Testing of Functional & Technical Textiles
Prof. Apurba Das
Department of Textile Technology
Indian Institute of Technology, Delhi

Lecture-18
Testing of Geotextiles

Hello everyone. So, we will continue with the course Testing of Functional and Technical Textiles. Now let us first see what we have already covered in this course. Here in this course we have already covered the testing of functional textile part, then we have started testing of technical textiles segment.

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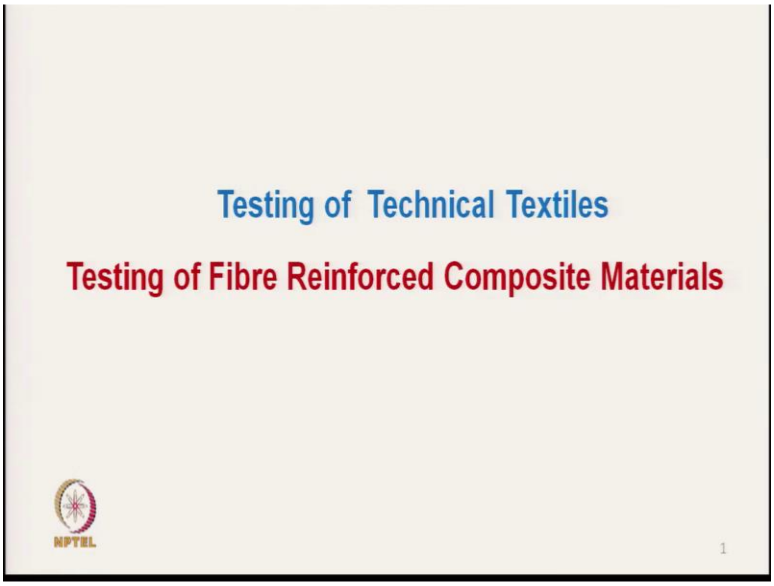

And in this segment we have already discussed testing of fibre reinforced composite material.

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After finishing that, we have discussed testing of filter fabrics. Now we have completed that segment and today we will start Testing of Geotextiles.

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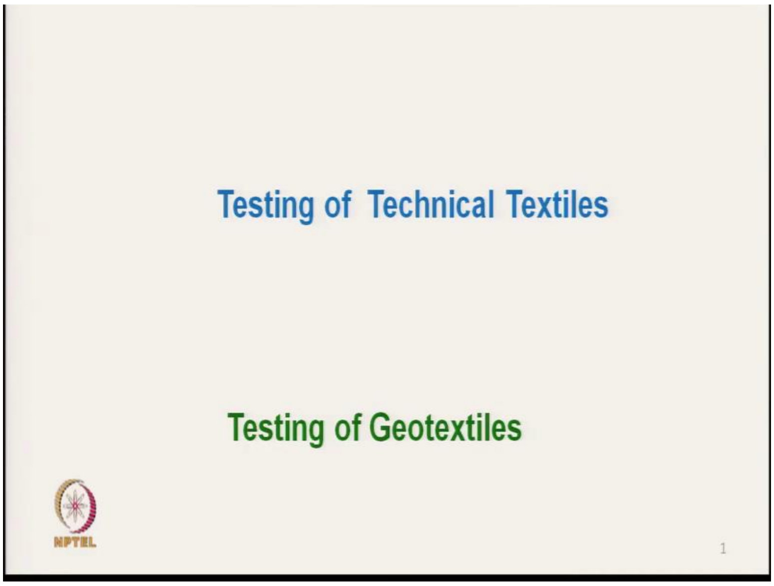

So, first we will try to understand, what is geotextiles, what are their functions? And then we will discuss various test methods for geotextiles.

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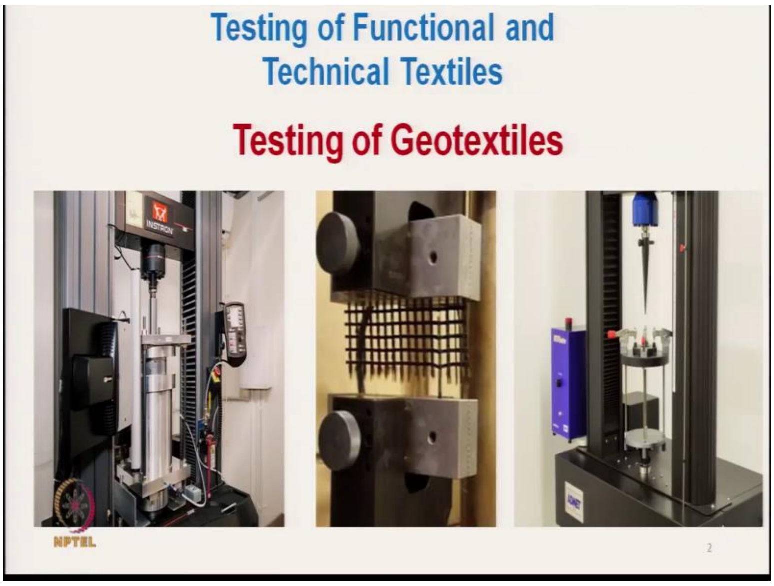

So, geotextile testing are of different types; tensile, puncture, compression, hydraulic characteristics.

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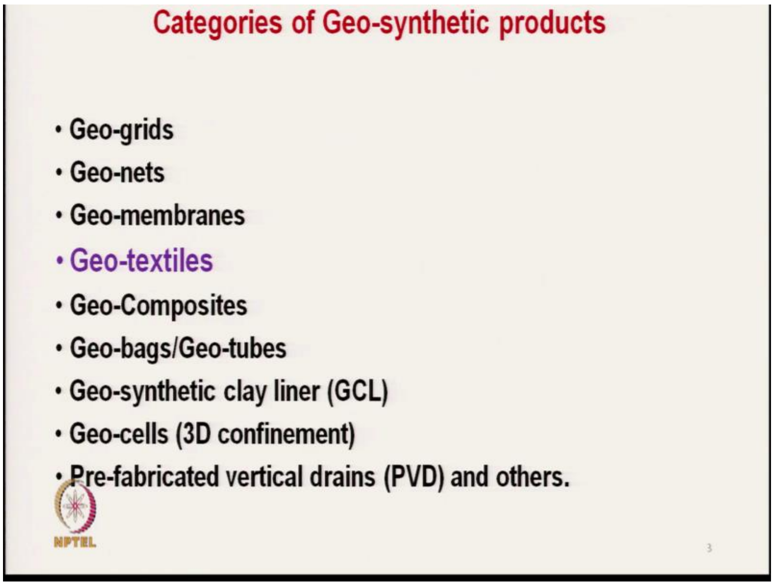

So, if we try to categorise the geosynthetics; that means, geosynthetics are the material which are used for civil engineering construction related to soil or related to any other construction. So, this geosynthetic products can be categorised in terms of geo grids, geo nets, geo membranes, geotextiles the part which we will cover here, geocomposites, geobag or geotubes, geo synthetic clay liner, geocell which is 3 dimensional confinement

Prefabricated Vertical Drains PVD and there are different other materials. But in this course our main focus will be on testing of geotextile products.

