Geosynthetics and Reinforced Soil Structures
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Lecture - 6
Testing of Geosynthetics – I

In the next few lectures, let us discuss about how to test their properties, because that is very important part of our design and other construction aspects.

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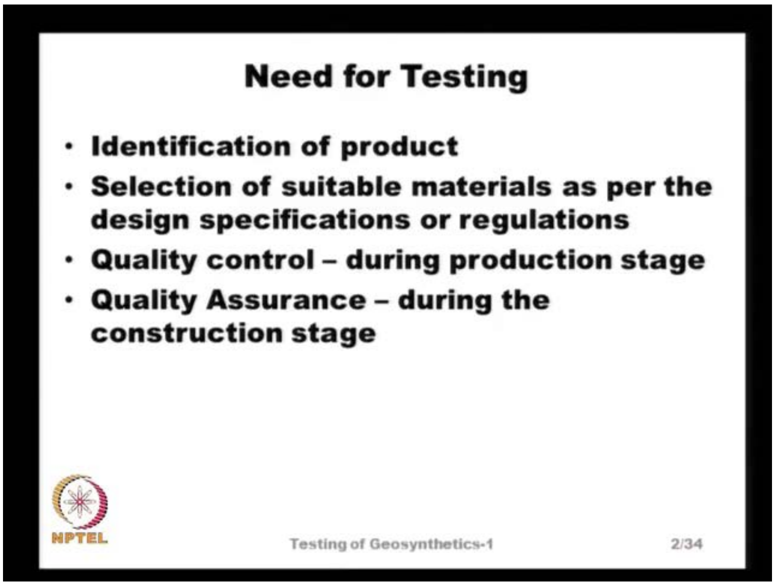

Well, why do we need the testing? The testing is required for several purposes; the first of all to identify the product, because sometimes we may not be able to identify the type of polymer or the type of material and so on, and we need to do the testing. And then of course for selecting a suitable material based on the design gym, and based on the design specifications regulations, we need to select a product and even for that we need to test a given number of products, and then select a suitable material that is good for our construction works.

Then during the manufacturing process we need to do the quality control, and frequently we collect samples from the production lots and do the testing, just to make sure that the finish product has the properties that it is meant for. And during the construction in order to assure the quality of the construction, they collect the samples at different rates and do the testing and that is called as the quality assurance.

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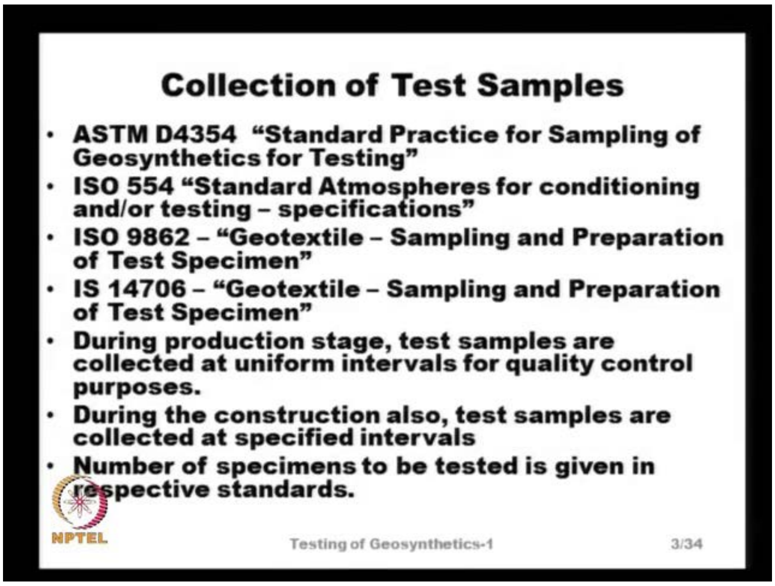

And there are different standards ASTM Indian standard and then the international standard organization ISO, for the testing about collect the geosynthetics samples, and then how to send them for laboratory and so on. The foremost among these is the ASTMD 4354, that is the standard practice for sampling of geosynthetics for testing. And the ISO 554 is also very popular, because it explicitly mention the types of atmosphere, and then other specifications for the different test, then our own Indian standard IS 14706 for the testing of geotextiles, it specifies the sampling how to do the sampling, and then how to prepare a sample and do the testing, and during the production stage is very important that the samples are collected at periodic intervals and tested. So, that the finish product has the properties that we intent to…

And of course, during the construction we do collect the samples at some required intervals and subject them to testing, so that the quality of the finished construction is assured. And the number of specimens to be tested is given in respective standards in both ASTM and the ISO, and the minimum invariable is about 6 samples, and depending upon the type of variations that we get we may need to test more number of samples.

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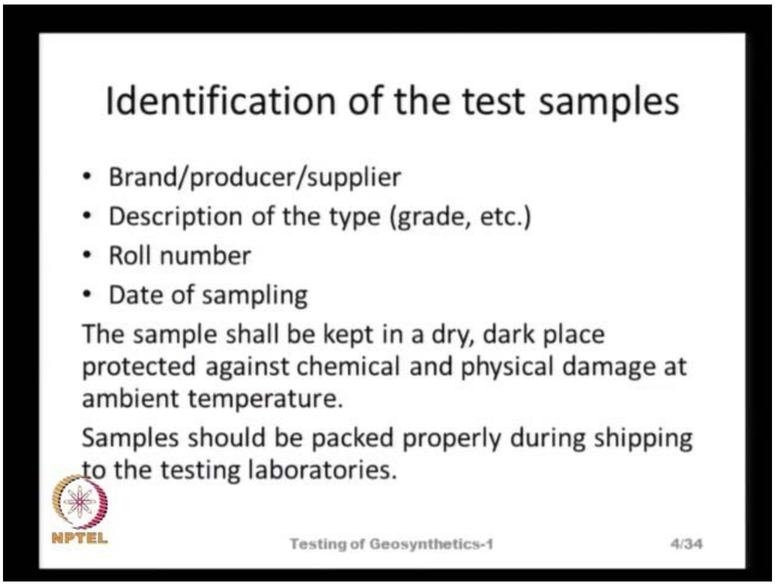

And when we collect the geosynthetics sample see that during the production stage or during the construction stage, we need to identify properly before we send them to the testing laboratory. And some of the items that we need to mark along with the sample is the brand the producer or the supplier and then the description of the type. The type of the synthetic, for example the grade of the material in terms of either the strength or the thickness or so on, and then the roll number, especially when it is the manufacturing stage we need to know the roll number and then the date and time of the sampling.

And the collected samples they should be kept in a dry and dark place, protected against chemical and physical damage and preferably at ambient temperature, and the samples that are shipped for testing, they should be adequately packed, so that they do not get damaged during the shipping process itself.

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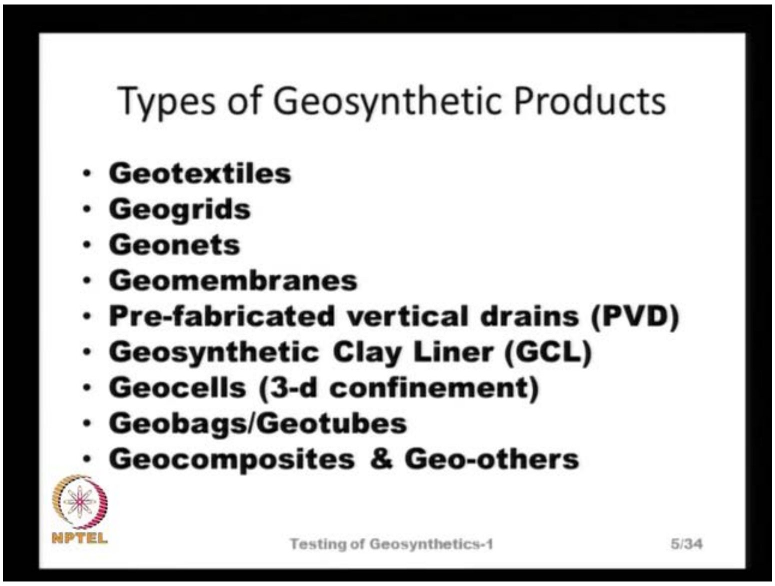

Well before we discuss the different type of tests, let us briefly have an overview of the type of geosynthetics that we have, the earliest product is the geotextile, and so I have listed it as the first product. And then geogrids then we have geonets, geomembranes pre-fabricated vertical drains, geosynthetics clay liners, the geocells that provide the three dimensional confinement, and then the geobags or the geotubes, and then geocomposites, and other type of geosynthetics products.

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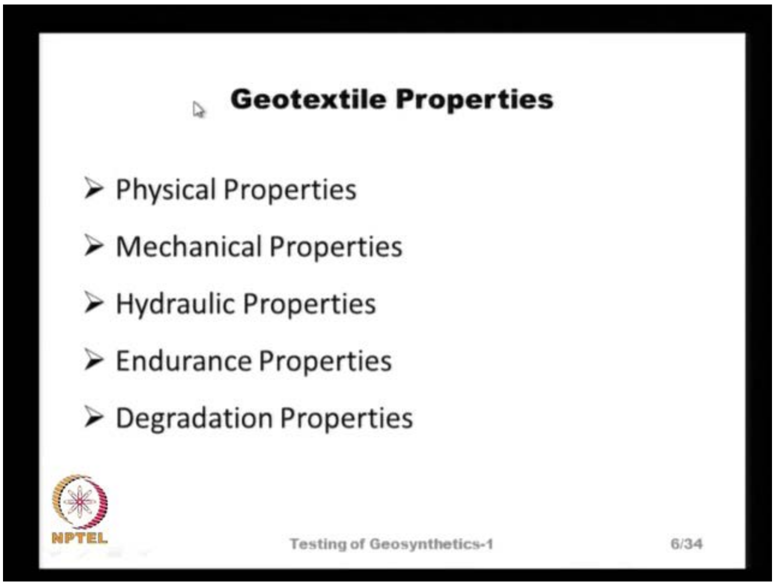

And let us briefly run through the different test that we can subject each of these product to, well let us first look at the properties of the geotextiles, the different properties can be categorized into physical properties, mechanical properties, hydraulic properties, endurance properties and then the degradation properties. Among these the physical properties they are the fundamental properties, that describe the material itself and then the mechanical properties, they define the strength of the product and then its interaction with some other materials like soil or stones and so on.

