Geosynthetics Engineering: In Theory and Practices
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Module - 3
Lecture - 10
Geosynthetic Properties and Test Methods

Welcome to lecture 10, I am professor J N Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India. This module 3, lecture 10. Now, I will begin this geosynthetics properties and test method.

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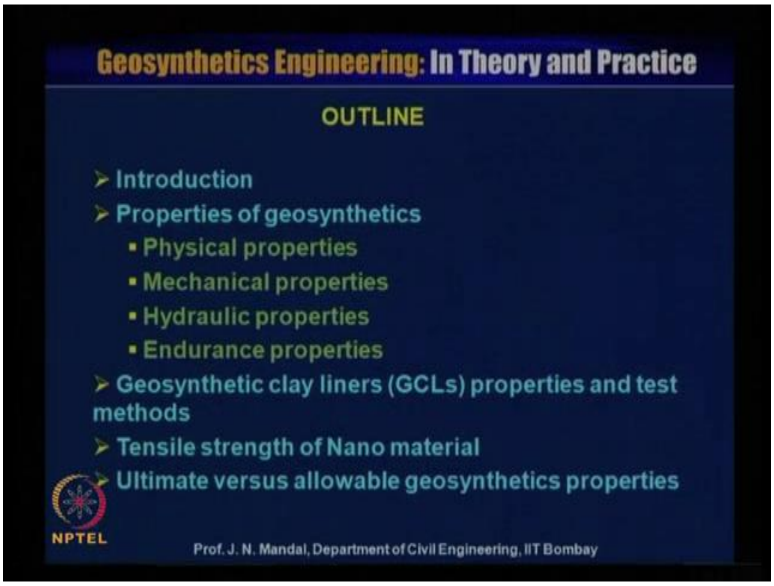

This is outline of the geosynthetics and test properties is introduction properties of geosynthetic that is physical properties, mechanical property, hydraulic properties, endurance property. Geosynthetics clay liner, which we call G C L S properties and test methodtensile strength of nano material, ultimate versus allowable geosynthetics properties.

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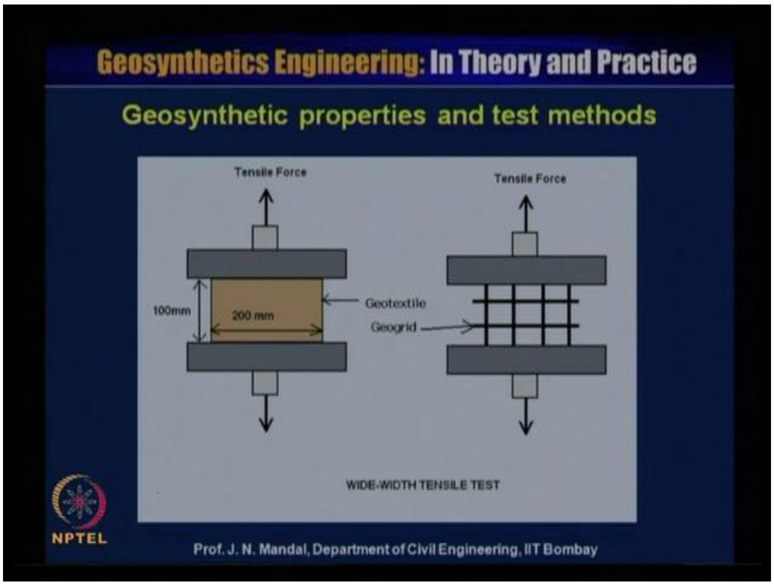

So, I will cover this during this lecture number 10, on the course geosynthetics engineering, in theory and practice. When to test geosynthetics? Firstly for any project the design engineer must check the required specification of geosynthetics material.

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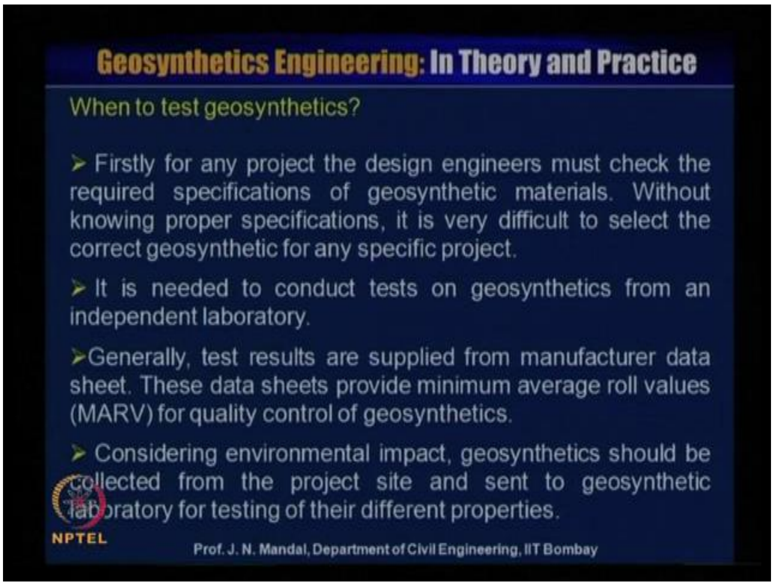

Without knowing proper specification, it is very difficult to select the correct geosynthetics for any specific project. It is needed to conduct test on geosynthetic from an independent laboratory. Generally, test result is supplied from manufacturer data sheet. These data sheet provide minimum average roll values that is MARV for quality control of geosynthetics material. Considering environmental impact, geosynthetics should be collected from the project site and sent to geosynthetics laboratory for testing of the different properties.

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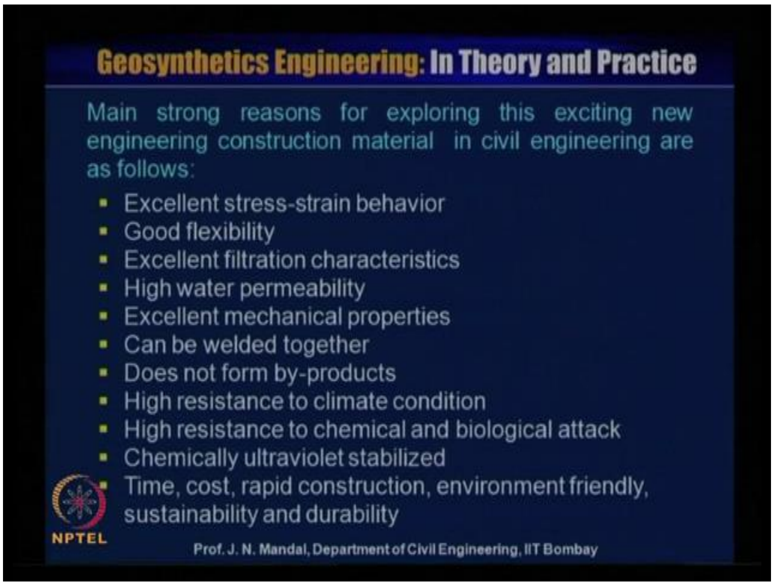

Main strong reason for exploring this exciting new engineering construction material in civil engineering are as follow. It give excellent stress strain behavior, good flexibility, excellent filtration characteristic, high water permeability, excellent mechanical property can be welded together, does not form by-products, high resistant to climate condition, high resistant to chemical and biological attack, chemically ultraviolet stabilized and time, cost, rapid construction, environmental friendly, sustainability and durability.

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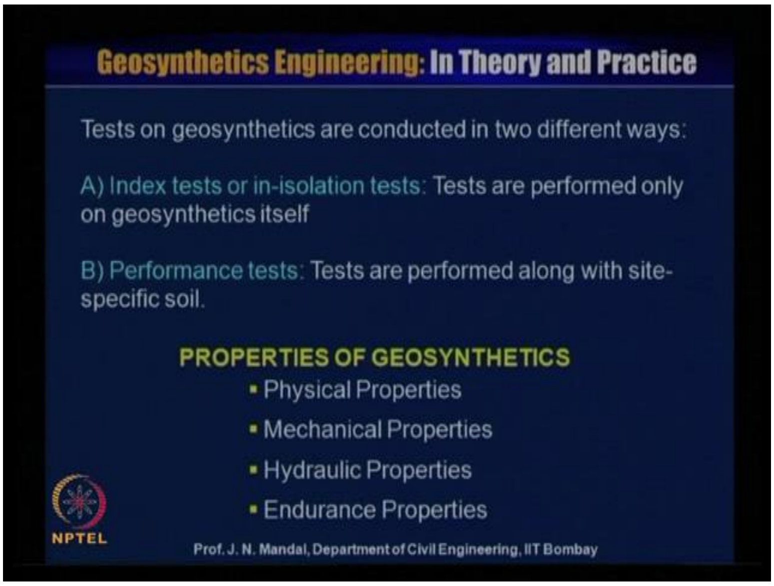

Test on geosynthetics are conducted in two different ways: a) index test or in-isolation test, test are performed only on geosynthetics material itself and b) performance test. Tests are performed along with site specific soil. Now, we will discuss the properties of geosynthetics, their physical properties, mechanical properties, hydraulics property and endurance property.

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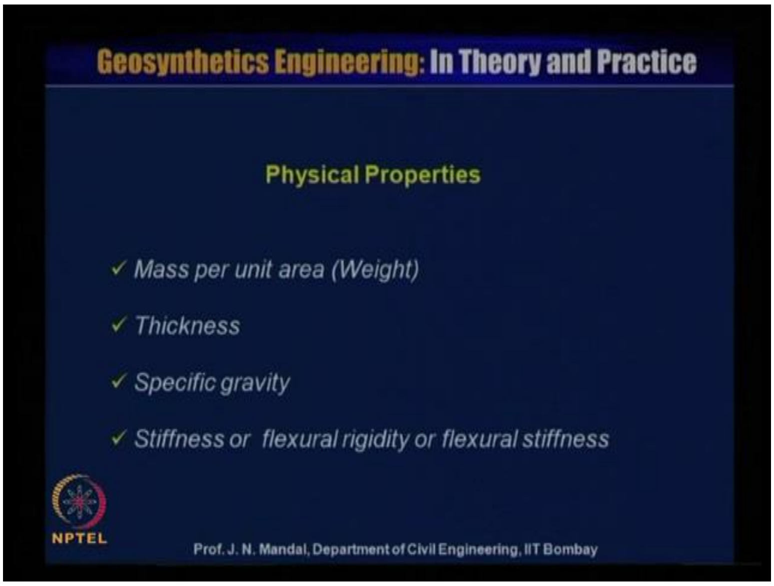

So, we will discuss the different properties of the geosynthetics material. It may be woven geosynthetics material, non woven geosynthetics material, it may be geogrid, it may be geomembrane, it may be geosynthetic clay liner, it may be geo cell and we will teach you about their different properties.

