Geosynthetics Engineering: In Theory and Practices
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Lecture - 11
Geosynthetic properties and test methods

Welcome to lecture 11. My name is Professor J. N. Mandal Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai, India. The name of the course geosynthetics engineering in theory and practice, this is module number 3, lecture number 11 geosynthetics properties and test methods.

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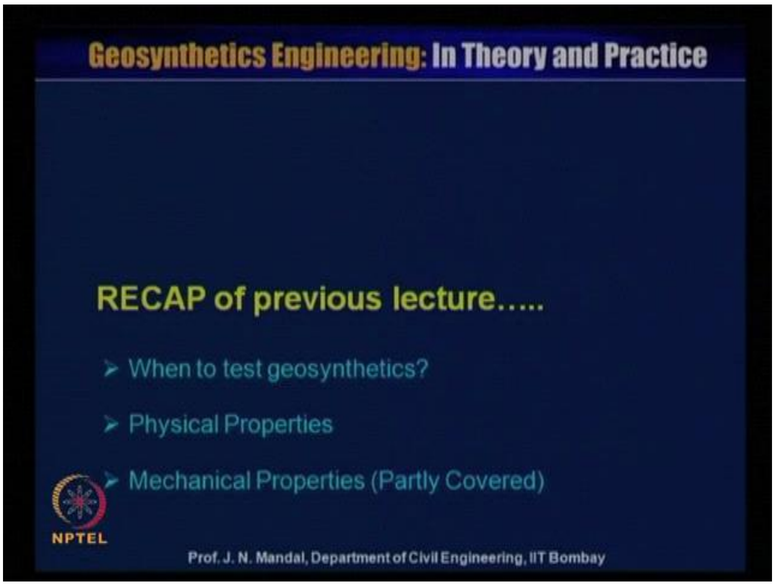

Now, I address the recap of previous lecture. Earlier we covered when to test geosynthetics? Physical properties and we also partly covered mechanical properties.

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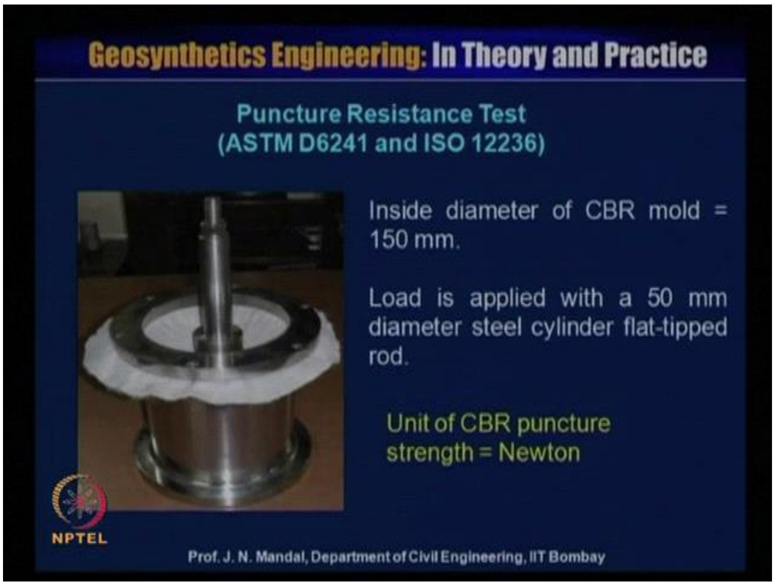

Now, we will show you puncture resistance test as far ASTM D6241 and ISO 12236. You can see this is the puncture resistance test equipment and this inside diameter of the CBR mold that is about 150 millimeter. This white color, this is geotextile material is clamped, into the CBR mold and the load is applied with a 50 millimeter diameter steel cylinder and flat tipped rod. Then you can measure what should be the severe puncture strength and severe puncture strength is expressed as Newton. The material may punch, so you should know what should be the puncture strength of the geosynthetics material.

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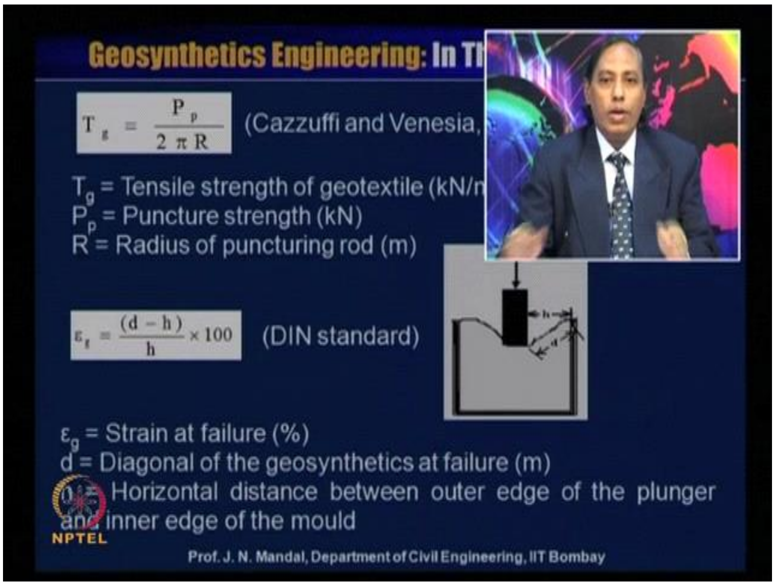

Now, Cazzuffi and Venesia in nineteen eight six give a correlation between the tensile strength of the geotextile and the puncture strength and here given this equation T g is equal to P p divided by 2 pi R. So, T g is equal to tensile strength of geotextile, P p is equal to puncture strength in kiloNewton and R is the radius of puncturing rod.

So, you cancalculate also what will be the strain at failure this you can calculate by d minus h by h into 100. This is as per DIN standard, you can see this is the d and this d is the diagonal of the geosynthetics at failure, this is H h is equal to horizontal distance between the outer edge of the puncture and inner edge of the mold. So, if you know d and the h, so you can calculate what will be the strain at failure in percentage using this equation.

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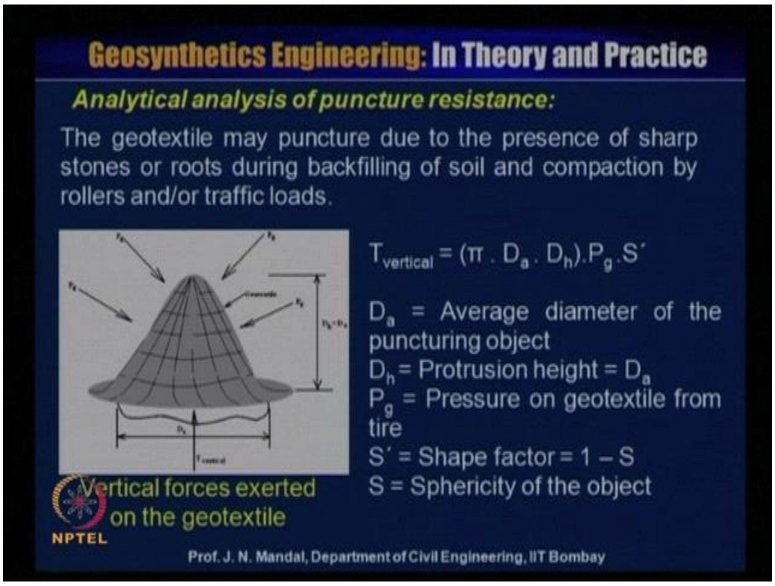

Now, we will discuss analytical analysis of puncture resistance, now geotextile may puncture due to the presence of any sharp stoneor root during the backfilling of the soil and compaction by the roller and traffic load. You can see that here this is a geotextile material and vertical force exerted on to the geotextile material here. So, this T vertical can be expressed as pi into D a into D h into P g into S dash, where D a is the average diameter of the puncture objective and D h is the protrusion height that is equal to d of a and P g is the pressure on the j textile from tire and S dash, which we call shape factor is equal to 1 minus s is equal to sphericity of the object.

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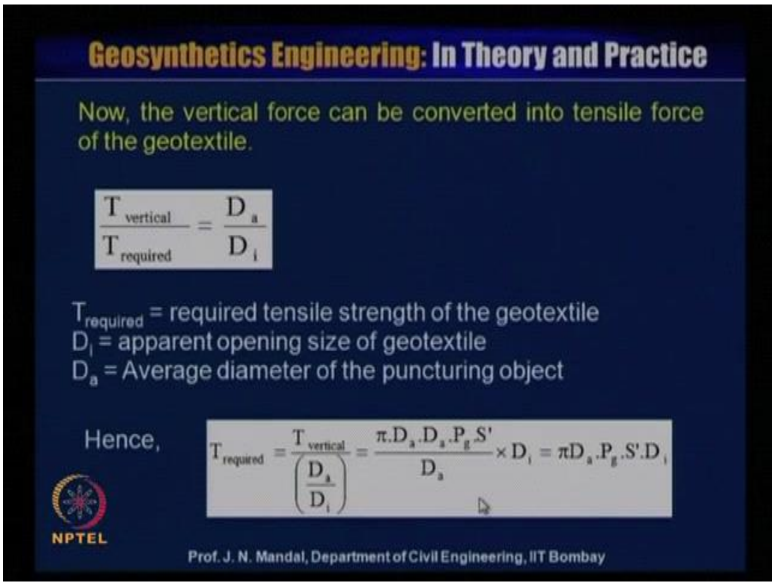

So, if you know this right hand side then you can calculate also the, what will be the t vertical or then vertical force exerted on the Geotextile. Now, this vertical force can be converted into the tensile force of the geotextile, so T vertical by T required D a by Di. So, T required is the required tensile strength of the geotextile and D a is average diameter of the punching objective and D i is the apparent opening size of the geotextile.

Hence, T required you can calculate that T vertical divided by D a by Di again, you have calculated earlier what is T vertical, so T vertical is this pi into D a into D h into P g into S dash. So, you can substitute this value of T vertical pi into D a into this D a into P g into S bar by D i, so divided by D of a, so you can have that pi into D a into P g into S dash into D i.

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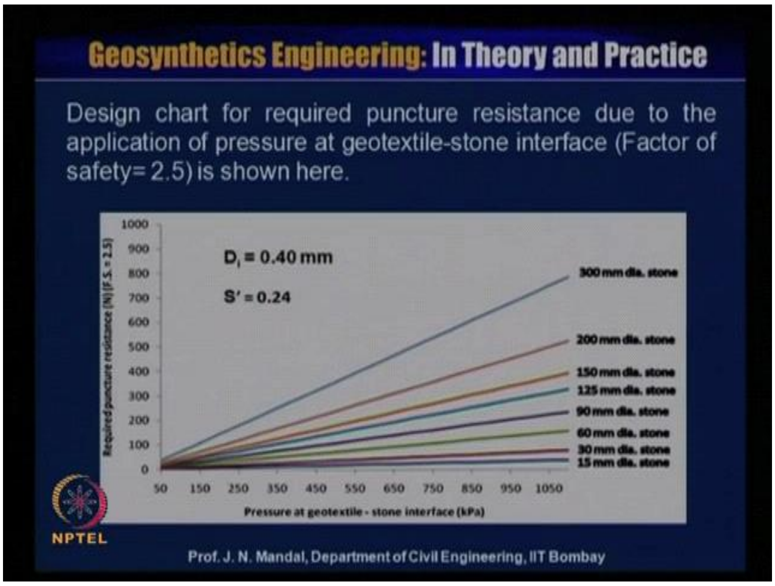

So, you can make a design chart for required puncture resistance, due to the application of the pressure at the geotextile stone interface and you considering that what should be the factor of safety assuming the factor of safety is equal to 2.5. So, this figure shows the relationship between pressure and the geotextile stone interface and this y axis shows that what will be the required puncture resistant with this factor of safety and with that stress value is 0.25 and D i is 0.40. And this is the number of the stone diameter starting from 25 millimeter diameter to 50, 60, 90, 125,150, 200 and 300 millimeter diameter stone. So, if you know that what should be the pressure of geotextile stone interface, so then if you know that what will be the stone diameter you have, then correspondingly you can also calculate that what will be the puncture resistance of the geotextile material.