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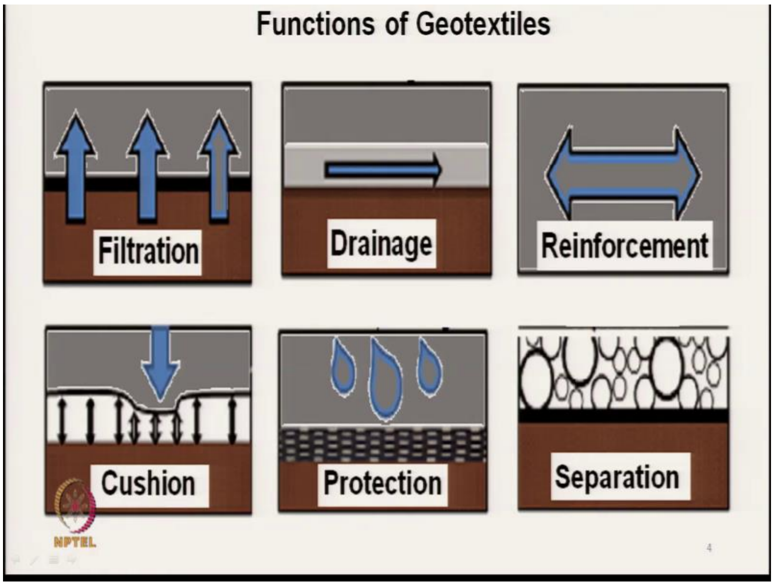

First let us try to understand, what are the different functions of geotextiles? See if we understand the functions then we can access the needs and types of the testings. First is the filtration which is extremely important function, where geotextile has to restrict the soil or sand particles, but at the same time it should allow the water to flow through. So, for that we need to understand the filtration behaviour. And next function is the drainage its also very important function where geotextile needs to drain out the excess water so, that accumulation of water is not there in a particular place. And if accumulation is there then the strength of the structures that is soil structure will be dropped.

So, the drainage behaviour is extremely important. Third another important characteristics is reinforcement characters. The geotextile is used to reinforce the soil structure. We will see as the moisture content in the soil increases, the soil strength reduces. So, geotextile is used to reinforce the structure. Next function is cushioning; when the load is applied or vertical pressure is applied on the structure, geotextile has to absorb certain amount of load so, that the structure remains intact. Next function is protection; protection of the structure like penetration of water reduces the strength of the soil structure.

So, to protect the structure if we use water impermeable geotextile, then the strength of the structure will be intact. Another most important function of geotextile is the separation. If we see for any construction like road, railway track this type of constructions the soil layers are of different type. At the bottom which is shown here by the brown colour if it is sub soil soft soil and after that if we use the gravel of stones of certain size directly then this stone will penetrate inside the soft soil and the structure will collapse.

So, the permeability characteristics of this structure will be lost therefore, we need to separate out this two entirely different materials so, that individual component will have their own identity. So, here geotextile is placed in between these 2 surfaces and their individual identities are maintained. So, after understanding the functions that is basic functions of geotextiles, let us first try to see why do you need to test geotextiles?

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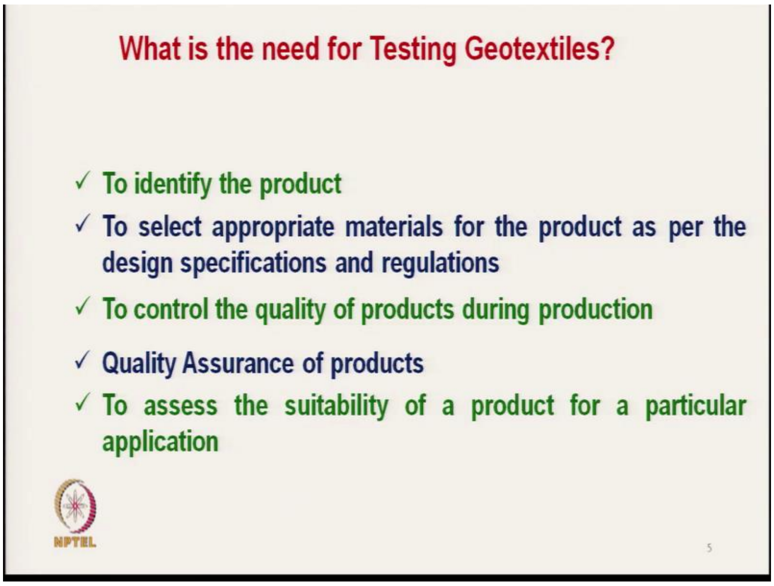

So, first need is that to identify the product. So, we have say n number of products, we need to apply particular geotextile material for a particular use, where we need particular strength or particular thickness or may be any other characteristics. So, to identify that, we must to we must test the product. Next is that to select appropriate material for the product as per the design specification and regulation. So, our targeted product is there as per the design specification or as per the regulation. So, for that product, we need to select raw materials and for that we need to test them.

Next requirement is that the quality control during production. We must test the material during production to achieve required product. Then for quality assurance of the product we need to test them to assess the suitability of a product for a particular application. So, there are different applications and those applications will require different products of different specification. So, for that we need to test the material.

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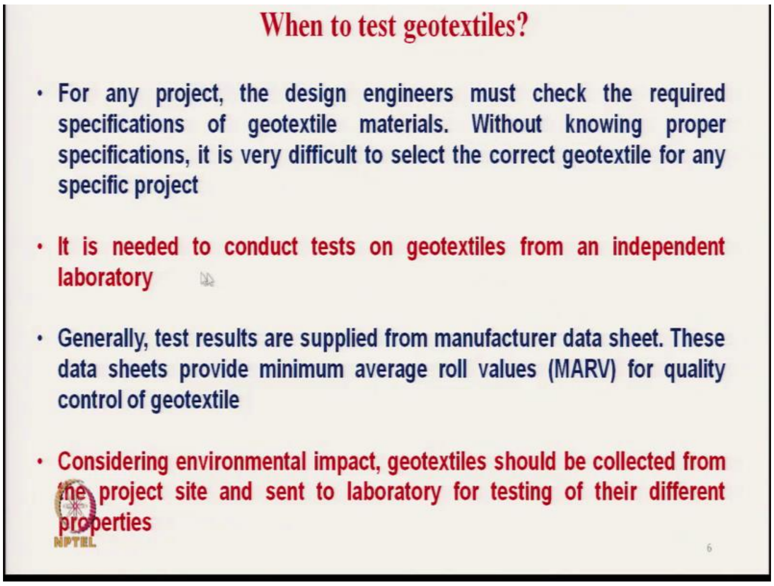

Now, when to test geotextile? For any project for any civil engineering project the design engineer must check the required specifications of geotextile material without knowing proper specification it is very difficult to select correct geotextile for any specific project.

Suppose a particular project requires a filtration characteristics, there the strength may not be required. So, you must test the material as per the requirement. It is necessary to conduct test on geotextile from an independent laboratory why is it necessary? Because the supplier will also try to project the product with the positive attributes.

So, it is important to get the material tested from an independent laboratory, to get correct picture. Because after using geotextile if it fails then not only the geotextile will fail total structure will be collapsed. Generally, test results are supplied from the manufacturer these data sheets provide Minimum Average Roll Value MARV for quality control only, but actual test data we have to get from an independent laboratory.

Considering environmental impact, geotextiles should be collected from the project site. The test which we normally do in isolation that may not be suitable for most of the geotextile testing. So, we have to get the sample collected from the exact site and then the sample should be tested in the laboratory. Now there are standards for collection of test specimens.