Then the hydraulic properties, these properties they describe how they can allow the water to flow to through the geotextile or flow across the geotextile, then the endurance properties when these geosynthetics are applied in the soil. How do they last or how do they endure during the service life, and then the degradation properties like when it is subject to some degrading environment like the ultraviolet late, the ultraviolet rays or the absurd environment, how do they degrade with time.

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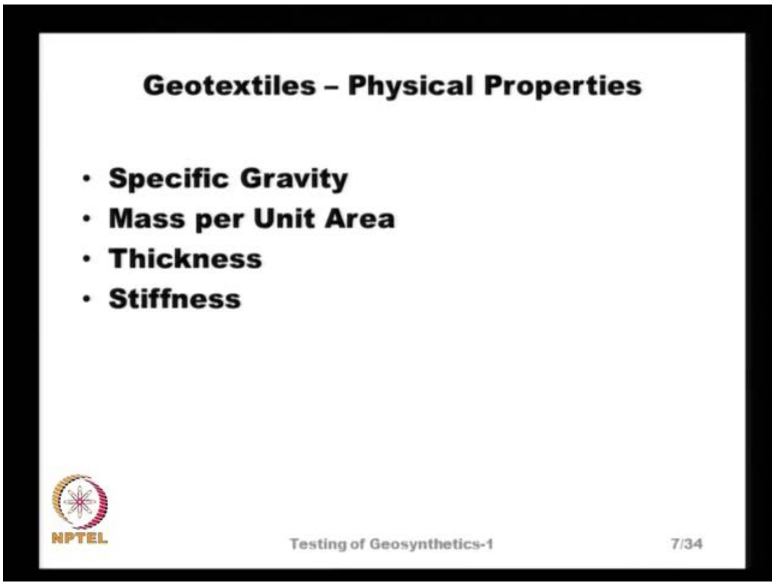

So, we need to determine all these properties for proper application, the different types of physical properties, that we normally test or the specific gravity, the mass per unit area or the thickness, and then the stiffness.

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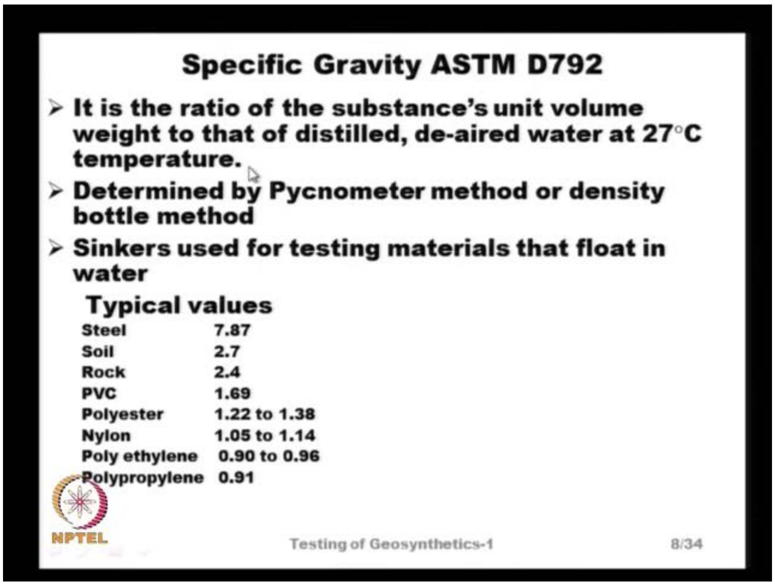

Specific gravity is one of the fundamental properties and the ASTM standard is D 792, specific gravity is defined as the ratio of the substances, unit volume weight to that of distilled de-aired water standard at a temperature of 27 degree centigrade as per the relevant Indian standard. And we determine the specific gravity of geosynthetics by or geotextiles by the pycnometer or the density bottle method, and in case of products that float in water, that has specific gravity of less than 1.

We need to use some sinkers, so that they sink into the into the water, and some typical values of the specific gravities of the geosynthetics as compared to some other construction materials like steel and soil are given here. Steel has the highest specific gravity, 7.87 soil has anywhere from about 2.68 to 2.72 with an average of about 2.7, rock has specific gravity of about 2.4, the PVC has a specific gravity of 1.69. And if you look at the poly ethylene and the polypropylene, they have the specific gravities less than 1, and then the polyester which is one common material for production of the geogrids and geotextiles, it has a specific gravity of about 1.22 to 1.38.

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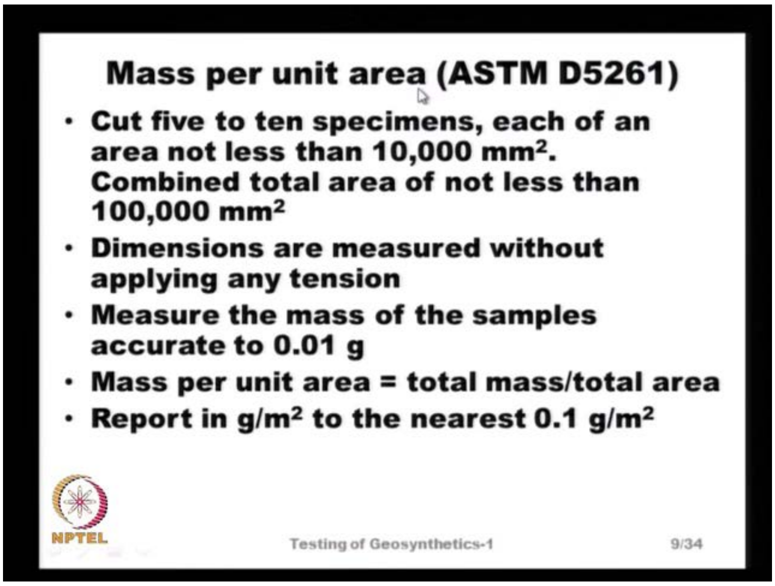

Then the other property that we test for is the mass per unit area, the ASTM standard is ASTM D5621, and basically this mass per unit area tells us, how much material is there in the product. And typically what we do is cut about 5 to 10 specimens, each of an area not less than 10,000 square millimeters, and the combined total area of all the specimens should not be less than 100,000 square millimeters. And when we measure the dimensions typically, we take samples about 100 mm long and 100 mm wide, that gives us an area of 10,000 square millimeters.

We do this measurement without applying any tension, the normally we place them on the table and take the measurements, and we measure the mass of each of these samples accurate to 0.01 grams. And the mass per unit area is total mass divided by the total area, and the units for reporting the mass per unit area or grams per meter square, and we report this to the nearest point one grams per meter square.

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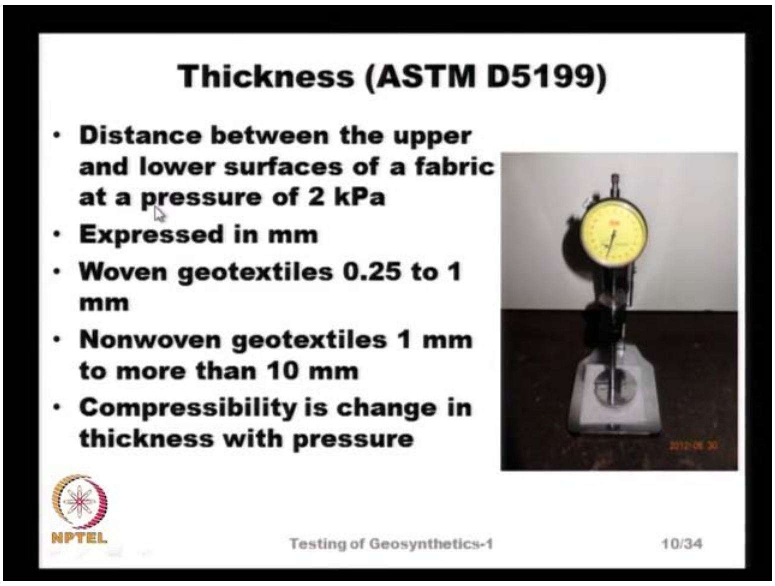

And typically the mass per unit area depends upon the material, that is used as the thickness of the material and other manufacturing processes, and another fundamental property of the geotextiles is the thickness. The ASTM standard is ASTM D5199 and the definition wise the thickness is defined as the distance between the two surfaces the upper surface and the lower surface of a fabric.

And because the thickness of the geotextiles specially of the non-woven type, they vary with the pressure the standard pressure given in the standard ASTM is 2 k P a, at a pressure of two k P a. We measure the distance between the upper surface and the lower surface, and the report that value in terms of millimeters, and the typical thickness gauge is given here. We have a this thickness gauge has a flat surface at the bottom, and then it has a provision to put in loads, corresponding to different pressures.

