Technical Textiles
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Lecture No- 37
Additional Lecture on Geotextiles (contd…)

Hello everyone, we will continue with the geotextile strength calculation part. In last class we have discussed the geotextile strength related to bursting type loading and also the tensile related loading condition.

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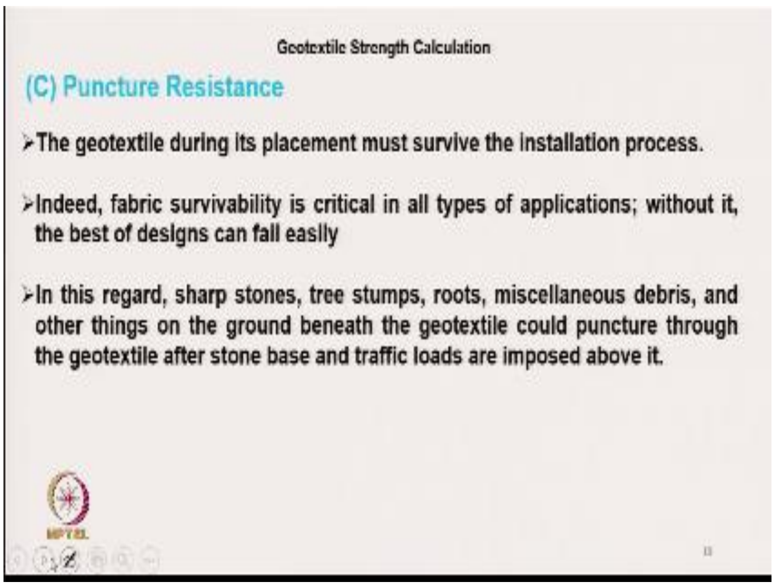

Today we will discuss the other types of strength conditions like puncture, tear and impact. First let us start with the puncture type condition. So geotextile during its placement must survive the installation process. It is not only the performance during the use, long term performance. But during installation it may counteract different types of stresses. So puncture is one of them, basically it is a survivability type condition which is critical in all types of application.

Without it the best design and best type of geotextile may fail. Suppose a best type geotextile and very good design criteria is there but due to some mishandling there is a puncture created. That means total structure will fail. So we must know the puncture resistance of geotextile. So in this regard, where sharp stone, tree stumps, roots or different types of debris, these debris contain different sharp objects and apart from this there are different types of objects which are present under the ground where geotextile is placed.

So these objects may create puncture in the geotextile where the vertical forces are exerted by these objects on the geotextiles which may create puncture. So we must know the puncture resistance of geotextile for all these survivability characteristics.

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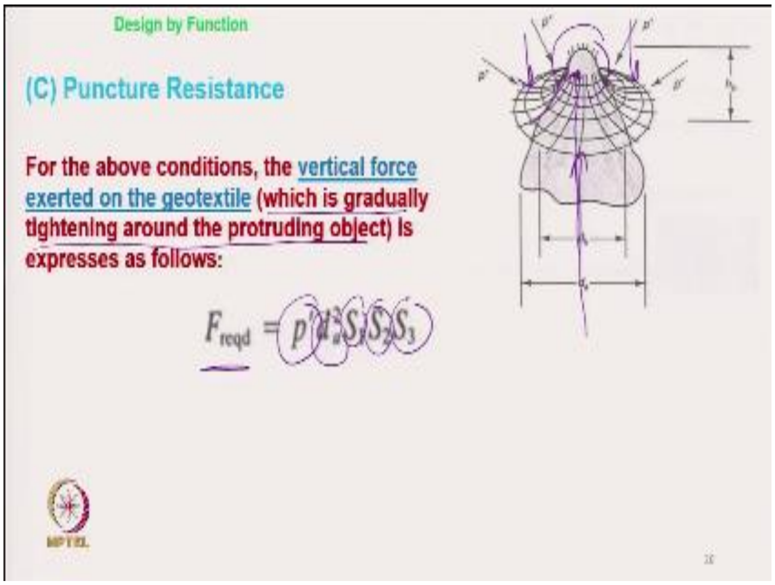

So this survivability function is very important. So whatever conditions we have discussed, the vertical force here it is the vertical force is exerted on the geotextile which is gradually tightening around the protruding object. So there is some object. So it is vertically moving upward and it is getting tightened, the geotextile is getting tightened due to the pressure applied from the top and the damage occurs.

And this damage occurs basically tear type of damage. So we can actually get the tear resistance also. So theoretically the expression here is required. So that puncture resistance F required is given by p dash which is the tire inflation pressure da is the diameter of stone da square, S1, S2, and S3. What are these S1, S2, S3? I will just explain.