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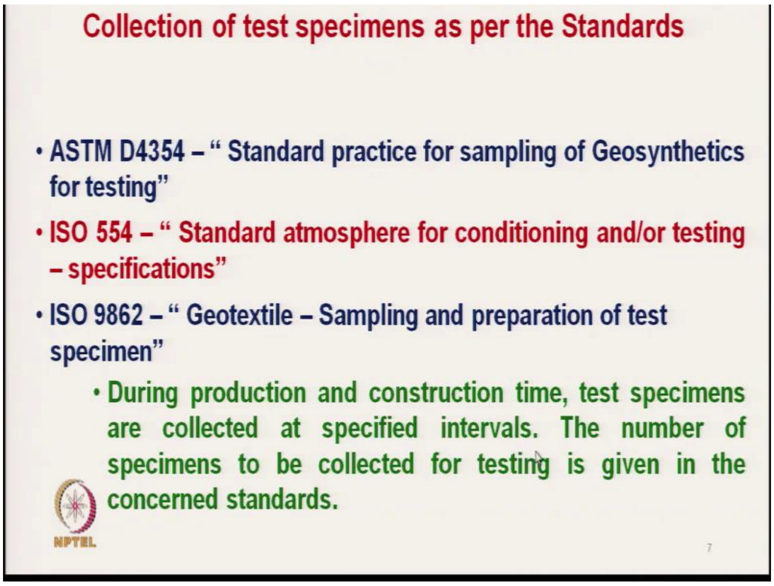

So, this standards are ASTM D4354 which is standard practice for sampling of geo synthetics for testing, then ISO 554 which is specifying the standard atmosphere for conditioning and or testing specifications ISO 9862 Geotextile sampling and preparation of test specimen.

So, during production and construction time, test specimens are collected at specified interval. The number of specimens to be collected for testing is given in the concerned standard. So, we have to collect the specimen from the site.

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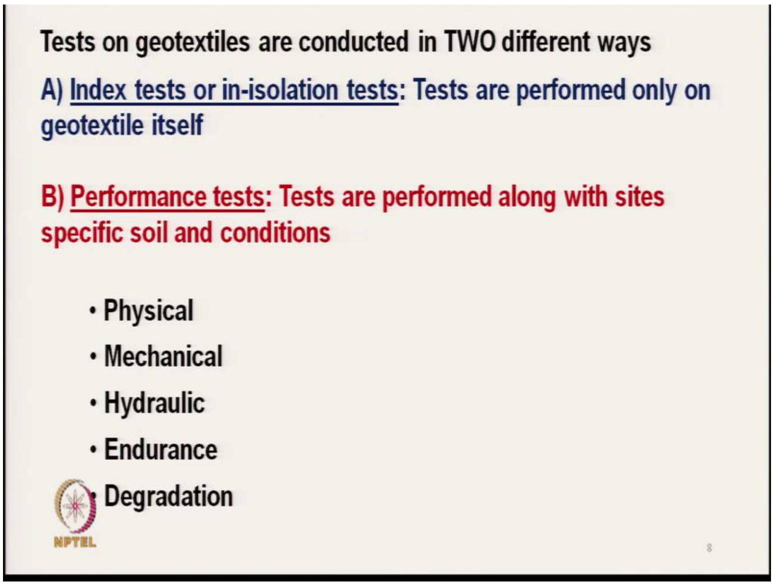

So, there are two different types of test which are conducted on geotextiles. One is called index testing or in isolation test, which actually test in the laboratory condition. So, only the tests are performed on geotextile next is that its called performance test what is that? The performance test are performed along with site specified soil and conditions.

So, index test will only give an idea and comparative value between the geotextiles which is good or which is bad comparatively, but the better geotextiles as per index test may not perform well in performance test. Because in performance test we have to test along with the site specified soil and site specified condition. So, there are different types of tests conducted on geotextile materials, these are physical testing, mechanical test, hydraulic test, endurance test degradation test. So, we will discuss each and every methods in our next discussion.

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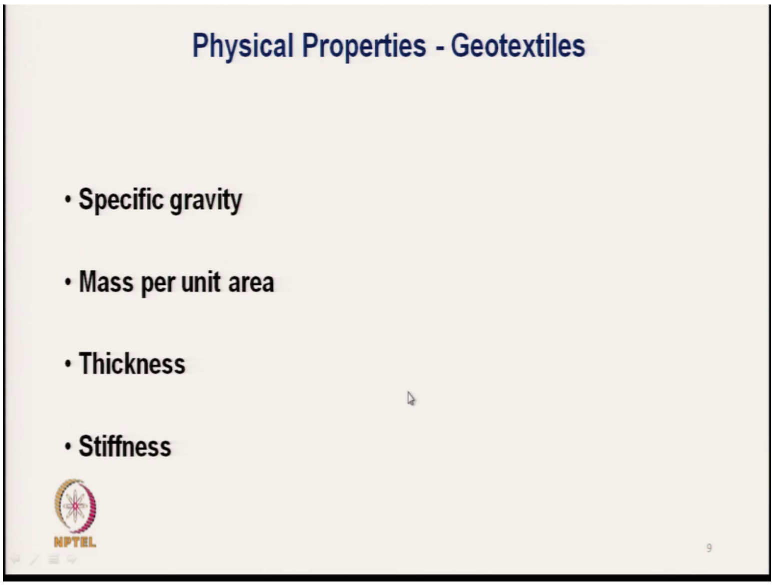

In physical test if you see physical properties of geotextiles, mainly specific gravity, mass per unit area, thickness and stiffness. These tests are coming under physical properties of geotextiles first let us see how to test the specific gravity.

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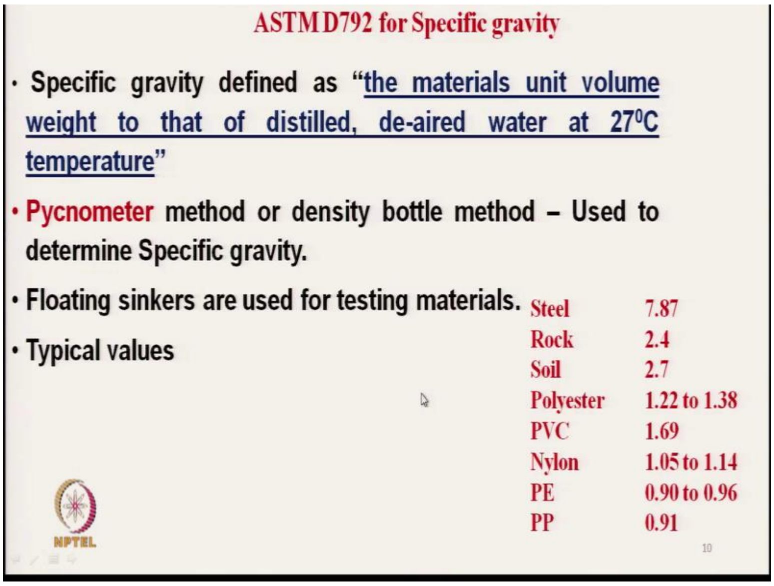

So, this specific gravity is actually defined as the materials unit volume weight; that means, mass per unit volume that is density to that of distilled, de aired water at 27 degree Celsius temperature. That means, ratio of mass per unit volume that is ratio of density of material to that of distilled water.

So, there are different methods of measurement of specific gravity. The method is pycnometer method; pycnometer method or density bottle method, which is used to determine the specific gravity of geotextile material. So, pycnometer or density bottle method they are very commonly used for measuring the specific gravity, floating sinkers are used for testing materials. The typical values are these are the typical values of specific gravity for comparison like steel 7.87, rock 2.4, soil 2.7 like this polyester 1.22 to 1.38, PVC 1.69, nylon 1.05 to 1.14 polyethylene 0.90 to 0.96 polypropylene 0.91 like this. So, we can test the specific gravity using pycnometer method.

