Technical Textiles
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Lecture - 18
Geotextiles (Contd.,)

Hello everyone, today's topic is testing of geotextiles. In geotextile part, we have discussed the functions, the characteristics, applications. In addition to all these testing and characterization of geotextile is extremely important, because the total structure, the performance of total structure geotechnical structure or civil engineering structure depends on the characteristics of geotextiles.

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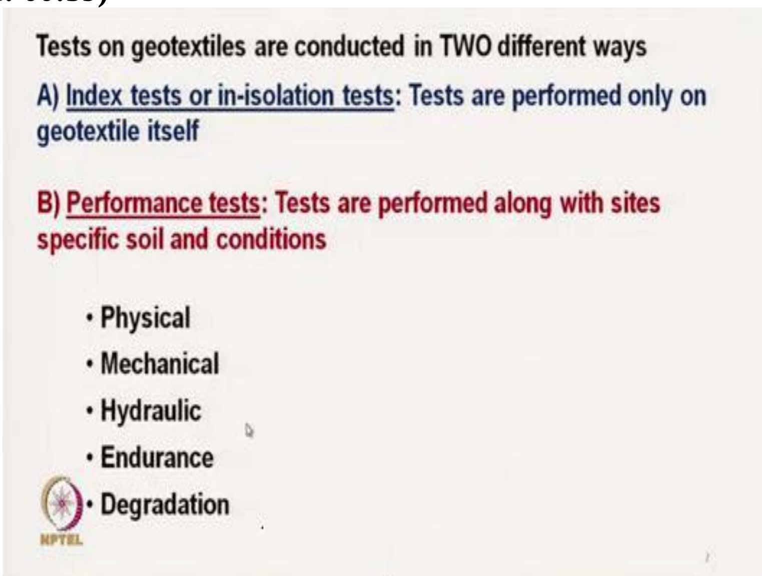

So, if we divide the test for geotextiles we can divide into 2 broad ways. So, first is index test that is in isolation test, where we do not need any field trial field tests or the textile material is tested separately in isolation. And if you want to know the performance characteristics that is performance test is required, this performance test is carried out with the site specific soil and conditions, we should take the specific soil and we should create the particular condition during test, so that we can actually predict the performance of geotextile in use.

The index test is simple, it is quick. On the other hand the performance test, it is time consuming and it requires a different setup. So among the qualities or characteristics of geotextile, they are divided into 3 categories mainly, one is physical category physical test, which deals about the physical characteristics of geotextile material, mechanical tests and hydraulic test. Apart from this there are endurance test and degradation test. So, endurance test it is basically combination of mechanical and hydraulic characteristics and degradation is mainly related to polymer characteristics.

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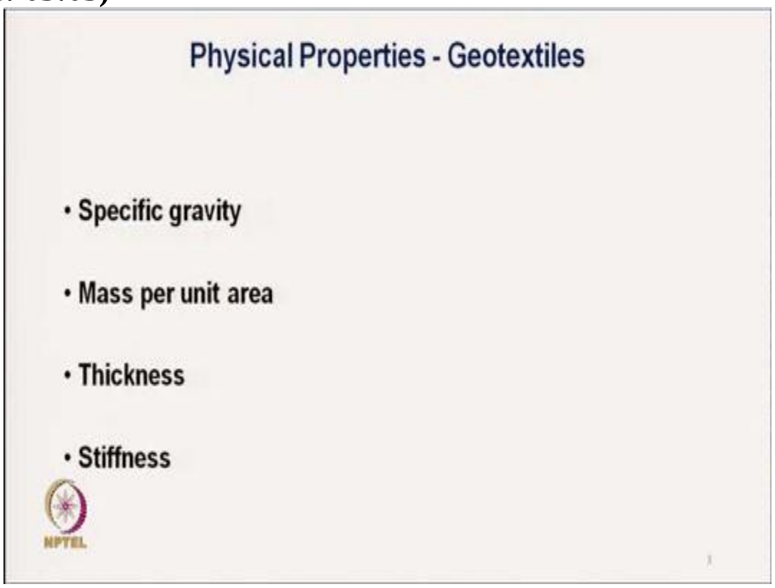

So, in terms of physical properties, they are mainly specific gravity, mass per unit area, thickness, stiffness, they are very important characteristics as far as geotextile is concerned.

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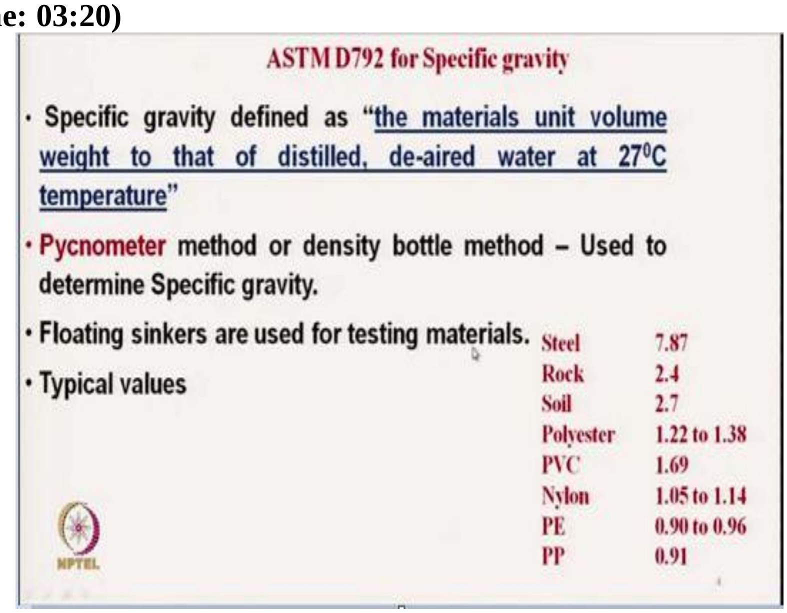

And specific gravity if we see, it is defined as the material present per unit volume of that is the material in unit volume. So, whatever material present per unit volume and if we take the ratio with the density of the distilled water, so that we will get the specific gravity it is measured using pycnometer method or density bottle method, where floating sinkers are used for testing materials. The typical value we see if we compare it is a rock the density is 2.4, polyester its changing from 1.22 to 1.38, polypropylene 0.91. So, for designing geotextile we must know or we must measure the specific gravity.

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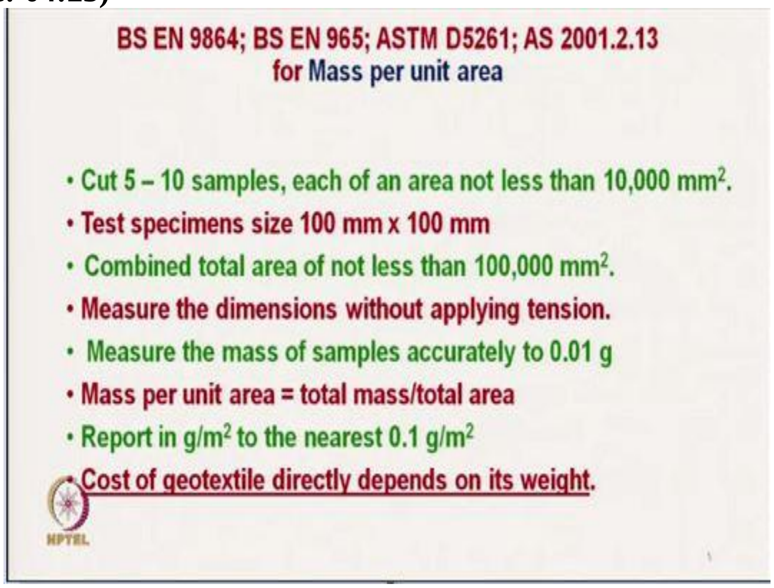

Then mass per unit area is very important, the tensile characteristics mainly correlate with the mass per unit area of material. So, here are the materials are cut in a specific dimension. And the material then is its weight its mass is taken and that when we divide the mass with the area, we get the mass per unit area, while measuring the dimension you should take precaution it should not be stretched.

So you should cut the material without any tension. So mass per unit area is total mass by total area. And cost of geotextile is normally it depends on the weight of that is mass per unit area of geotextile.

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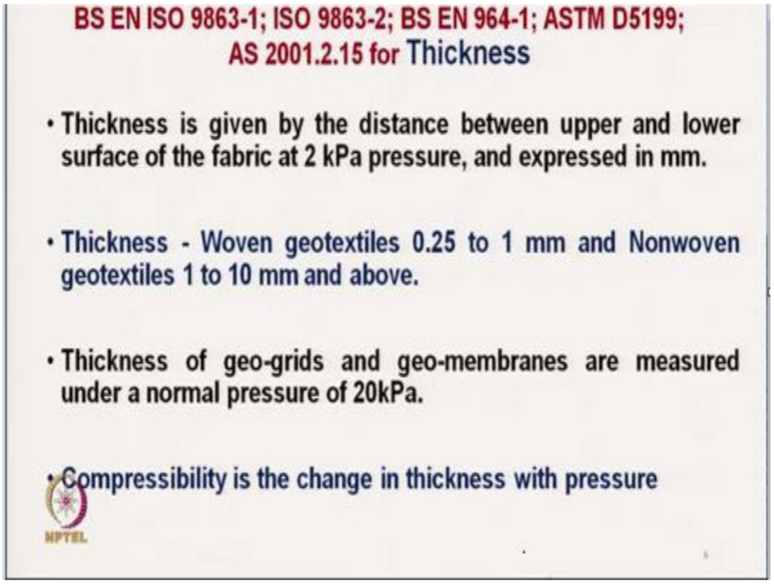

Thickness is basically it is given by the distance between upper and lower surfaces of the fabric. For textile material we take the pressure 2 kPa pressure, because the material is normally it is a compressible material, most of the geotextiles are compressible. So we must specify the pressure. If we see the range of thickness, the woven or heat bonded nonwovens are thinner. So, woven geotextiles the range of thickness is 0.25 to 1 millimeter, sometime it can go beyond 1 millimeter.

And nonwoven if we see the thickness range from 1 millimeter to 10 millimeter and above, we can get very high thickness, this thickness is very important for the drainage and filtration application and also you must know the compressibility of geotextile because, with the compression, the flow characteristics also change. When we measure the thickness of geogrid or geomembrane, we try to keep higher pressures that is 20 kPa pressure is used as the standard. So, these geotextiles as I have mentioned, these are compressible. So, you must measure at certain pressure that is 2 kPa for a compressible geotextile we measure the thickness at 2 kPa pressure.