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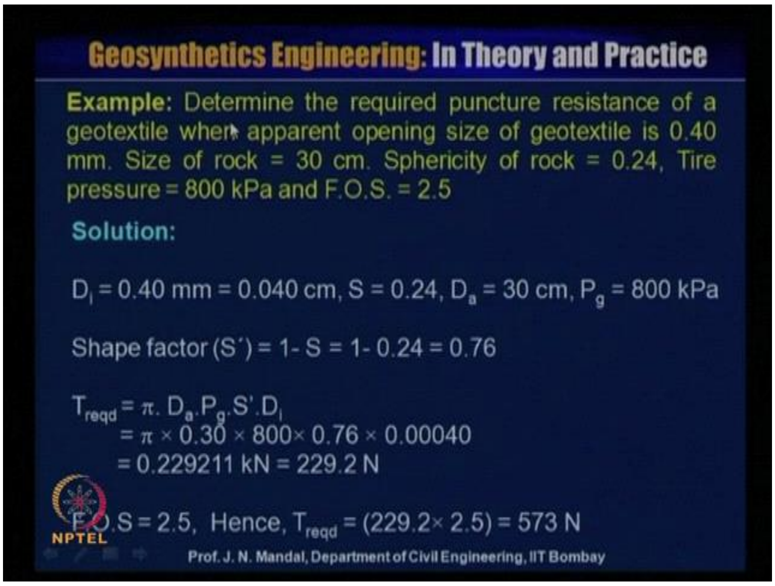

Giving one exam determine the required puncture resistance of a geotextile when apparent opening size of the geotextile is 0.40 millimeter size of the rock 30 centimeter sphericity of the rock 0.24 tire pressure 800 kilo Pascal and factor of safety 2.5. So, we know what is D i 0.40 millimeter is equal to 0.040 centimeter, S value is given is 0.24 sphericity of the rock and D a we know that is 30 centimeter that is this size of the rock and P g is equal to 800 kilo Pascal.

So, this is the tire pressure 800 kilo Pascal and you know safe factor s that is equal to 1 minus s is given 0.24. So, shape factor S dash will be equal to 1 minus 0.24 mean 0.76. So, T required we know this equation pi into D a into P g into S dash into D i pi into D a is equal to your this 0.30. Then your P g is equal to 800 kilo pascal and then your S dash is equal to 0.76 into your D of i, which is this that means 0.000040, because in terms of the kilo Newton it will be 0. 229211 kilo Newton that means 220.92 Newton. So, factor of safety with 2.5, so T required will be 222229.2 into 2.5 is equal to 573 Newton, so it will be 573 Newton. So, you can see also from this figure if you consider that diameter is about size of the rock that means 30 centimeter your tire pressure 800 kilopascal.

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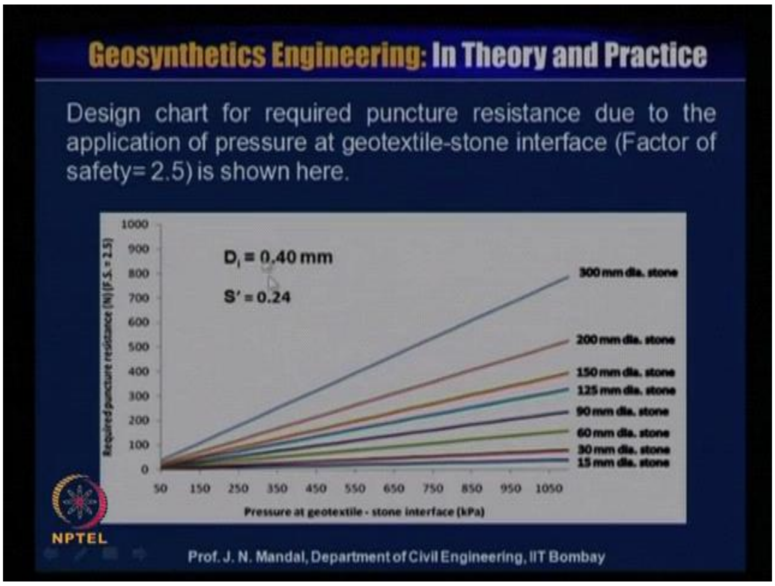

You can see tire pressure somewhere here 800 kilopascal and diameter is 30, so you can calculate also what would be the puncture strength that which will be about 573 somewhere here somewhere here 573 somewhere here. So, from this curve also you can calculate what will be the puncture strength.

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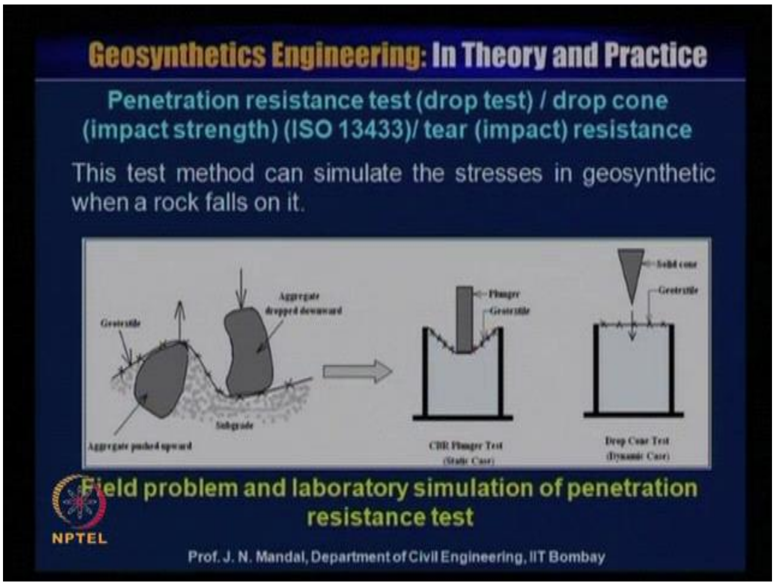

Next, we will conduct the penetration resistance test or it called drop test or drop down it is called impact strength as per ISO 13433 or it called the T r or impact resistance, now this test method can be simulate the stresses in geosynthetics. When a rock fall on it, now how we can simulate the field problem and the laboratory problem of penetration resistance test look at it this picture, this is the geotextile material.

And sometimes may some aggregate drop in the downward direction towards the sub grade with may this geotextile material may damage. So, the this aggregate can be penetrated into the geotextile material or there is a possibility for any aggregate is pushed upward, also the geotextile material may damage or sometimes you can have very angular type of the aggregate, which also can damage the geotextile material.

So, this is in the field and this also can be analogue with the laboratory test using the CBR plunger test. This is in the static case this is a CBR plunger mold and this is the geotextile material and this plunger is just pushed through the geotextile material. So, this is flatter this may be the flatter or it may be that what you call the drop cone text this is pointed, so this is the mold this you call the drop test and this is the dynamic case. Because, this cone solid cone will drop from a particular height onto the geotextile material, which is clamped with this mold and then geotextile material will be tear it up or it form a hole, so this hole also can be measured.

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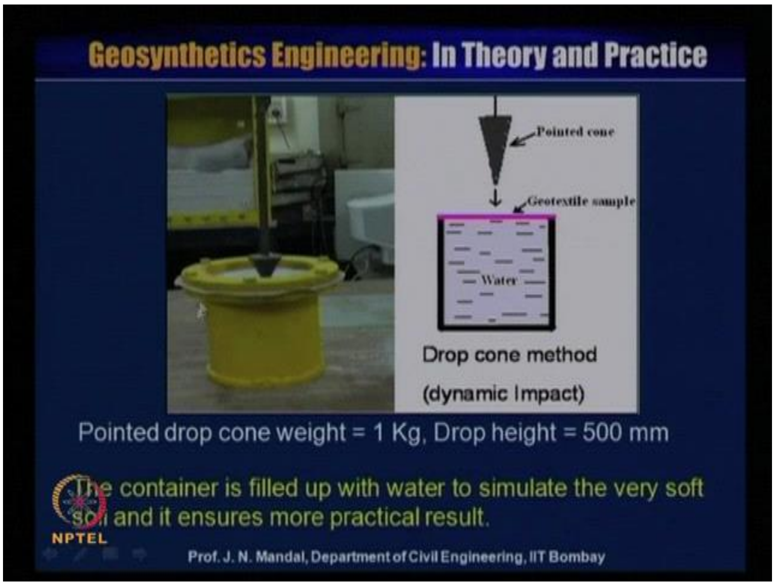

So, you can see here that CBR mold and this is you can see that cone, which is dropped from a particular height then this is a pointed cone and this is filled up with the water drop cone ((Refer Time: 13:29)) method this is dynamic impact cone. This is a geotextile material, which is fixed to the mole and the container is filled with the water to simulate the very soft soil and it ensure more practical result.

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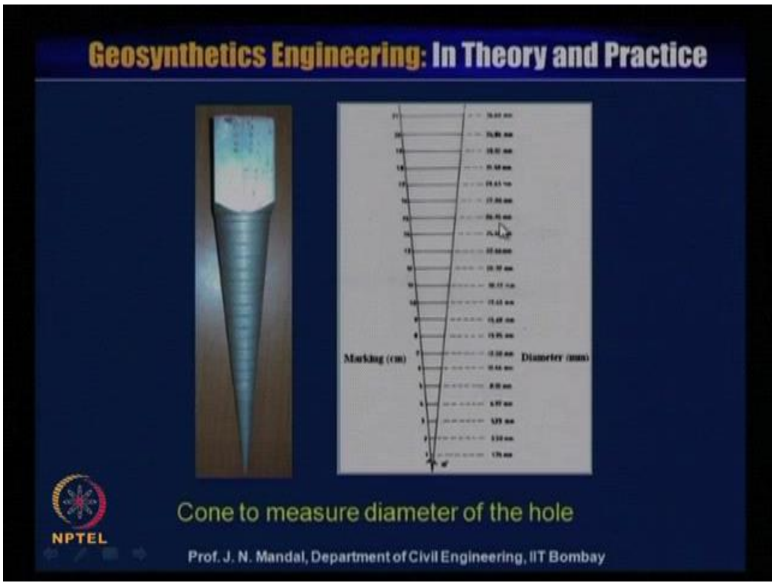

So, when you drop this pointed cone into the geotextile material and this geotextile material will form a hole and then you can measure. So, this is the prefabricated cone to measure the diameter of the hole you can see this is like this it has been calibrated like this, so this rod can be inserted into the hole of this geotextile material. Then you can see that what should be the diameter. So, diameter may be whatever it is in millimeter that you have to express in diameter some analytical analysis of T r or impact resistance. So, when a rock fall freely on the geotextile from a height geotextile resist the impact and or damage and consequently gravitational energy gets developed. So, how we can measure the energy? So, energy is small y can be written as m into g into z.