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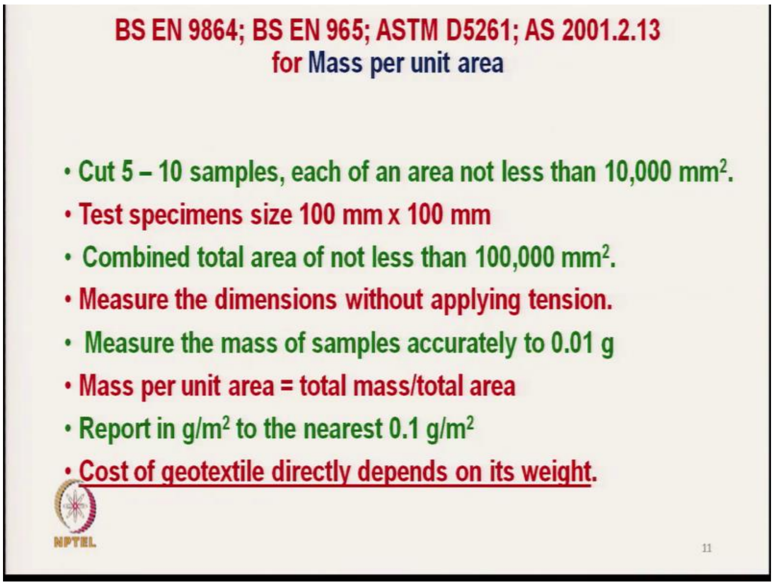

Next characteristics is mass per unit area; we can test mass per unit area by many standards like BS EN 9864, BS EN 965 ASTM D 5261 ASTM 2001.2.13 any method we can use and this methods if you follow, we can get the mass per unit area of geotextiles. So, here what we have to do we have to cut typically 5 to 10 samples each of having area not less than 10000 square millimetre; that means, if you want to get the sample specimen.

So, minimum size should be 10 centimeter by 10 centimeter. So, that is the test specimen size and combined total area of not less than 100000 square millimetre. So, for geotextile we need to test larger size. So, at least such 10 samples should be there, measure the dimensions without applying tension. So, we have to test in relaxed condition. Then we have to take the mass of this specimen with an accuracy of 0.01 gram and from there we can calculate the mass per unit area total mass by total area. So, we have to add all the specimen's area and you have to add all the specimen's mass to get the mass per unit area and reporting the mass per unit area with an accuracy of 0.1 gram per square meter.

Basically the importance of mass per unit area is that the cost of geotextiles, they are directly dependent on the mass per unit area next is the thickness.

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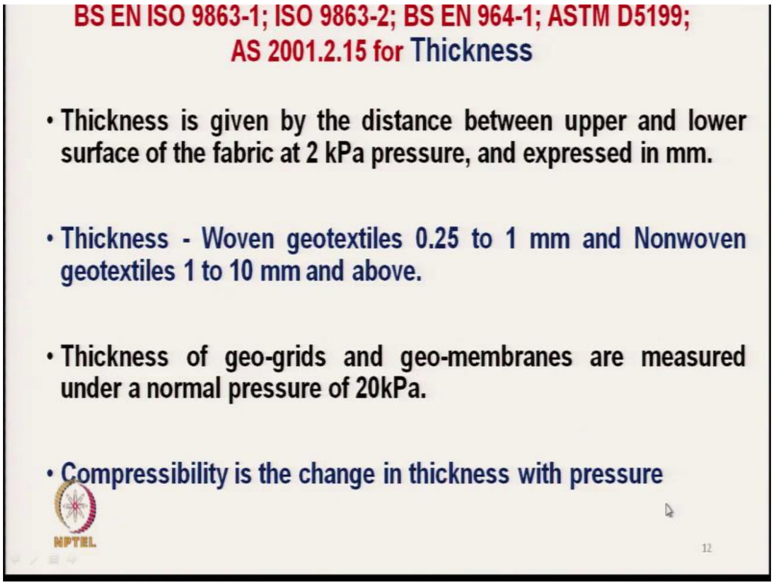

So, we can use all these methods like BSEN ISO 9863-1, ISO 9863-2 BSEN 964-1 ASTM D 5199, Australian Standard AS 2001.2.15. So, any of the methods we can follow. So, thickness is given by the distance between upper and lower surface of geotextile, when we apply a pressure of 2 kilo Pascal and its normally its expressed in terms of millimetre. And for geotextile if it is woven geotextile the range is typically around 0.25 to 1 millimetre, the thickness and nonwoven geotextiles it is around 1 millimeter to 10 millimeter and above.

So, very thick nonwoven geotextiles are used, but if it is woven its around 0.25 to 1 millimeter thickness. Thickness of geogrid and geomembranes which are not so, compressible, the pressure which is applied is of the order of 20 kilo Pascal. For geotextile we use 2 kilo Pascal for geogrid and geomembranes we use 20 kilo Pascal and compressibility is the change in thickness with pressure. So, we can test compressibility also if we change the normal pressure and record the thickness of the material.

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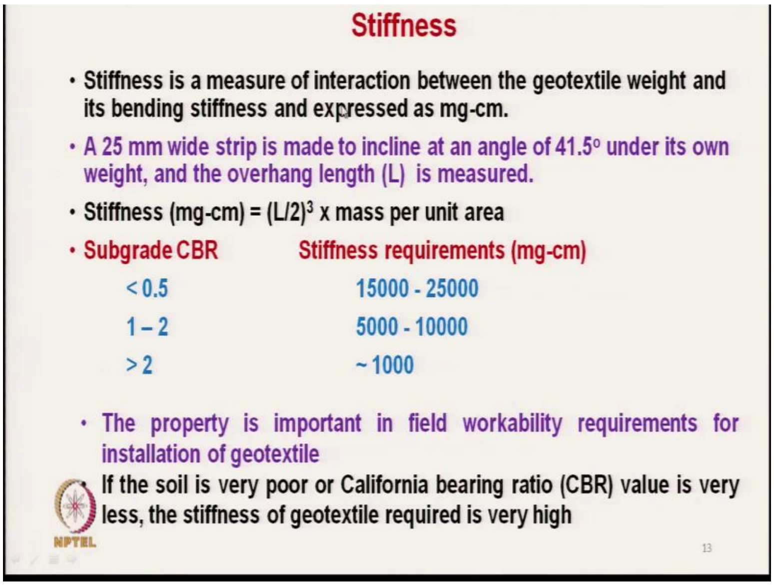

Next important physical characteristic is the stiffness; what is that? Stiffness is measure of interaction between the geotextile mass and the bending stiffness and which is expressed in terms of milligram centimetre. So, where the bending stiffness and mass of geotextiles are incorporated. For same bending stiffness if the mass of geotextile is changed then the stiffness value will get changed. So, that is why in the equation both the stiffness value and the mass per unit area these are incorporated.

How do we get the stiffness value? Bending stiffness value we get when 25 millimeter wide strip is made to incline at an angle of 41.5 degree under its own weight and the overhanging length L is measured. Its as per the shirley stiffness tester which you have learnt in other course, here also in this course we have discussed in functional textile segment.

And we can measure the overhanging length L and stiffness value in milligram centimetre we can calculate by using the formula,

- **Stiffness (mg-cm) = $(L/2)^3$ x mass per unit area**

And this stiffness value is very important for design application like subgrade soils CBR value CBR what is CBR? CBR is California Bearing Ratio we will discuss in detail which represent the strength or hardness of soil. So, higher the CBR value; that means, harder will be the soil. So, if CBR value is less than 0.5; that means, its a soft soil in that case we require stiffer material. So, higher stiffness means higher more the stiffer stiffness of the material. So, if it is 0.5 or less we require 15000 to 25000 1 to 2 CBR value of soil subgrade 5000 to 10000 and more than 2 its typically around 1000 stiffness.

So, for soft soil we need stiffer geotextile. So, that the structural integrity is maintained. We can have flexible geotextile if the subsoil is strong enough or hard enough the property is important in field workability requirement as I have just discussed. If the soil is very poor or CBR value is very less, we need stiffer textiles. After physical characteristics now we will start the mechanical properties of geotextiles.