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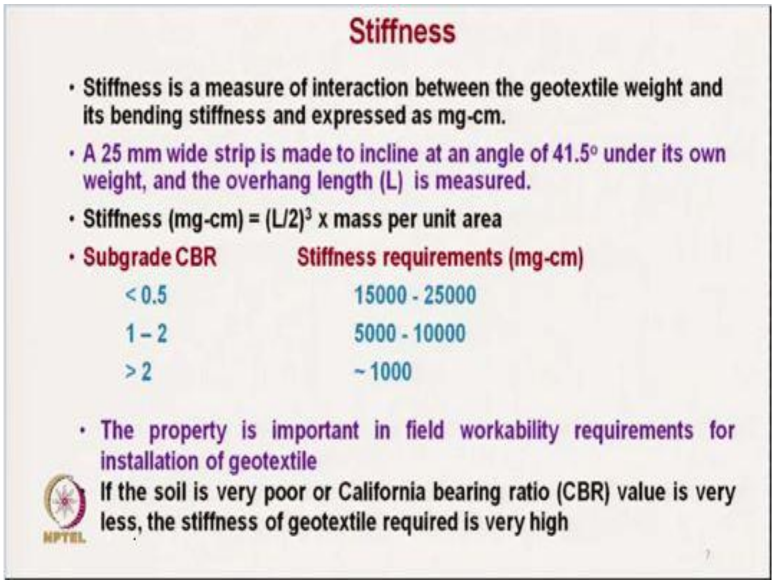

Next coming the important characteristics for geotextiles it is a stiffness. Stiffness as we know, for apparel fabric, the stiffness is important for the comfort characteristics, tactile comfort, or for home furnishing mainly, it is related with the drape, but for geotextile stiffness is extremely important for application with the different types of soil. Now, the measurement techniques of stiffness is similar to that of apparel textile.

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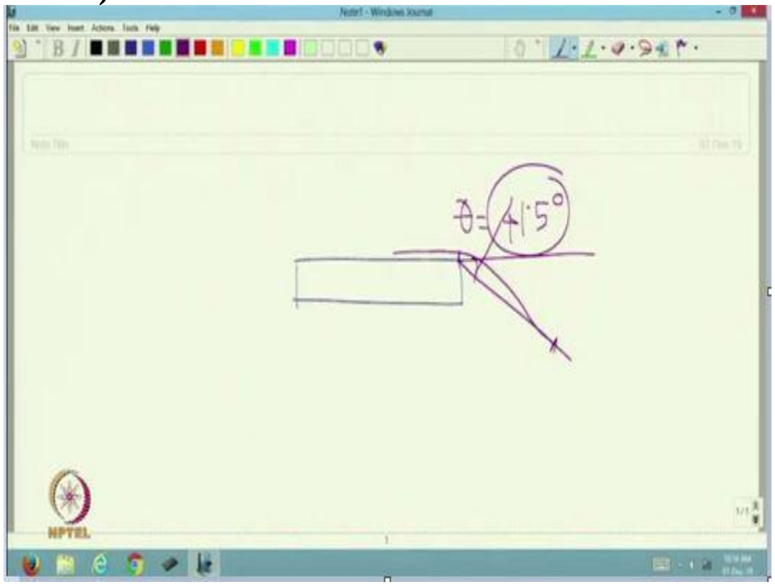

Here the stiffness tester like Shirley stiffness tester can be used the length, overhanging length which is making 41.5 degree angle, that overhanging length is taken as stiffness. So, higher the, this length, higher will be the stiffness. So, 25 millimeter approximately 1 inch wide strip is made to incline at an angle of 41.5 degree and that length is measured and the stiffness value is calculated by this formula that is stiffness in milligrams centimeter is equal to L / 2.

L is the overhanging length by 2 cube multiplied by mass per unit area, that is the stiffness equation. So we can get the stiffness value. Now, how this stiffness value is important for geotextile. Let us assume there are 2 types of soil.

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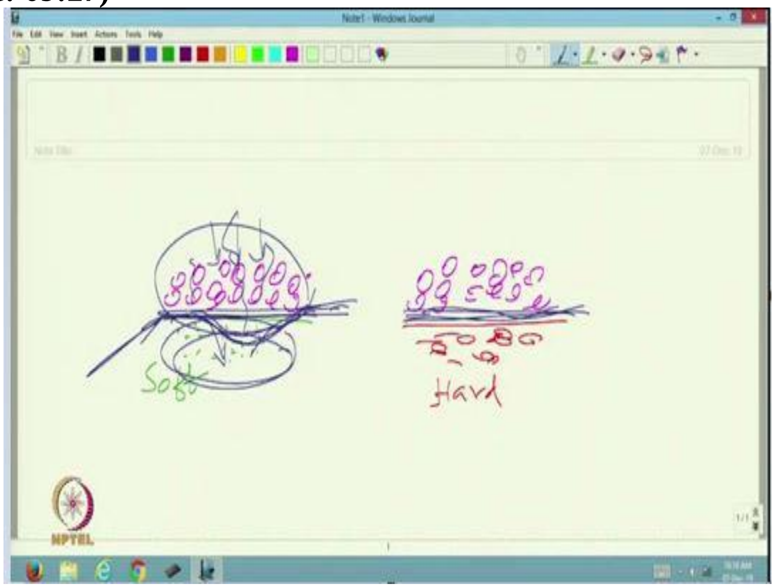

This is soil 1 very soft soil and here another soil which is hard soil. Now, these 2 soils, for these 2 soils we have to lay geotextiles, here geotextile is laid for the separation purpose. Suppose this is stone, these are the stones. Now, here I am putting geotextile this is geotextile and here we are putting geotextile. Now, before selecting geotextile, we must know the characteristics of soil. This soil being a very soft they will get deformed easily, the geotextile will get deformed very easily by applied pressure.

But here the soil is hard the deformation will be less or negligible deformation. Now if you want to use geotextile with the soft soil in that case, we have to select geotextile with a higher stiffness value, so that this deformation is not that high, ultimately this structure will remain intact. On the other hand, if we use here with the soft soil if we use the flexible geotextile with a lower stiffness then the structure may get distorted.

So, that is why the stiffness selection is extremely important for the geotextile application. Here, if we say this table, the subgrade CBR, California Bearing Ratio, this California bearing ratio is one parameter that I will discuss in detail. This is the parameter which shows the stiffness of or compressibility of the soil higher this value, the stiffer will be or the harder will be the soil. So, if it is very soft, the value is less than 0.5. In that case we need the geotextile with very high stiffness.

So, 15,000 to 25,000 is selected for the subgrade soil with CBR value less than 0.5. But on the other hand, if we use the heard sub soil in that case like more than 2 in that case we can have geotextile with lower stiffness like around 1000 milligram centimeter. So, this way, we have to select the stiffness. So, for soft subgrade we always select the stiffer geotextile for example, the heat bonded nonwoven fabric we may use.

Or sometime we use in combination. The property is important in field workability requiremen,t as I have already discussed for installation of geotextiles. If the soil is very poor or California bearing ratio CBR is very low, in that case we need stiffer geotextile.

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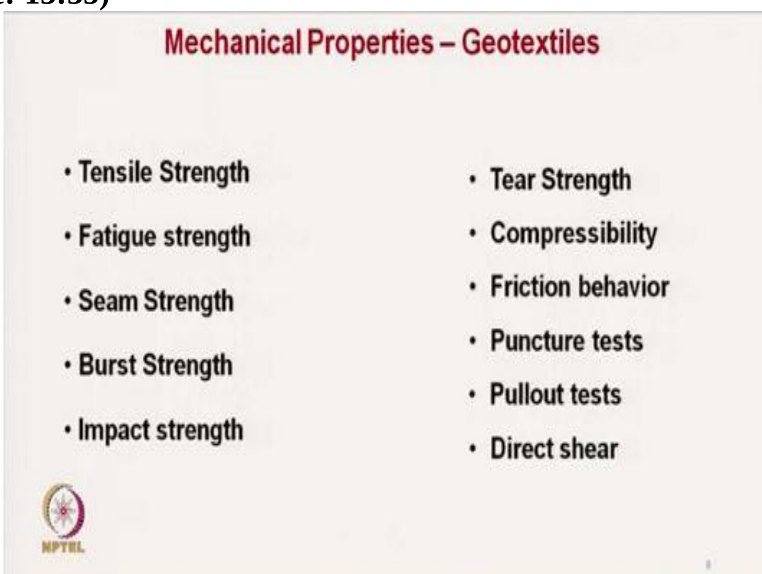

Now coming to mechanical properties, there are a large number of properties. We can test tensile strength, fatigue strength, seam strength, bust strength, impact strength, tear strength, compressibility, frictional behavior, puncture test, pullout test, direct shear test, these are the tests we must perform to get the characteristic to get a clear picture about the performance of geotextiles. So, we will discuss one by one.

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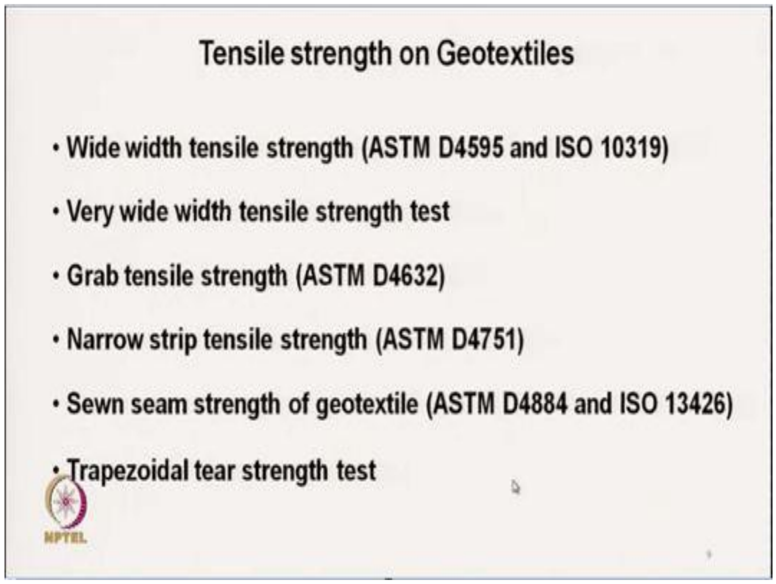

So, as far as tensile strength is concerned here, it is not like the apparel tensile characteristics. In apparel fabric, we use the strip test, where the width of the strip is very low, but in geotextile, this strip test result will not actually simulate the actual field condition. In actual application in field application we need wide width tensile testing as per ASTM D4595 or ISO 10319 system. So, the width is very wide, we can perform grab test to simulate actual condition, narrow strip test for only comparison, but it will not simulate the actual condition.