And we can this base area is large enough to support the samples as per the ASTM standards, and then we apply the pressure and then we can directly measure the thickness through this dial gauge. And this dial gauge it should be accurate to 0.01 millimeters and the typical thickness is of the woven geotextiles are about 0.25 to 1 millimeter whereas, the nonwoven geotextiles specially of the needle punch variety they are much thicker 1 millimeter to more than 10 millimeters.

Some of them are as thick as 30 millimeters especially when they are used as cushions, and the compressibility is the change in the thickness with pressure because the compressibility is a parameter, that describes how the and the thickness of the geotextiles varies with the pressure, that also we will see a bit later on.

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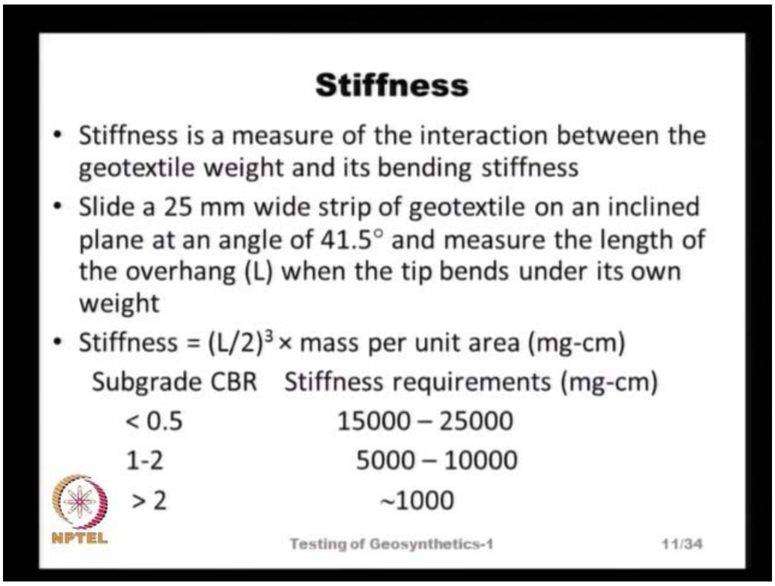

The another physical property that we give to the geotextiles is the stiffness, the stiffness is the measure of the interaction between the geotextile weight and its bending stiffness. Basically, it is it defines the mass per unit area that is put in the geotextile and its bending stiffness, and the text itself we perform by taking a thin strip of geotextile cut 25 millimeters wide very long sample. And then we slide it on an inclined plain at an angle of 41.5 degrees and measure the length of the overhang when the tip bends under its own weight.

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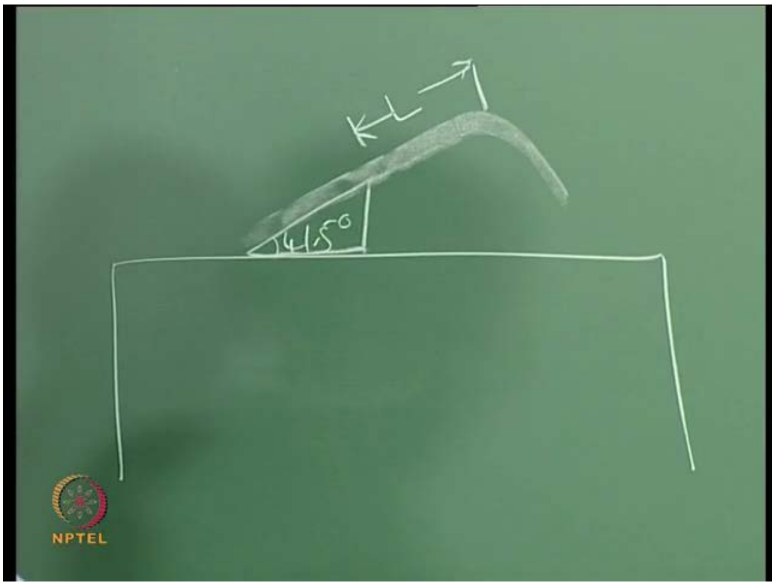

Typically this test we perform like this I will try to sketch it on the black board, we take a table, and then we put in a slope that is at 41.5 degrees, and then we take a strip of geotextile and stretch it on this. And at some point it will start bending and this we call as the overhang length and once we get this overhang length, where the geotextile starts starts bending under its own weight.

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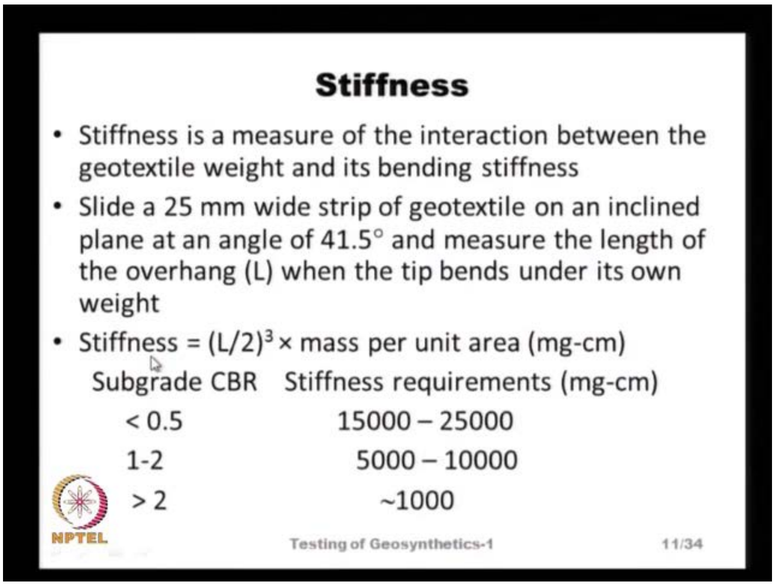

We can measure that length and then calculate the stiffness as one half of the length to the power cube multiplies by mass per unit area, and the units for reporting the stiffness or milligram centimeter units. And typically the geotextile recommendation is made in terms of the stiffness for different types of sub-grade soils.

Say for example, when the sub-grade soil has a very low CBR value of 0.5, which corresponds to very soft soil the stiffness of the geotextile, that we require for base layer should be very high of the order of 15,000 to 25,000. And when the sub-grade is relatively stiffer with CBR value of 1 to 2 stiffness requirement is reduced 5,000 to 10,000, and when the sub-grade CBR is greater than 2 the stiffness of the geotextile that is required at the base layer is of the order of 1,000 milligram centimeters.

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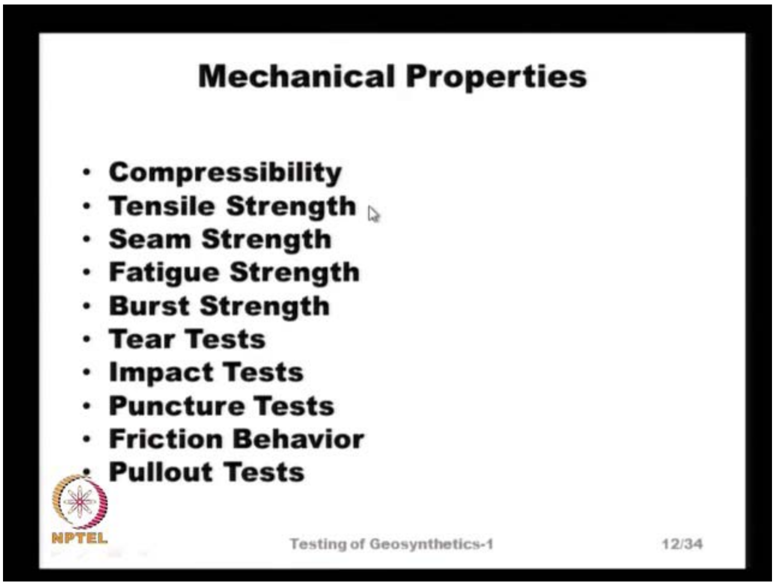

And the next property that we are going to discuss is the strength of the mechanical property, and there are different types of tests that we perform under the mechanical properties. The first one is the compressibility, that is the sensitivity of the thickness of the geotextile to the applied pressure, and then the tensile strength, and then the seam strength, the fatigue strength, burst strength, tear strength, impact strength, puncture strength, frictional behavior, then the pullout pull behavior and so on.

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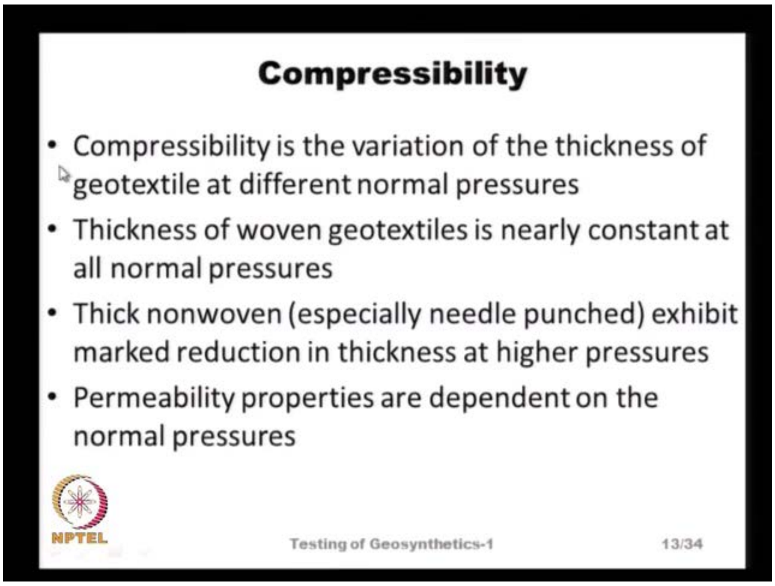

The compressibility is basically the variation of the thickness of the geotextile at different normal pressures, and the thickness of the woven geotextiles is nearly constant at all the normal pressures. Basically, because by themselves there very thin and the fabric that is used is very stiff because this it is only it is a woven fabric with some fibers whereas, the nonwoven products their manufacturing process itself. We give the volume to the sample by putting in very large number of fibers, which are loosely bonded together by some needle punching process and so on.