So, first of all I will talk about the physical property. In the physical property, we require, what is mass per unit area or weight, what is thickness, what is specific gravity, what is stiffness or flexural rigidity or the flexural stiffness? So, we should know that how to conduct the test. This is very, very important for quality control and quality assurance. So, mass per unit area as per ASTM D5261.

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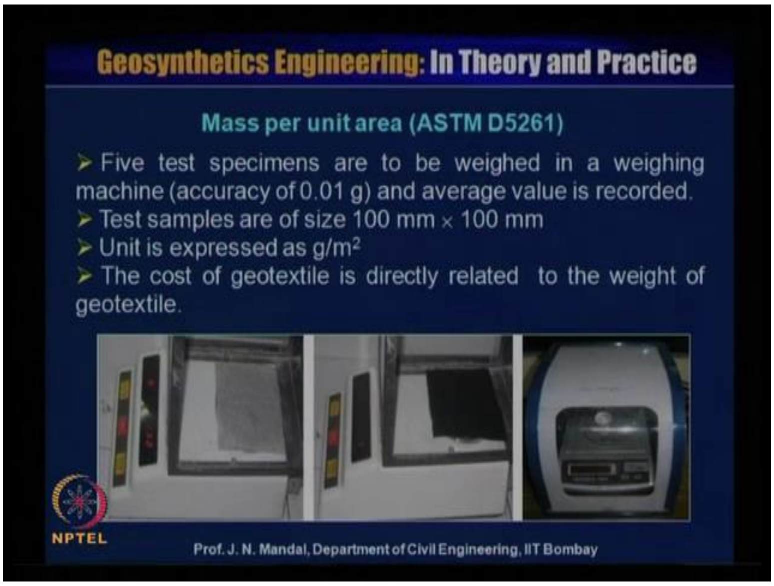

So, five test specimen are to be weighed in a weighting machine accuracy of 0.01 gram and average value is recorded test sample are of size 100 millimeter into 100 millimeter and the unit is expressed as gram per meter square. Cost of geotextile is directly related to the weight of the geotextile material. You can see here, this is the geotextile sample is 100 meter by 100 meter. This is another also type of the geotextile material and then you can place on this machine and then you can find out what will be the weight and the accuracy of this machine is of 0.01 gram.

So, it is very simple test and you can measure the, what will be the weight of the geosynthetics material and because if you need more weight that mean cost of the geotextile material automatically will be the more.

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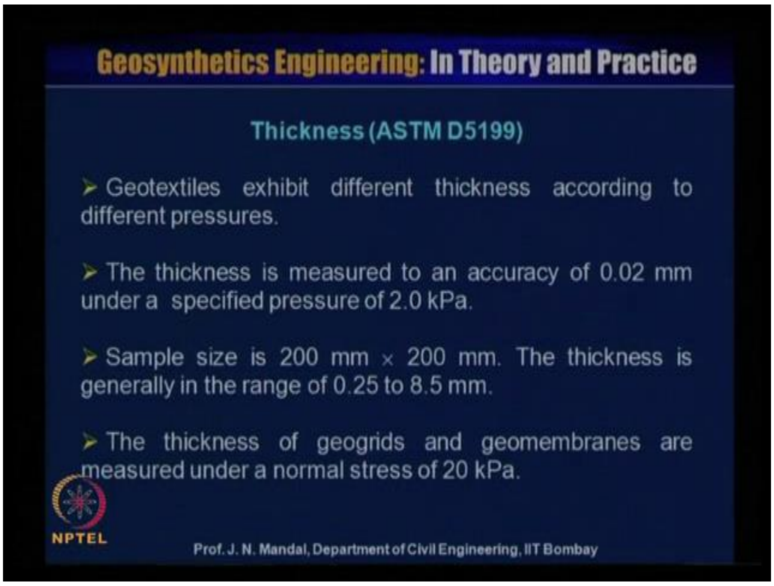

Next property is thickness ASTM D5199: Geotextile exhibit different thickness according to the different pressure. The thickness is measured to an accuracy of 0.02 millimeter under a specified pressure of 2 kilopascal and sample size is 200 millimeter into 200 millimeter. The thickness is generally in the range of 0.25 to 8.5millimeter. The thickness of geogrid and geomembranes are measured under a normal stress of 20 kilopascal.

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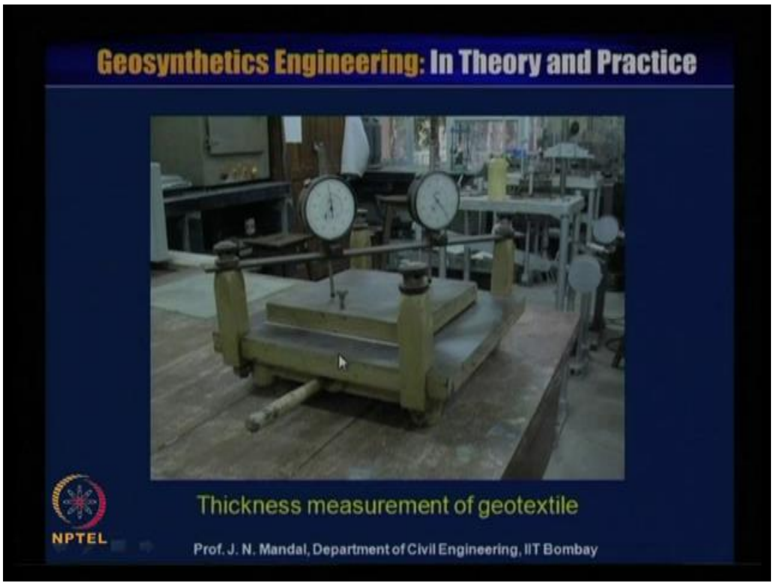

You can see here, thickness measurement in a geotextile. You have to, you have to place this, you have to place this geotextile material here and where size is 200 millimeter into 200 millimeter. So, this is 200 millimeter by 200 millimeter and this weight of this is 2kilopascal under a specified pressure. So, you have to place under a specified pressure of 2 kilopascal, so you can take a five sample and we apply the load and then you measure that what will be the change before and after applying the load.

Then you measure the thickness and this thickness is lies between 0.25 to 8.5 millimeter. So, when you are measuring the thickness for the woven and nonwoven geotextile material, then you are applying the pressure up to 2 kilopascal, but in case of the geogrid or the geomembrane, you can go under a pressure of 20 kilopascal.

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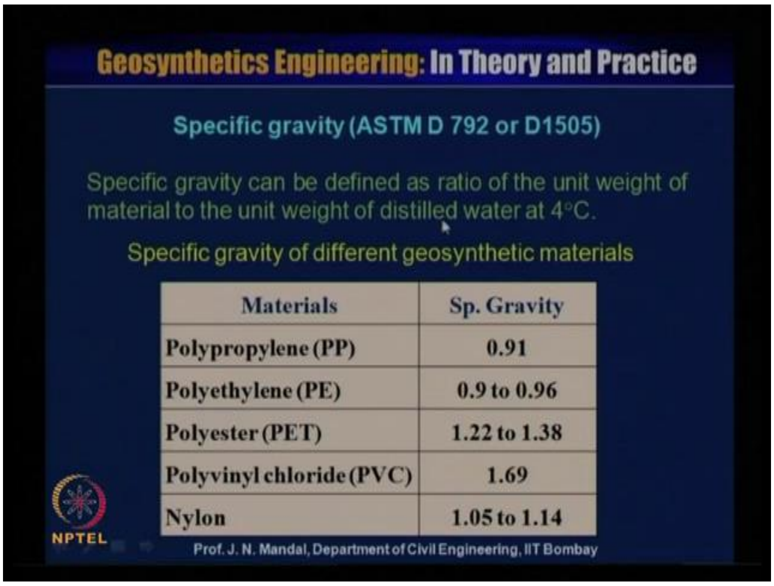

Materials	Sp. Gravity
Polypropylene (PP)	0.91
Polyethylene (PE)	0.9 to 0.96
Polyester (PET)	1.22 to 1.38
Polyvinyl chloride (PVC)	1.69
Nylon	1.05 to 1.14

Now, specific gravity as per ASTM D792 or D1505 specificgravity can be defined as a ratio of the unit weight of the material to the unit weight of distilled water at four degree centigrade specific gravity of different geosynthetics material. You can see here that, if it is apolypropylene material specific gravity is 0.91, polyethylene specific gravity is 0.9 to 0.96, polyester PET the specific gravity 1.22 to 1.38, polyvinyl chloride PVC specific gravity is 1.69, nylon specific gravity lies between 1.05 to 1.14. So, different material have their different specific gravity.

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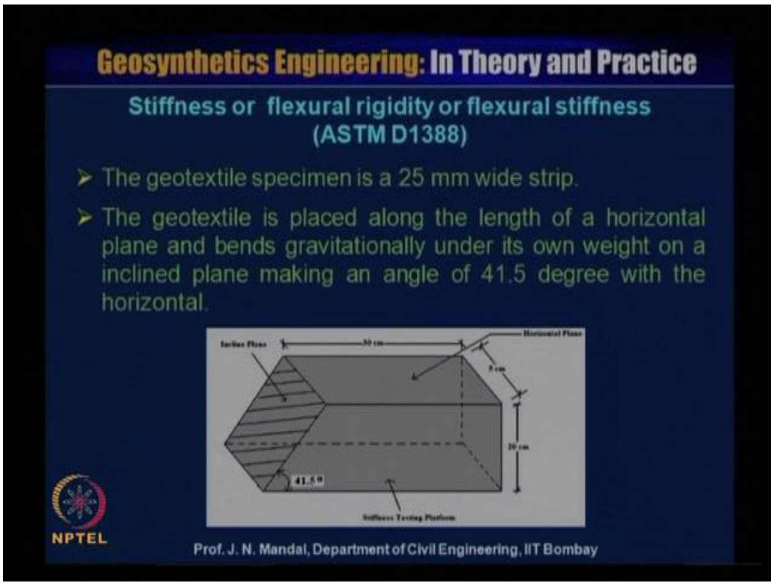

Now, the stiffness of flexural rigidity or flexural stiffness as per ASTMD 1388. So, geotextile specimen is 25 millimeter wide strip, geotextile is placed along the length, along the length of a horizontal plane and bends gravitationally under its own weigh ton a inclined plane making at an angle of 41.5 degree with the horizontal.