Sewn seam strength of geotextile can be done because actually geotextile the size we get is less than actual application, for that we need to stitch so the stitch strength we should get, trapezoidal tear strength is required, because in case of any puncher, this puncture should not propagate.

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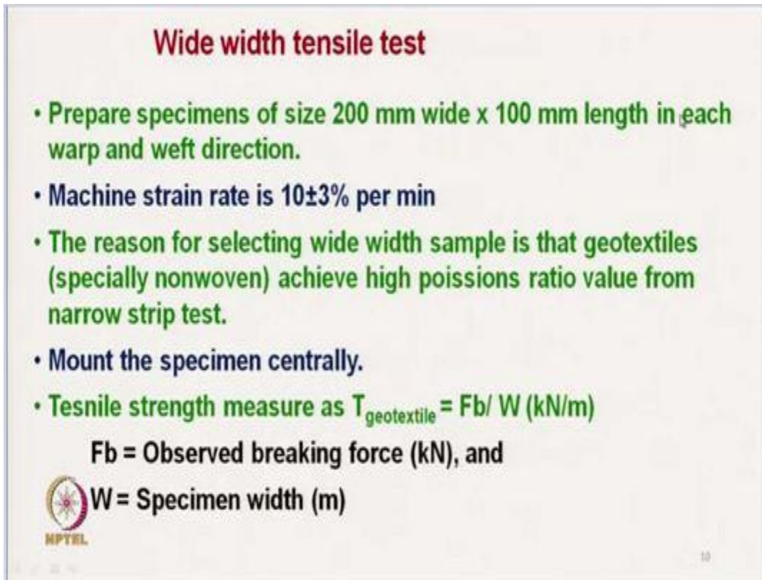

So wide width test here sample width is 20 centimeter and length is 10 centimeter. In case of woven fabric we have to test both in warp and weft directions. So, machine strain rate is specified as per standard it is 10 plus minus 3% per minute. The reason for selecting the wide width sample is that geotextile, particularly nonwoven achieve high poissions ratio from narrow strip. So, that will not give actual result. So, to reduce the poissions ratio, so, we perform the wide width test, that is sample is mounted centrally.

And tensile strength is measured in terms of kilo newton per meter. So, per unit width, we get the tensile strength value, in the strip test for apparel we do not get in this form normally get in terms of gram per tex or centinewton per tex format.

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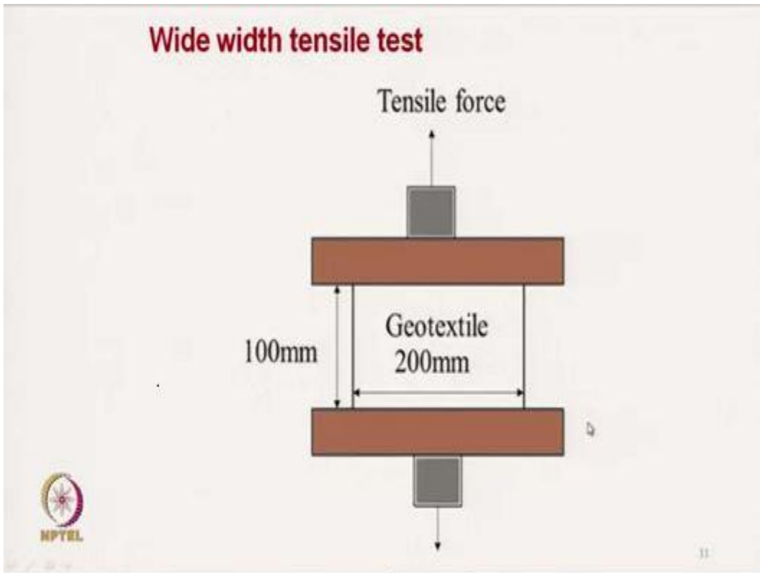

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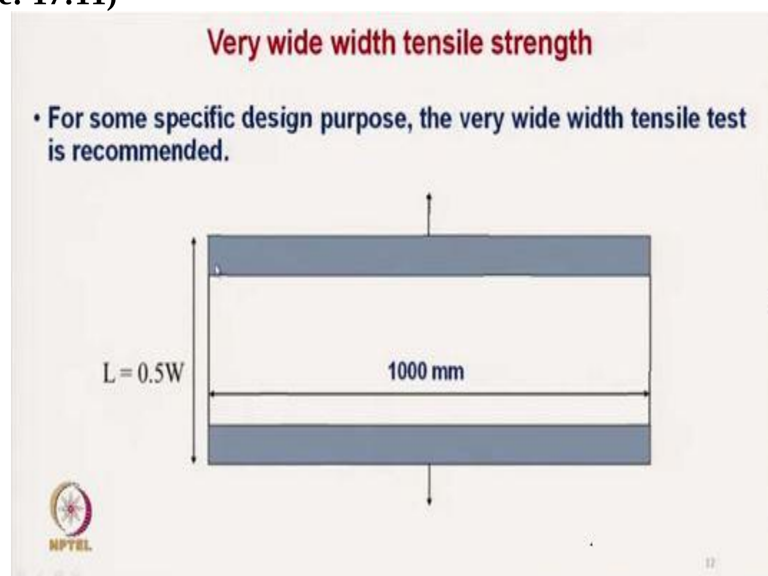

This is the test this the diagram shows the dimensions 200 millimeter and 10 millimeter, for very wide width, the dimension is the width is 1 meter and the length is half of the width. So, this is some time recommended for geotextile application.

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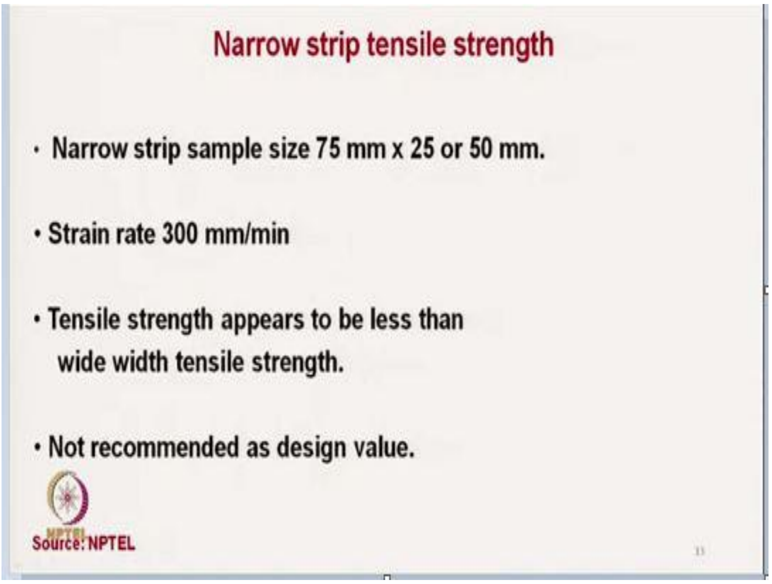

Narrow strip, we can test for just getting the idea, the index value we can get, the tensile strength appears to be less than the wide width tensile strength. As I have already mentioned, this test is not recommended for geotextile design only for getting the idea about the tensile characteristics.

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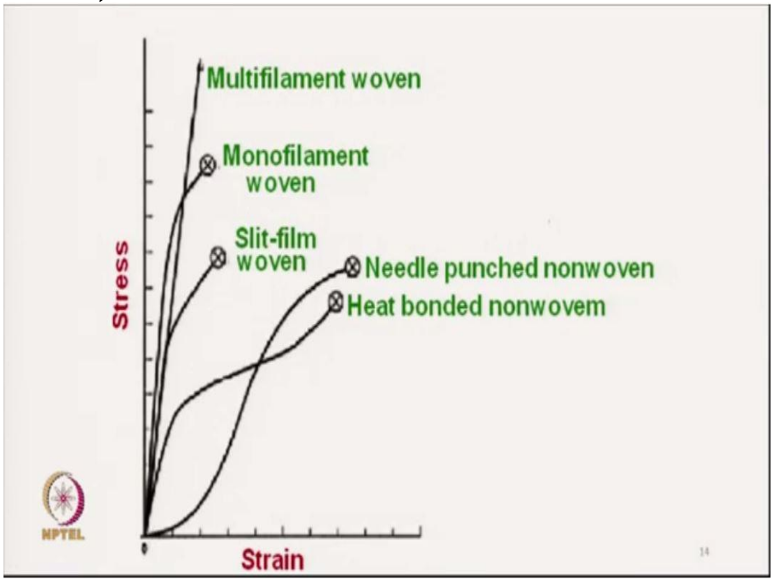

As I have already mentioned earlier along with the tensile strength value, we must get the total stress strain curve. So, from there we can get an idea about the performance at lower strain. Now, for example, if we take the heat bond nonwoven and needle punch nonwoven there, if we see the needle punch nonwoven is having higher baking strength than heat bond, but at lower strain, the heat bond nonwoven is stiffer. So, accordingly, depending on our requirement, we can select for that we need to have total stress strain curve.

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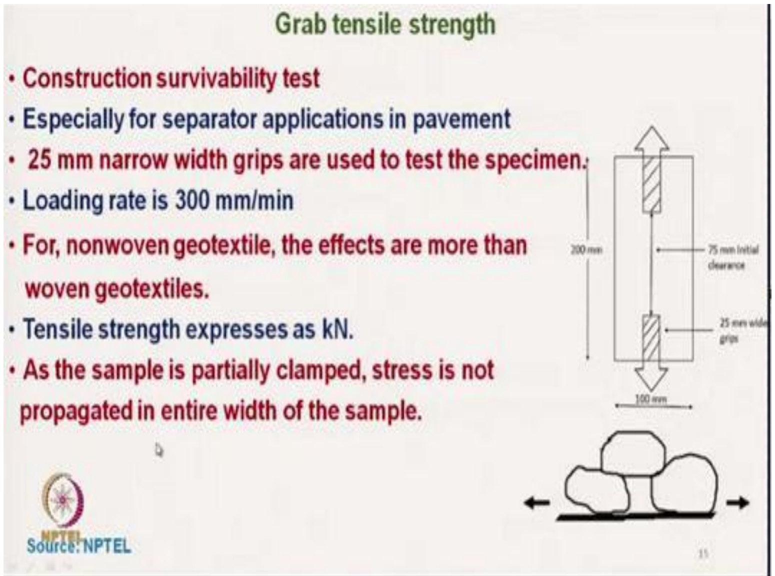

Now, grab test as far as geotextile is concerned, the grab test is extremely important. This is for construction survivability test. Tensile test gives an idea about the mechanical characteristics, but grab test most of the condition the geotextiles are subjected to grab test like situation. In grab test the geotextile material a sample is not gripped throughout the width, it is gripped at center, this situation normally occurs during application.