And the thick nonwoven geotextiles they exhibit a marked reduction in the thickness as the pressure is increased, and the reason why we are interested in compressibility properties the permeability properties they depend very much on the normal pressures. Because basically the aperture opening size also may be sensitive to the pressures, and then the thickness, and then the void ratio, so on they all depend on the and the pressures that we apply.

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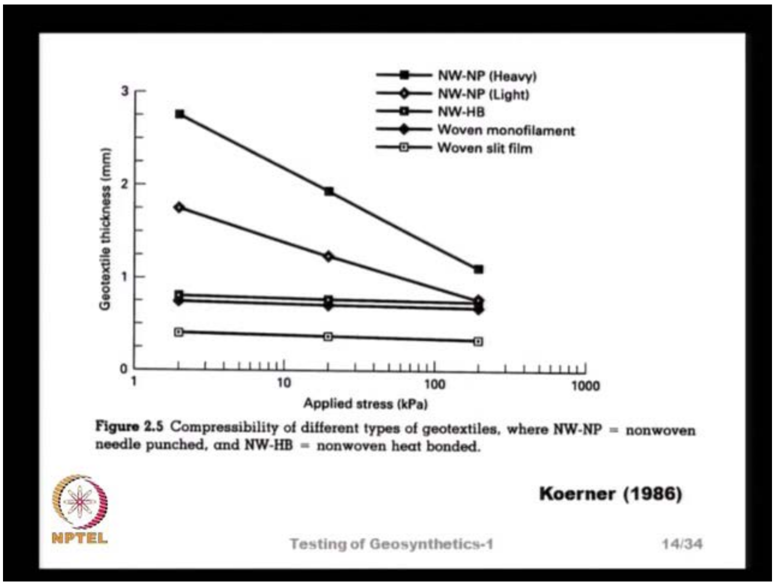

Now, this is a graph that shows the typical variation of the thickness with the applied pressure, at the bottom most we have a woven fabric which is about 0.5 millimeter thick at a standard pressure of 2 k P a. And even when the pressure is increased to 200 k P a the thickness has not changed very much whereas, when we take very thick nonwoven needle punch fabric, at a pressure of 2 k P a the thickness is about 2.8 millimeters.

And when the pressure is increased to 200 k P a, the thickness reduces almost about 1.25 millimeters, and if we take the nonwoven heat bonding products, which are relatively thin and much stiffer, the thickness does not change very much. For example, here is a heat bonded product with an initial thickness of about 0.8 millimeters, even when the pressure is increased 200 k P a the thickness is not changed very much, so it is still at about 0.8 k P a.

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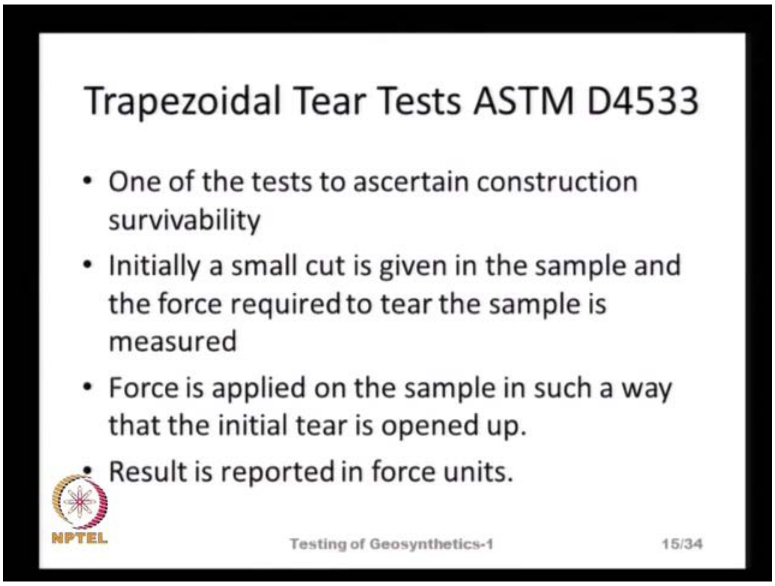

And we performed a very large number of tests to ascertain the survivability of the geotextiles during the construction, and one such test is the trapezoidal tear test, which described in the ASTM standard D4533. And what we do is we stimulate how a defect in the geotextile, either because of manufacturing process or because of some rupture that takes place during the construction process by giving it a small initial cut.

And then we see how this cut propagates, when the fabric is subjected to tension and so we initially give a small cut and we measure the force required to clear the sample and report it as the trapezoidal tear strength. And the force is applied on the sample in such a way that the initial tear that we give is opened up and the result is reported in the force units in terms of Newton's or kilo Newton's depending on the value that we have.

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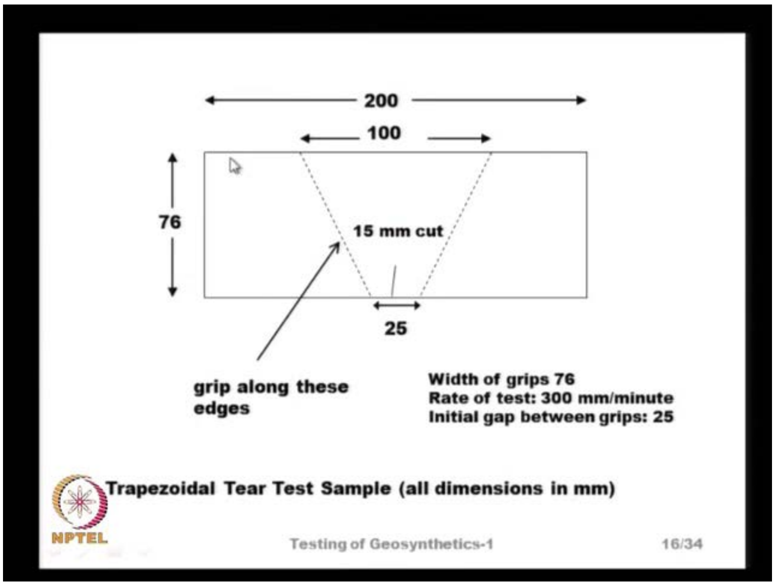

And the trapezoidal tear test sample is rectangular in shape which has a length of 200 millimeters and a width of 76 millimeters on this, we draw a trapezium having a length of 100 millimeters on one side and 25 millimeters on the other side. And then we give a small initial cut of 15 millimeters, and then we hold the fabric along these two dotted lines and then stretch it, so that the initial cut that is opened up and the type of grips that we use. They have a width of 76 millimeters and the initial gap between the grips is 25 millimeters corresponding to the smallest distance of the trapezium that is 25 millimeters, and we do this tests at a rate of 300 millimeters per minute.

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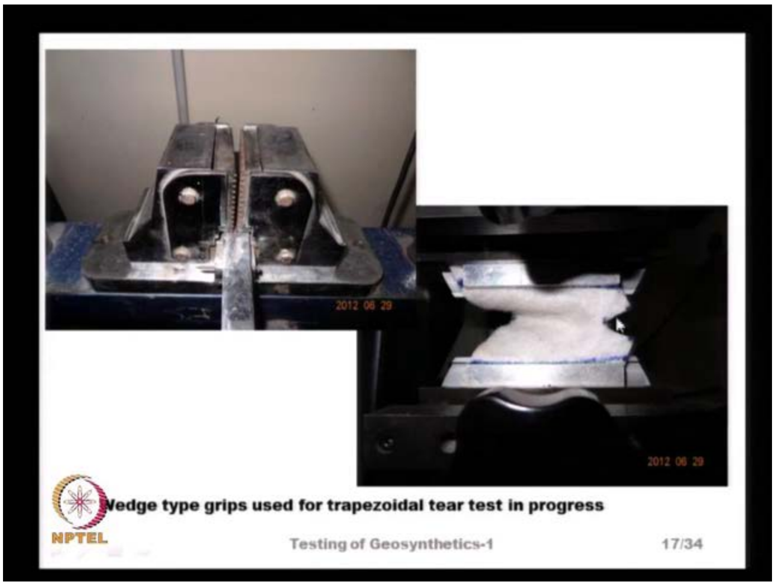

And the type of grips that we employee for this test typically a wedge type grips is actually here we see the cross section of a wedge type grip that once the geotextile is locked in by pushing this lever they hold the sample. So, tight that the geotextile will not slip and on right hand side we see the trapezoidal tear test under process and the right hand side we had given the initial cut and this gap was 25 millimeters initially.

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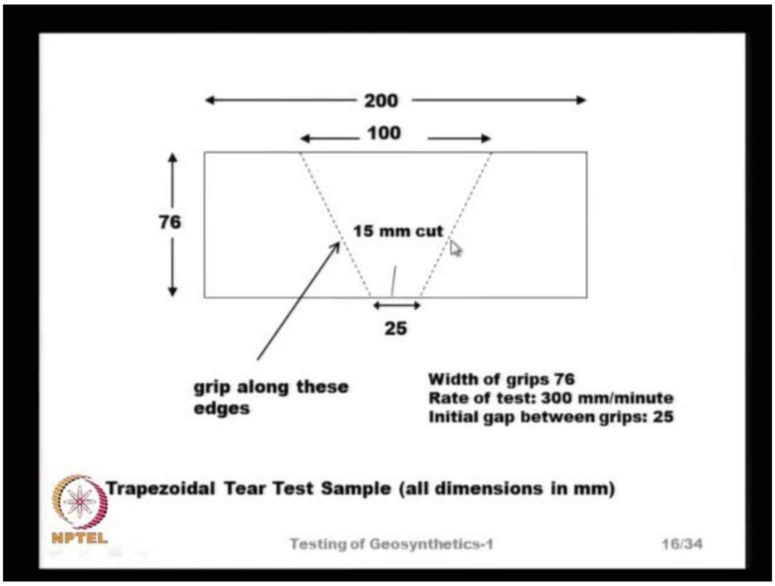

And then we are holding the sample along the two dotted lines, that are that are drawn here.