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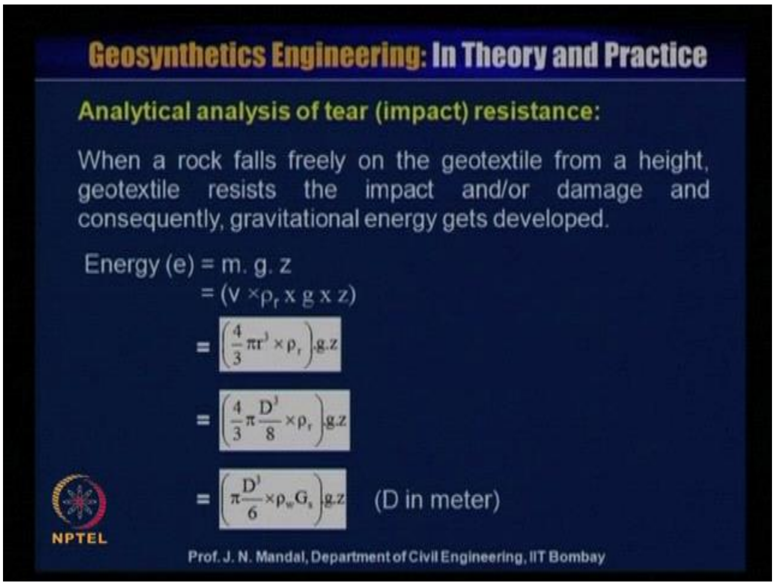

Where n is equal to mass of the rock z is equal to height of the fall this is height of the fall z and g is equal to acceleration, due to gravity that is 9.81 meter per second square.

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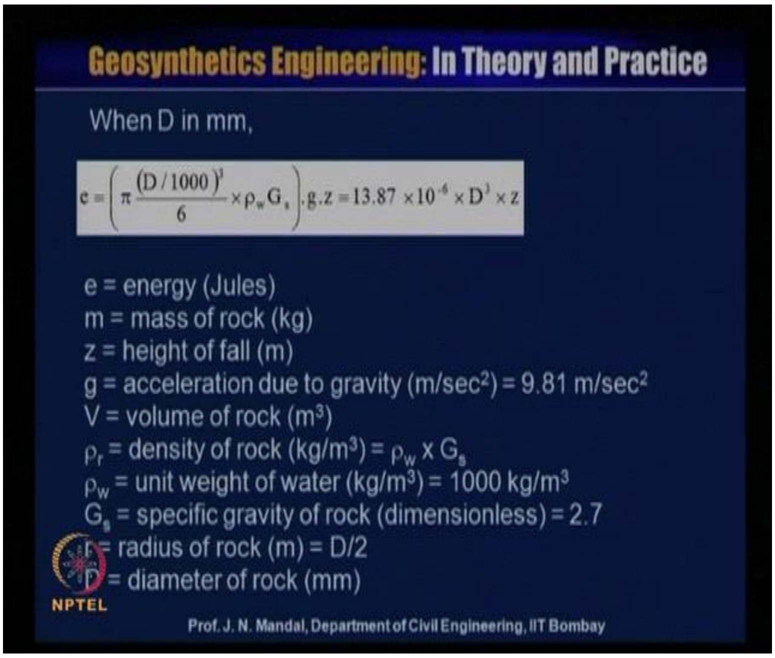

So, again this n mass you can write V into rho r, so mass is equal to V into rho r, so V is equal to volume of the rock and rho r is equal to density of the rock. So, again the density of the rock can be retained rho w into G s where rho w is equal to unit weight of the water that is 1000 kg per meter cube and G s is the specific gravity of the rock which is dimensionless that is 2.7.

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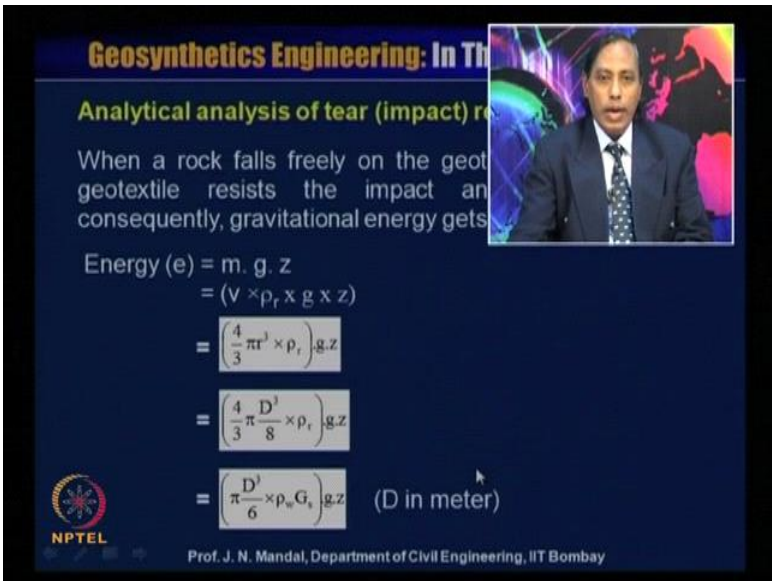

So, you can write then V into rho g into g into z, then v is equal to 4 by 3 pi r to the power cube into rho r. This r again is equal to radius of the rock that will be D by 2, because D is the diameter of the rock, so you can see if you substitute r is equal to D by two. So, this will be D cube by 8 into rho r into g into z, so this is pi if you calculate this is pi and this will be the D cube by 6 into rho w into G s into g into z. Because, rho r is equal to rho w into G s rho r density of the rock is equal to rho w into G s, so that is why we are writing rho r is equal to rho w into G s into g into z and here this diameter D in terms of the meter remember this is in terms of the meter.

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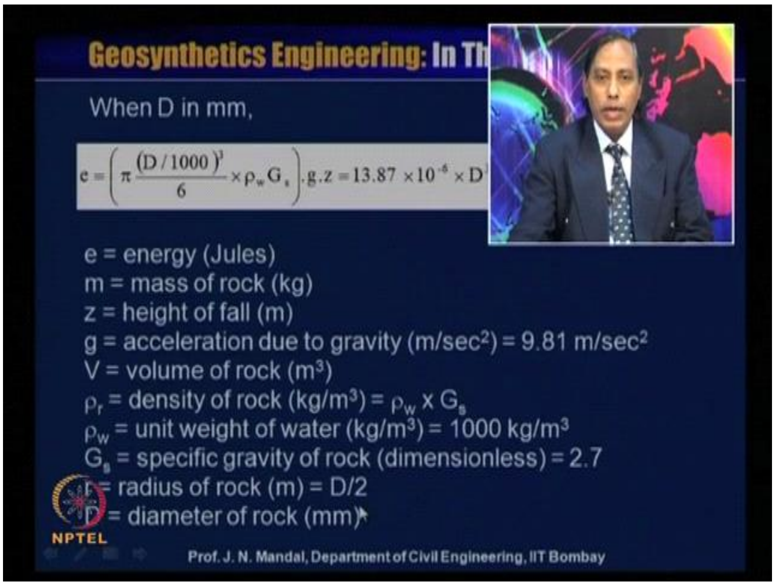

So, when D in millimeter so energy e can be expressed pi into d by 1000 whole to the power cube by 6 into rho w into G s into g into z. That means if you calculate this you can have13.87 to the power minus 6 d cube into z, because all these value is known to you rho w is equal to 1000 kilo gram per meter cube G s is equal to 2.7. So, you can write energy in terms of the d and the z, so you know that what is d, you know that what is z, z is equal to what will be the height of the fall.

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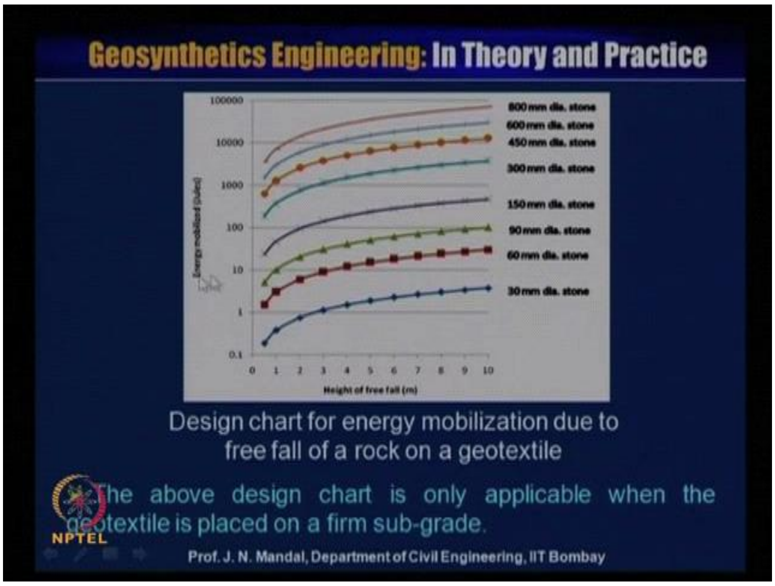

So, this is energy reverted with the d and z so we can draw a design chart between the energy mobilized and the x axis is the height of the free fall for different diameter of the stone. So, you can see at any height this stone can fall in know the what will be the diameter of the stone and then you can calculate that what will be the energy mobilized. So, this design chart for energy mobilization due to the free fall of a rock on the geotextile material.

Now, in this design chart is only applicable when the geotextile is placed on a firm sub grade, but if it is not firm sub grade then what then how you can solve the problem? Now, when the rock fall on a geotextile laid on a very soft sub grade soil that means geotextile will deform and also resist the high amount of impact energy. Therefore, it is necessary to determine the modified factor of safety as given by Koerner 2005.