Now, here if we see it shows 3 stones of certain dimension and it is placed over geotextiles and beneath the geotextile its there are soft soils and here geotextile is acting as separation and reinforcement purpose. Once the load is applied on this top stone.

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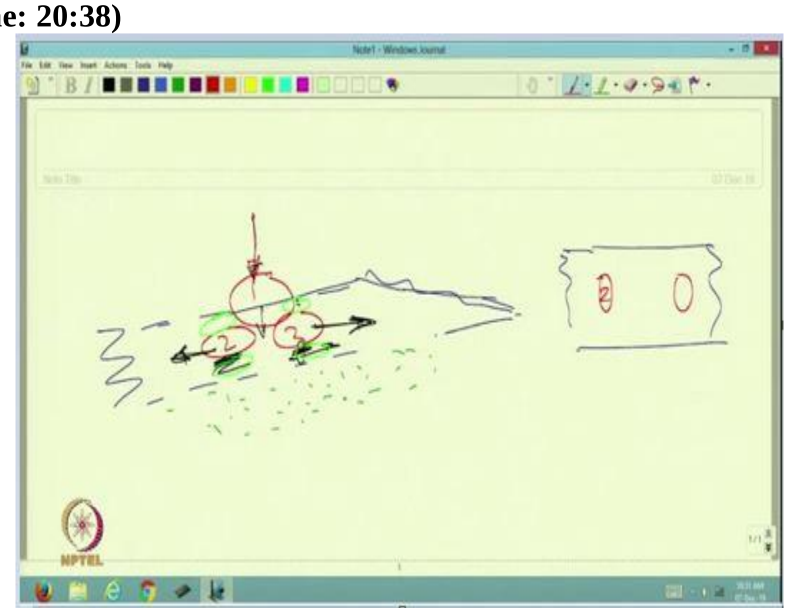

I will show here now here this is a geotextile, this is geotextile. Below that there are soft soils and above the geotextile say this is one stone, another stone this gravel so there now, once the load is being applied on this stone due to the downward force these 2 stones will try to move sideways and due to the contact point and at this point of geotextile, geotextile will be pulled. So, this zones are not being pooled. This is creating one situation.

This is geotextile and here there is a grip. So, 1, 2, 3 this is grip, second grip at this point and this is third and they are trying to pull the, similar situation which is actually created here like has been tested in grab test. So grab test is important characteristics and as I mentioned, it is especially for separation application in pavement. So 25 millimeter narrow wide grip is there, loading rate is that is the strain rate 300 millimeter per minute.

Nonwoven geotextiles the effects are more than woven geotextiles. So, it is expressed in kilo newton. So, as the sample is partially clamped, the stress is not propagated in the entire specimen and which is actually simulating the actual condition.

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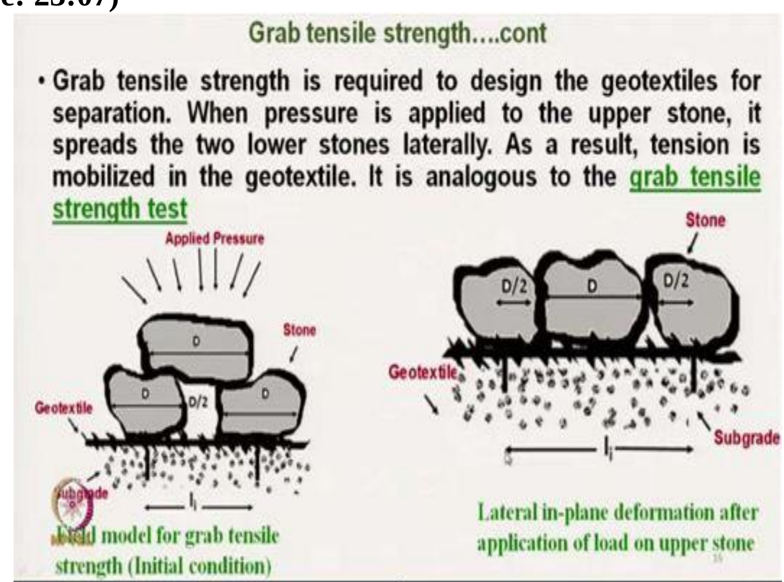

So, this is the diagram. These are the diagrams, the grab tensile strength is required to design the geotextile for separation application. When pressure is applied to the upper stone, it spreads the 2 lower stones laterally, it is trying to spread. As a result tension is mobilized on the geotextile and it is just analogous to grab tensile strength.

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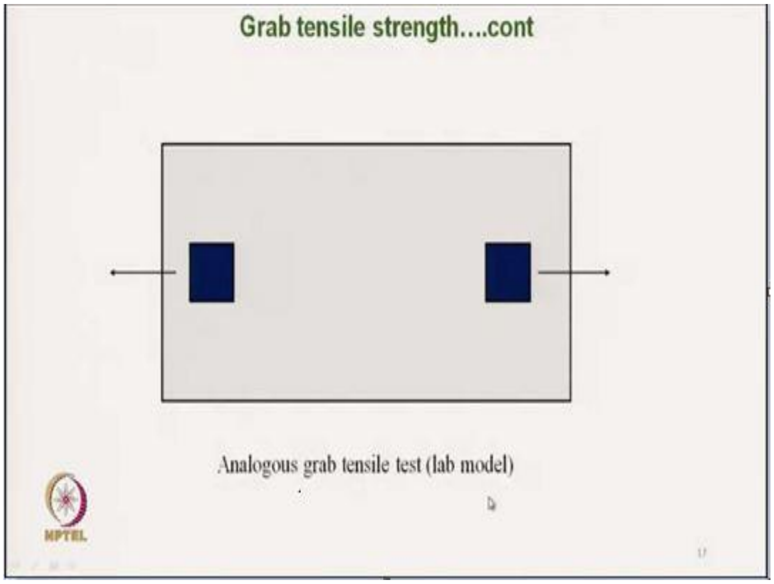

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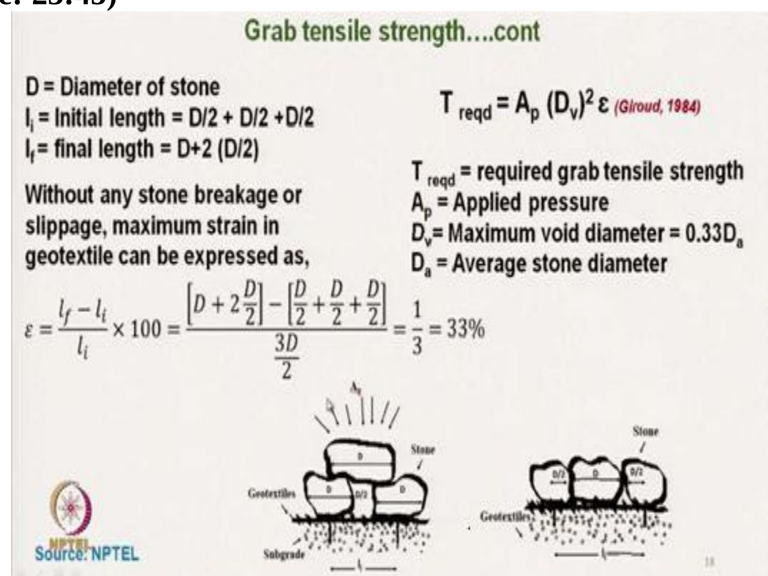

These are the grips and dark blue color and this is the specimen. Now, as per Giroud, he has proposed one empirical equation, we can get the grab test by this empirical equation. If, you see the diameter of stone D, let us see it is a average diameter all the stones are of having this diameter and here this is the diameter D and it is assumed that the space between the lower 2 stones are D / 2. So, total area here total area it is D / 2 and the total length initial length is that this D / 2, D / 2 and D / 2 this is the, from this point to this point.

So, this is the total initial length is 3D / 2 and final length D, this is D it has come inside D and D / 2 and D / 2. So, this is l 1 and this one is l 2. So, if we take the strain in this case, the strain is 33% or 1 / 3, .33 is the strain and T required is A p is the applied pressure from the top, we know the if we know the applied pressure and maximum void diameter, this void diameter maximum void diameter for the stone system with a diameter D is 0.33 and D a is the average stone diameter.

So, this equation can be used to calculate the required grab strength. So, if we know the required grab strength from all these data and if we know the actual grab strength of textile material, we can calculate the factor of safety.

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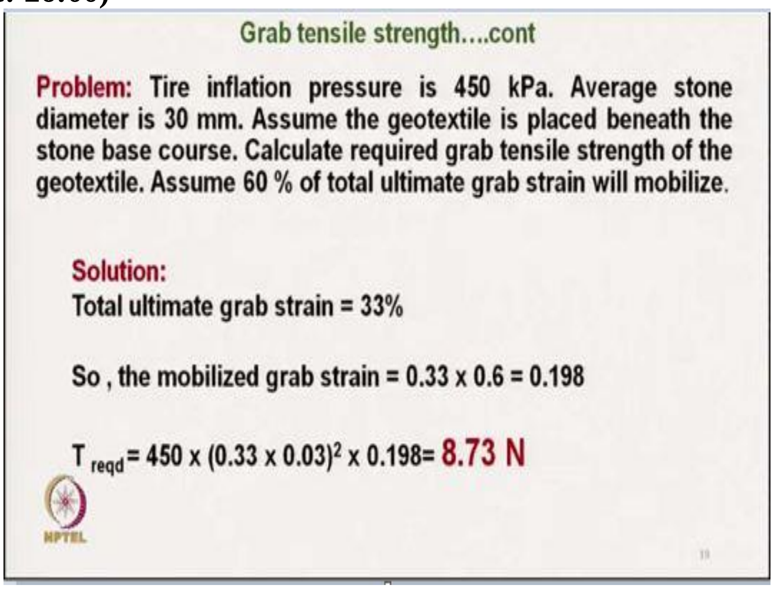

So, this is a simple problem. The tire inflation pressure which is actually actual, the applied pressure, it is 450 kilo Pascal, the average stone diameter is 30 millimeter, assume the geotextile is placed beneath the stone base course, that is stone base courses there, calculate the required grab tensile strength of geotextile. So, we have to calculate the T required, required grab strength, here assumption is that 60% of the total ultimate grab strain is being utilized.

So, here in this condition we have not considered any slippage. So, 60% strain is being used means there is 40% slippage to plus during this sliding, so, if we assume that the grip is proper there is no sliding then it will be 0.33, if 60% is being used that means, actual mobilized grab strain is 0.6 multiplied by 0.33. So, 0.33 is that is 1 / 3 that strain, so, that strain multiplied by 0.6. So, 0.198 is the actual strain of geotextile.