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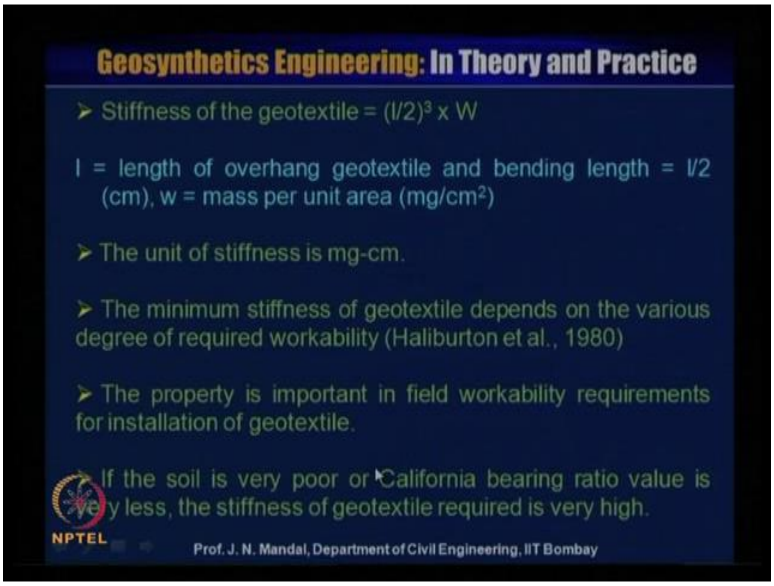

Then you can measure what will be the stiffness of the geotextile. Stiffness of the geotextileis l by 2 whole to the cube into w, where this l is equal to length of over hang geotextile and the bending length is l by 2 and this expressed is centimeter and w is the mass per unit area, where mass per unit area and which express as mg per centimeter square. So, therefore the stiffness of the geotextile or unit of stiffness is mg centimeter.

So, do not confuse that what you are talking about the stiffness of the geotextile material. Stiffness of the geotextile unit is mg centimeter. You can see here, this the l length of the overhang geotextile. This is in centimeter and the weight is mg per centimeter, so unit will be mg centimeter. Minimum thickness, stiffness of geotextile depend on various degree of required work ability that Halburton et al 1980. The property is important in the field workability requirement for installation of geotextile.

If the soil is very poor or California bearing ratio value is very less, the stiffness of the geotextile required is very high. So, when you select for any project what should be the stiffness of the geotextile material? That also depend upon that what will be the type of soil, what will be their California bearing ratio or undrained shear strength. So, these are all I talk about the physical property.

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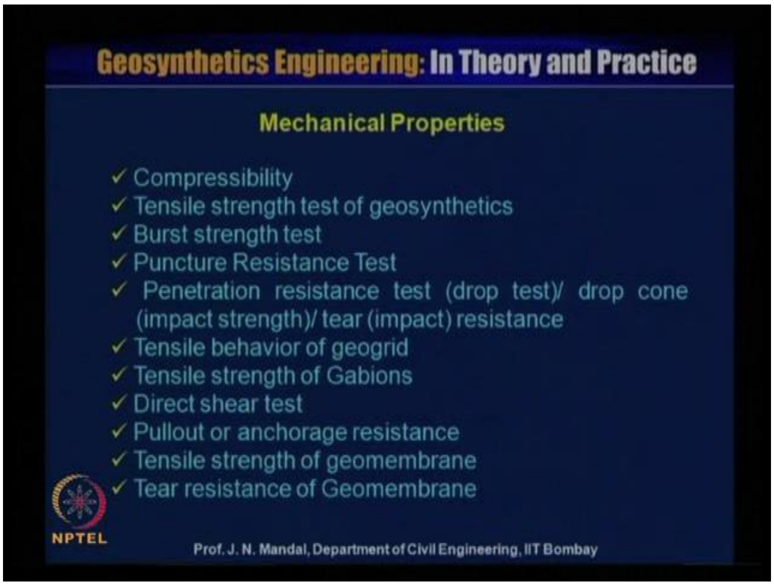

Now, we will address the mechanical property, which will cover: compressibility, tensile strength of geosynthetics material, burst strength test, puncture resistance test, penetration resistance test or drop test or drop cone it called impact strength tear impact resistance, tensile behavior of geogrid, tensile strength of gabion, direct shear test, pullout or anchorage resistance, tensile strength of Geomembrane, tear resistance of Geomembrane.

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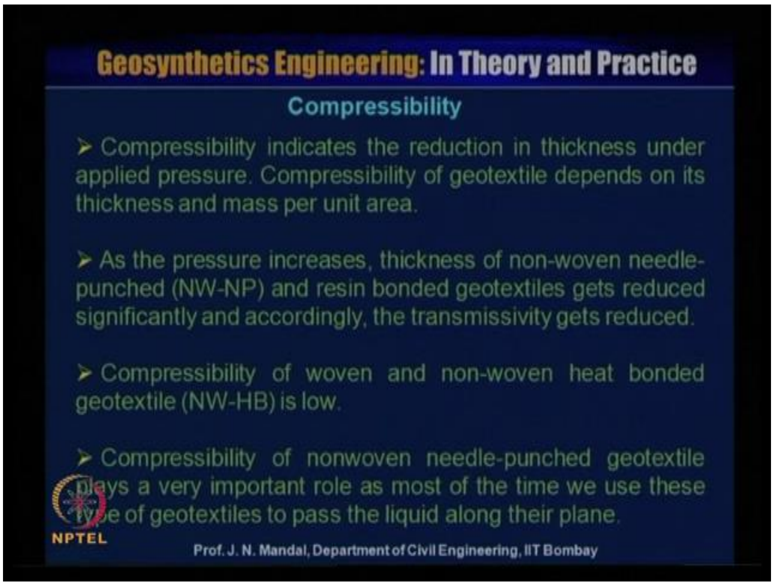

So, what is compressibility? Compressibility indicates the reduction in thickness underapplied pressure. Compressibility of geotextile depends on its thickness and mass per unit area. As the pressure increases, thickness of nonwoven needle punched in NW-NP and resin bonded geotextile get reduced significantly and accordingly, the transmissivity get reduced. Compressibility of woven and nonwoven heat bonded geotextile or NW-HB is low. Compressibility of nonwoven needle-punched geotextile plays a very important role as most of the time we use this type of geotextiles to pass the liquid along the plane.

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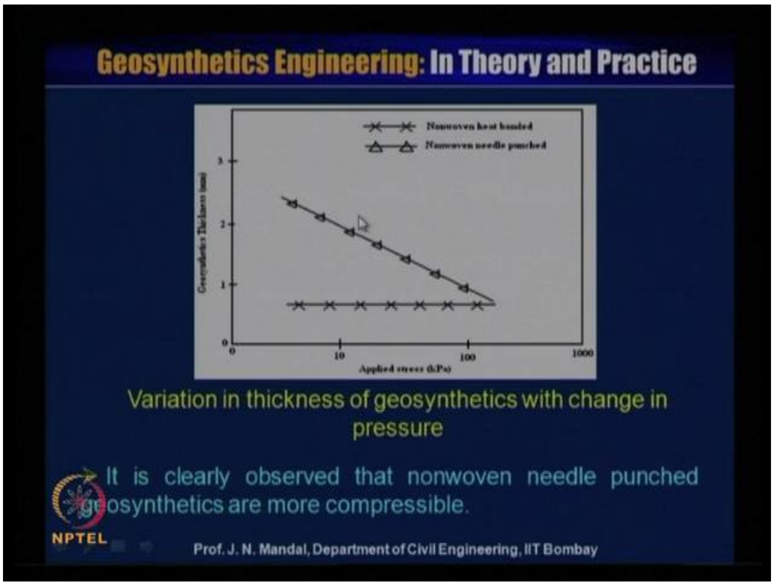

You can see this figure, that is related between the geotextile thickness in millimeter and this is the applied pressure in kilopascal. You can see, there are the two types of the geosynthetics material, how the variation in thickness of geosynthetics with change in the pressure this is its nonwoven heat bonded material and this is nonwoven needle punched material. You can see, this is non woven needle punched material and this is nonwoven heat bonded material.

So, it is clearly observed that non woven needle punched geosynthetics are more compressible.

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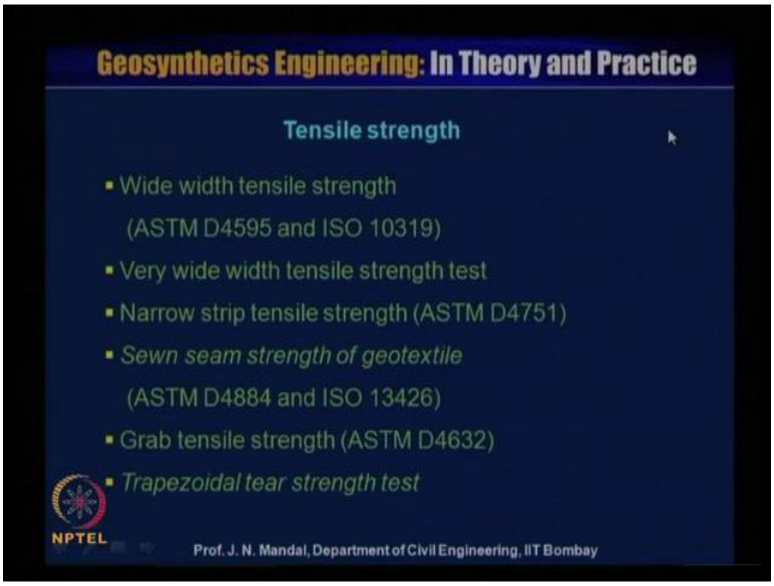

Tensile strength, there are various type of the tensile strength, that is wide width tensile strength, that is ASTM D4595 and ISO10319,very wide width tensile strength test, narrow strip tensile strength ASTM D4751, sewn seam strength of geotextile ASTM D4884 and ISO 13426, grab tensile strength ASTM D4632, trapezoidal tear strength test.