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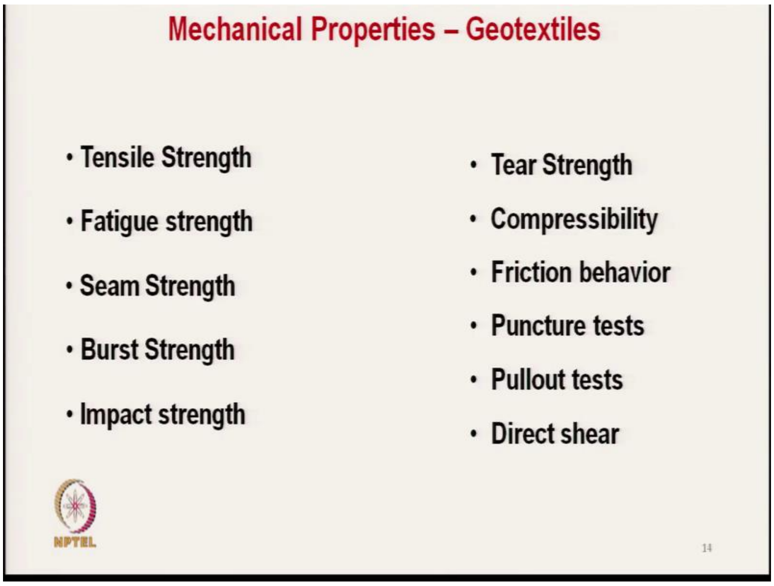

In mechanical properties there are tensile strength, fatigue strength, seam strength, bursting strength, impact strength, tear strength, compressibility of geotextiles, frictional behaviour of geotextiles, puncture tests, pullout test and direct shear test. So, we will discuss all these test methods one by one first let us start with the measurement of tensile strength.

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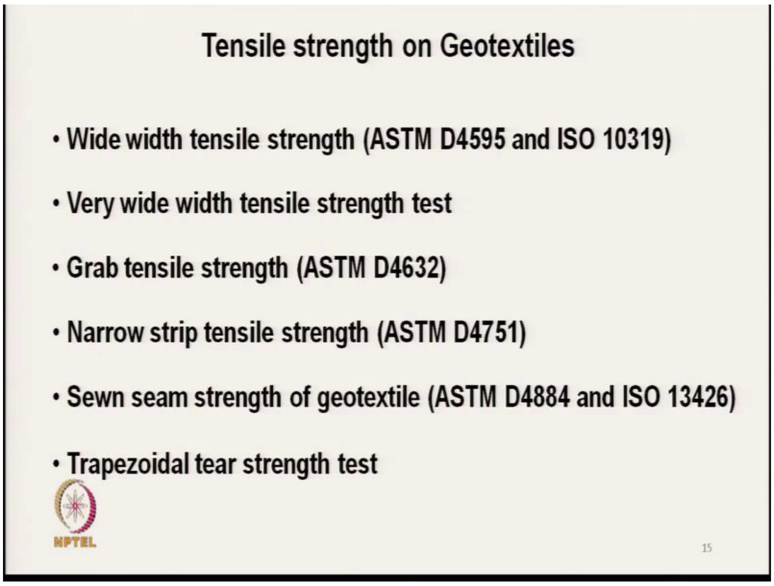

So, there are different types of tensile strengths, first is wide width tensile strength its as per ASTM D 4595 and ISO 10319, then very wide width tensile strength next is grab tensile strength as per ASTM D 4632, then narrow strip tensile strength which is as per ASTM D 4751, third sewn seam strength of geotextile this is actually tensile strength, but in the seam portion because geotextile when we are laying we must incorporate stitches.

And the strength of the stitched portion is evaluated by this method. So, sewn seam strength of geotextile is measured as per ASTM D 4884 and ISO 13426 method. Another tensile strength is in terms of trapezoidal tear strength test. Although we can place this in different categories, but as the test procedure is similar to tensile strength we can discuss here also.

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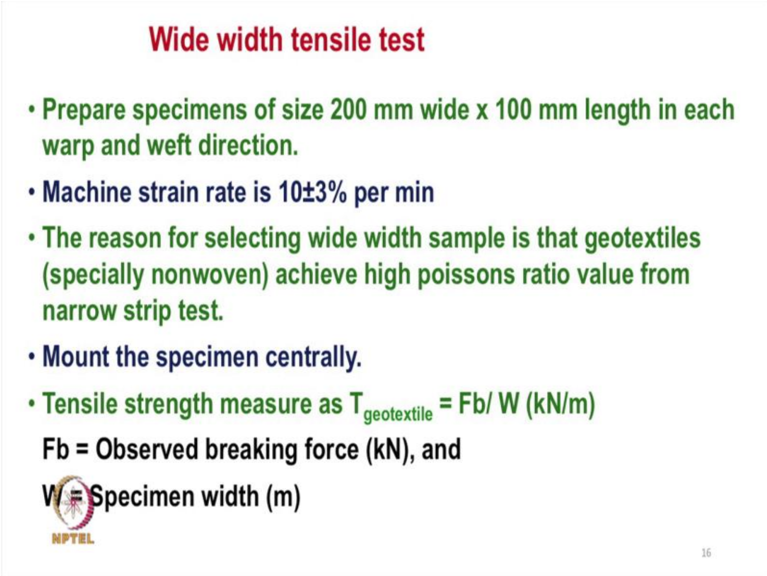

First we will discuss the wide width tensile test, where you must prepare a specimen of size 200 millimeter wide, so, 20 centimetre wide and 10 centimeter length in each warp and weft direction.

If it is woven we need to test wide width tensile test, because when geotextile is laid under the ground this wide width tensile strength is actually stimulating the insitu condition. Machine strain rate is 10 ± 3/min that is 10 ± 3 % of the breaking elongation. The reason for selecting wide width sample is that, geotextile specially non woven geotextile achieve high Poisson's ratio when we test the narrow width test. So, to reduce the Poisson's ratio we try to test in wide width tensile test. So, we have to mount the sample centrally and tensile strength is measured by observed breaking force in kilo Newton by width of the specimen.

So, Fb/W (kN/m). Here we do not measure in terms of Newton per tex or like that as we test normally for narrow width test, but in wide width tensile test to expressed in terms of kN/m.

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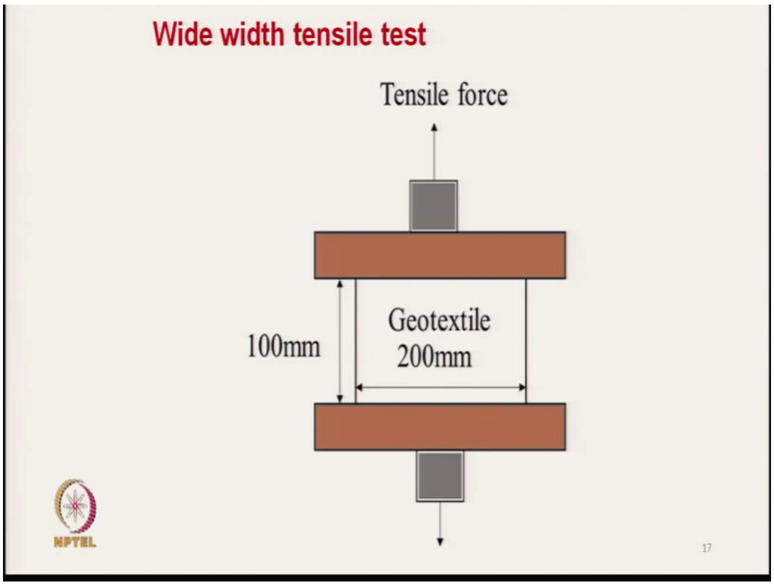

This is the schematic diagram where width of the geotextile is 200 mm and length of the specimen is 100 mm, actual specimen length will be more than this, but gauge initial gauge length is 100 mm. So, due to this wide width the Poisson's ratio is restricted and this value the result which we get here from wide width tensile test it simulates the actual field condition.