So, we know this pressure and here it is a 30 millimeter diameter, 30 millimeter diameter means 0.03 meter, the unit is in meter, 0.03 meter is the diameter of the stone average diameter. And if we go back to earlier slide, the D v is the maximum void diameter which is 0.33 into average diameter. So, this D v so, 0.33 into average diameter square multiplied by 0.198. So, the required grab strength here is 8.73. So, if we want say factor of safety of say 4 or 5.

So, if we want a factor of safety of 5, so, we must have on material geotextile whose grab strength will be 8.73 multiplied by 5. So, typically, we try to keep higher factor of safety in geotextile application, because they are there for protecting the structure.

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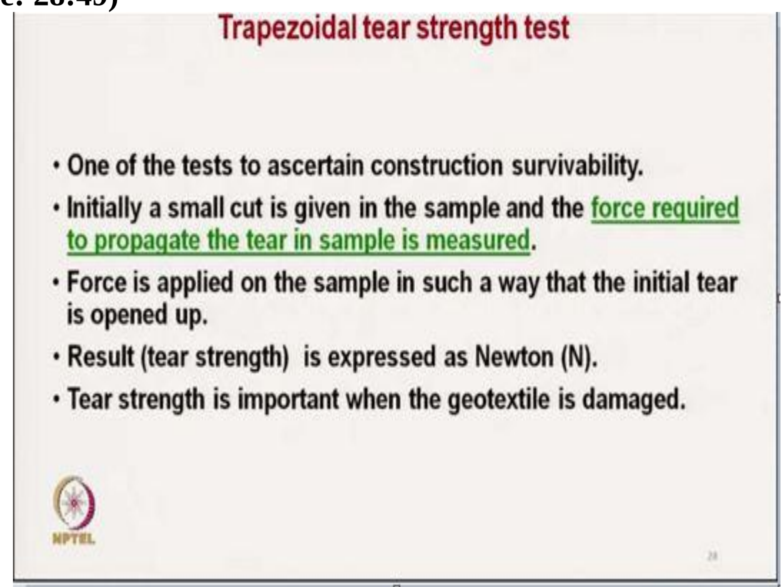

Trapezoidal tear strength, here it is tested to ascertain construction survivability, in case of any puncher, how quickly that puncher will propagate that is tested. So, initially small cut is given in the sample and the force required to propagate the tear in the sample is measured. The force is applied on the sample in such a way that initial tear is opened up. So, there is an initial tear is created and result is in Newton, expressed in Newton. So, the tear strength is important when geotextile is damaged. So, during laying up or during use, there will be some portions which is which are damaged and we need higher tear strength so that it can prevent the propagation.

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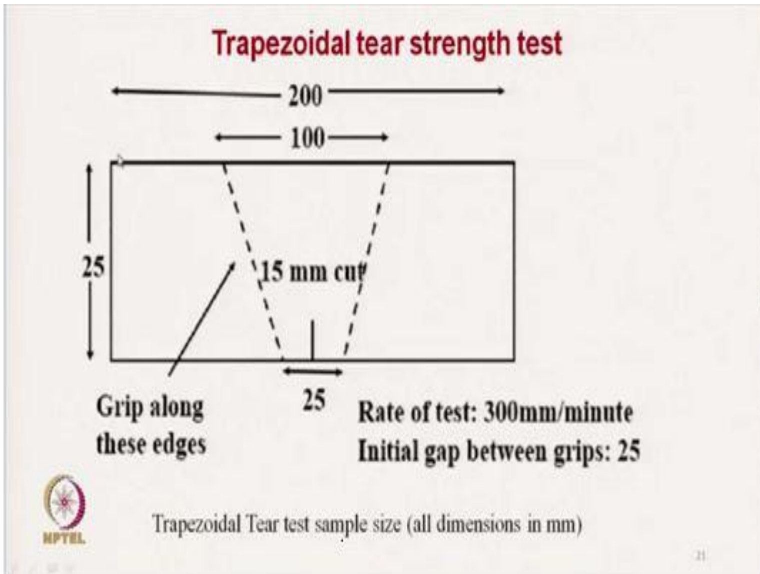

This is the sample size as far ASTM, 200 millimeter length this is 100 and this is the grip line and here the cut is made and we measure the strength required to propagate this cut.

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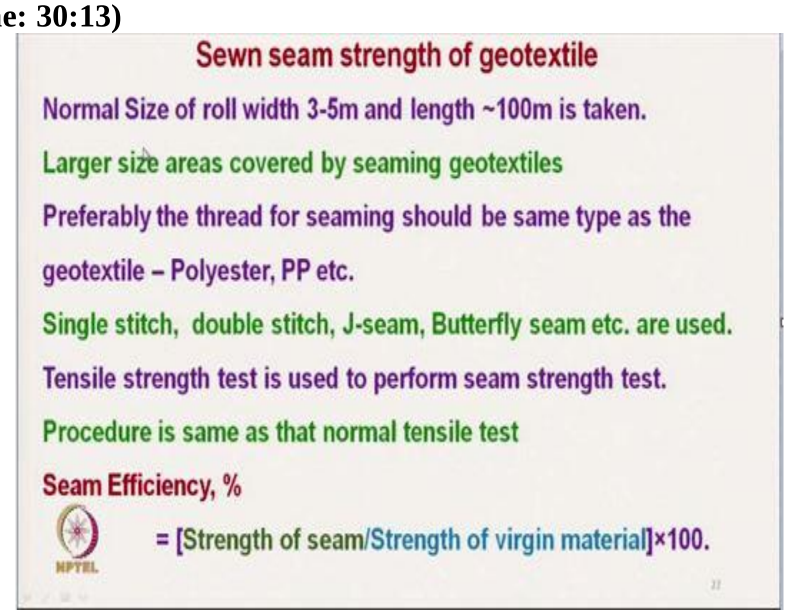

So normal sized roll with this 3 to 5 millimeter. So, now we can discuss the sewn seam strength of geotextile. So larger area has to be covered. So, we need to have stitching, there are different types of stitches, single stitch double stitch J-seam, butterfly seam they are commonly used and tensile strength of normal portion and tensile strength of stitched portion is measured and the ratio of strength at seam and strength at the virgin material is calculated as percent and which is seam efficiency.

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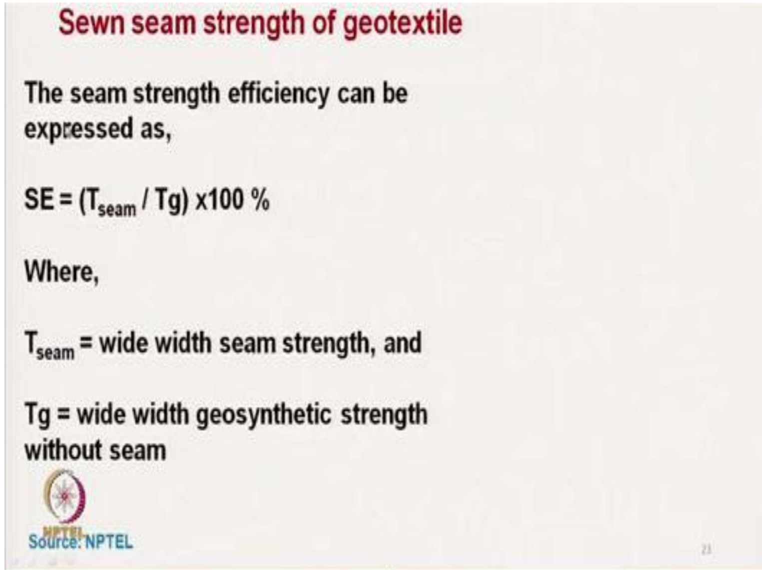

Seam strength efficiency is that the T seam and T strength of geotextile without seam. So, that ratio.

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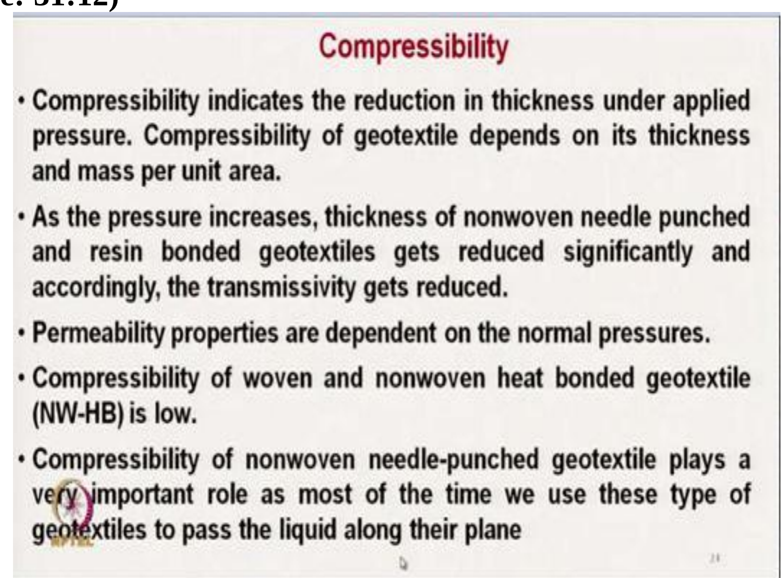

Now coming to another characteristic that is compressibility which is very important as far as the geotextile drainage and filtration application, which indicates that is compressiblity indicates the reduction in thickness under pressure and as we have discussed earlier that nonwoven particular needle punched nonwoven the compressibility is very high due to higher compressibility when load is applied, their transmission characteristics gets reduced and the permeability property are dependent on normal pressure.

So, higher normal pressure means that the structure will get compressed and permeability and transmissivity gets reduced and compressibility of woven and nonwoven heat bonded geotextile is low. Whereas, for needle punch it is very high.

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Next characteristics is the puncher resistance. Here, the puncher resistance is measured by 8 millimeter diameter probe, this is 8 millimeter diameter probe and the container diameter is 45 millimeter, this is 45 millimeter here, this is the geotextile material and before just before at or at the time of punching, the peak load is measured and it is expressed in terms of newton and this puncher moves at a certain specified speed.