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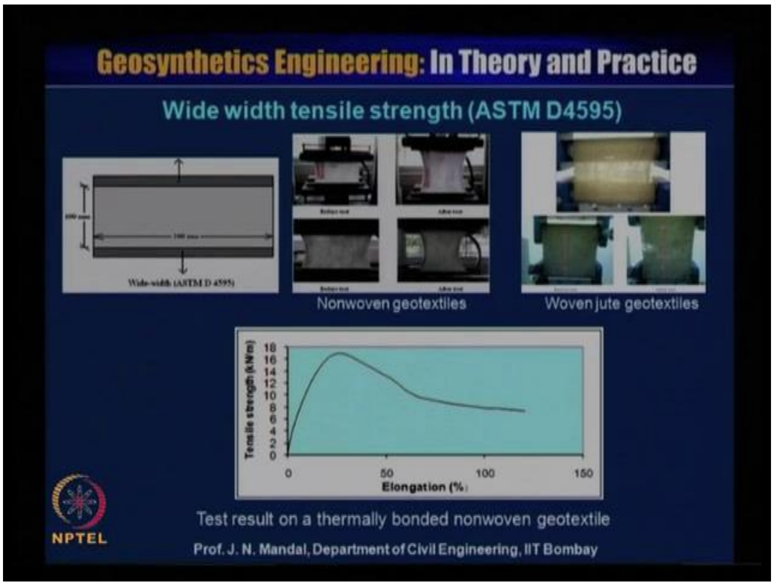

So, we can see that this is a wide width tensile strength has per ASTM D4594, the size of the sample, that is 200 millimeter by 100 millimeter. So, this type of strength test is highly recommended, because we adopt the tensile strength value of all the geosynthetics material based on the wide width tensile stress. So, here gauge length is about 100 millimeter. You can see that you have conducted some test on the non woven geotextile material, even then woven geotextile material, you can see in case of the nonwoven geotextile material, how there is a permission of net and also in case of the woven geotextile material you can see that typical failure pattern.

So, we can obtain from the test, what will be the tensile strength of the geosynthetics material and what will be the corresponding that elongation, and this is the test result on thermally bonded nonwoven geotextile material. Whenever you will conduct the test you have to maintain the machine strength rate. The machine strength rate is 10 plus minus 3percentages.

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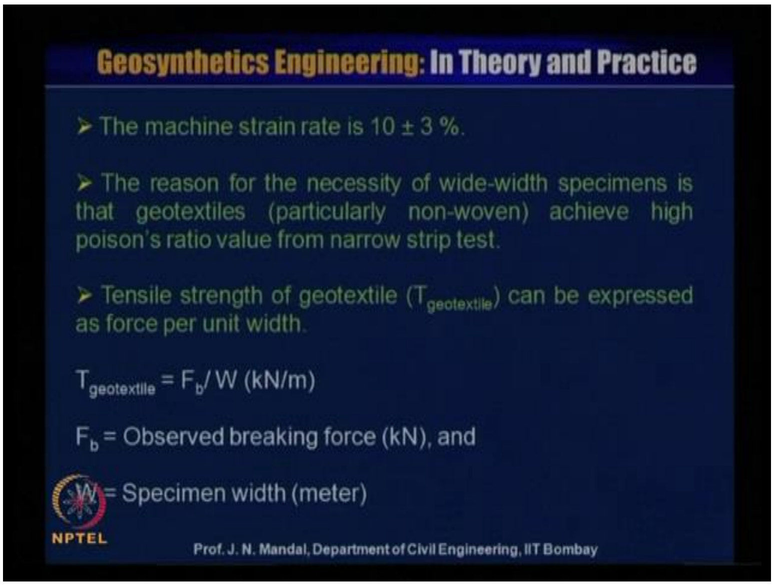

The reason for the necessary of wide width specimen is that geotextile particularly nonwovenachieve high poison's ratio value from narrow strip test. The tensile strength of the geotextile which is designated as t geotextile can be expressed as force per unit width, so T geotextile is equal to F b by W, so strength of the geotextile is expressed as kilo newton per meter where F b is the observed breaking force in kilonewton and W is the specimen width that is in meter that is why the tensile strength of the geotextile is expressed in kilonewton per meter. So, you remember it is kilo Newton per meter not kilo Newton per meter square.

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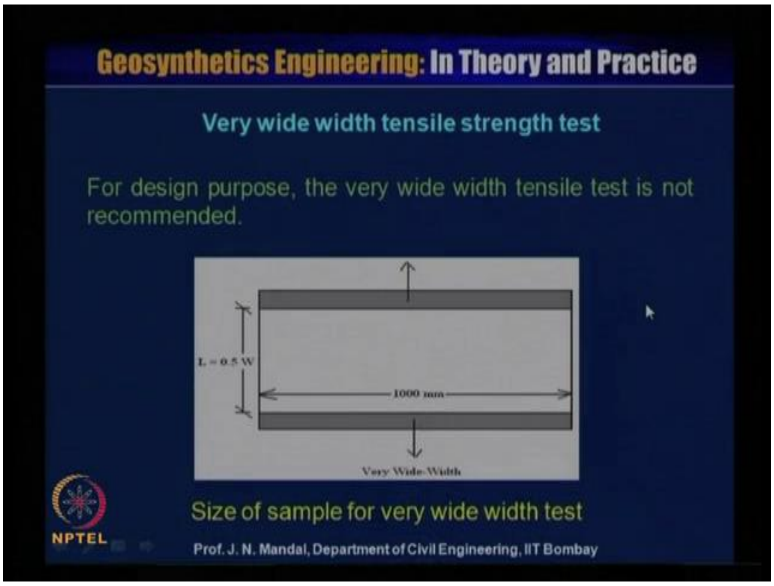

There are also other very wide width tensile strength, test for design purpose very wide width tensile test is not recommended. You can see this is the width of the sample about that 1 0 0 0 millimeter and this is about 0.5 times of W. So, this test is not recommended.

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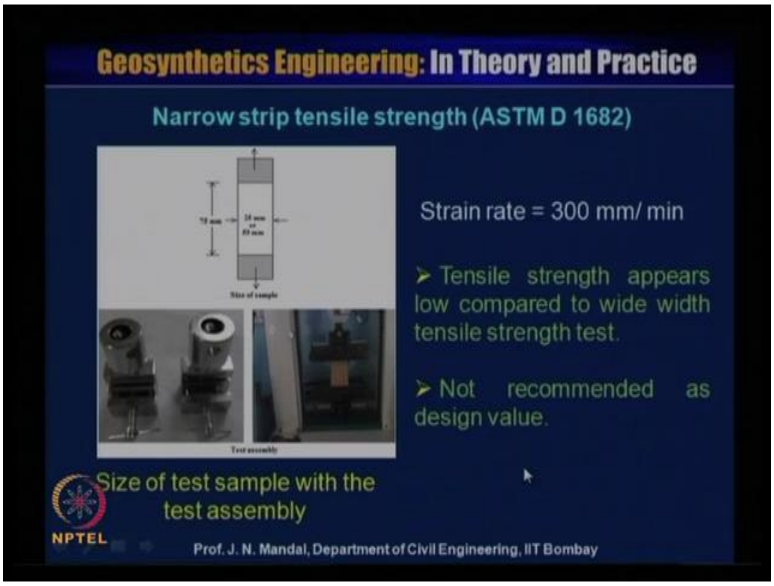

Then narrow strip tensile strength as far ASTM D1682, so here it is a very narrow, it is a very narrow you can have a 25 millimeter or 50 millimeter and this gauge length about 75 millimeter and strain rate is 300 millimeter per minute. You can see this is the size of the test sample with the test assembly and you have to, you have to perform the tensile strength appear low, compared to the wide width tensile strength test. So, this kind of the test is not recommended.

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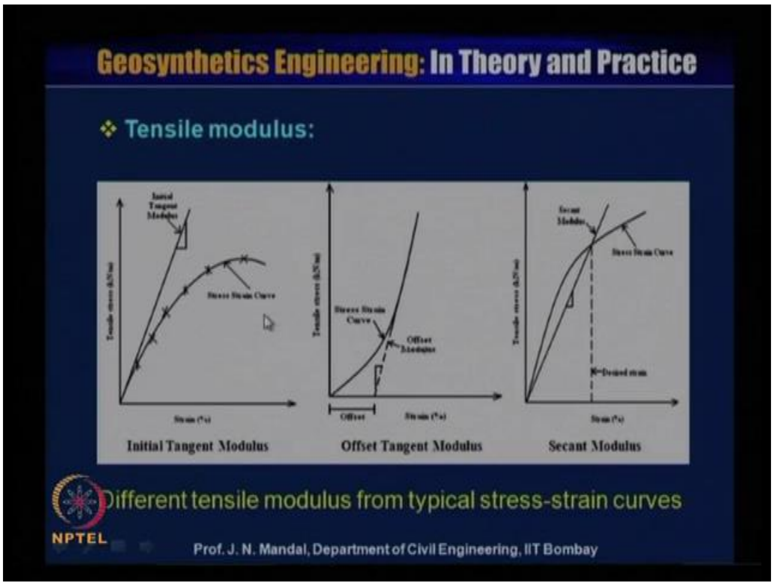

So,we always recommend, that wide width tensile strength for geosynthetics material. Here shows the different tensile modulus from typical stress strain curve. So, how you can calculate the initial tangent modulus, offset tangent modulus and the secant modulus? In the first, this is the tensile strength and this is the strain and you can see the nature of the curve. This is the stress strain curve for geotextile material, so you can draw an initial tangent from the origin, you can make a slope, so you can determine what will be the initial tangent modulus. These data also will be very useful for the design and also for the computational problem. Now, from this slope you can determine that what will be the initial tangent modulus of geotextile.

Now, sometimes you can see if you perform the test you can have a nature of the curve is like this that means this is a something offset modulus you can draw from this straight line and you can make at an slope here and this is the offset, so this is the stress strain curve for the geotextile and this is the relation between tensile strength and the tensile strain, so you can also determine what should be the offset modulus, I will show you one of the example and how you can calculate the offset modulus. This also figure shows the relationship between tensile strength and the strain and you can see this is the nature of the curve for the geotextile material and we wanted to calculate that what will be the secant modulus.