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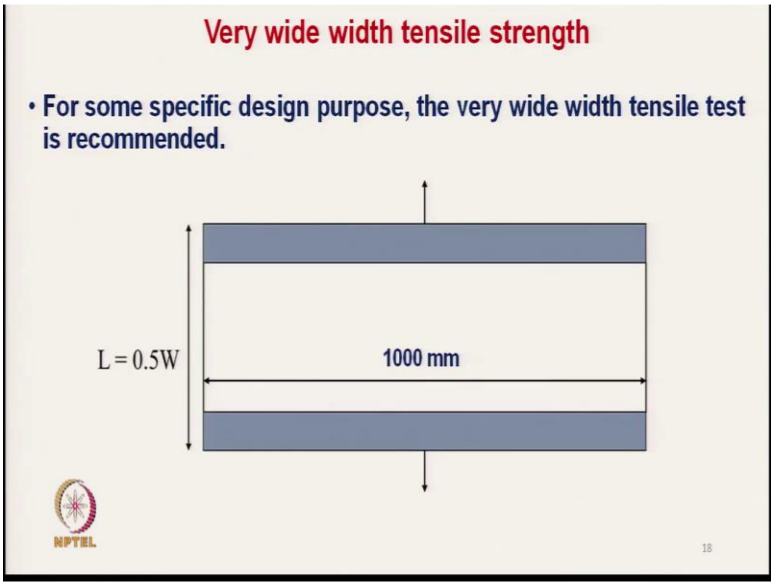

In some application we may need very wide width tensile strength. So, where the width of the specimen is as high as 1 meter width. So, we have to design the jaw accordingly and the length is half of that. So, half metre, 1 meter by half metre its the actual test specimen size.

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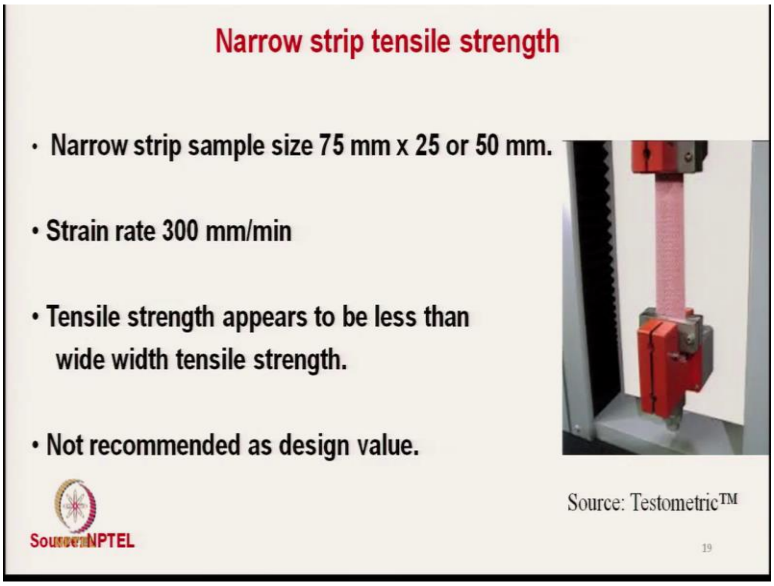

We sometime test the geotextile in narrow strip tensile mode also, but size of the strip is 75 mm by 25 mm strain rate is 300 mm/minute tensile strength appear to be less than the wide width tensile strength here. And this test its for index testing only, its not recommended for design value. So, the value we cannot use for designing the geotextiles for using in any project.

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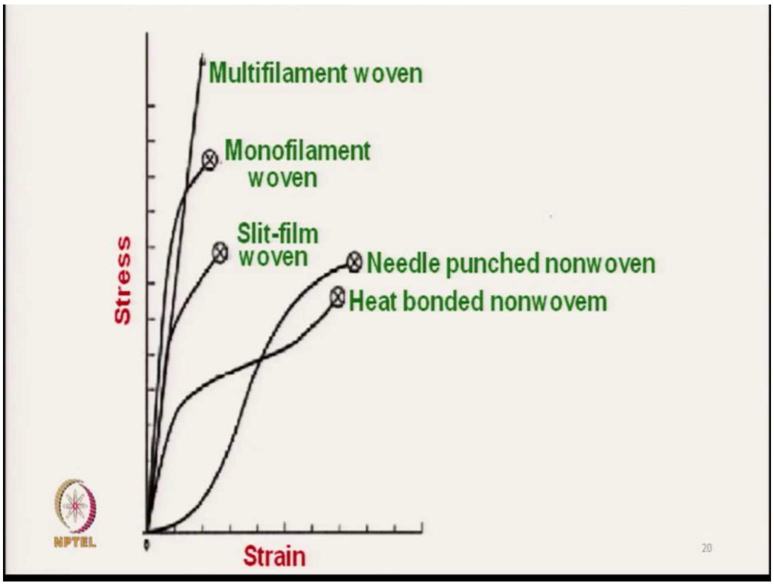

So, if we see the comparative stress strain curves for different types of geotextiles, here its a monofilament woven fabric and next one is multifilament woven fabric. So, monofilament woven fabric although the breaking stress is less than the multifilament woven fabric, but the monofilament woven fabric has got higher modulus. Multifilament woven fabric has relatively lesser modulus than monofilament, but this multifilament woven fabric has got very high tensile strength.

Next is the slit film woven fabric which has lesser strength, but it has got high modulus value. And as far as non woven geotextiles are concerned, the needle punched non woven geotextile has got least modulus and after certain strain the fabric starts showing of stress due to re orientation of the fibres whereas, heat bonded non woven fabrics they have relatively higher modulus.

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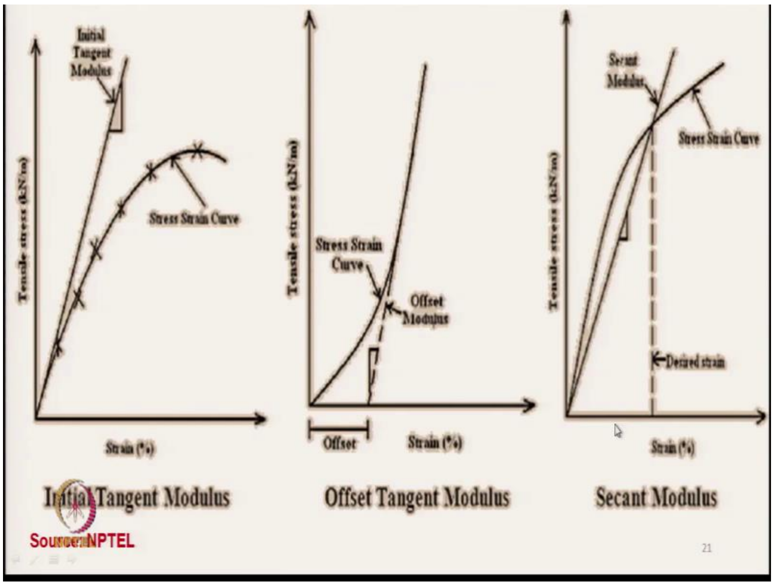

So, these are the different curves stress strain curve this curve in the left side which shows the initial tangent modulus. So, this is actual curve stress strain curve if we take the tangent and from there we can calculate the initial tangent modulus. We can also calculate the offset tangent modulus which is required for geotextile design for any construction. This offset tangent modulus is that, its a modulus for any offset value for any particular stress value or strain value, we can get the tangent at that point.

Another important parameter is a secant modulus this is again the modulus between the origin and any specific point. So, at say particular strain value desired strain value if we want to know the secant modulus. So, we can calculate by drawing the straight line between origin and at that point.