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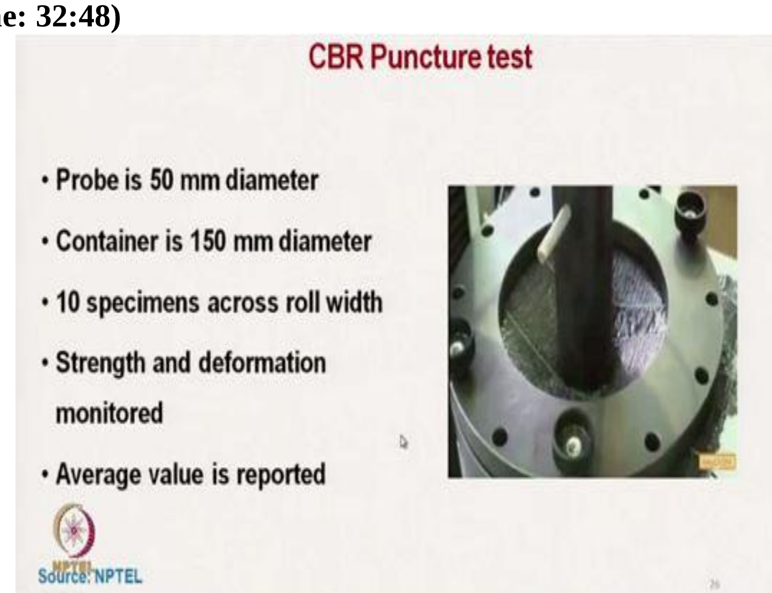

Next punching test is done by CBR Puncture test, the CBR test California bearing ratio test as it is basically for the soil particles, it measures the compressibility of soil. But using this technique, we can measure the puncture strength also, it is similar to earlier test that puncher resistance test where probe diameter was 8 millimeter, but in CBR test, the standard probe diameter is 50 millimeters.

In earlier case container diameter was 45 millimeter, here container diameter is 150 millimeter. So, the 10 normally standard 10 specimens are taken average is reported here. And using this value puncher resistance value, we can also calculate the tensile strength.

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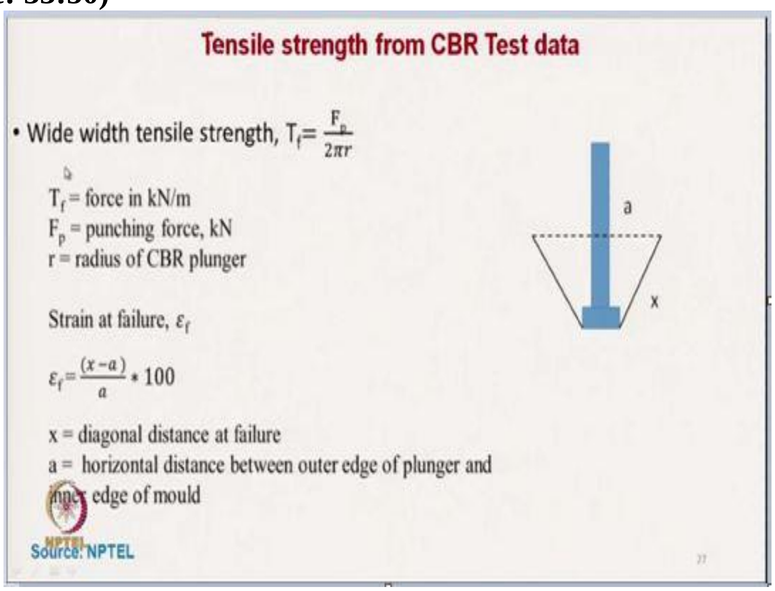

Like wide width tensile strength can be predicted using this CBR puncture data. So, this is the value T f is a tensile strength in terms of kilo Newton per meter, this is the puncher force is in kilo Newton, if we know the force and if we can calculate the circumference of the puncher, that is the 2 pi r, r is the radius of CBR puncture. Here radius is 25 millimeter this puncture radius and this is the circumference is the total width if we talk about the tensile testing, so, that's how it is calculated F p divided by 2 pi r.

Here, we get the idea about the tensile strength and also we can get idea about the tensile strain where a is the initial length of the specimen. The initial length that means that is radius of the specimen. And here this inclined length this is the strained length, length extended length, which is x. So, by this ratio we can calculate the strain value. So, using the CBR puncture test, we can also get idea about the tensile strength and tensile strain.

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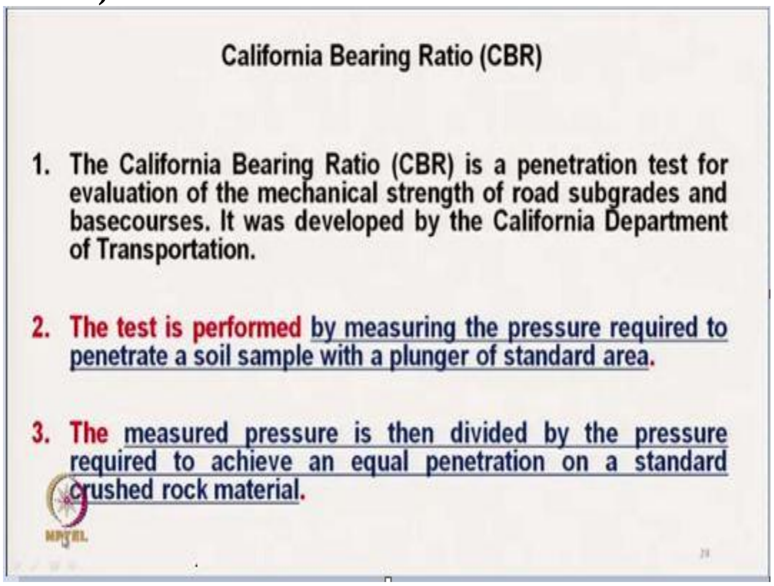

Now, coming to actual CBR, CBR testing California bearing ratio test for soil particles, it is a penetration test for evaluation of mechanical strength of roads subgrade and basecourse. So, road subgrade strength compressive strength we must know, it is developed by the California Department of Transportation that is why the name is California bearing ratio. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area.

The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. So, this standard crushed rock material is basically which is very hard. And if we compare the pressure required with the actual actual specimen, then we will get a one ratio that is called California gearing ratio.

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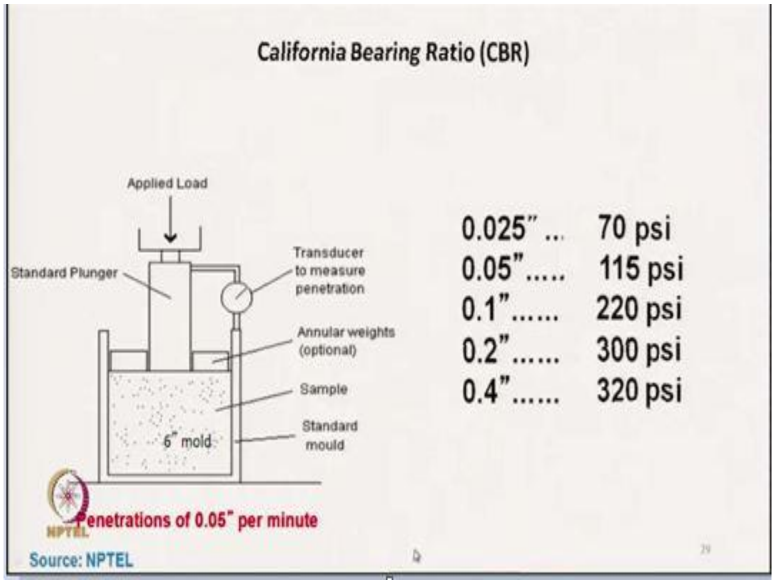

Here if we see that for a given soil we have got a data this data 0.025 inch penetration for that penetration we need to apply 70 psi pounds per square inch. And gradually if we want to penetrate the this plunger at higher distance, we need to apply higher pressure, typically 0.1 inch and 0.2 inch this to data are taken, the pressure required to penetrate 0.1 inch and pressure required to penetrate 0.2 inch is taken to calculate the California bearing ratio.

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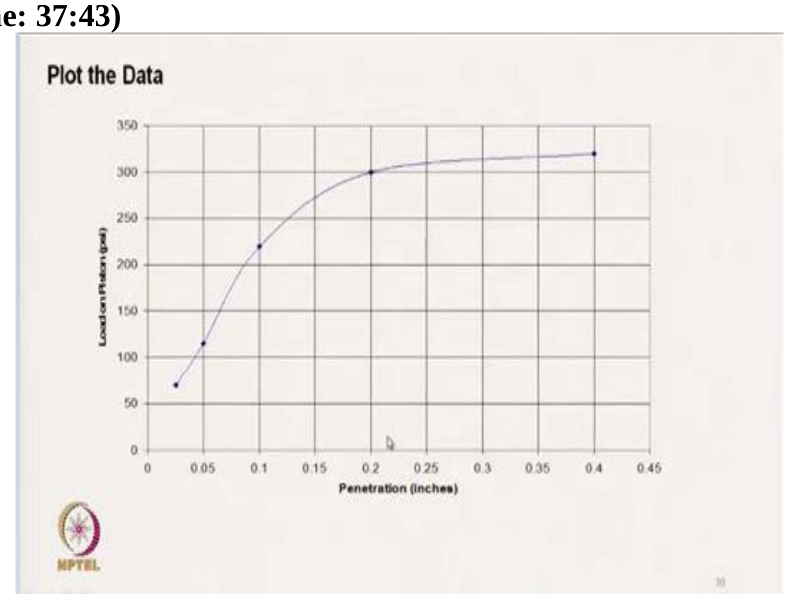

This is the plot we get that is the penetration and the load value or we can get the pressure value. this from this data. This is a plot and from this data we can calculate the CBR value. So let us take 0.1. Here it is 0.1 is coming it is a 220 psi, 0.2 here it is a 300 psi, 0.2 inch.

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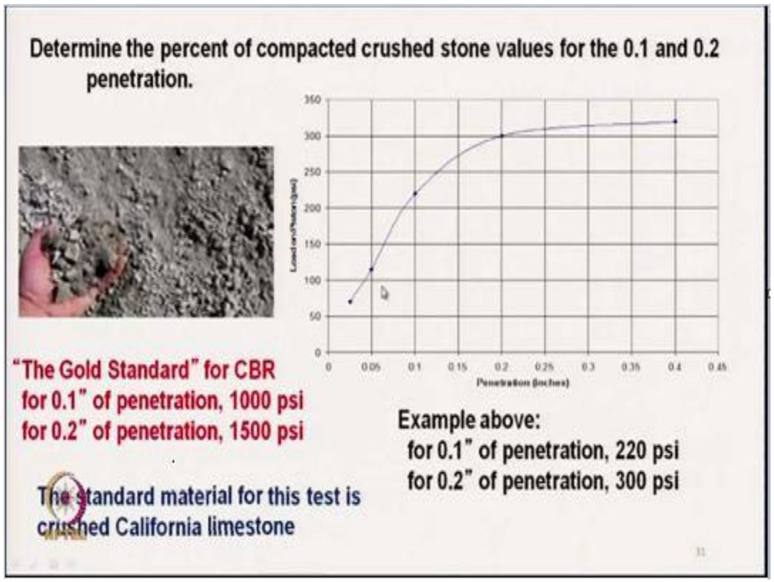

And for standard value is that for gold standard CBR is 0.1 inch. This is the standard material for the test in crushed, California limestone. This is the crushed California limestone. This is the standard value for 0.1 inch penetration, we need 1000 psi or for 0.2 inch penetration we need 1500 psi. Now if we get the ratio between, say 0.1 or if we take in 0.1 inch penetration 220 divided by 1000 multiplied by 100. So that is the percentage that is the actually called California bearing ratio and if we want to calculate at 0.2 penetration, so, that will be 300 divided by 1500.