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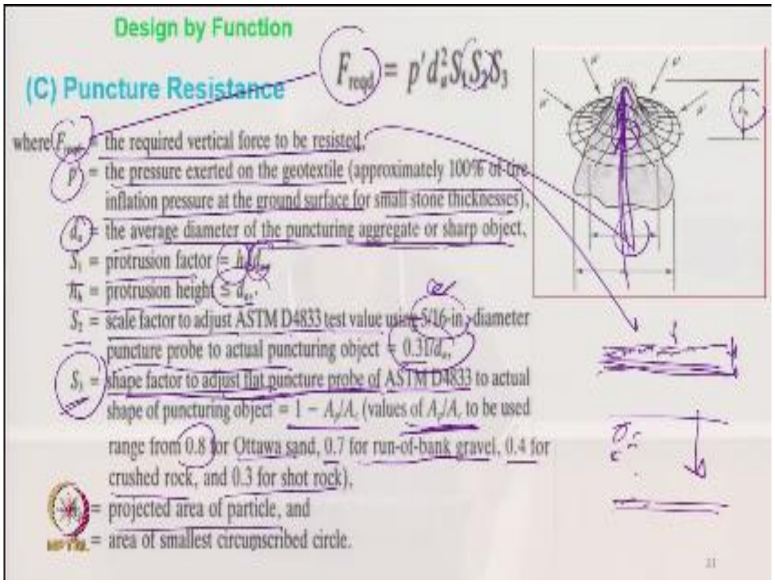

So F required here is the required vertical force to be resisted. This is the vertical force here, this has to be resisted. That is the required puncture resistance, whatever this vertical force by the stone or sharp object that is the F required. p dash is the pressure exerted on the geotextiles, which is approximately equal to 100% tire inflation pressure for small stone thickness. If the stone thickness, this is the road stone thickness and if it is a geotextile.

So for a small stone depth, stone thickness means for the smaller depth of geotextile placement this we can assume as 100%. If it is larger depth we are placing geotextile at the larger depth, so this may reduce little bit. da is again the average diameter of the sharp object here, the stone or something. So this is the average diameter of the puncturing aggregate or sharp object. S1 is the protrusion factor.

What is protrusion factor here? hh by da, hh means the amount the extent it is entering, penetrating that is height h. The expected penetrating inside the geotextile and diameter of the stone or object hh protrusion height, typically it is less than or equal to the diameter of the stone. S2 is the scale factor adjusted as per the ASTM standard test, the diameter which we use using 5 by 16 inch diameter puncture probe which is used as per ASTM D4833.

That we use the puncture diameter as 5 by 16 that means it is coming out to be 0.31 by da. So da here it is assumption it is the diameter of the stone and in our test we assume it is 5 by 16 inch.

So that S1 is the scale factor just we have to scale up or scale down, depending on the actual diameter of the stone that is S2. S3 is the shape factor of the stone which is adjusted to the flat puncturing probe as ASTM D4833 that as per ASTM the puncturing probe is flat, but actual shape of the stone is not flat.

So from there, we can calculate the S3, which is the adjusted shape factor. So this is nothing but 1 minus Ap by Ac. Ap by Ac is the sphericity of the stone which is giving the value of one that is 0.8 for Ottawa sand, 0.7 for run-of-bank gravel, 0.4 for crushed rock and 0.3 for shot rock. So these are the values standard value given from there we can calculate the S3 value, that is the safe factor. It is adjusted safe factor, and Ap, here Ap is the projected area of particle and Ac is the area of the smallest circumscribed circle.

So from there we can calculate the actual safe factor or adjusted safe factor. So if we know all this parameter we can calculate the required particle force to be resisted.

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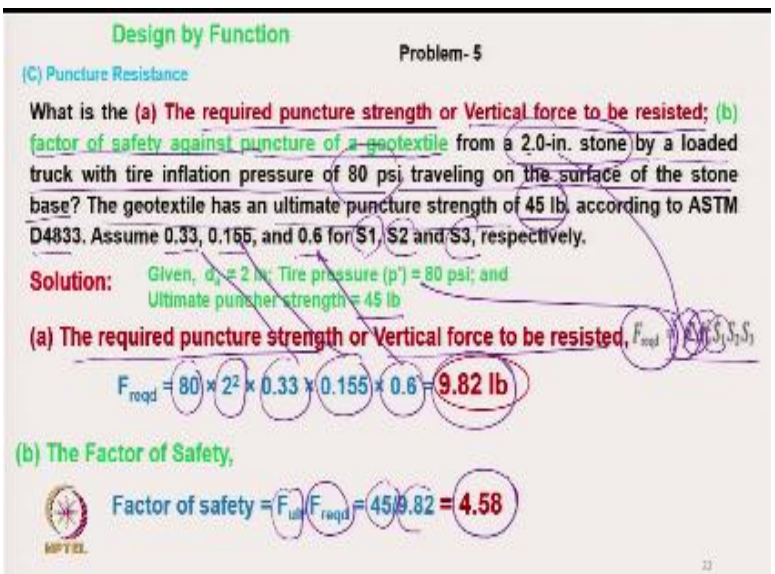