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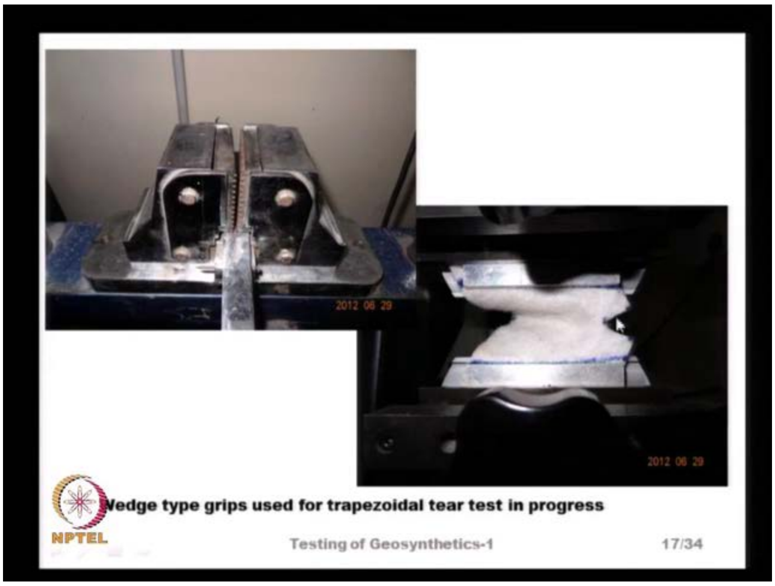

And then as we stretch the sample the this initial tear goes one widening and at some point the entire width is cut, and this side we see the slag because of the longer length of the sample.

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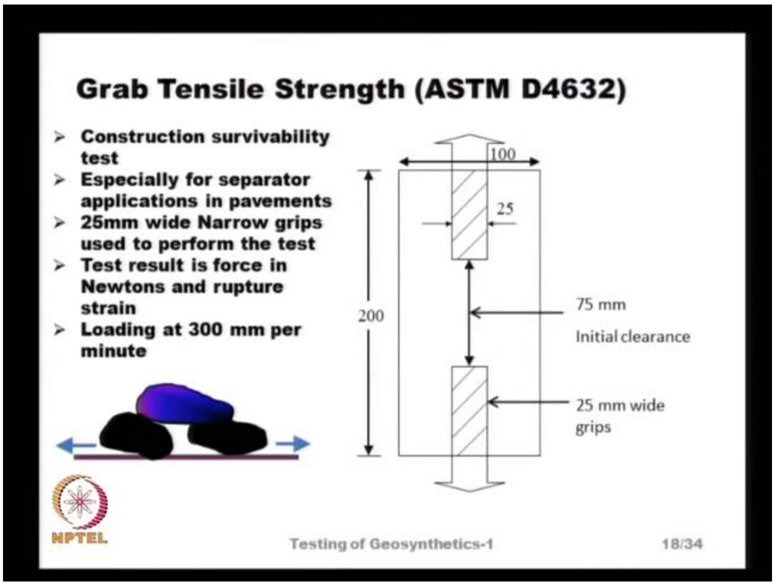

And the other test that we do is the a grab tension test and the grab tension test is specially required on the geotextiles that are used as separators in the pavements and in the railway tracks, is a typical situation that may arise field is illustrated here. Let us imagine that this is a geotextile, and then we are placing some aggregate and doing some compaction, in the process let us say that the two stones were embedded into the geotextile.

And then there are loaded by some other larger piece of aggregate that pushes them and then in the process the two stones they try to move away from each other and in turn there are grabbing the geotextile. And then stretch the geotextile and this is the type of situation that we try to stimulate in this grab tension test, and we take a sample 100 mm wide and 200 mm long, and we hold it with a very thin grip which is 25 millimeters wide and very long.

So, that we can hold the geotextile or a very long length with an initial gap of 75 millimeters and once the sample is held in place normally we use the wedge type grips, because it is easy to hold this geotextiles, and we pull the geotextile at a rate of 300 millimeters per minute. And the test result that we report is the force in the Newton's and then the rupture range for example, 30 percent or 40 percent at what test range the sample has ruptured.

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And here we see a typical test these are the two wedge type grips and this is our geotextile sample which is 100 millimeters long, and in total this sample is 200 millimeters long. And the initial gap between the two grips is 75 millimeters and then once we hold them we just simply stretch, and here you can see the geotextile just about to get turned.

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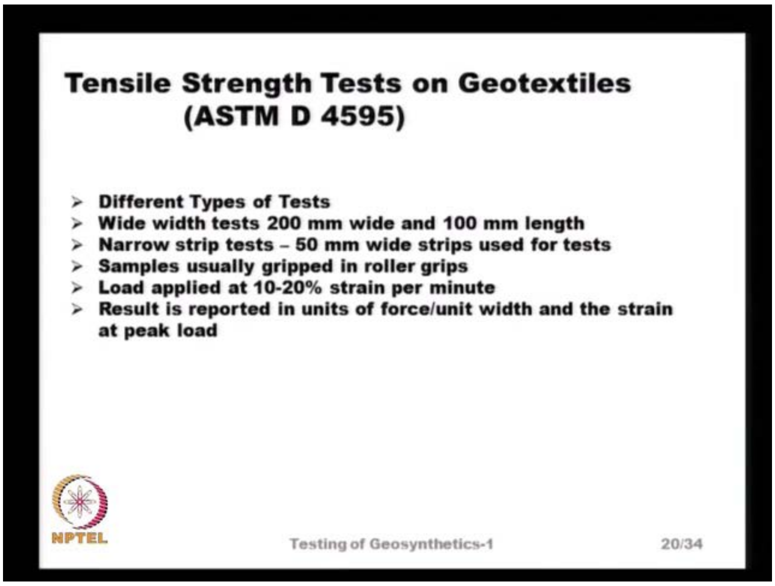

And we do perform very large varieties of tensile tests on the on the geotextiles and the ASTM standard is the ASTM D 4595 and one popular test that we do is called as the wide width tensile strength test. We take a sample that is 200 millimeters wide and with a gauge length of 100 millimeters, and we do we do the tensile test and we also do narrow strip test which are performed on 50 mm, wide strips and 200 millimeters long.

And these geotextiles samples usually there are gripped in roller grips which provide in a smooth support for this textiles, and then the load is applied typically at a strain rate of anywhere from 10 to 20 percent strain per minute. And when we report the result we also repot the corresponding strain rate at which we have tested this sample, and these results there are reported in the units of force per unit width and the strain corresponding to the peak load.

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And the typical wide width tensile test sample is shown here, this width is 200 millimeters and the gauge length, that is used for calculating the deformations of the strains is 100 millimeters and typical results from this wide width tensile test are shown here.

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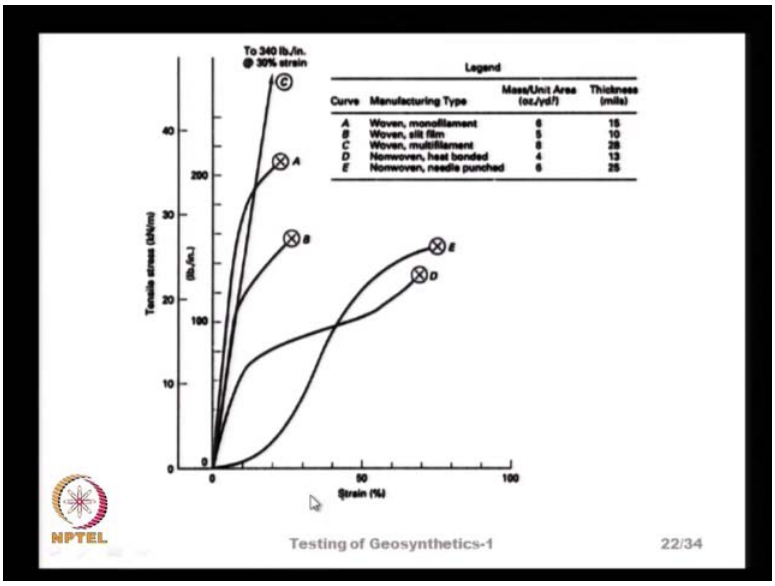

And the x axis we have the strain and the y axis we have the loaded in kilo Newton's per meter, and usually the loaded is expressed only in so many kilo Newton's per meter width, rather than the stress. If we see the stress strain graphs of soils or the steel we report it in terms of the stress on the y axis and the strain on the x axis, but then the thickness of the geotextiles are the geosynthetics is quite sensitive to the amount of tensile force that we apply. And in order not to complicate the issues, because of the change in thickness we just simply report the force on the y axis in terms of kilo Newton per meter.

And so the y axis we have the force and the x axis we have the strain and the A and C, they correspond to woven geotextiles which exhibits very large strength and typically at a lowest strain. And herein for example, both of these they have developed the peak loads at about 15 to 20 percent strain whereas, if we see this B and D which are nonwoven heat bonded and needle punched fabrics. They develop their peak load at a very large strain, here in this case about 70 to 80 percent strain and comparatively their strength is much lower than the strength of woven geotextiles.