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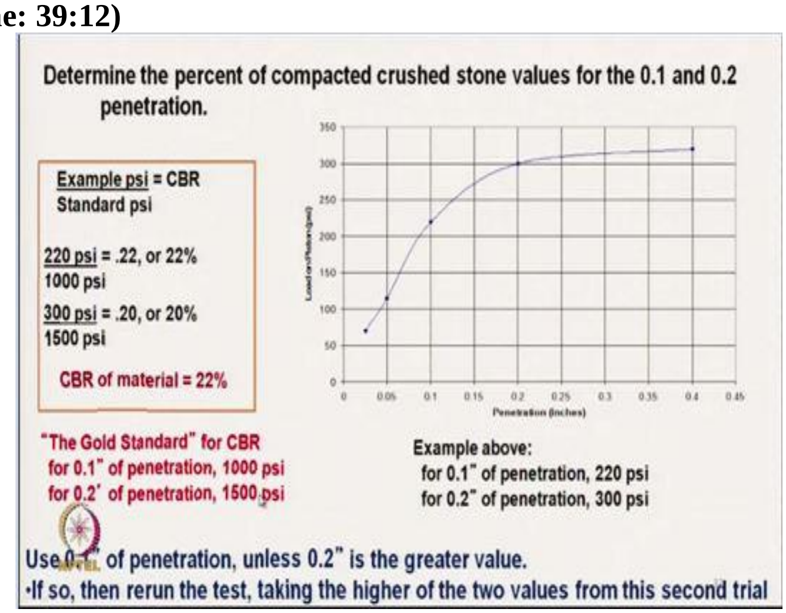

So, in this way, if we see for 0.1 penetration, we are getting 22% is the CBR value or directly we can normally we express 22 and 0.2 penetration we get 20%. So, among 0.1 and 0.2, we tried to get the CBR value which is higher, that is the standard value. So, for this example, the CBR of the material is 22%. So, accordingly if we know the CBR value, we will get idea about the, the compactness of the soil or compressibility of this soil.

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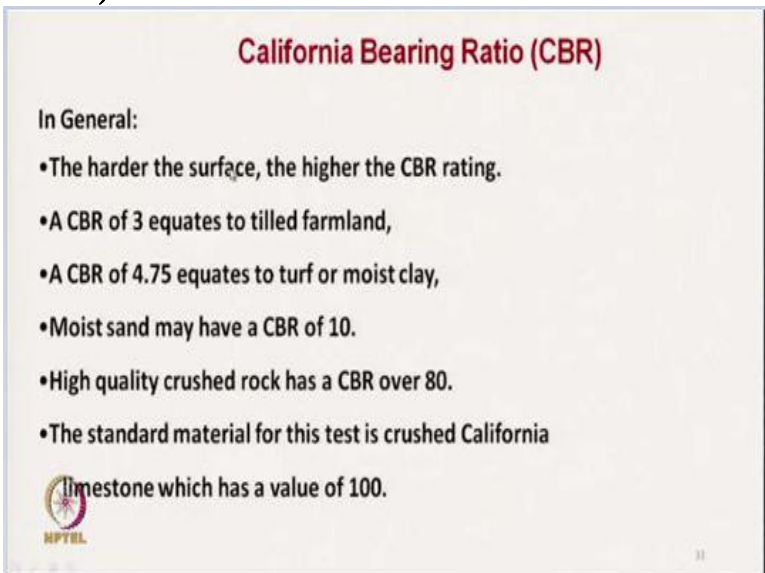

So, if we get the, try to see the standard value CBR value, the harder the surface the higher is the CBR value, a CBR of 3 equates to tilled farmland, very weak farmland, the CBR is 3 and moist clay it is 4.5 and high quality crushed rock CBR is 80, like that and California limestone which is definitely 100. So, as this is the reference value and accordingly we can calculate the CBR value. So, higher the CBR value the stronger that is the rock or the surface will be very hard.

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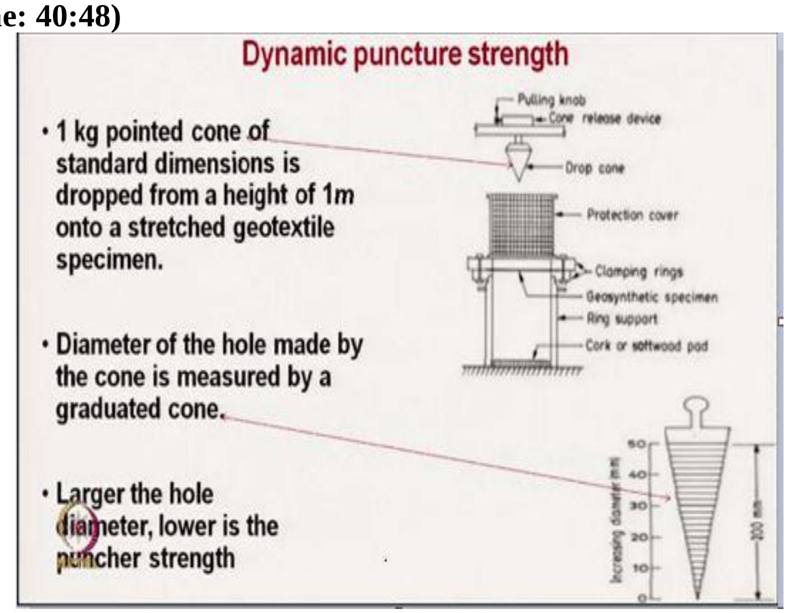

Another parameter which is important is a dynamic puncture strength. This type of situation can occur during laying of geotextile so, where the 1 kg pointed cone is dropped freely on geotextile and the length of penetration we can calculate. So, here it is gazed at different height, it is gazed and the diameter we know at different height, the diameter will be different. So, the diameter of the hole made by the cone is measured by a graduated cone. This is the graduated cone we can directly measure the, what is the diameter of the hole, larger the hole, lower is the puncture strength we will get direct idea.

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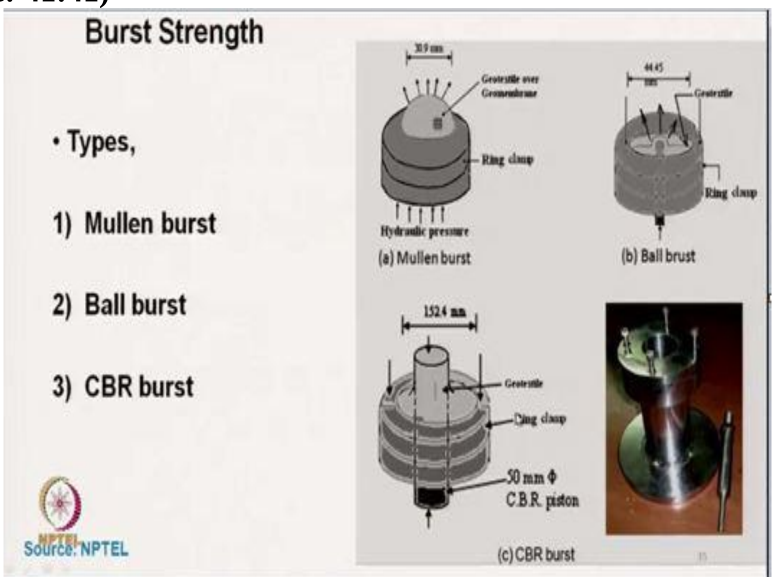

Then another mechanical characteristic which is Mullen as the busting strength. There are 3 types, Mullen bursting strength, ball bursting strength and CBR bursting strength. This CBR testing it is used for puncture resistance also and here we can use as bursting data. So in Mullen bursting strength where the diaphragm is used and ball bursting strength, here one puncher will be used with a ball at the seam and CBR bursting strength is here one plunger with it is a cylindrical plunger is used.

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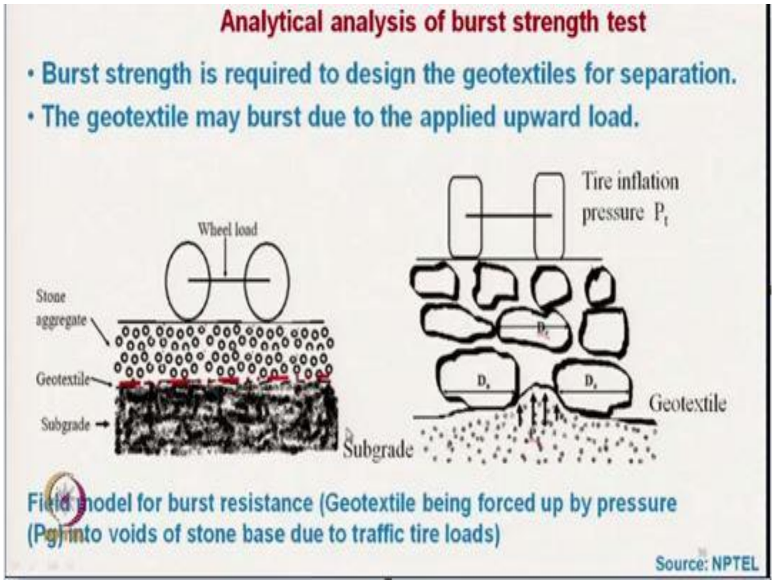

In most of the applications it is actually this type of Mullen bursting strength is used. So, burst strength is required to design the geotextile for separation again, the geotextile may bust due to the applied upward pressure.