So, we can take any point on this curve and then you can take a slope of this, which will give you that what will be the secant modulus. Also, in many designs we use for the secant modulus, so this is the ratio of the stress and the strain, which will give you the secant modulus. So, in this slide we have shown the different tensile modulus.

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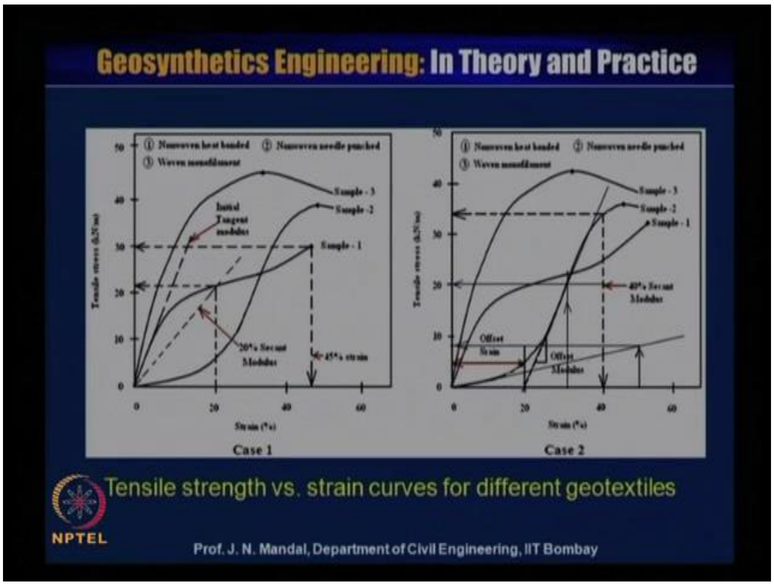

For the typical stress strain curve, this figure shows the tensile strength versus strain curve for different geotextile material. This is the tensile strength in Y axis and strain in the X axis three different types of the material, one is non woven heat bonded material, non woven needle punched material number two and number three woven needle punched material.

So, these are the three curve are shown number sample number one sample number two and sample number three. On the right hand side, in case two, here also I have shown the tensile strength versus strain relationship for the three geotextile sample, that is non woven heat bonded number one, number two non woven needle punched geotextile material and woven mono filament geotextile material. You can see, that different nature of the stress strain curve for the different type of the material.

Now, we wanted to calculate that how you can determine the initial tangent modulus or how you can determine the secant modulus at a particular strain. For example, if you want to determine secant modulus for a 20 percent strain for this sample number one. So, for the 20 percent strain, you can calculate what will be the tensile strength. So, let us say about 12 kilo newton per meter for the strain of 20 percentage.

Similarly, for this sample also you can determine, what should be the initial tangent modulus. Also, you can determine that for the sample one, what should be the maximum tensile strength value for the sample number one. So, this is the strain, this is about 45 percentage strain and corresponding the maximum tensile strength value about 30 kilo Newton per meter, I am showing it here.

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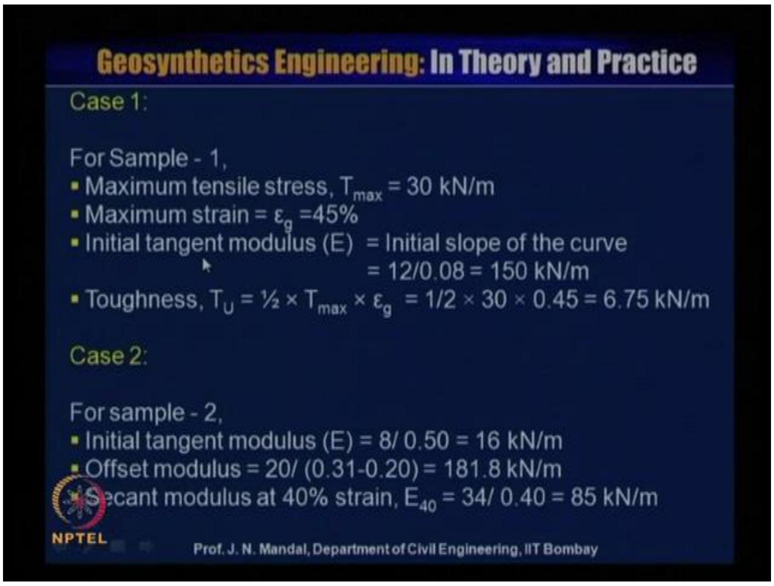

For a sample number one, maximum tensile stress T maximum is 30 kilo Newton per meter and maximum strain epsilon g is equal to 45 degree. From here we can calculate. So, this is 45 degree, for sample number one and corresponding tensile strength value is 30 kilo Newton per meter. Now, the initial tangent modulus, the initial tangent modulus E is equal to initial slope of the curve. So, initial tangent modulus means, this is initial slope of the curve, this is initial slope of the curve. So, correspondingly you can determine that what will be the tensile strain and corresponding the strain value.

So, you can see that it is initial tangent modulus and about, near about here12 and corresponding strain value is 0.08 and this strain, so you can have 12 by 0.08 is equal to 150 kilo Newton per meter. Now, toughness which is designated as T u is equal to 1 by 2 into T maximum into epsilon g now toughness is equal to 1 by 2 into T maximum is thirty, thirty and epsilon g is 45 percentage that means 0.045, so this is equal to 6.75 kilo Newton per meter.

So, from the case one for the sample number one, we observe, how you can calculate the secant modulus, how you can calculate the maximum tensile strength and also how you can calculate the maximum strain value. At the same time, for the sample number one, we have calculated, what should be the initial tangent modulus and also corresponding strain. So, if you know the initial tangent modulus and maximum tensile strength for the sample number one, then also you can determine that what will be the toughness, so that toughness is equal to 1 by 2 into T max into epsilon g.

Now, I am showing for sample number two, and you see there are three sample, sample one, sample two and sample three. So, this for the sample two, you can see nature of the tensile stress and strain curve like this, this is for sample two, hits like this, so this what we call the offset. This is the offset modulus, this is offset modulus. So, the slope of this will be the offset modulus. So, we want to calculate what should be the offset modulusand what should be the initial tangent modulus. This is the curve for the sample number two, so this is the initial tangent modulus. You can is this is the initial tangent modulus. So, initial tangent modulus at any strain and you know corresponding strain.

So, for the sample number two or case two, we want to calculate initial tangent modulus E is equal to 8 by 0.50, you can see this is the initial tangent modulus and this is the 8 tensile strength value and corresponding to strain value is here this is near about in between 40 to 60, so it is it is comes about 50, so 8 divided by 0.50. So, initial tangent modulus will be equal to 16kilo Newton per meter. Now, how you can calculate the offset modulus? This is offset modulus, this is offset modulus this slope.

So, this is the 20, this is 20 and you are taking this slope this slope, so we are taking this point, so this is 20 and this is in between 20 to 40, so this is 31 and corresponding tensile strength value is 20, so if this is a 31, so this 20 divided by 31 minus 20, will give you ratio, will give you the offset modulus. You can see, that offset modulus is equal to 20 divided by 0.31 minus 0.20, is equal to 181.8 kilo Newton per meter.

So, secant modulus at 40 percent strain you can designated as E 40 is equal to 34 by 0.4. So, you can go secant modulus value, you can also calculate that what will be the secant modulus value. Suppose, this is the 40 percent strain, this is the per sample number two case two and corresponding, you can see what should be the tensile stress value. It is also lies between 30 to 40, so that is why it is coming 34 this dived by 0.40, because this 0.40 is the strain, so this will be equal to 85 kilo Newton per meter.

So, for the sample two or case two, we calculate what will be the initial tangent modulus. How to calculate offset modulus and also we show how to calculate the secant modulus and a 40 percent strain. So, any strain you can calculate the second modulus. So, when we will perform the tensile strength of the geotextile material, we also have to perform these w n seam strength of geotextile.

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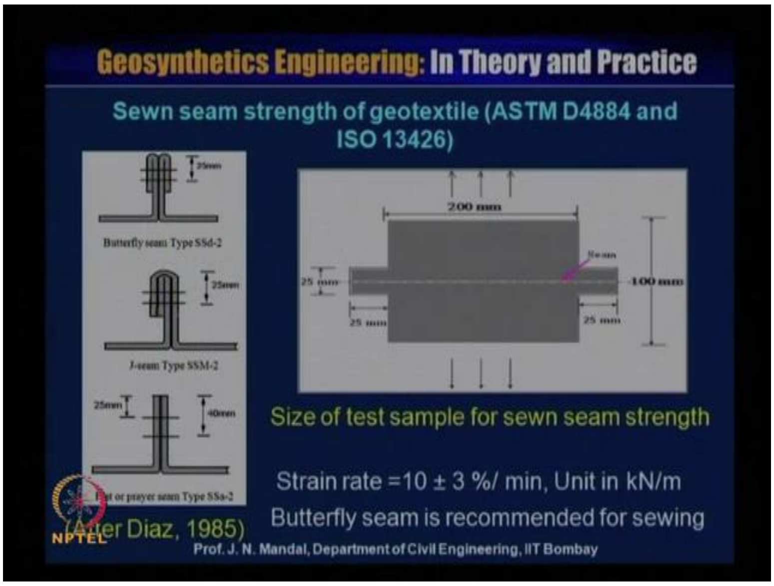

Here, you have shown that sewn seam strength of geotextile and as per ASTM D4884 and ISO 13426. So, this is the size of the sample, this is 200 millimeter and this is 100 millimeter. It is like a wide width tensile strength sample, but in case of strain sample, you have to be projected by 25 millimeter by 25 millimeter and this middle portion, this middle portion is the seam. The sample has been joined by stitching, so it has been stretched and this sample has been perform.

The sewn seam strength in a universal testing machine at a strain rate of 10 plus minus 3 percent per minute and unit of the seam strength is, kilo Newton per meter. So, you have to check, what will be the tensile strength of the geotextile material, without and with seam strength and from that also you can calculate what will be the efficiency of the geotextile material. I have already told you about the how to calculate the efficiency.

So, if you know the tensile strength of the geotextile material and if you know the tensile strength of the seam strength of geotextile material. So, you can calculate now, when you will join the geotextile material in the field. There are different types of the joining, one is the butterfly seam type. That is SSD two or it may be the your J seam type SSM two or flat or pair seam type SSA two. So, you can see that how the butterfly, it is like a geotextile material and then wrap, this side also geotextile material wrap and then you can stitch at a particular placing 20millimeter, so this is called the butterfly. This is J seam it looks like a J, so this is one geotextile material and this is another geotextile material and then I am stitching it here.