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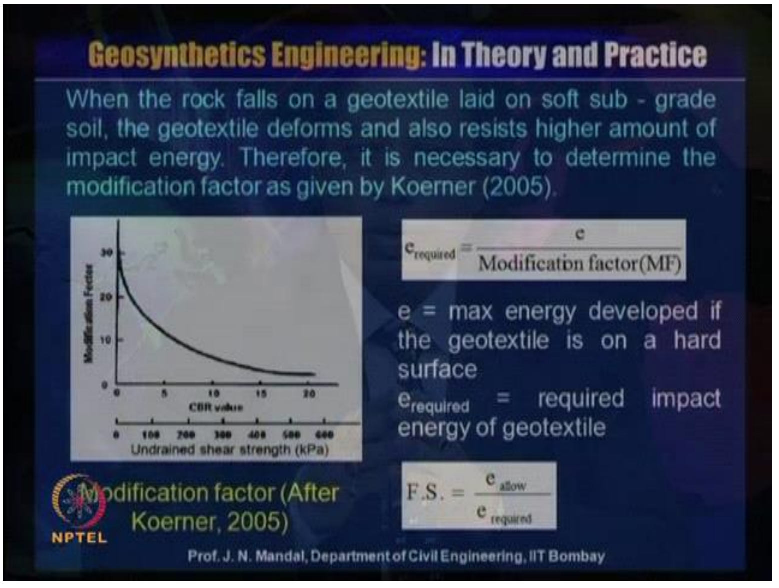

So, you can see that this is the modified factor this is the y axis is the modification factor and the x axis is the CBR value or undrained shear strength value of the soil. So, if you know what is the undrained shear strength value or the CBR value, then you can calculate what will be the modification factor. So, then if required e required will be e by modification factor, so e is the maximum energy developed if the geotextile is on the hard surface and e required is equal to required impact energy of geotextile. So, you can calculate factor of safety is equal to e allowable divided by e required.

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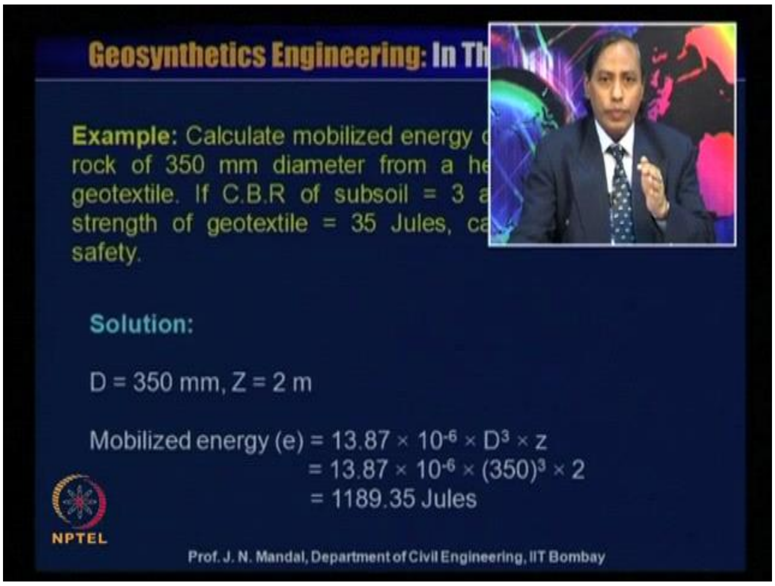

So, let us solve one example you calculate the mobilized energy due to free falling of a rock of 350 diameter from a height of two meter of the geotextile. If the CBR of the subsoil is three allowable impact strength of geotextile is 35 Joule, calculate the factor of safety? So, we know that D is equal to that means rock diameter D is equal to 350 millimeter ton and height two meter this fall height 2 meter to the geotextile. So, mobilized energy e you know the equation 13.87, 10 to the power minus 6 D to the power 3 into z. So, D is 350 into q into z is 2 meter, so if we calculate you will have the mobilized energy 1189.35 joule.

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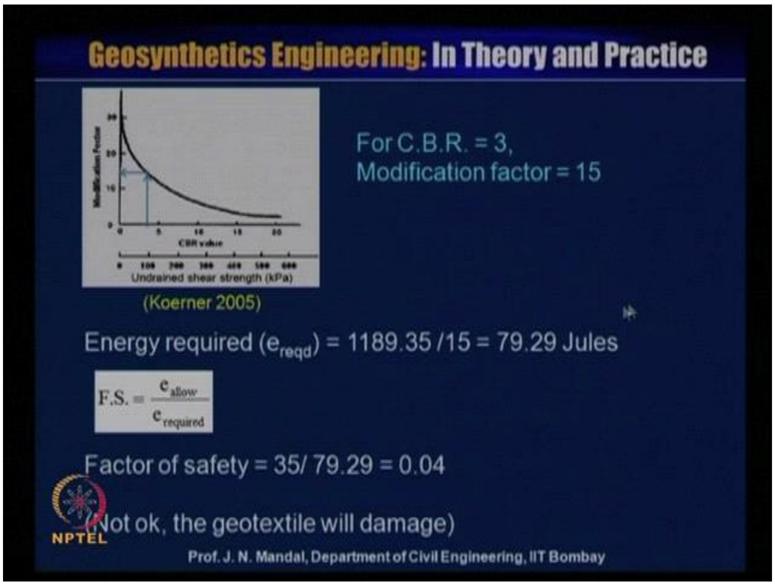

Now, let us say that for CBR value three what will be the modification factor? So, from this curve if you know the CBR value here 3, so modification factor is between 10 to 20, it will be the 50. So, energy required e required will be equal to 1189.35 by 15 we have got the mobilized energy this divided by 15 is the modification factor this will give the energy required 79.29 joules.

So, factor of safety is equal to e allowable by e required, so factor of safety is equal to 35, this divided by 79.29 that is e required and we have calculated that is what is e allowable. So, you can see that here factor of safety value is on the lower side that means 0.04. So, it is not geotextile will damage, so you have to be think about the alternative geotextile material in order that the geotextile may not be damaged.

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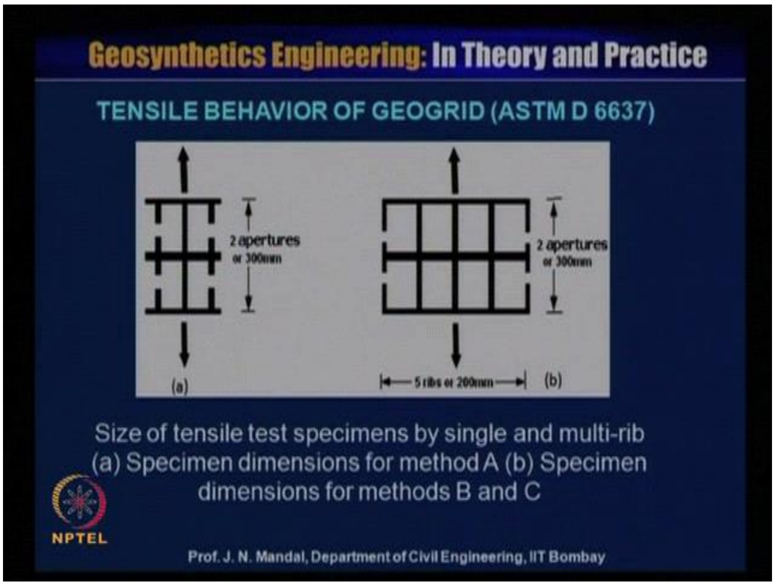

Next, we will discuss the tensile behavior of geogrid ASTMD 6637. This is one of the very important parameter of geosynthetics engineering, because this material will be used in many areas in civil engineering. Now, I discuss also the earlier for this tensile strength of the geotextile material, now geotextile material may be the woven geotextile material or it may be the non woven geotextile material. The size of the sample if this is the 200 millimeter and this will be 100 millimeter, so this is the size of the sample. So, there are woven geotextile there may be non woven geotextile or there may be geogrid.

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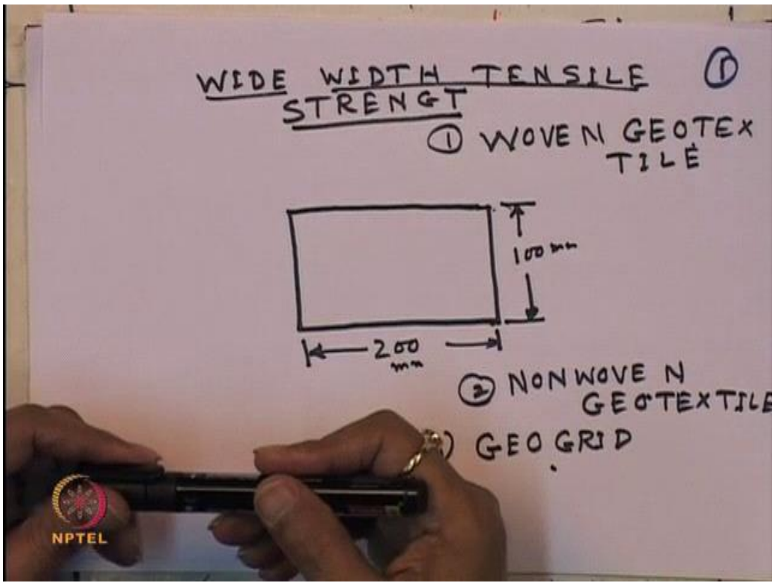

So, I always say that you should go for the wide width tensile strength wide width tensile strength. So, you have to follow the wide width tensile strength for the calculation of the tensile strength of the woven geotextile material non woven geotextile material and geogrid. The size of the specimen will be 200 by 100 millimeter, so this gauge length will be about 100 millimeter. So, I am showing you that some sample that for the, this is the woven geotextile material. You can see this is woven geotextile material I said that whose filament is very random. So, it may be the tensile strength in machine direction and cross machine direction even then diagonal direction also same.

This is the size of the sample 200 by 100 millimeter, so this should be the gauge length. So, this wall gauge tensile strength is recommended for the non woven geotextile material, whose filament are very random, but in case of the woven geotextile material this is woven geotextile material, you can see that whose filament this filament and this filament is perpendicular to each other that is why it is woven geotextile material and when you will perform the test this clamp this is 100 millimeter, this is 200 millimeter. Before clamping some of the filament you have to take this out from both the side otherwise that proper trampling will not occur and there is a possibility for the slippage.

So, you have to be very careful for the preparation of the sample how to prepare the sample? What should be the gauge length? Also, what should be the strain rate? So, this is also wide with tensile strength for the woven geotextile material apart from that you can also calculate the wall retaining strength for a geogrid material. This is 200 millimeter and this gauge length about 100 millimeter and you always cut the geotextile material in the middle of here. So, and then you have to conduct the tensile strength of the geogrid material and this is also wide grid tensile strength material.

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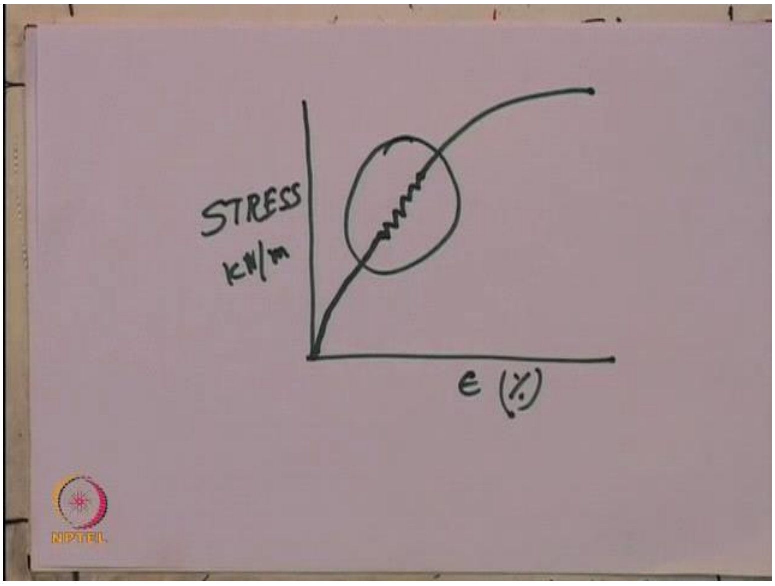

So, when you will conduct this kind of the test whether it is a woven geotextile material or the non woven geotextile material. So, you can draw the relationship between the between the tensile strength and the strength in percentage this is kilo Newton per meter. So, you can have a nature of curve, let us say like this, but you have to be very careful about the clamping, if clamping is not proper if it is a slippage it is sometimes very difficult to understand. So, we can see that if there is any slippage problem then if you can draw the curve or from the you can obtain. Let us say this is the stress same this is kilo Newton per meter and this is the strain in percentage and you will observe that something like this.