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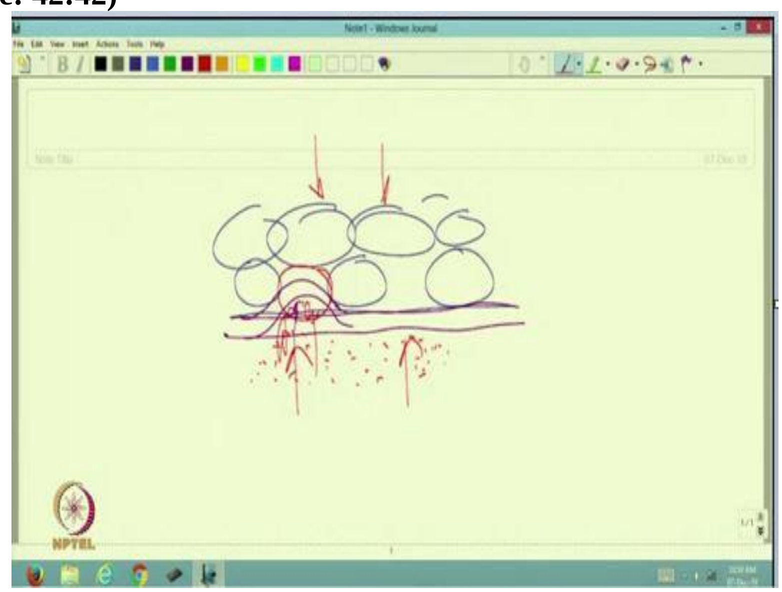

Now here this is these are the stones ok. Here it is used as separating material, geotextile is used as separator and at the bottom there are soft soils. So, this separation function is that this geotextile is actually not allowing this soft soil to penetrate inside, but once the pressure is applied this soft soil will be pumped, try to be pumped inside and this type of situation will occur. So, this soil will try to penetrate inside.

So, here the bursting situation is created. So, field model for bust resistance. This is a picture here, geotextile being forced up by pressure Pg. This is the Pg pressure geotextile, into void of stone due to these are base soil, there is a stone that is why it is pumped inside and mainly bursting pressure is created in this zone.

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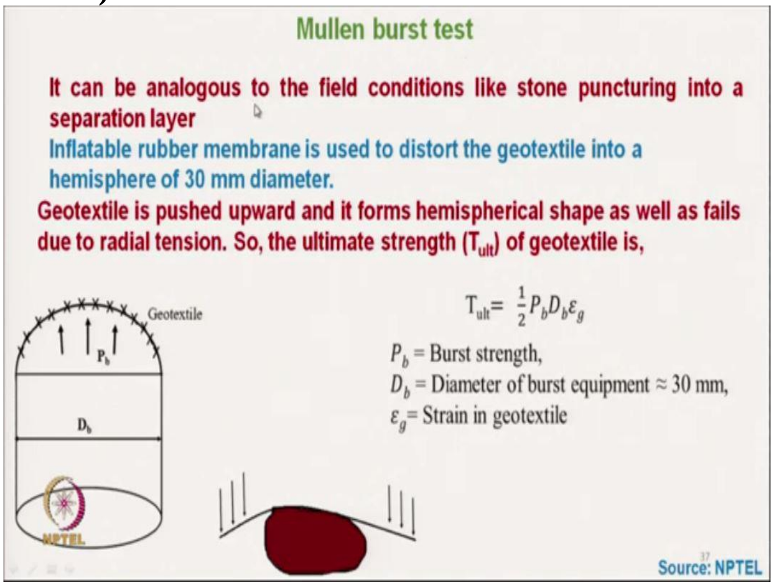

So this Mullen burst test it is analogous to the field condition like stone punching into the separation layer that I have explained the inflated rubber of certain diameter, the hemispherical condition is created and here as geotextile is pushed inside, so we can calculate the ultimate strength. This is the ultimate strength of the geotextile, it is tensile strength and that can be related with the busting strength by this empirical formula. Its half P b, which is the bursting strength D b is the diameter of burst equipment.

This is the diameter of bust equipment and E g is a strain in geotextile. So, if we know the strain in geotextile, and diameter and bursting strain, so that we can predict the tensile strength or on the other hand, if we know the tensile strength and diameter and allowable elongation or elongation taking place in geotextile, we can calculate the bursting pressure.

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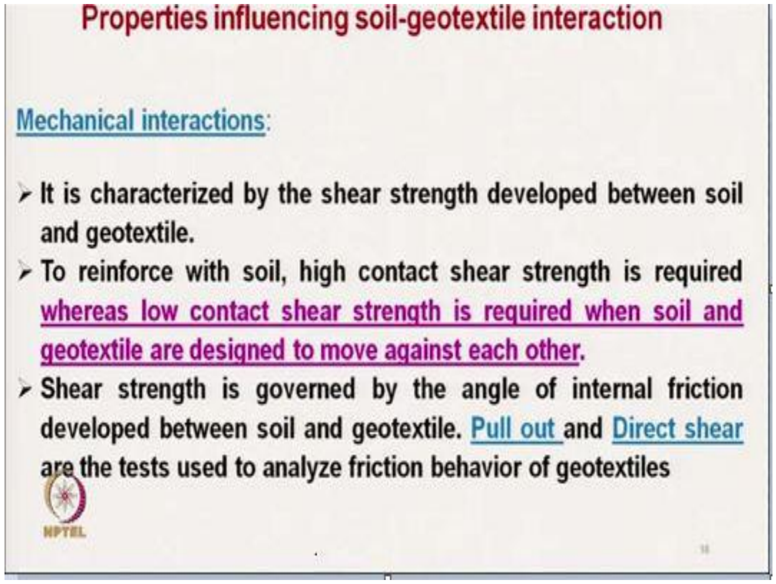

Next mechanical characteristic is that which I have already explained, I am not going to explain here in detail. So, mechanical characteristic is the mechanical interaction, the shear stress is developed shear strength is calculated against the soil. So, it is done by pullout test and direct shear strength test.

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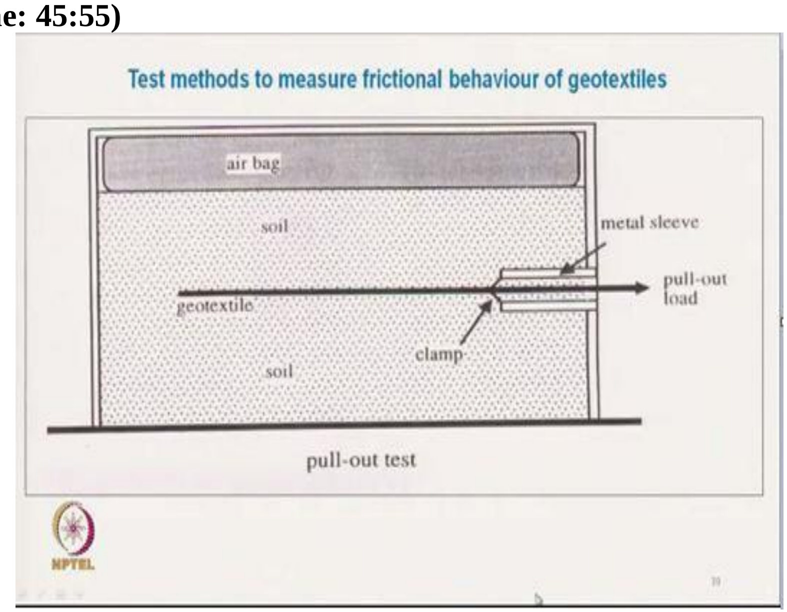

So, here the geotextile is confined in between the soil in both the sides. So, it then pulling force applied and depending on the fictional interaction, the pulling force will change so, from this pulling force we can calculate the interaction between the geotextile and soil.

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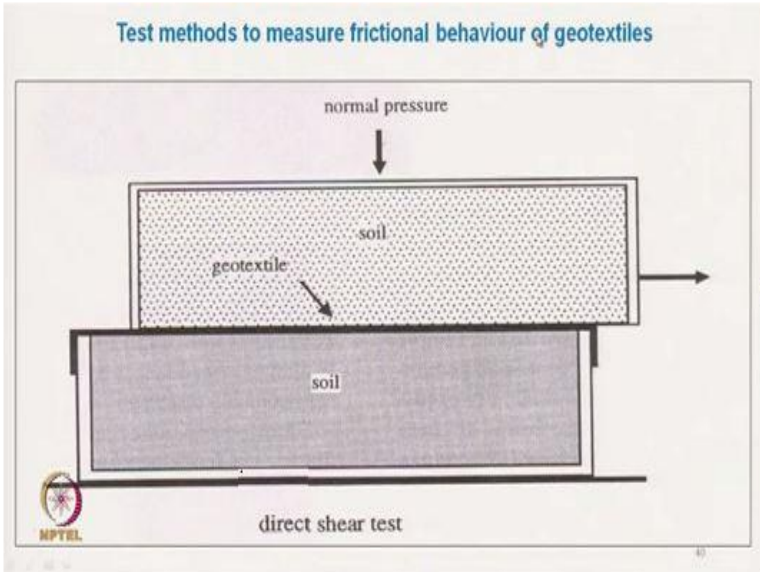

Another method is that it is a direct shear test. Where this is a base soil and top soil is there and on the base soil, there are 2 blocks. On the lower block geotextile is covered with a geotextile and then top soil it is actually slide and it is sheared against the geotextile and we can calculate the shearing force.

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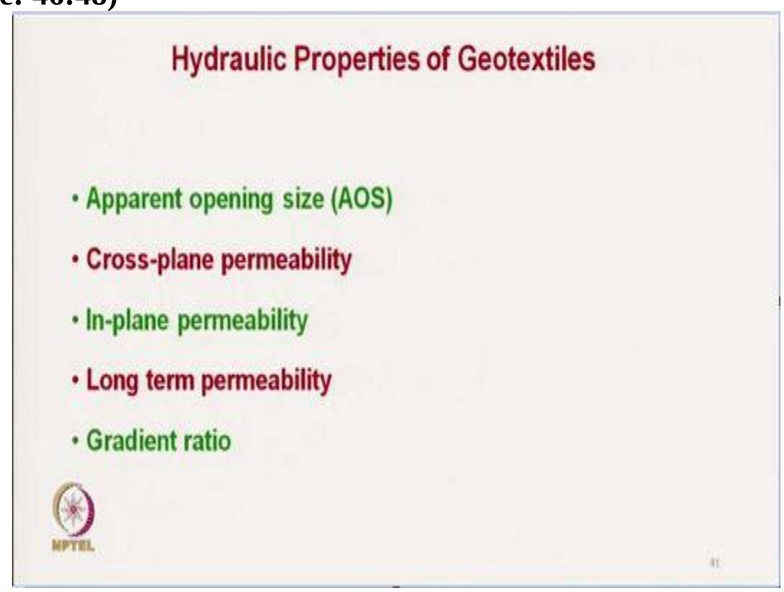

And next characteristics are hydraulic properties and that I will discuss in next class. Till then thank you.