So, this call the J seam type joint and this one is like a flat or like a pair, so this is a geotextile material, this is the geotextile material and then I am stitching two layers of stitching at a particular facing 25, 40 millimeter or like that. So, you have to stitch properly and you have to use proper kind of the material for teaching. So, what you will use whether you will use polypropylene polyester nylon? You have to provide with the very good strength of the fiber element for stitching a thread for stitching, so most of the cases it has been observed, that butterfly is recommended for the stitching. Of course, now a days you can wear the nonwoven geotextile material.

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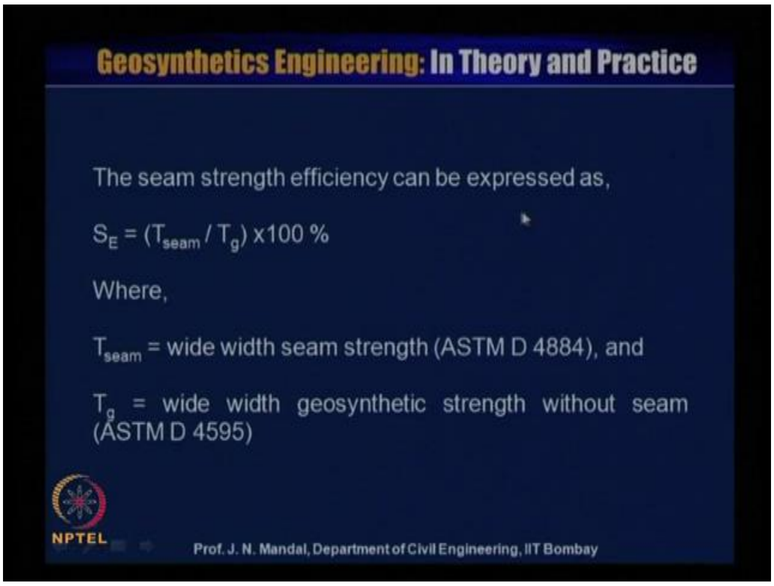

So, seam strength efficiency can be expressed as SE is equal to T of seam divided by T g into 100 percentage, where T of seam in wide width seam strength as far ASTM D4884.

So, you can calculate the, what will be the seam strength. T g is wide width geosynthetic strength without seam as per ASTM D4595. You know for what will be the wide width geosynthetic strength without seam and then you know what will be the wide seam for seam strength. You take the ratio in the 100 percent, which will give you that what will be the seam strength efficiency. So, you know what is seam net efficiency?

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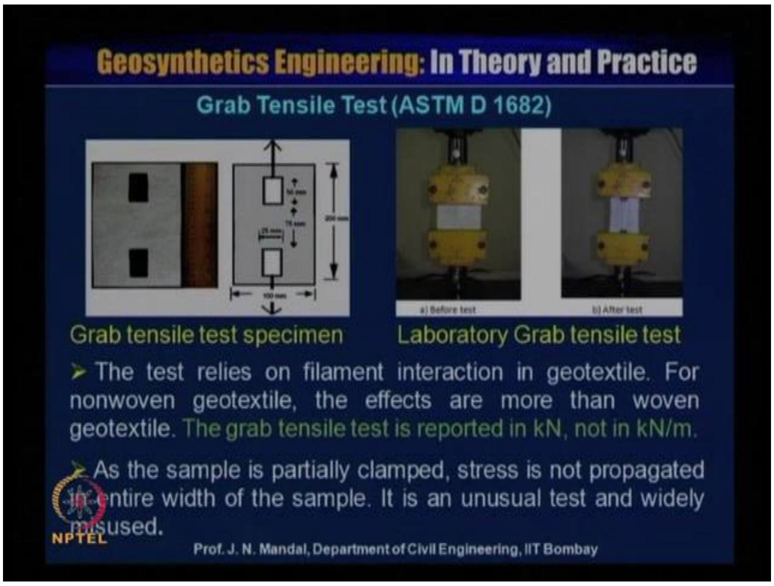

Next, we will talk about the grab tensile strength as per ASTM D1682. So, this test you can see the sample like this, and here is size is about 50 millimeter and in between is 75 millimeter this is again the 25 millimeter and this the clamp, this will be clamp this will be clamp and this is 100 millimeter and this is 200 millimeter. Then you have to clamp here like this, clamp here this is the test I have been conducted in IIT Bombay and this you can see that before test and you can see that after test.

So, this test relies on the filament interaction in geotextile material for non woven geotextile material the effect are more than the woven geotextile material and the grab tensile test is reported in kilo Newton, not in kilo Newton per meter. As the sample is partially clamped, you can see that here sample is partially clamped. This portion only clamped stress is not propagated the entire width only. This portion stress is propagated not the entire width of the sample, so it is unusual test and widely misused, so grab tensile strength should not be used as a design parameter.

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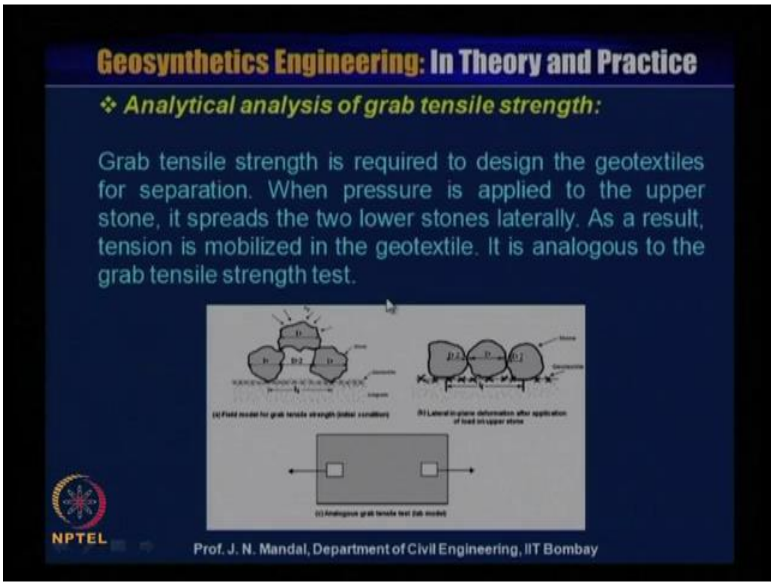

Now, we will address the analytical analysis of grab tensile strength. Now, what is happening in the field and how you can analog in the experiment? So, this is analog of grab tensile strength in the laboratory and this is field method for grab tensile strength. So, you can see here this is l i that is initial strength length of this. If this is the aggregate, this is the aggregate and on the top of this, is aggregate and where A p is the applied pressure and this is D and this is also D, this stone are aggregate and in between is equal to D of two and this is the subgrade and geotextile is placed between this aggregate and the sub grade.

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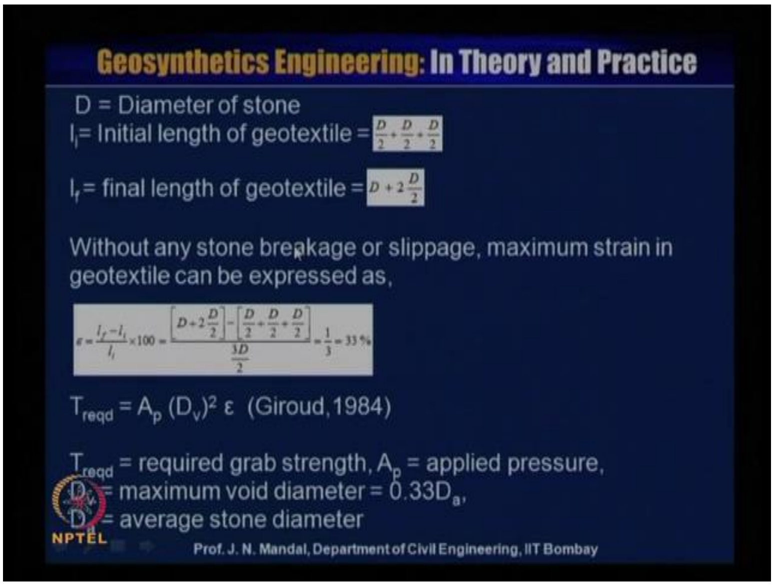

So, initial length is l this is showing this initial length l i length of the geotextile material. This is l i initial length of the geotextile material and this is the D, D is the diameter of the stone, so this is diameter of, this is diameter of the stone all three diameter of the stone and here is a p. You see applying the pressure. If apply the pressure then you can see here, how is the lateral in plain deformation after application of load, after application of load on the upper stone. So, if we apply the load on the upper stone then you can see the how is stone laterally deform and this you can say l f plane you can see, that l f is the final length of the geotextile, this is l f is the final length of geotextile.

So, look at here that this li, that means initial length will be D this is D by 2. I am showing that D by 2 and then this is also D by 2 and then D by 2. So, this will be D by 2,D by plus D by 2 plus D by 2and l f is the final length of the geotextile. That means, this final length of the geotextile l f, that is D, this is D by 2 and D by 2. So, you can write D plus 2, D by 2. So, that is why you are writing, D plus 2, D by 2. This is the final length of the geotextile.

So, without any breakage or the slippage, maximum strain in the geotextile can be expressed as epsilon, is equal to if minus l f minus l i divided by l i into 100. So, we know that l f is equal to final length, D plus 2,D by 2 and minus that initial length of the geotextile that is, D by 2, plus D by 2 plus D by 2. So, this is D by 2 plus D by 2, plus D by 2, this divided by the final length of the geotextile material, so this will be equal to 3D by 2.

So, if you calculate, then you have that epsilon is equal to one-third, means it is about 33percentage.Now, Giroud give an equation for the determination of required grab strength, so that is T require is equal to A p into D v square into epsilon. This is given by Giroud, 1984 and T require is the required grab strength A p is equal to applied pressure, what you are putting the pressure A p and D v is equal to maximum void diameter, so maximum void diameter is equal to 0.33 of D a for D a is equal to, average stone diameter.

So, if you know that what will be the average stone diameter D a, so you can calculate the, what will be the maximum void diameter. So, if you know D v, if you know epsilon and if you know what is the applied pressure, then analytically, you can determine, what will be the required grab strength of the geotextile material. Here one example I have shown.