Nowadays, we have some polyester woven geotextiles that have a tensile strength as much as 1,000 kilo newton per meter, the polyester geotextiles they normally rupture at around strain of 9 to about 12 percent strain whereas, the nonwoven geotextiles they can take strain as much as 70 percent or 80 percent without rupturing.

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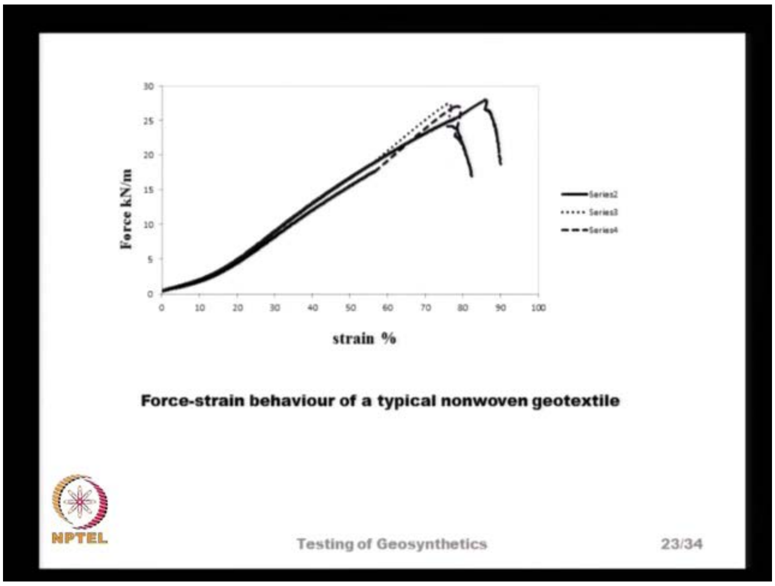

And here we see some data from a load strain test on a nonwoven geotextile, and the tensile strength of this textile is of the order of about 27 kilo Newton per meter. And the peak load is developed at a strain of nearly 80 percent, and when we select a product it is very important that the products meet the requirements that we have in the field.

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For example, when we think of constructing an embankment or a retaining wall, where we want the lateral strains to be as low as possible we use a very stiff geogrid or a geotextile and for that we require a high strength geotextile that can develop the strength at a very low strain. Whereas some other applications like for example, the application of the geosynthetics, for cross line stabilization we employee very large number of geotextiles tubes and so on.

Here, these tubes are very large in size and they undergo very large defamations because of the changes in the sea bed profile or because of the wave forces or because of the tidal action, they undergo very large defamations and very large strains. And in the process our tubular structure it should not break, it should not rupture, and the experience shows that the force developed in this fabrics is very low, because mainly because these tubular structures these are not completely filled, they are partially filled.

So, there is lot of sag in them that, even if some defamation takes place they can deform without developing any force. And here we see two applications and this is a very, very large diameter nonwoven type geotextile tube, and the right hand side we see a tube which is about 3 meters diameters and the length is 20 meters and this particular one on the right hand side it is made of a woven geotextiles. Whereas, on this side on the left hand side we see a nonwoven geotextiles tube, and the forces that develop on this geotextiles is also depends on the fill ratio that we have, and theoretically we can we can actually calculate by assuming some shape.

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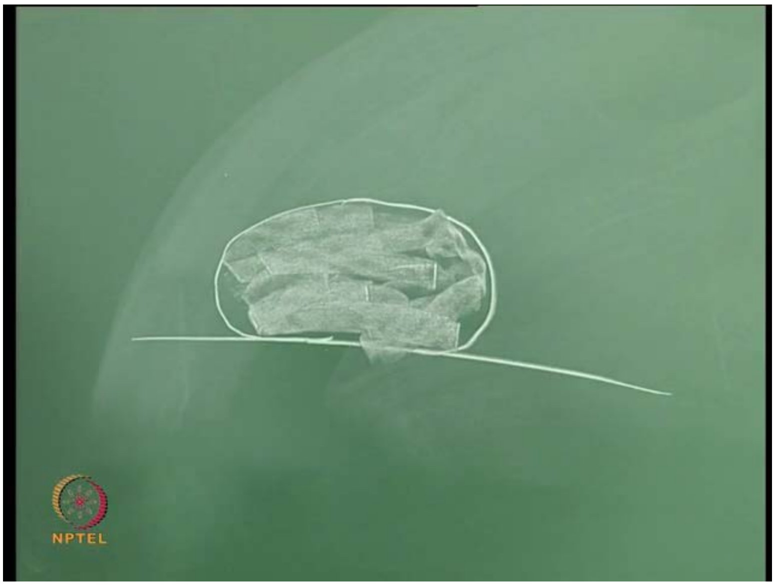

We can assume some shape for these geotextiles structures and calculate the strain and then the and the force developed, and we can theoretically prove that the strains could be very large, whereas the forces that are developed are very low.

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And for such application we prefer using a nonwoven geotextiles, that can along it and without rupturing.

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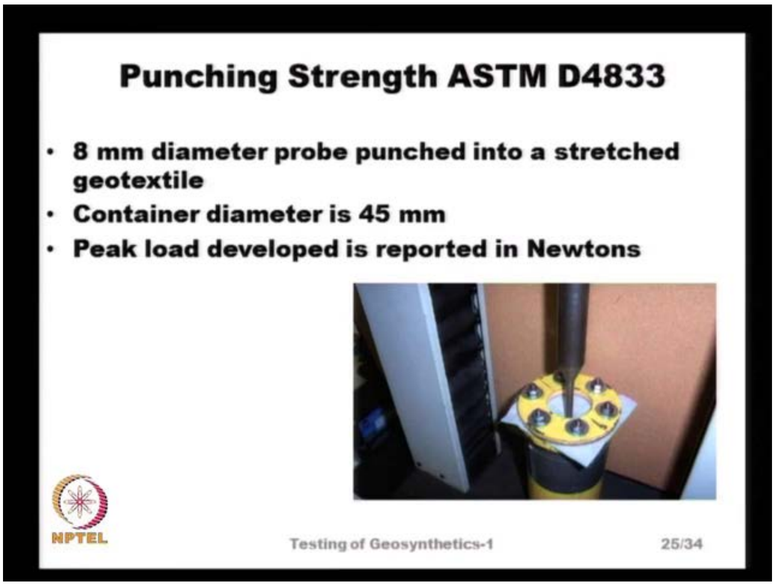

Another property that describes the survivability of this geosynthetics is the punching strength test punching strength that is described by ASTM D 4833, and here we take a geotextiles sample stretch it across a opening in a tube, in a container having a diameter of 45 millimeters. And then we take a probe which is 8 millimeters diameter and then we push it through the geotextile at a defamation rate of 300 millimeters per minute, and we measure the force and report it in terms of Newton's. And this the punching strength is representative of the strength of the geotextile, when it is applied in a separator layer like when a stone or anything it tries to penetrate into the geotextile, that is stimulated by this punching strength test.

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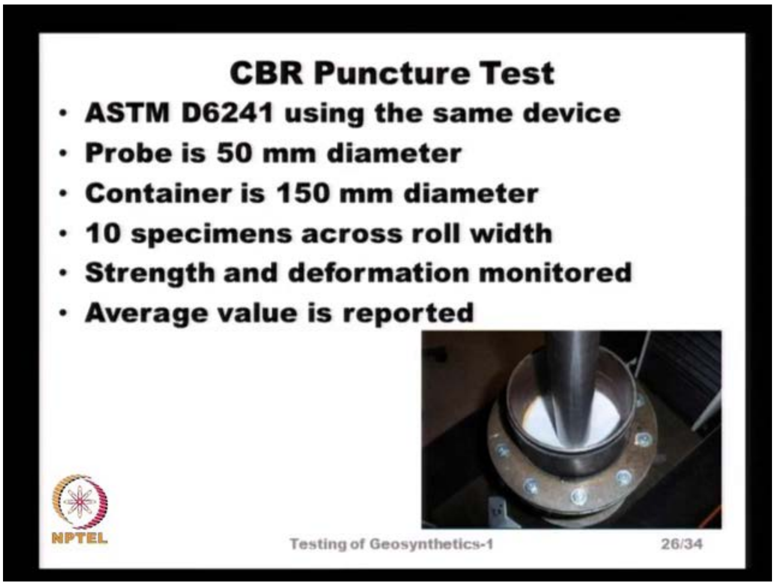

And the small variation of the punching strength test is the CBR puncture test, wherein we use the normal convention CBR mould having a diameter of 150 millimeters, and the probe now is 50 millimeters diameters. And typically, the ASTM standard it recommends that minimum of 10 specimens are tested, and then we take an average of all these values.

And here, we see a picture of the of the CBR puncture test, we have a sample that is stretched on this mould having a diameter of 150 millimeters, and this the CBR plunger has a diameter of 50 millimeters. And we push it through the stretch geotextiles at a rate of 300 millimeters per minute and then measure the force, and we can interpret this for other properties we can derive the wide width tensile strength of the fabric in terms of the CBR puncture load.

