is allowed to flow through the opening of 25 millimetre diameter volume flow is given per unit time. So, that is the volume in litre per second that is called volume flow, temperature correction is needed to be applied finally if the temperature changes so we can apply some correction.

$$q = k_n iA = k_n \frac{\Delta h}{t} A$$

$$\frac{k_n}{t} = \psi = \frac{q}{\Delta hA}$$

Where, **k_n = permeability coefficient (m/s)**

Δh = head difference (m)

A = area of flow (m^2)

ψ = permittivity (s^{-1})

t = thickness of geotextile

q = flow rate (m^3/s)

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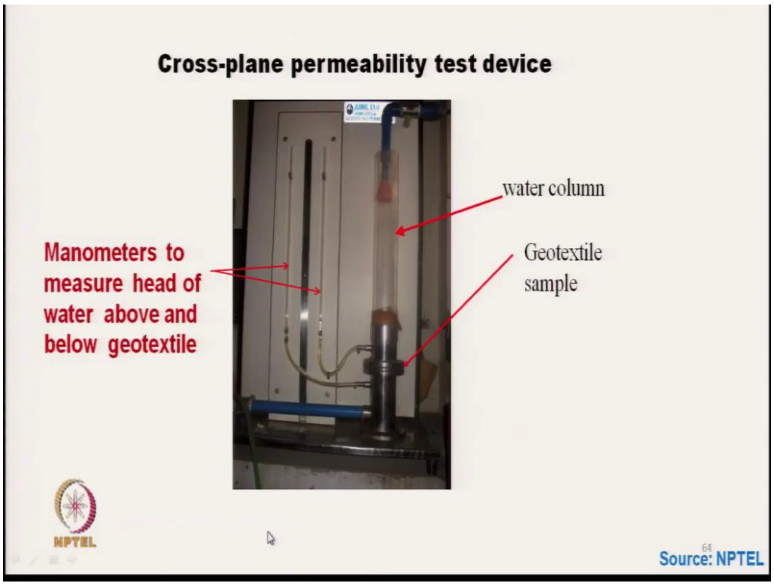

And this is the setup for measuring the cross plane permeability, manometers are used to measure the water head and this is water column geotextile sample and here it is a water outlet.

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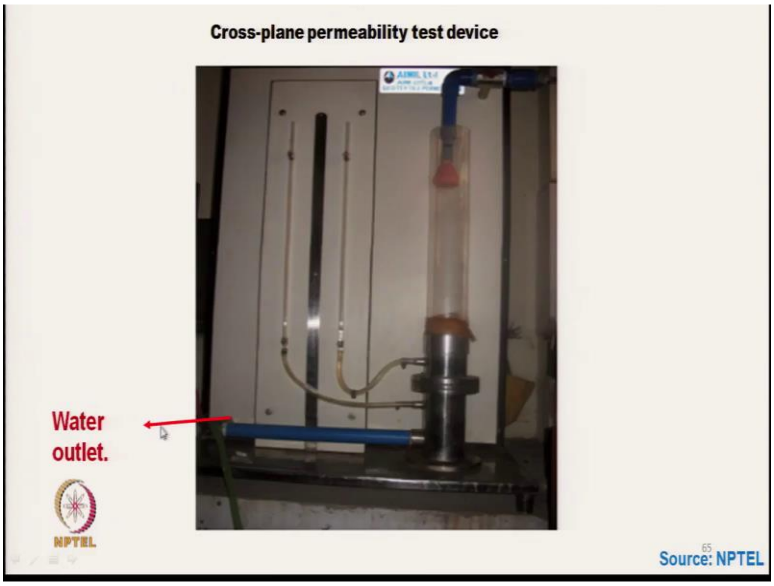

And we can measure the volume of water passing through geotextile per unit time.

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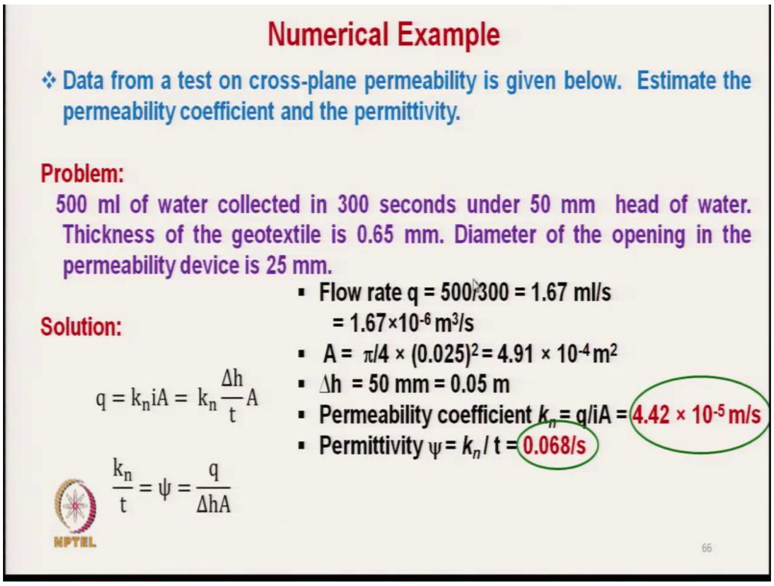

So, we will now see the numerical how do we measure the permeability coefficient or permittivity with the given data. So, this data from a test of cross plane permeability is given below, estimate the permeability coefficient and the permittivity. So, 500 millilitre of water collected in 300 seconds under 50 millimetre head of water, thickness of geotextile is given as 0.65 millimetre, diameter of opening of permeability device is 25 millimetre.

$$\frac{k_n}{t} = \psi = \frac{q}{\Delta h A}$$

$$q = k_n i A = k_n \frac{\Delta h}{t} A$$

$= 1.67\times10^{-6}$ m^3/s

- **A = $\pi/4 \times (0.025)^2 = 4.91 \times 10^{-4}$ m^2**
- **Δh = 50 mm = 0.05 m**
- **Permeability coefficient k_n = q/iA = 4.42×10^{-5} m/s**

- **Permittivity ψ = k_n / t = 0.068/s**

Thank you.