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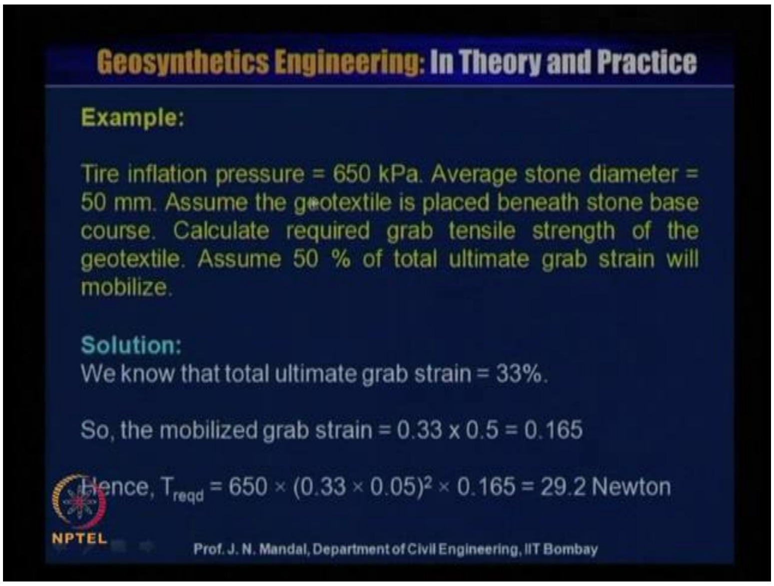

The tire inflation pressure is equal to 650 kilopascal, average stone diameter is equal to 50 millimeter. Assume, the geotextile is placed beneath the stone base course and calculate required grab tensile strength of the geotextile assume 50 percent of total ultimate grab strain will mobilized. So, now we go for solution, we know that total ultimate grab strain is 33percentage.So, what should be the mobilized grab strain 50 percent of the total? So, 50 percent of the total grab strain mean, 0.33 into 0.5 is equal to 0.165. What is T required, T required is equal to you have seen the earlier equation, A p into D v square into epsilon. So, here what is A p? That pressure, that is 650 kilopascal into D v square, so D v square will be equal to D v square will be equal to, 0.33 times that 0.05.

So, because D v is equal to 0.33 of D of a d a ((Refer Time 44:40)) is equal to average stone diameter and average stone diameter here is 50 millimeter, so D v will be equal to 0.333 times of point 0.05, because this is the stone that is the diameter average stone diameter so average stone diameter is 50 millimeter. So, that is why this from this equation D v square d maximum void diameter 0.33 D a, so D a is this 50, so that is why 0.33 into 0.05 whole square into what will be the strain value strain value is 0.165. So, this will be equal to 29.2 Newton. So, from this stress analytical, so we can also calculate what should be the grab strength value.

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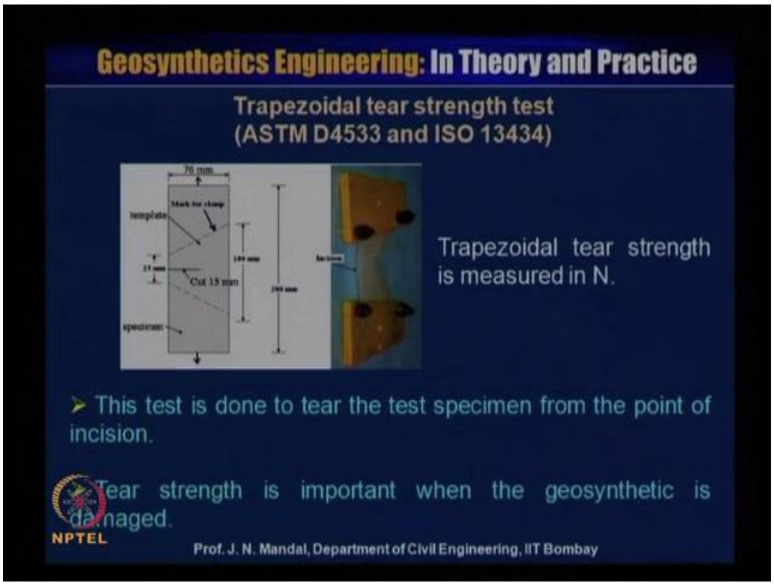

Now, we will discuss trapezoidal tear strength test. As far ASTM D4533 and ISO13434. So, trapezoid altear strength is generally measured in newton. You can see, this is the sample, this is the sample and in this specimen this is about 100 millimeter and this is 200 millimeter, so it looks like a trapezoid like this and in between this is about 25 millimeter and there is a cut is 15 millimeter. So, this trapezoidal is to be clamped like this and this test is done to tear the test specimen from the point of incision here. So, tear strength is important when the geosynthetics is damage, so one has to conduct the tear strength.

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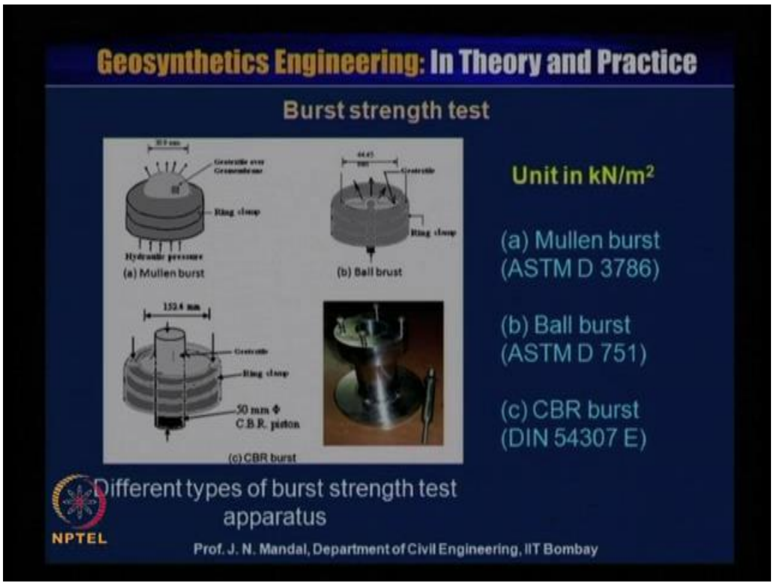

Next, burst strength test. So, you can see here different types of the burst strength test apparatus and this Mullen burst strength, ball burst strength CBR burst strength Mullen burst strength as per ASTM D3786, ball burst strength as per ASTM D751, CBR burst strength DIN 54307E. So, in case of this Mullen burst strength, you can see there is a hydrostatic pressure and the geotextile sample with the geo membrane, is just to clamp here and hydrostatic pressure is pushed from the bottom and this geotextile material is burst and you can pressure, what will be the pressure. Also, you can go for the ball burst and the CBR burst.

So, this is an equipment in which also you can also determine the burst stress, this is also modified CBR burst and this is you can, you can see this rod and geotextile material is clamped here, and you have to push and then there is a pressure meter you can measure the pressure.

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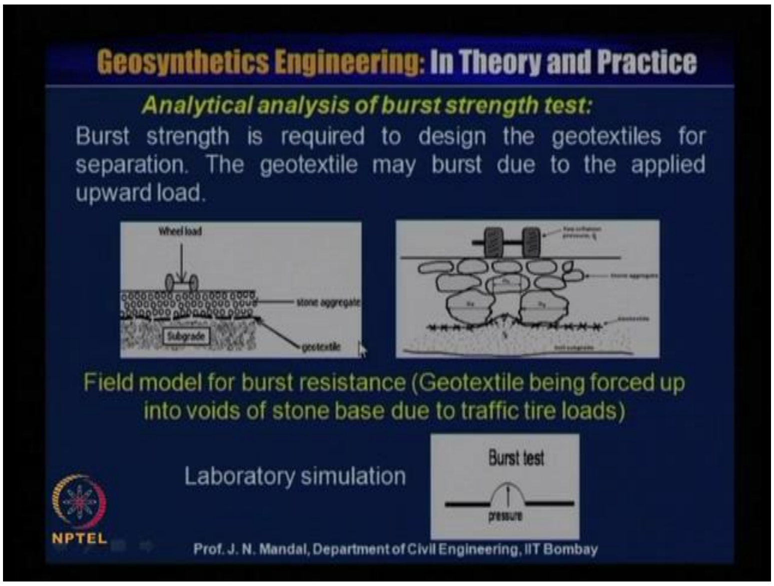

At what pressure the geotextile material is burst? So, you can calculate this burst pressure. Now, how you can analytical analysis for the burst strength test, burst strength is required to design the geotextile for separation geotextile may burst due to the applied upward load. We can see here that how you can compare the field model of burst resistance to the laboratory simulation. So, here is the subgrade here is the geotextile material, here is the stone aggregate. Now, in the stone aggregate, there is a void in the stone. When due to the traffic load or the wheel load, this geosynthetics material may push into the void of the aggregate.

So, you can see that, what is happening in the field. If you can simulate this see, you can see here is the aggregate here, is the aggregate here, is the void between the stone and due to the, due to the application of the wheel load or the tire pressure. This geotextile material push into the void of the aggregate, and the geotextile material may burst, which in the field can be simulated in the laboratory. So, it is you can clamp in a model and you can see this is geotextile material it may push the upward and then geotextile material may fell. So, this way we calculate the burst stress.

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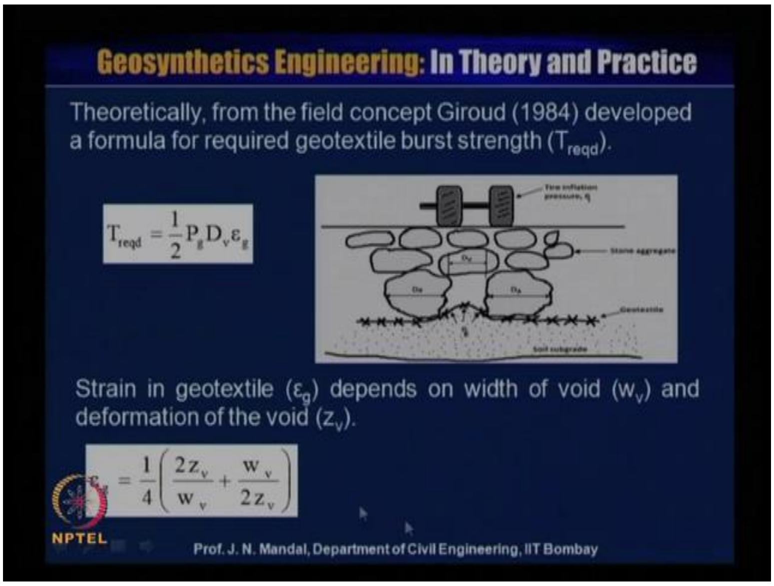

Now, some theoretically from the field concept Giroud, 1984, developed a formula required for geotextile burst strength that is T required is equal to 1 by 2 into P g into D v into epsilon g. So, you can see here this is the P g and this is the D and there will be the strain in the geotextile depend on the width of the void, that is W v and the deformation of the void is Z w. So, this strain you can calculate with this equation epsilon g is equal to 1 by 42Z v by W v plus W v by 2 Z v for this, Z v is the deformation of the void and this W v is the width of the void. So, you can calculate that, what should be the strain value that means epsilon g.