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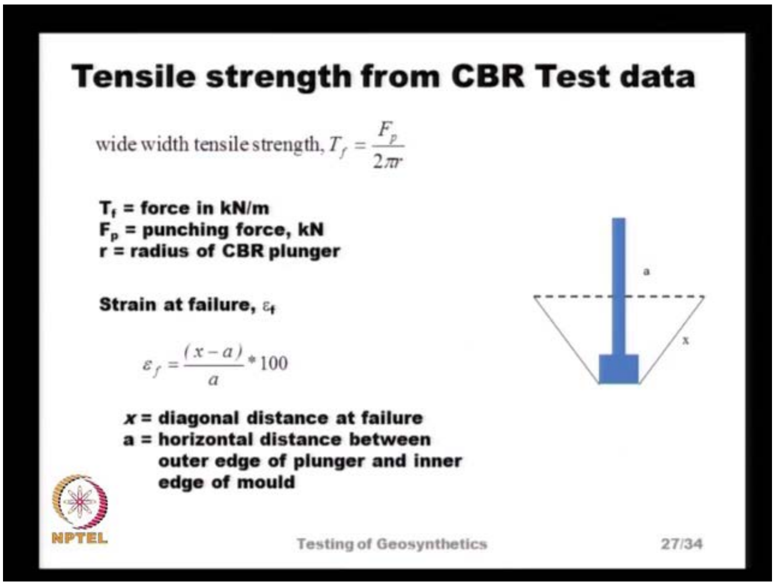

As the puncture load f p, that is the punching force in so many kilo Newton's divided by 2 pi r, 2 pi r is nothing, but of the circumference of the probe of the plunger that we have so r is the radius of the plunger. And in case we are not able to perform the wide width tensile strength test we can directly interpret for the wide width tensile strength test from the test data, or if you have the wide width tensile strength, we can cross check the that value from the C B R resistance using this formula.

And then this strain corresponding to the rupture can be calculated using this formula, where epsilon is x minus a by a times 100, where a is the distance from the outer edge of the plunger to the inner edge of the mole. So, for example, if this distance is a initially it was the geotextile is horizontal and as we push the plunger down, the geotextile assumes a shape, and by assuming that the geotextile remains tight.

And this surface is remains straight and with an inclined length of x, because the x is the new length where a is the original length by using the formula for the strain is the final length minus the initial length divided by the initial length we can get the strain. And so this once again this strain at failure from this formula can be co-related to the into the strain corresponding to the peak load from the wide width tensile strength test.

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And here we see a slight adaptation of the CBR puncture test for testing of the rope net gabions, these rope net gabions they are very commonly applied in many of the coastal erosion protection structures in India and at the top we see a typical structure. Gabion is nothing, but a wire basket make up of either steel wires or rope nets, and here the rope nets are made up of either polyester ropes or polyethylene ropes, and they have certain openings depending on the type of aggregate that we place in and depending on the size of the stones and other things.

And here we see that the structure is deforming excessively, the reason is the rope may not have the strength, and in order for us to assist the stiffness of this rope nets we can use this the test device. Here, we have a container that has a diameter of 300 millimeters and we take a plunger that has a diameter of 250 millimeters, and we push it through at a displacement rate of 300 millimeters per minute, and then we can assist the strength of this rope net and then the stiffness and typical data is as shown here and the x axis we have this strain.

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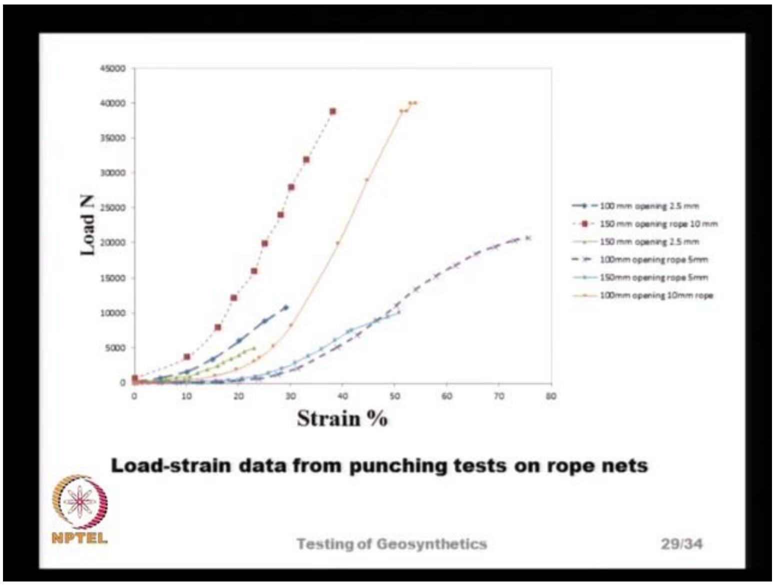

And the y axis the force applied in Newton's and for different types of for rope nets depending on the diameter of the rope that is used, and then the aperture opening size. For example, this particular data in this stiffness response is obtained for rope net made of 10 millimeters diameters rope with 100 mm opening space, whereas the softest response is obtained, when this gabion the rope net is made with the smallest diameter ropes having a diameter from 2.5 millimeters.

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And the slope of this will give us the stiffness and we should be able to predict the deformations that a rope net gabion undergoes, once we have the stiffness of this rope net and then the strength also can be assist.

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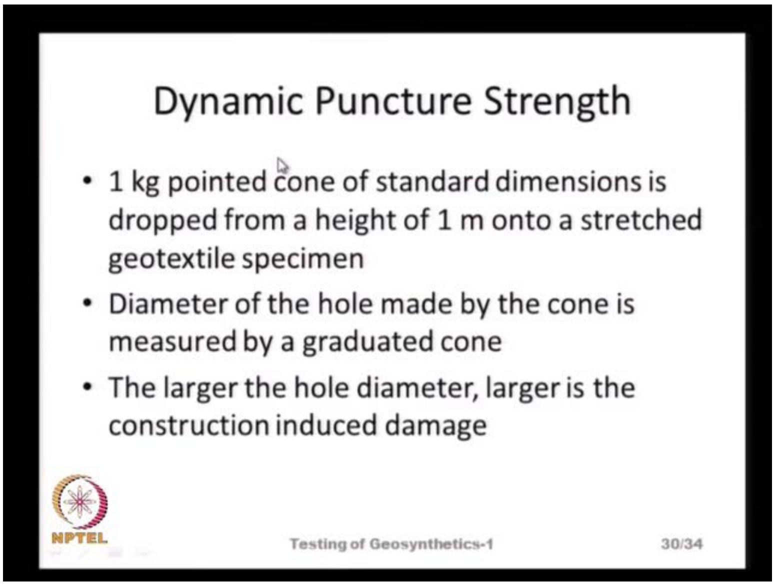

Another, type of test that we perform is called as the dynamic puncture strength test, the previous one's they are called as static puncture test because we just simply push a plunger either 8 mm diameter plunger or 50 mm diameter plunger. Whereas, the dynamic puncture strength is to stimulate the falling stones or falling aggregate on the geotextile that is used at the ground level.

Here, we drop a one kilo gram mass cone of standard dimensions having an apex angle of 30 degrees from a height of 1 meter onto a stretched geotextile sample that is fixed inside the apparatus. And we measure the diameter of the hole that is made by the by the cone by using a graduated cone, and the diameter of the hole in turn represents the resistance of the geotextile against construction induced damage, because of stone chips or because of sharp edges of the stone, that are compacted against the geotextile.

So, in fact, the larger the hole diameter larger is the construction induced damage and we can specify a given geotextile product, in terms of the dynamic puncture strength value. And this the result from the dynamic puncture strength test is reported in terms of the hole diametric in terms in millimeters.

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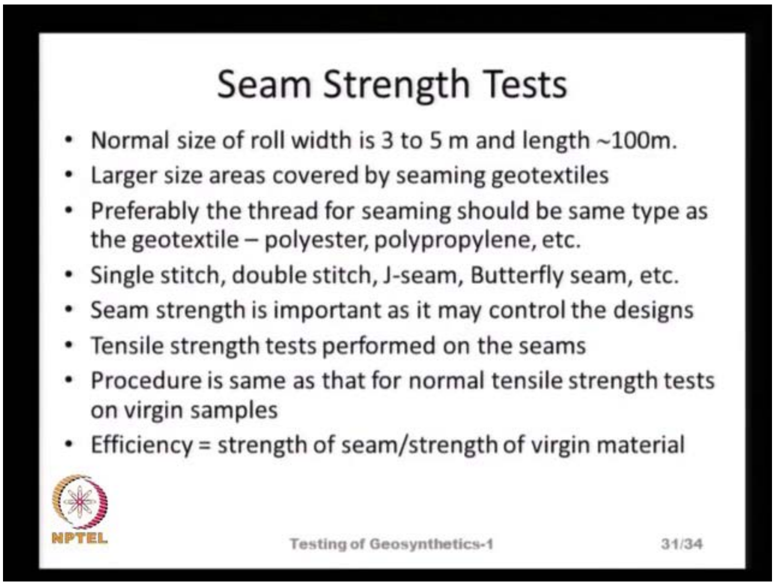

And many times when we deal with a very large areas like where we need to cover large areas with a geotextile, in the case of landfills or in pavement applications, we may need to join the geotextiles, because the normal size of the geotextiles rolls there are about 3 meters to 5 meters with a roll length of 100 meters. And if we need to cover larger areas we need obliviously or join the geotextiles together, and when this joining by stitching is called as the seaming, and the type of tread that we use for making these joints should be preferably of the same type as used for fabricating the geotextiles.

Say for example, if the geotextile is made of polyester, preferably we use a polyester rope, so that the rope that is used is compatible with the aspirate material or polypropylene. If the polypropylene is used for making the textile, we can use a polypropylene rope for a for the stitching purpose, and there are different types of firm stitches or the single stitch, double stitch, j-seam butterfly seam and so on.