So, this shows that there is a possibility for the slip slipping, so when we find this kind of the result you should reject that, because the clamping is not proper, so it is required further proper clamping of the geotextile material when you will perform the test. So, because when you go for this kind of the material for testing and if it is a very high strength material, then sometimes it is very difficult to perform the test across the wall and that is the why the A S T M has modified the tensile strength.

And that is as per ASTMD 6637 and the tensile strength of the geogrid material has been much more simplified. You can see we can go for the with the clamping or hydrostatic pressure certain strength of the geotextile material and if the strength of the geogrid material is very high. So, you cannot do by clamping you may require some alternative the royal clamping, which I will show you.

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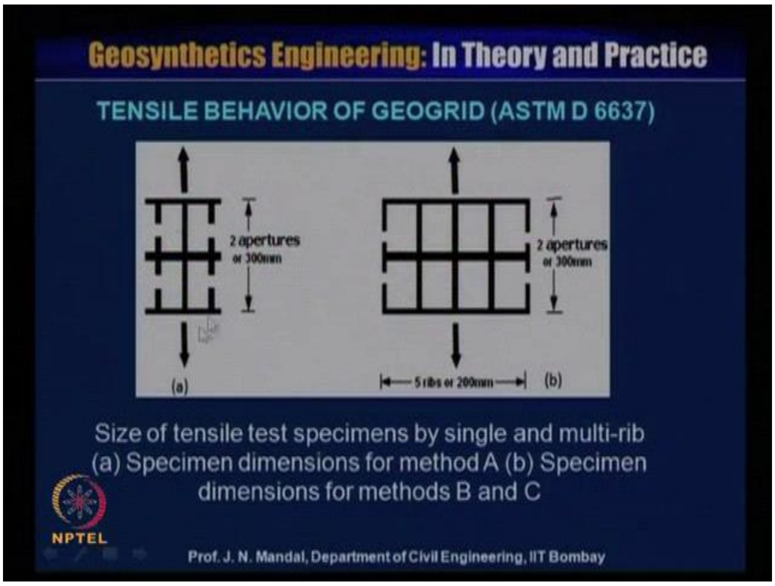

So, now the tensile behavior of geogrid that modified version is may be about 2001 you can see here that, this is a single this is the specimen dimensional that is single and also the multi-rib. So, there specified by specimen dimension for the method A and specimen dimension for the method this is B and C and you can see this is the only single here and this will be the two aperture or 300 millimeter. So, you can conduct the test or you can make a five rib or 200 millimeter and this is two aperture or 300 millimeter, then you can perform the tensile stress by the universal testing machine, so this test is much more simplified.

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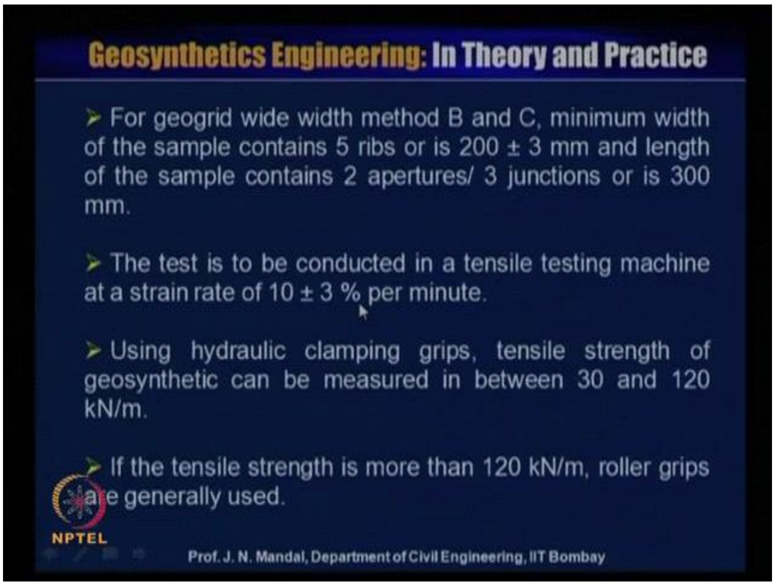

So, for the geogrid wide width method B and C minimum width of the sample contain 5 rib or is 200 plus minus 3 millimeter and length of the sample contain 2 aperture or 3 junction or is 300 millimeter. Because, different manufacturer have their different opening size and the junction. So, that is why some variation is there and test we conducted in the tensile testing machine at a strain rate of 10 plus minus 3 percent per minute, but if you use the ISO method. This strain rate is about 20 plus minus 3 percent per minute using the hydraulic clamping grip the tensile strength of the geotextile can be measured in between 30 to 120 kilo Newton per meter, because you cannot go beyond that in a hydraulic clamping because there is a possibility for slipping.

If the tensile strength is more than 120 kilo Newton per meter most of the cases in case of the geogrid, but in general in case of woven and non woven geotextile material, you can go by the hydraulic clamping. Which the tensile strength value may be lies between 30 to 120 kilo Newton per meter, but in case of the geogrid material then it is sometimes difficult to use the hydraulic clamping grip, because the tensile strength value is much higher. So, if the tensile strength value is more than 120 kilo Newton per meter, so you should use the roller grip.

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So, roller grip generally used, so you can see this is multi-rib geogrid tensile testing machine with the hydraulic clamping you can see type of the failure after test and this is the multi-rib geogrid tensile testing. This is the roller grip, this is the roller, this is the roller grip if we to perform with the very strength of the geogrid. So, we could use this roller grip.

So, this figure shows the force versus that extension of the geogrid material with wide width tensile strength. Then you have to calculate what would be the tensile strength of the geogrid? So, you can see what will be the breaking load into C, what is C? C is equal to N m by N s, N m is equal to minimum number of tensile element within one meter width of the product.

So, you have to check that how many elements in the geogrid material within a one meter width because different manufacturer have their different number of the tensile element. So, that is why you have to measure that what will be the minimum number of tensile element within one meter width of the product and n s is equal to number of tensile element within the test specimen.

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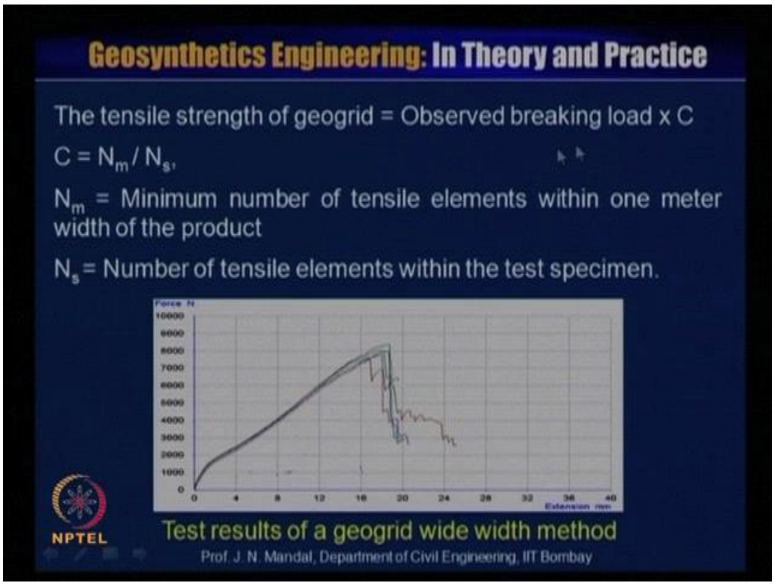

So, C can be calculated as a N m by N s, so if you know the N m by N s? Then you can calculate what is tensile strength of the geogrid. You know what is the observed breaking load and then you measure the C with this N m by N s, so you can determine the tensile strength.

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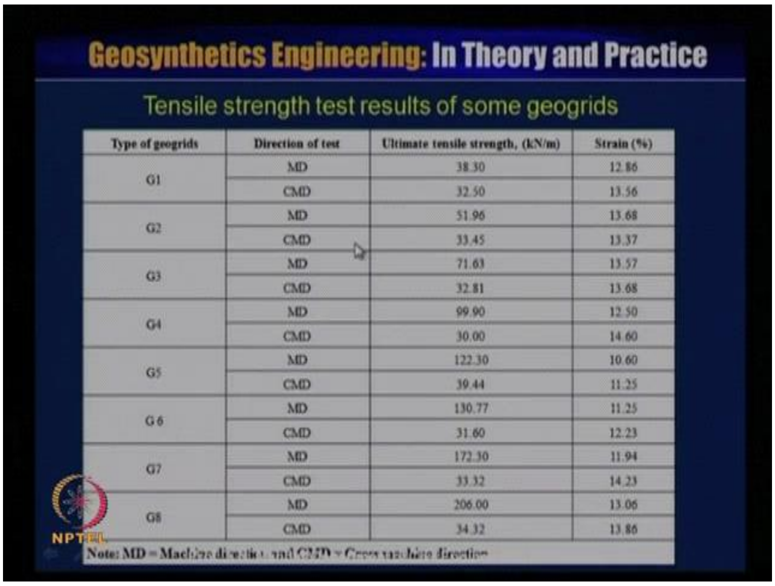

Type of geogrids	Direction of test	Ultimate tensile strength, (kN/m)	Strain (%)
G1	MD	38.30	12.86
	CMD	32.50	13.56
G2	MD	51.96	13.68
	CMD	33.45	13.37
G3	MD	71.63	13.57
	CMD	32.81	13.68
G4	MD	99.90	12.50
	CMD	30.00	14.60
G5	MD	122.30	10.60
	CMD	39.44	11.25
G 6	MD	130.77	11.25
	CMD	31.60	12.23
G7	MD	172.30	11.94
	CMD	33.32	14.23
G8	MD	206.00	13.06
	CMD	34.32	13.86

Note: MD = Machine direction and CMD = Cross machine direction

So, we have performed many test of geogrid test, this in the MD's machine reaction, this is in a cross machine reaction you can see ultimate tensile strength value of 38.30 kilo Newton per meter and cross machine direction it is 32.50. The strain in the machine reaction 12.86 percentage and strain in the cross machine direction 13.56. Like that, so you have performed many test very high strength also it is starting from 38, 50 and 71, then 99, then 100 and 22, then 100 and 31, 77 and 100 and 72.3, 0 and 200 and 6. You can see that machine direction it is increasing, but cross machine direction 30, 40, 30, 30. So, you do not require the very high strength in the cross machine direction it is you can see almost lying between 32 to 35 like that.