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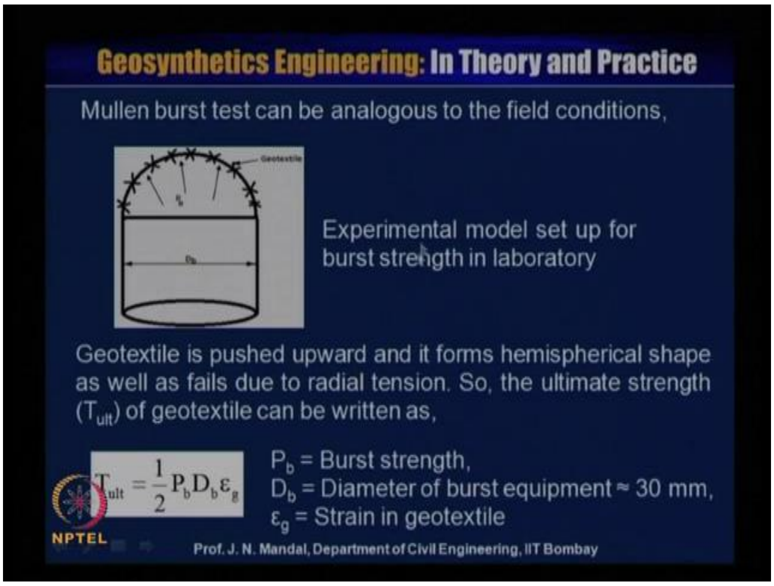

Now, Mullen burst test can be analog to the field condition, so this is the experimental model set up for burst strength in the laboratory and this is the D b, which call the diameter of the burst equipment and this equal to about 30 millimeter and this is the gravitational material clamp and there is a upward force, that is P v, this is, this is what we call the burst strength.

So, geotextile is pushed upward and it forms a hemispherical shape, as well as fail due to radial tension. So, the ultimate strength of the geotextile can be written as T ultimate is equal to 1 by 2 into P b into D b into epsilon g where, P b is the burst strength and D b is the diameter of the burst equipment. This in the laboratory this equipment and that is known value that is 30 millimeter diameter and epsilon g is the strain in the geotextile.

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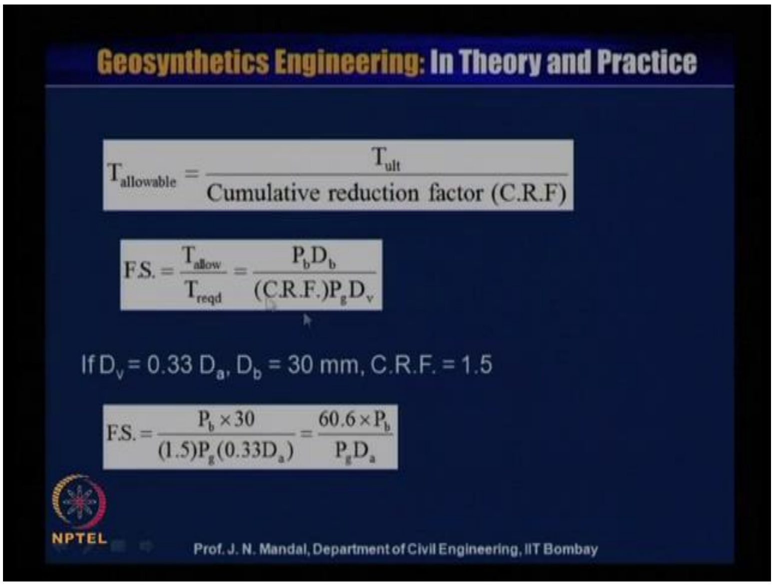

So, we can calculate that what will be the allowable tensile strength of the geotextile that is the ratio of ultimate tensile strain and all cumulative reduction factor. I will discuss more about the cumulative reduction factor. Let us say, that cumulative reduction factor is 1.5,so you can calculate factor of safety is equal to T allowable by T required. So, we have calculated earlier that what should be this T required value here,1 by 2 into P g into D v into epsilon g. So, T required is known and T ultimate is also known. So, we can calculate what will be the T allowable, because T ultimate is known, so T allowable you can calculate, T ultimate by cumulative reduction factor. This divided by T required and T required also you have calculated, this 1 by 2 P g into D v into epsilon g.

So, we can write a factor of safety T allowable by T required P b into D b by cumulative reduction factor into P g into D v. Now, for example that D v you known 0.33 times, this is D a diameter and D b is equal to 30 millimeter, that is D b is this diameter of the burst equipment 30 millimeter. So, D b also is known 30 millimeter and cumulative reduction factor 1.5. So, we can write the factor of safety is P b into 30 divided by 1.5CRP and P g and this D v is 0.33 D a. So, if you can calculate f s is equal to 6.6 P b by P g into D a. So, with this equation we can draw this curve.

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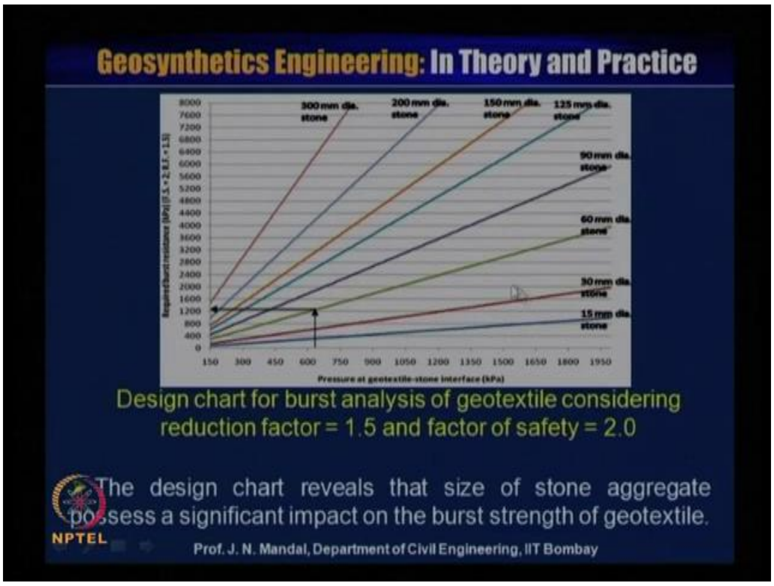

So, we can curve a design chart, burst analysis of the geotextile, considering reduction factor 1.5 and the factor of safety two, so this design chart reveal that, what will be the size of the stone this such shows that what should be the required the what is the required burst resistance and this X axis, which show the pressure, at the geotextile stone interface. This the different diameter of the stone, so this may be 15 millimeter, 30millimeter , 69 millimeter, 125, 200, 300 millimeter, like this. So, this design chart reveal that size of the stone aggregate possess a significant impact on the burst strength of the geotextile. If you know, what will be the pressure, add the geotextile stone interface.

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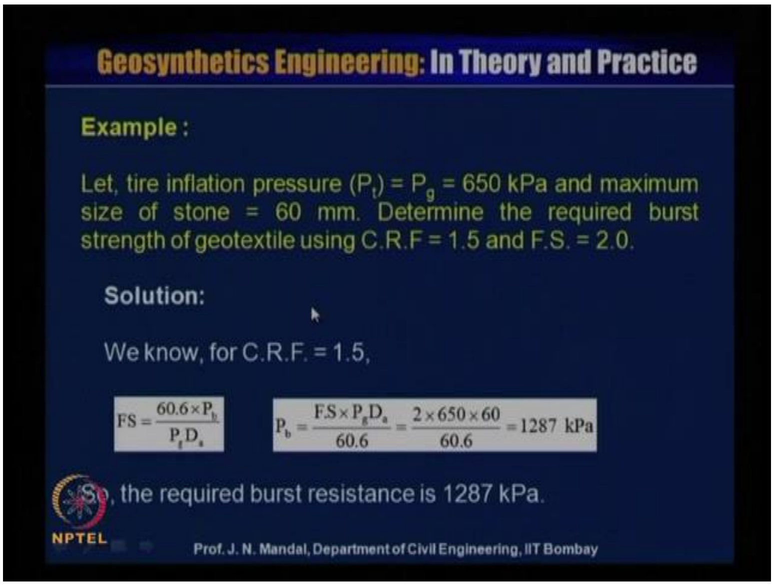

So, and then if you know, that what will be the diameter of the aggregates, then you can calculate what will be the required burst strength, for an example let the tire inflation pressure P tis equal to P g 650 kilopascal and maximum size of the stone is 60 millimeter. Determine the required burst strength of geotextile, using cumulative reduction factor is equal to 1.5 and factor of safety is equal to 2.0, so we know that cumulative reduction factor 1.5, so we know the earlier that factor of safety is 60.6 P b by P g into D a. So, we have to calculate, what will be the burst strength. This is P b so P b will be equal to f s into P g into D s divided by 60.6 and factor of safety, we have taken2, this is 2. This pressure is 650 P g is 650 into D a, D a, we know that diameter of the maximum size of the stone that is 60 millimeter, this divided by 60.6. So, it will given12.87 kilopascal.

So, the required burst resistance is 1287,you can see for this pressure you can have this 1287 kilopascal burst strength you can draw, you can also simulate from this curve. You can see that when the your that pressure is 650 kilopascal, you can see the pressure is 650 kilopascal and this diameter of the stone is 60 millimeter. So, you can directly also calculate, what will be the burst resistance. That is 1.87 kilopascal. So, these I have been test, I have just talked about. Please let us hear from you. Any question? Thanks for listening.