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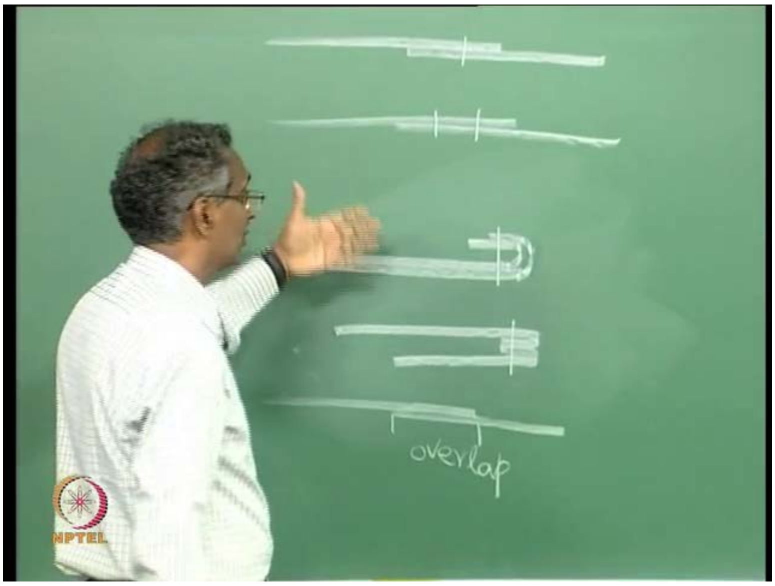

I will try to sketch them on the black board single stitch is a very simple one Say for example, we have two geotextiles, we can have a single stitch, we can have a double stitch, the j-seam is like this or the other type of stitch that we have is the is the butterfly stitch. And if the ground is very stiff we can just simply use overlap instead of stitching this we call as overlap, if the ground is very stiff having a CBR value of greater than 6, you have an overlap and if the ground is very soft we need to go in for different type of stitching process. So, that we form this joint and sometimes if the joint is not made well, the joint may form the weak link in the structure.

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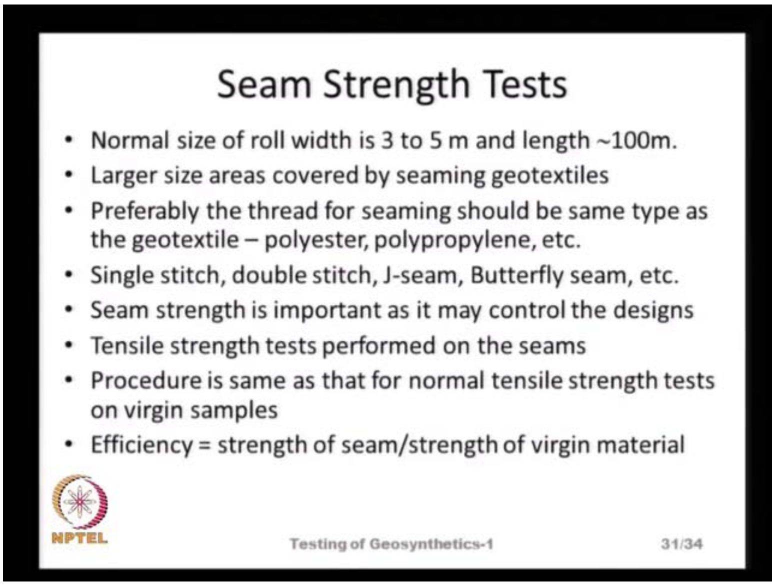

So, we define in an efficiency of the seam as the strength of the seam we perform the normal tensile strength the wide width tensile strength test or the narrow width tensile strength test on the seam. And that we call as strength of the seam that divided by the strength of the apparent material will give us the efficiency, and usually an efficiency of about eighty to ninety percent is required. So, that the failure does not happen at the joints and if the seam is very good we can have efficiency of as much as 100 percent; that means, that the seam is as strong as the apparent material.

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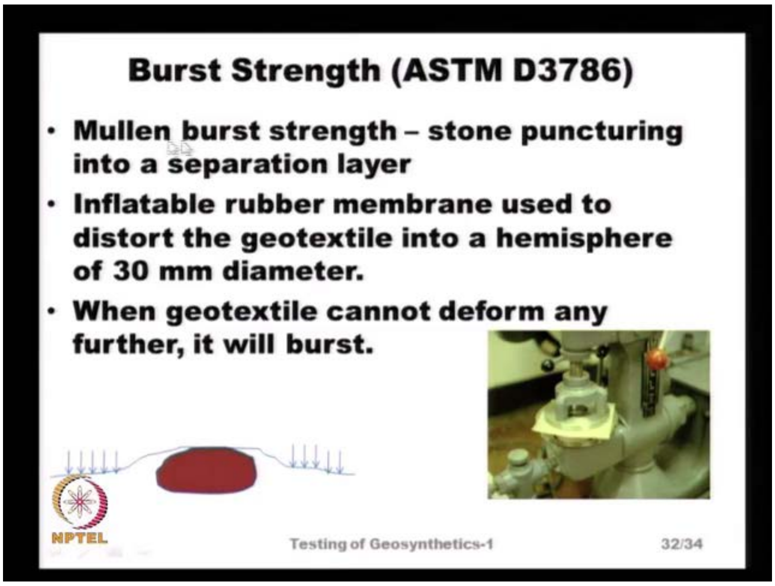

And another test that we have is the is the burst strength test and as described as ASTM D 3786, we call it as the Mullen burst strength, and this is to stimulate a stone puncturing into a separation layer. It is actually illustrated here let us say we have a large stone and we place a geotextile, and when we apply the pressure the stone tries to punch into the geotextile, and that phenomenon is stimulated by the Mullen burst strength test.

And here we use and inflatable rubber membrane to distract the geotextile into the hemispherical shape having a diameter 30 millimeters, is actually here we see the Mullen burst apparatus. Here, we have the geotextile and there is the opening 30 millimeter opening and there is a rubber membrane inside that is inflated and that stretches the geotextile, and the geotextile goes on stretching at some point it cannot stretch anymore it will just simply burst.

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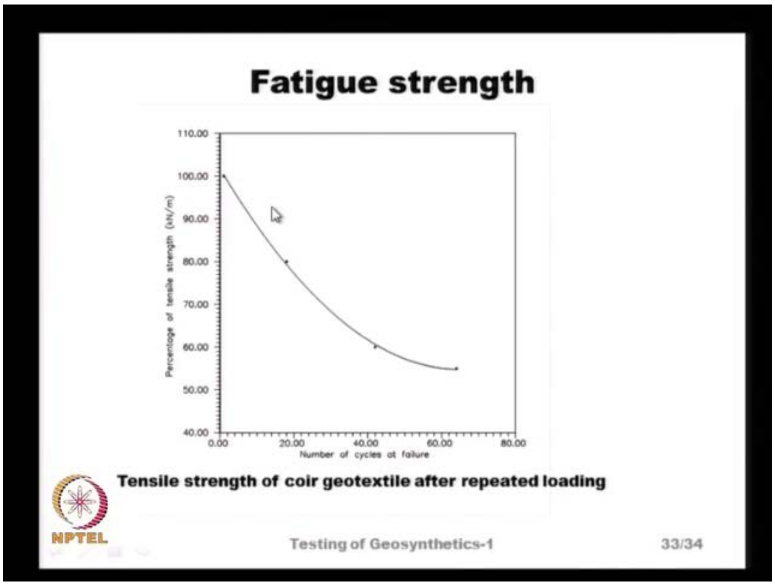

And that pressure that is required to burst a geotextile is reported as the burst strength of the geotextile, and another property that that we have is the fatigue strength, that is sometimes our load are repeated applied. For example, in the case of seismic loads or in the case of wave loading on the offshore structures, the load is repeatedly applied and then we remove the load apply the load and so on. In such case some geotextiles their strength may go on reducing with time, that we call as a fatigue strength.

And here this is a typical data that we have from test on coir geotextile, here we see that as the number of load cycles increases the strength decreases the strength at the end of one cycle is nearly 100 kilo Newton's per meter, and as the number of load cycles increase the strength comes down to about 55 kilo Newton's per meter.

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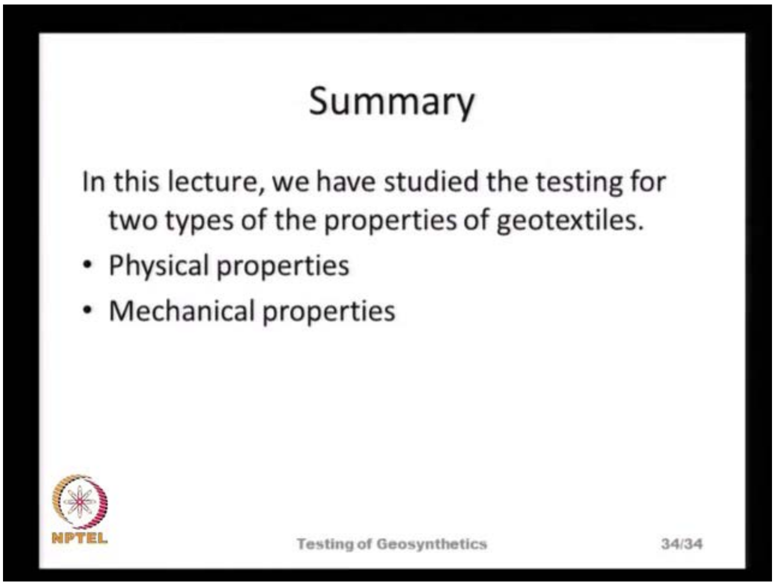

So, just summarize in this lecture we have studied the different tests to determine the physical and mechanical properties of the geotextiles, and in other lectures we will continue the other types of tests.

Thank you.