Also, at the same time you can look the strain value that is also very important and in all cases whether is a machine direction and cross machine direction is lies between 10 to about 13 or 14, but it is permissible is up to 15 percentage. So, this material is reasonably, now apart from the wide width tensile strength of the geogrid material. So, we also calculate the geogrid rib tensile strength that is as per GRI GGI 1 87.

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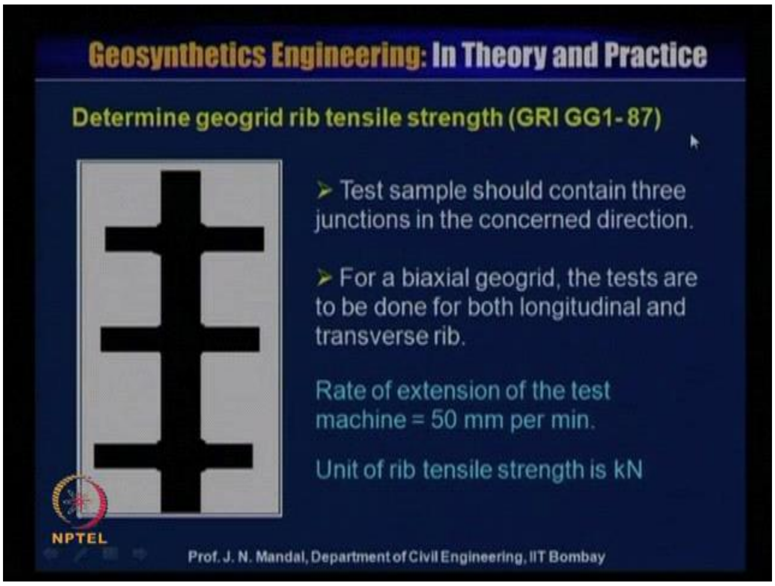

The test sample should contain the three junction in the concerned direction, and for a biaxial grid the test has to be done for both in the longitudinal direction and as well as well as transverse rib. So, rate of extension of the test machine is 50 millimeter per minute and unit of deep tension strength is kilo Newton.

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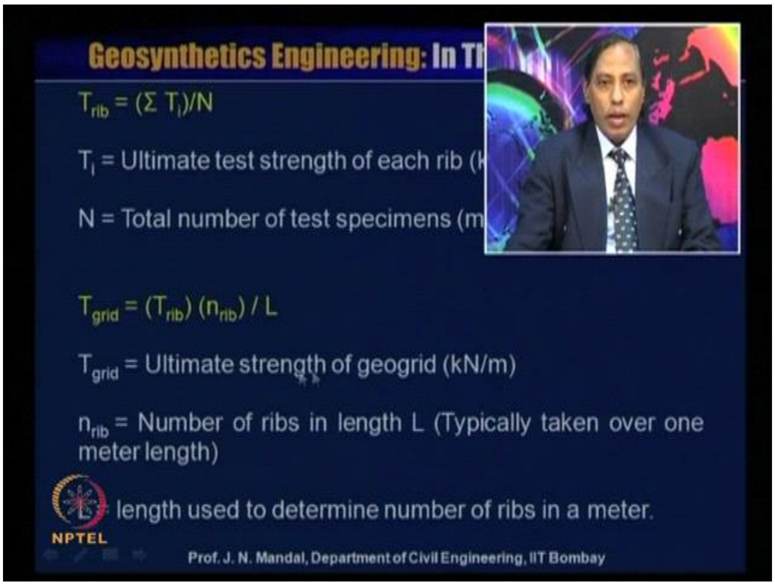

So, T rib will be equal to summation of T i by N, this Ti is equal to ultimate test strength of the each rib that is kilo Newton and N is equal to total number of test specimen the minimum ten number of sample is required. So, T grid that means ultimate tensile strength of the geogrid can be expressed as T rib into divided by l. So, n rib is equal to number of the rib in the length L typically taken over one meter n rib l is taken over one meter. So, l is the length used to determine the number of rib in a meter, so you can calculate what will be the T grid, so ultimately you can calculate what is T rib.

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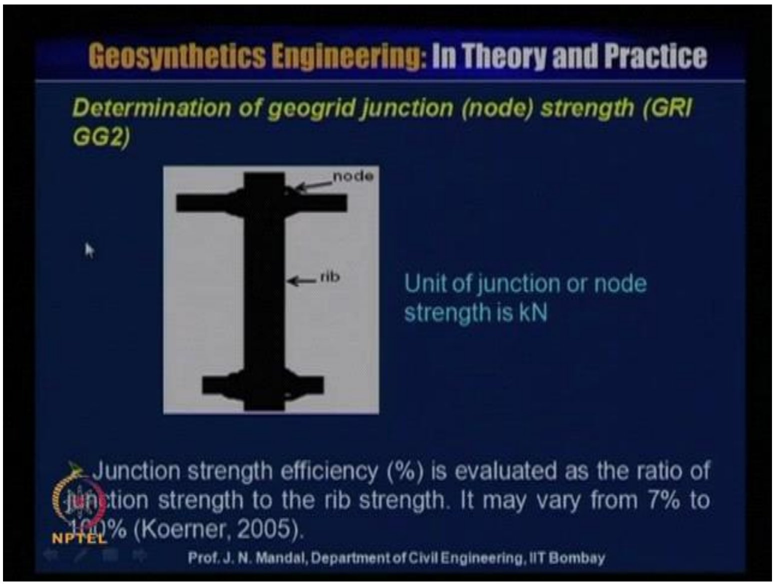

Similarly, if what to calculate that what will be the geogrid junction node strength this is as far GRI GG2 you can see that unit of junction or the node strength and this is expressed as kilo Newton. You have to this is the rib and this is the node, so junction strength efficiency is evaluated as a ratio of junction strength to the rib, then it may be vary from 7 percent to 100 percentage as say Koerner in 2005.

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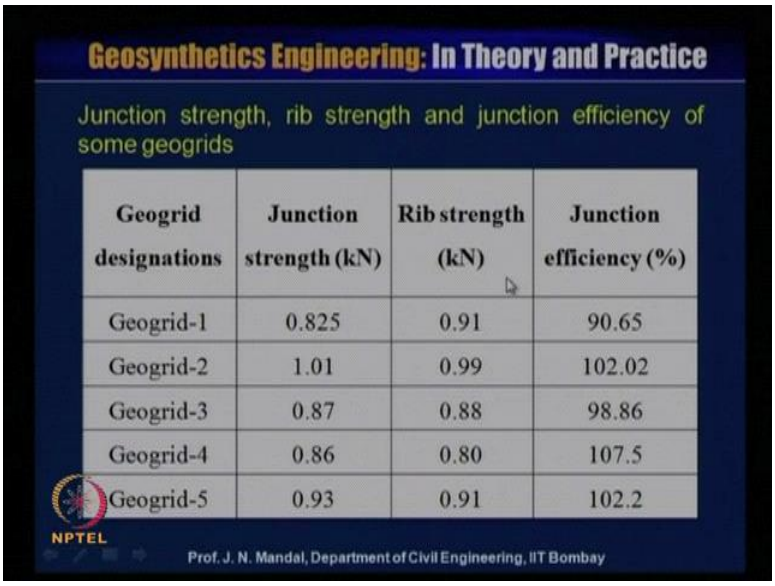

Geogrid designations	Junction strength (kN)	Rib strength (kN)	Junction efficiency (%)
Geogrid-1	0.825	0.91	90.65
Geogrid-2	1.01	0.99	102.02
Geogrid-3	0.87	0.88	98.86
Geogrid-4	0.86	0.80	107.5
Geogrid-5	0.93	0.91	102.2

So, we have also performed the junction strength rib strength and the junction efficiency for different category of geosynthetics material, you can see we can obtain the junction strength in kilo Newton. Some geogrid 1.825, geogrid 21.01, geogrid 3.87, geogrid 4.86 and geogrid 5.93.

Similarly, for this geogrid one we have the rib strength 0.91 geogrid 2.99, geogrid 3.98, geogrid 4.80 and geogrid 5.91. Then you are calculating the junction efficiency this is most important junction efficiency in terms of the parentage, so this from this you can have the 90.65 percentage, 102.02 percentage, 98.86 percentage, 107.5 percentage, 102.2 percentage. It is more than 100 percentage also the efficiency come, so this is very important that, because sometimes the biaxial geogrid used at the between the subgrade and the balance for the railway. So, this efficiency is very important, so one has to perform the efficiency of the geogrid material.

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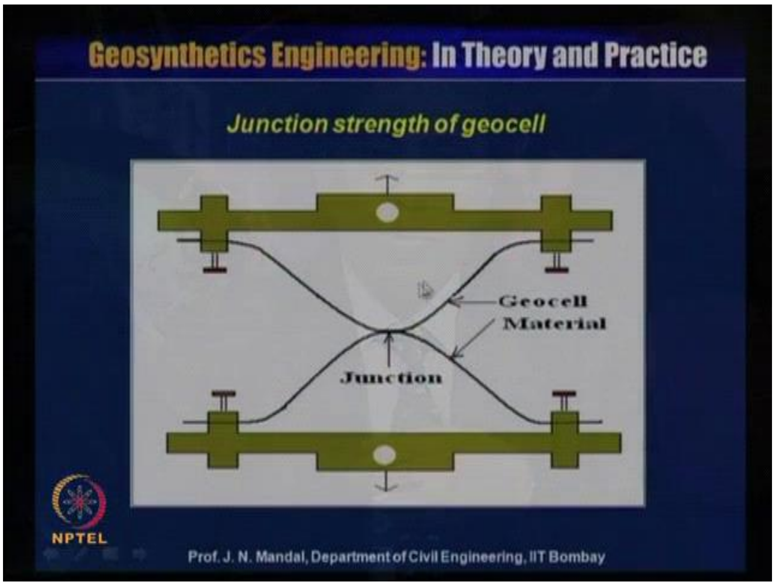

Also, there are geocell you have seen this is a hexagonal cell. And also you have to determine that what will be the junction strength of the geocell material, this is just one clamping arrangement. I have shown that how you can calculate the junction strength of the geocell material.