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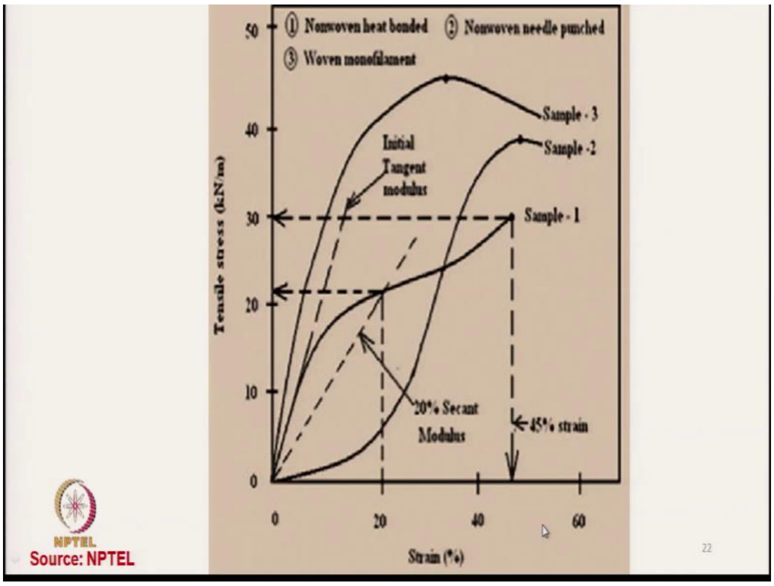

So, this curve shows the comparative values of non woven heat bonded sample 1 this is non-woven heat bonded, sample 2 non-woven needle punched fabric this is non woven needle punched fabric and woven monofilament fabric. So, this comparative curves showing the modulus values and tensile characteristics and its important to study the comparative values to select the specific material for a particular application. Where we need strength we may go for specimen 3 that is woven fabric suppose we need certain elasticity certain extensibility of a structure we may go for specimen 2 that is needle felt fabric like that.

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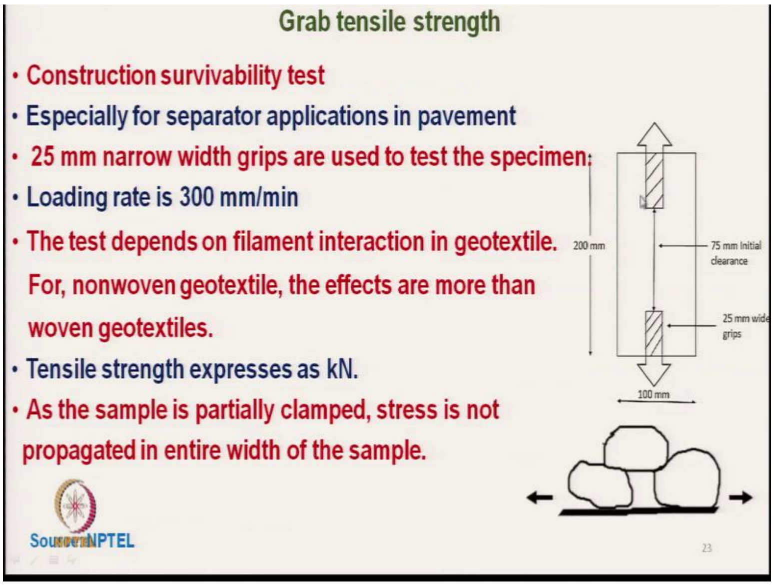

Next characteristics says that, grab tensile test. So, this is construction survivability test. Its not only the tensile test this test will give idea about the survivability of the structure how the structure will survive during application of load for long time specially for separator applications in pavement.

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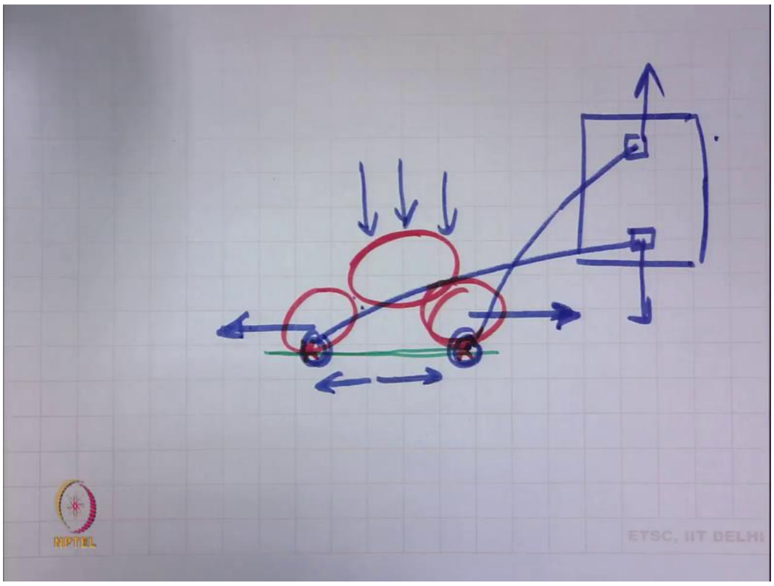

Here now let us discuss here this is geotextile and we have say stones and these are the contact points, gripping points we can say. Now when load is applied vertically, this stones will try to move sideways. Having this two points gripping point the geotextile will be stressed in lengthwise direction and the gripping point is not like wide width or narrow width tensile testing, here gripping points are much less than the actual width of the material.

Suppose this is the total material width and this grip point will be like this is the small grip point this is the point, this is here is a and they will be pulled apart. And this is actually simulated by the grab test where we use this geotextile for separation application 25 millimeter narrow width grips are used here.

So, this width of the grips are 25 mm and width of the specimen here is a 100 mm. So, 100 mm width specimen and its gripped by 25 mm wide jaw and rate of loading is that, the strain rate is 300 mm/min the test depends on filament interaction in geotextile, for non woven geotextile the effects are more than woven geotextile. So, for non woven if we use and if we compare the grab test and the strip test the effect will be more in case of non woven geotextiles. Tensile strength is expressed in terms of kN here its not like wide width tensile test where we express in terms of N/m or kN/m.

As the sample is partially clamped, so, this sample is not clamped fully as I have mentioned. Out of 100 mm woven width we grip only 25 mm at the centre, the stress here is not propagated in entire width of the specimen. So, basically the stress will be concentrated mainly on the central zone, but it will be assisted by the un gripped zone.

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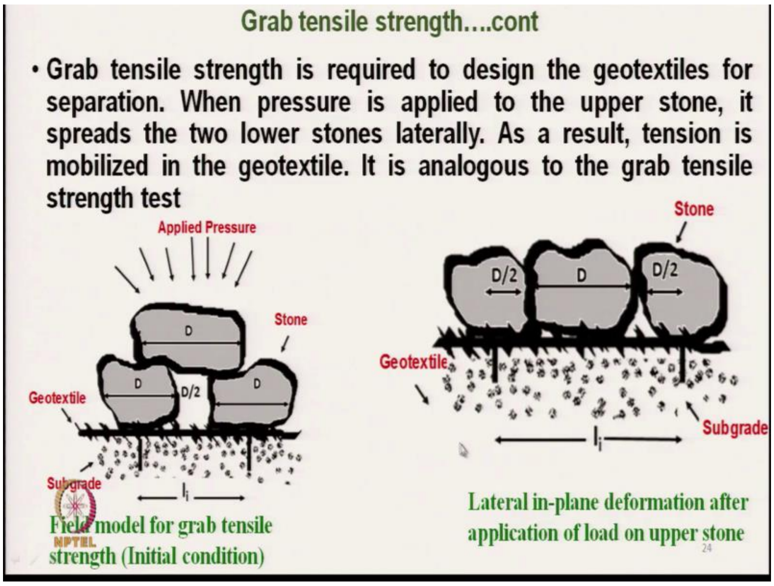

Now, let us try to see the analysis. A grab tensile strength is required to design the geotextile for separation. So, this is for separation purpose here when pressure is applied to the upper stone. So, when its applied it spreads the 2 lower stone laterally.