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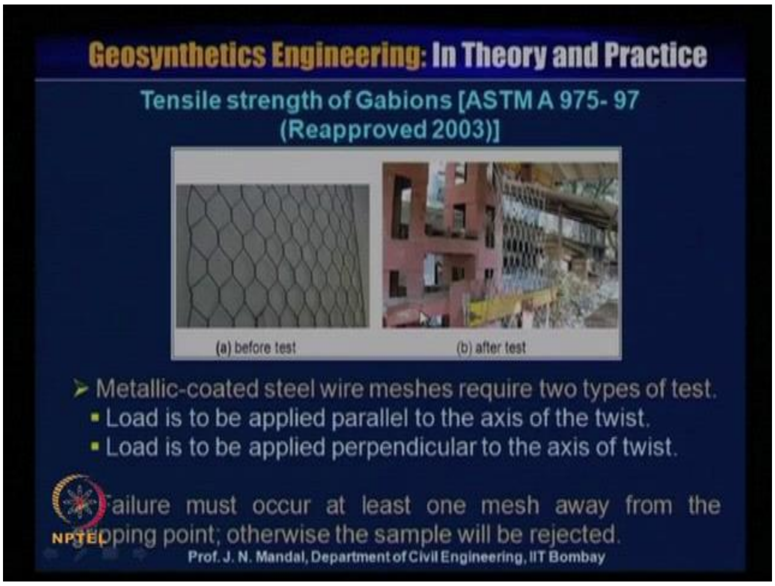

Next, we will discuss tensile strength of the gabion that is ASTMA 975 in 97 and this is we approve in 2003. So, this latent side this is the gabion this is the before the test you can see this is a hexagonal and these are the, this is galvanized mild steel and this galvanized a mild steel also is twisted here. So, this steel also metallic coated steel wire meshes require two type of the test one test load is to be applied prior to the axis of the twist you can see parallel to the axis. This is the twist and another load is applied to the perpendicular to the axis of the twist. This is our this IIT Bombay equipment for performing the gabion test this is a huge test and this is the clamping arrangement and this gabion is fixed here with the clamping at the bottom. At the top and then failure will occur at least one mesh fell away from the gripping point. Otherwise, sample is to be rejected, so I will say is that how what will be the, what will be the value of this gabion test, either in the longitudinal direction and also in the transverse direction.

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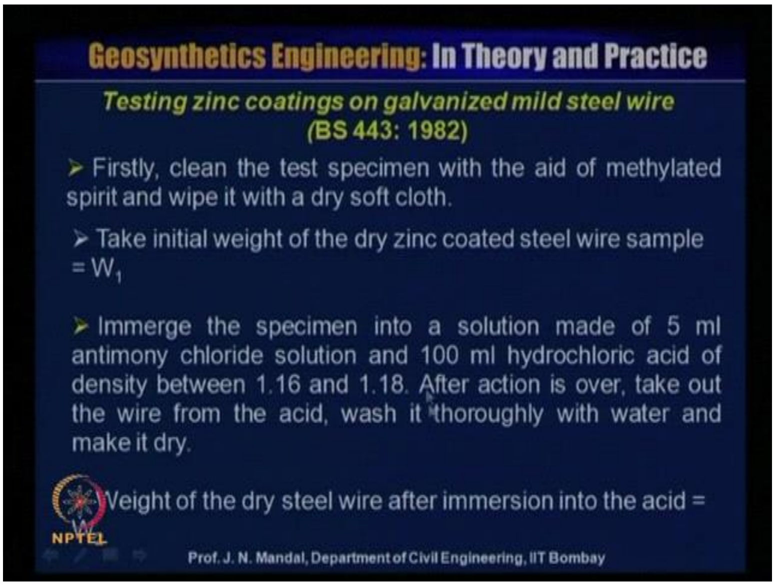

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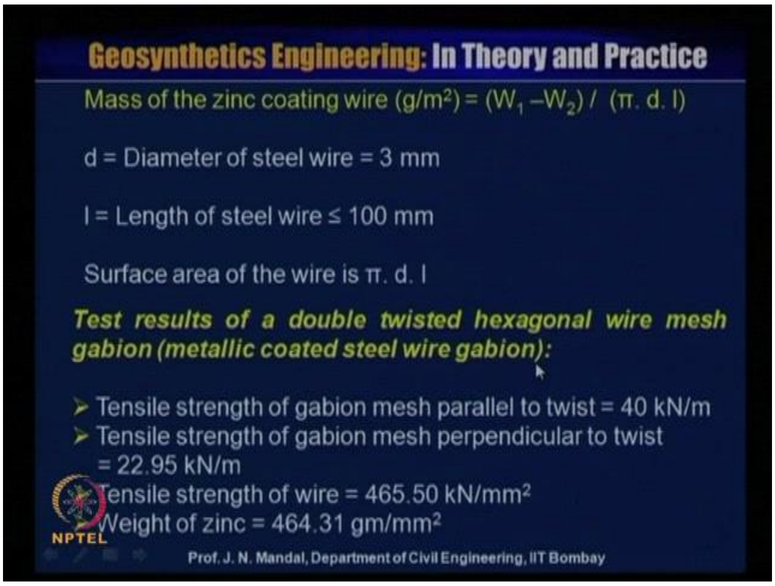

So, these are the result you can see that tensile strength of gabion may parallel to the twist is 40 kilo Newton per meter and tensile strength of gabion may perpendicular to the twist is 22.95 kilo Newton per meter. At the same time you have to calculate the tensile strength of the wire, which is 465.50 kilo Newton per millimeter square. Also, you have to calculate what will be the weight of the zinc, which is here 464.31 gram per millimeter square. So, how to calculate the weight of the zinc? This is tensile strength of the wire, as it is you know 25 centimeter rod. Then you conduct in structural engineering most of the time you know that this will be the strength what it is required for this, but how to calculate the weight of the zinc?

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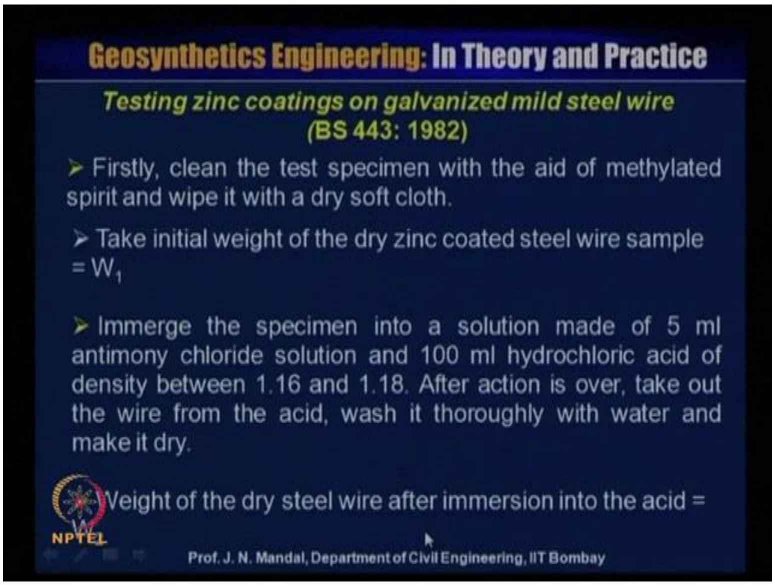

So, to calculate the weight of the zinc, so we have to perform the testing zinc coating on a galvanized mild steel of the wire. This is as per BS 443 1982. It is very important that one should know in the mild steel how much galvanized they are, otherwise there is a possibility for the corrosion. So, what you have to do that firstly clean the test specimen with the aid of the methylated spirit and wipe it with a dry soft cloth.

Then take the initial weight of the dry zinc coated steel wire sample, let us say that weight is W1. Then immerge the specimen into the solution made of 5 milliliter of antimony chloride solution and 100 m l hydrochloric acid of density between 1.16 and 1.18. After x n is over take out the wire from the acid, wash it thoroughly with water and make it dry and weight of the dry steel wire after emerging into the acid, let us say W 2.

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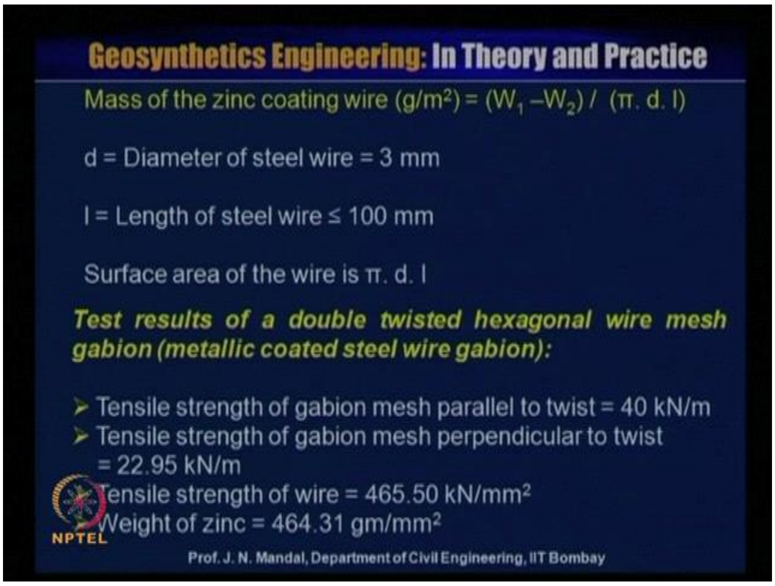

So, mass of the zinc coating wire is expressed as gram per meter square that means that is W 1minus W 2 divided by pi into d into l and where d is the diameter of the steel wire. Generally, we take the 3 millimeter and length of the steel wire is less than equal to 100 millimeter. Then you can calculate what will be the surface area of the wire, is pi b l. So, mass of the zinc coating area, you can calculate W 1 minus W 2 by pi d l or surface area of the 1.

So, test result of a double twisted hexagonal wire mesh gabion; that is metallic coated steel wire gabion. So, you can calculate on this that what will be the weight of zinc, so we have performed this test. We find that weight of the zinc about 464.31 gram per millimeter square, so it is within the permissible limit. Similarly, tensile strength also within the permissible limit.

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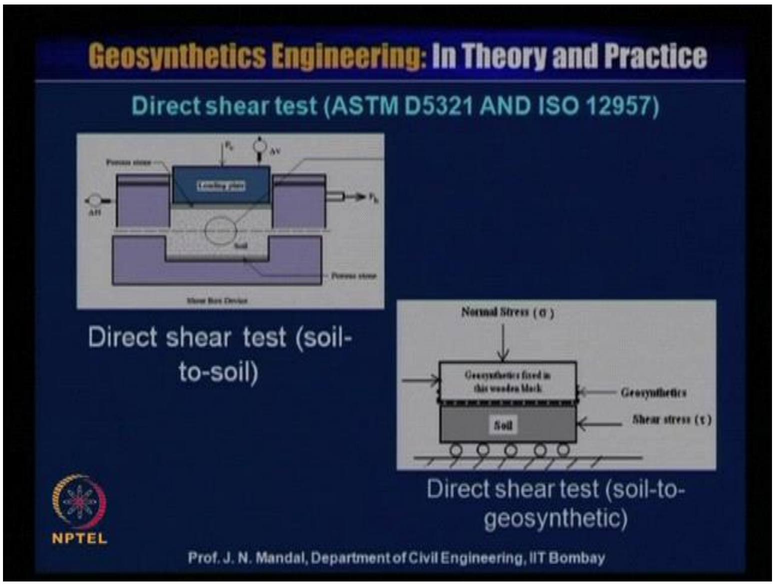

Next, we will discuss direct shear stress that is as per ASTM D 5321 and ISO 12957. So, when you will perform the direct shear test. There are two types of the direct shear test; one may be the small scale shear test and another is large scale direct shear test. Now, we can perform the direct shear test from soil to soil and we can also perform the direct shear test from soil to geosynthetics material.

So, when you will perform the soil testing soil to soil that is very traditional method we conduct. This is the direct shear test and the lower part of this direct shear test is the soil upper part. Also, direct shear test is soil and the ferrous material at the bottom and the top of the sample. There is a loading pack and then you are applying the load, and then you are applying the shear. So, you can measure this vertical and the horizontal tray, it is learn at a particular strain. So, you can calculate that what should be the c value cohesion value of the soil and also what should be the angle of internal friction angle of the soil?