So, this 2 lower stones will be laterally actually move away as a result tension is mobilized in the geotextile. So, geotextile at this is these are the gripping point the tension will be mobilized and it is simulating the grab tensile strength here it is actual field condition and after the stones are moved this is the condition.

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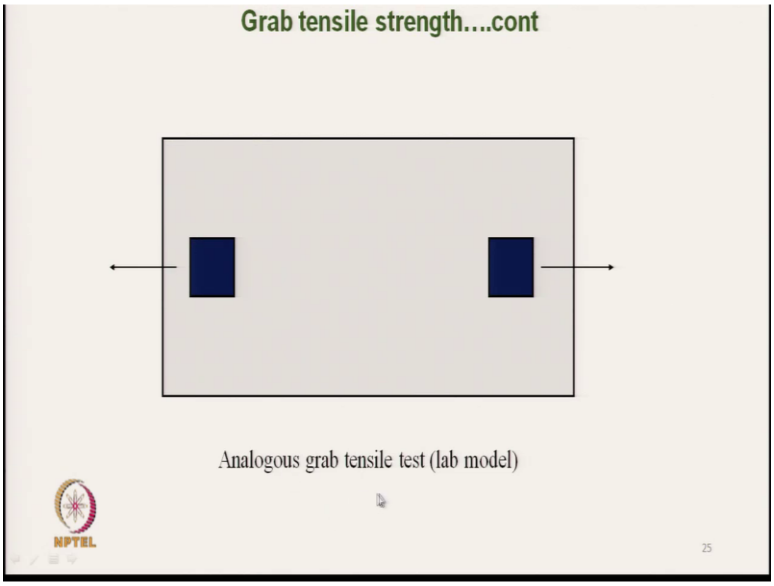

Now, this is a analogous grab tensile strength these are the gripping point.

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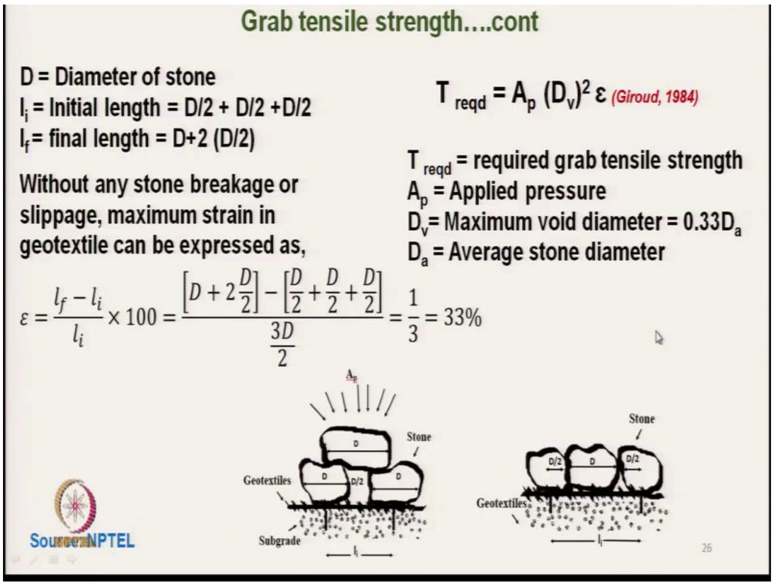

Now, let us see the analysis here D is the average diameter of stone, l 1 is the initial grip length this is the initial grip length here. Now assumption here is that they are the stones are spreaded equal equidistant.

So, distance between these stones are half of the average diameter, so, D/2. So, initial grip length will be this is D/2, D/2 plus D/2; this two points are gripped points. So, total grip length initial length will be 3D/2 and final length will be when this upper stone is actually taking space in between the lower stones. So, the gripping point has been stressed from this point to this point here; that means, total elongated length will be D by 2 plus D plus D by 2.

So, it will be 2 D is the total length after elongation that is the final length. Now if you consider that there is no slippage between the fabric specimen that is geotextile specimen and the stone and there is no crushing of stone. So, the maximum strain in geotextile can be expressed as the

$$\varepsilon = \frac{l_f - l_i}{l_i} \times 100 = \frac{\left[D + 2\frac{D}{2}\right] - \left[\frac{D}{2} + \frac{D}{2} + \frac{D}{2}\right]}{\frac{3D}{2}} = \frac{1}{3} = 33\%$$

So, effectively it will be one third and if we expresse in terms of percent it is 33 percent. So, with this condition simplified model, we can see the extension here is 33 percent and there was one empirical equation which is proposed by ***Giroud*** in 1984, which says that required grab strength of material that is we are talking about the required strength in the structure. Its not the material strength, its a required strength which is equal

$$T_{reqd} = A_p \, (D_v)^2 \, \varepsilon \quad \textit{(Giroud, 1984)}$$

Where,

T_{reqd} = required grab tensile strength

A_p = Applied pressure

D_v= Maximum void diameter = 0.33D_a

D_a = Average stone diameter

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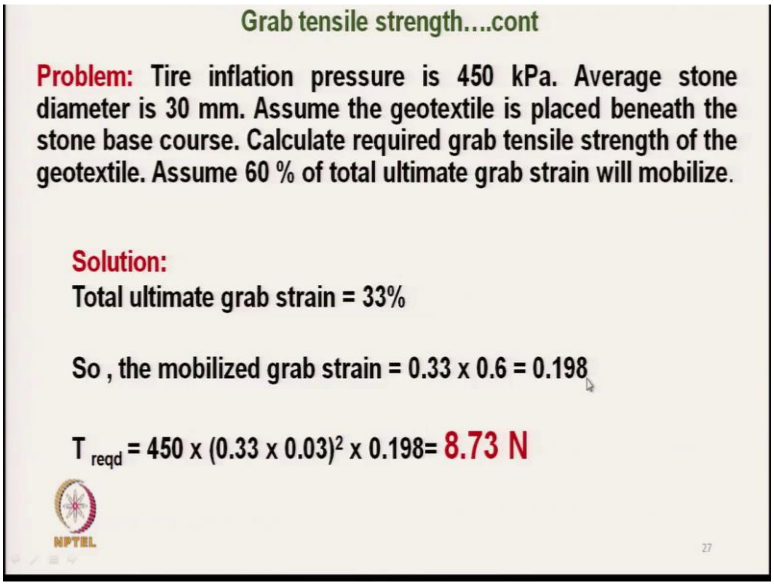

Now, let us try to see one practical problem to calculate the required grab strength of geotextile. The problem is that that a tire inflation pressure is 450 kilo Pascal; that means, the tire inflation pressure shows that tire will impart the vertical pressure of that amount 450 kilo Pascal that is a vertical pressure. Average stone diameter is 30 millimetre, assume the geotextile is placed beneath the stone base course calculate required grab strength of the geotextile. So, assuming here 60 percent of the total ultimate grab strength will be mobilized.

Solution:

Total ultimate grab strain = 33%

So , the mobilized grab strain = 0.33 x 0.6 = 0.198

$$T_{reqd} = 450 \times (0.33 \times 0.03)^2 \times 0.198 = 8.73\ N$$

So, if we know some given condition, so, we can calculate the required grab strength and then what we do?

We will take the specimen actual geotextile sample, we will test the grab strength and if it is more than this required strength with some factor, then we can accept that geotextile otherwise we can reject. So, next we will discuss the trapezoidal tear strength test, but this will continue in the next class till then thank you.

Thank you for patient hearing.