However, when you will perform the direct shear test in a of geogrid or geotextile material. Then you have to modify this system, so direct shear stress. So, when your test has to be conducted with the soil to geosynthetics material, so if the bottom part is the soil and compacted and then the upper part it is a geotextile, which is fixed with the wooden block. This is a geosynthetics material with a wooden blockage flick. Then we place on the soil. Then you apply the load you can see, how there will be interaction between the soil and this geosynthetics material? I am just showing you that, how it is that if this is the block upper, block upper wooden block. Then the geosynthetics material sometimes it is posted or it may be the anchor it like this.

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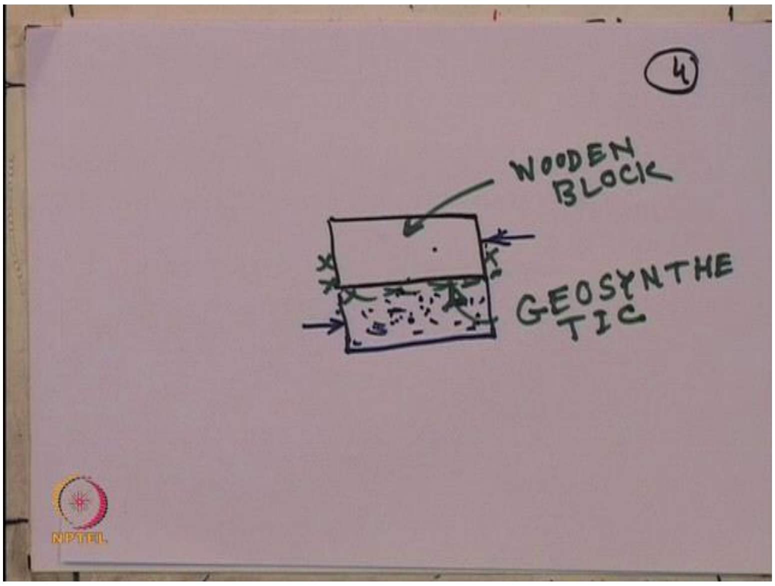

So, this is the wooden block and this is the geosynthetic, this is a geosynthetics material and this is the upper and the lower part is the lower part is the soil. So, lower part is the lower part is the soil lower part of the shear work, it is a soil. So, here to be fixed properly or tightening properly the geotextile material with the wooden block and this geotextile come in contact with the soil.

So, there will be a sphere between the geotextile and the soil. So, we can calculate that what should be the adhesion or the angle of internal friction, when we say the angle of we say the cohesion, when it is a soil to soil, when it is a soil to any other material, we say adhesion. So, you remember what is cohesion and what is adhesion? Soil to soil is cohesion and soil to geosynthetics is adhesion.

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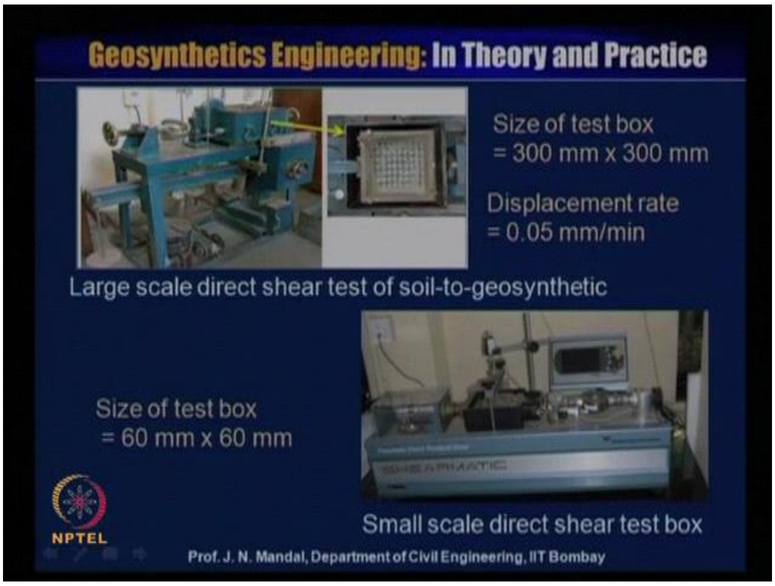

So, this is our very large scale direct shear test, why we perform the direct shear test and size of the test box is about 300 millimeter into 300 millimeter and displacement rate is 0.05 millimeter per minute. You can see this is the direct large scale direct shear test and here is the geogrid material, here is the geogrid material. So, you can place also bottom also top and can be fixed and can be conduct the test. This is a small scale direct shear test box, the size of the test box is generally 60 millimeter by 60 millimeter. You can also perform the direct shear test, but it is recommended that in case of the geogrid material, it should perform the large scale direct shear test value, so that will be much more appropriate.

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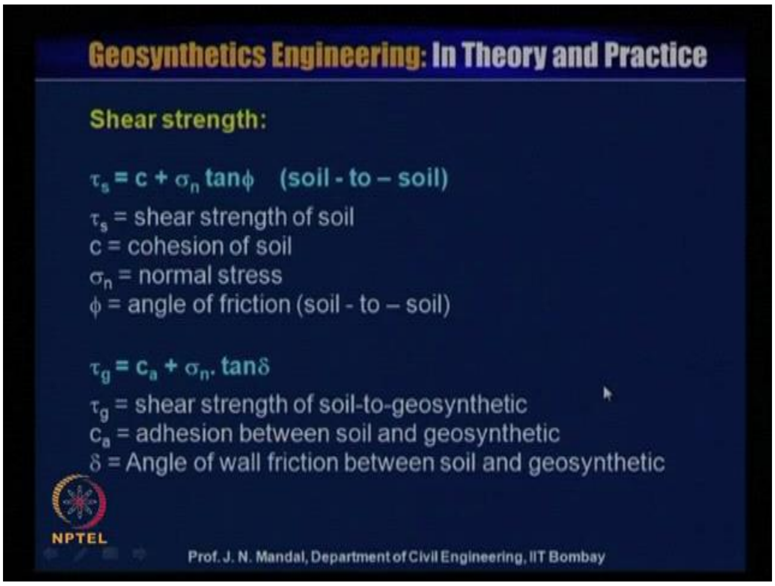

So, shear strength how you can calculate the shear strength, so when soil to soil we say that tau is shear strength of the soil is equal to C plus sigma n tan phi, where C is the cohesion of the soil sigma, n is the normal stress phi is equal to angle of friction. That means soil to soil when you perform the direct shear test in a soil to the geosynthetics material, so you can express tau g is equal to shear plus sigma n into tan delta. So, tau g is equal to shear strength of soil to geosynthetics material Ca is adhesion between soil and geosynthetics, and delta angle of wall friction between soil and geosynthetics material.

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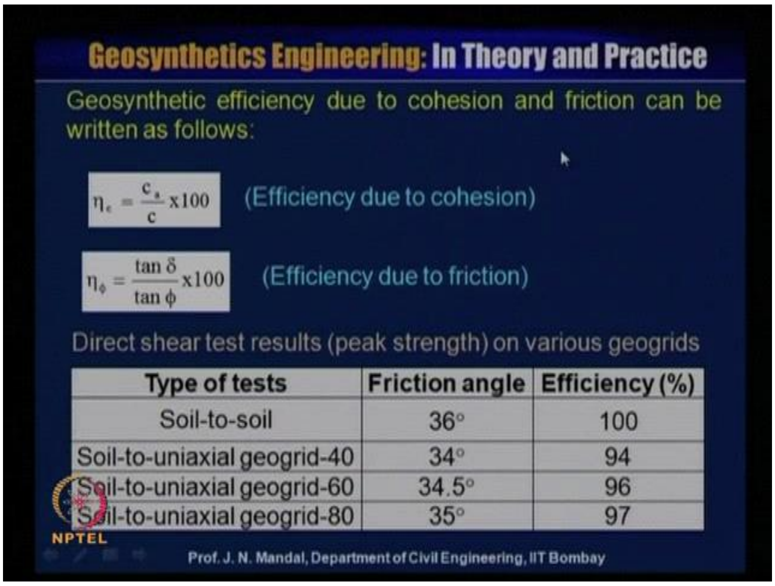

So, geosynthetics efficiency due to cohesion and friction can also be written as, this is the efficiency n of C due to the cohesion; that is C a by C into 100 and efficiency due to friction. That is n phi is equal to tan delta phi by tan phi into 100; that means if you know soil to geosynthetics adhesion and soil cohesion. So, you can calculate what will be the efficiency due to cohesion. Similarly, if you know what will be the friction angle of soil and what will be the friction angle between soil and geosynthetics. So, you can calculate what is efficiency due to friction.

So, we have calculated the efficiency by different types of the geogrid material. We conducted soil to soil friction and friction angle 36 degree efficiency 100 percentage soil to uni-axial geogird 40 with friction angle 34 degree. Efficiency 94 percent soil to uni-axial geogird 60 friction angle 34.5 degree and efficiency 96 percentage soil to uni-axial geogird 80 friction angle 35 and efficiency 97 percentage.

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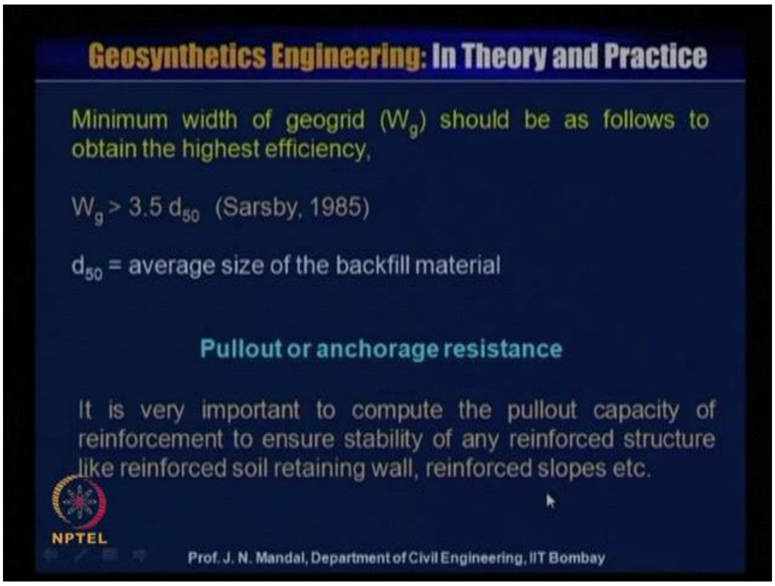

So, minimum we have got the geogrid W g should be as follow as to obtained by the highest efficiency. So, Sarsby1985, he has given the expression that W g that means width of the geogrid should be greater than 3.5 times of d of 50, where d 50 is the average size of the backfill material. So, if you know that what would be the average size of the backfill material, then you can calculate what is minimum width of geogrid.

If we adopt the minimum width of the geogrid within this for equation, then it will, it will perform better. So, one has to be taken care of the opening size of the geogrid material and that also depend upon, what will be the average size of the backfill material. So, with this I end it up the today's lecture, if you have any question?

Welcome, thank you very much for attention.