So let us see here. So let us try to calculate what is the required puncture strength or vertical force to be resisted? And b, factor of safety against the puncture of geotextile from a 2 inch stone by a loaded truck with tire inflation pressure of 80 psi travelling on surface of stone base. So what we have to calculate the puncture resistance and the factor of safety with the given dimension of stone and the tire inflation pressure is given.

The other data which are given here geotextile has an ultimate puncture strength of 45 pound according to ASTM D4833 as I have already mentioned and assume 0.33, 0.155 and 0.6 for S1, S2 and S3, respectively. These are the values given here. So we can use the earlier equation to get the puncture strength. So given here da is given ultimate strength is given. So the required puncture strength of geotextile or vertical force to be resisted is given by the earlier formula p dash is given here 80, da is given here it is a 2 inch, S1, S2, S3 are given.

So from there we can calculate the F required, directly we can use. So 80, 2 square, 0.33 is given here, 0.155 is for S2 and 0.6 for S3 so from there, we get the value of required puncture strength equal to 9.82 pound. Now coming to the next is the factor of safety here. Factor of safety is nothing but the ultimate factor of ultimate puncture strength by required puncture strength. So ultimate strength is given 45, 45 is the ultimate puncture strength.

And required we have calculated 9.82. So effectively factor of safety we get here is 4.58 that is the factor of safety we get.

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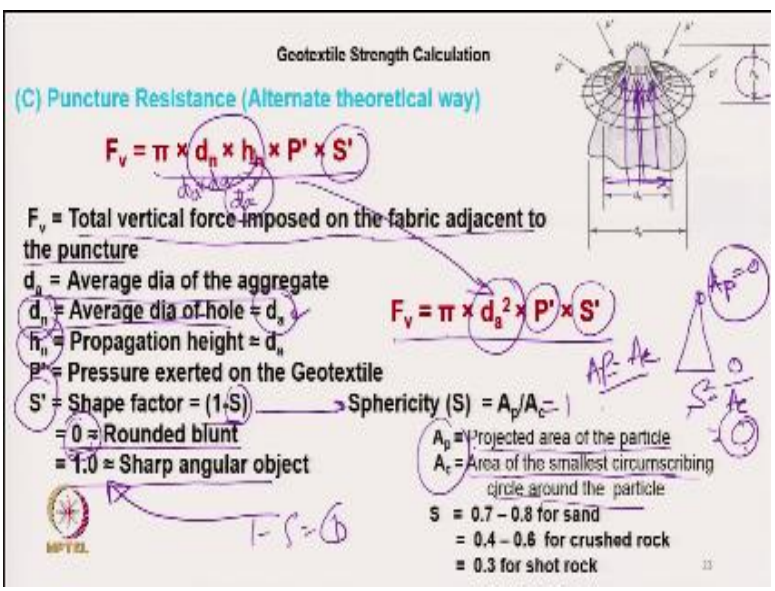

Now the alternate way of getting puncture is resistance is that given by which is the theoretical approach. It is Fv is equal to pi dn multiplied by hn multiplied by P dash multiplied by S dash. Now let us see what these parameters. Fv is total vertical force imposed on the fabric adjacent to the puncture. So in actual field condition, the total vertical force that is a vertical force inserted on the geotextile, it is imposed on the geotextiles, average diameter of aggregate da.

dn is the average diameter of hole, that is dn this is the average diameter of hole is dn here. Which is given by it is approximately here equal to da, this average diameter of hole, it is nothing but it is average diameter of stone because that hole is created by the stone because the stone is pushing the geotextile upward. So here the assumption is that the average diameter of hole is equal to average diameter of stone.

And propagation height, so propagation height hn, this hn propagation height is maximum propagation height can be equal to the diameter of the stones. Suppose this is one geotextile and we have one stone here. Now in the next condition when the pressure is applied, this geotextile can, this stone can propagate maximum this side. So this height it is a hn is nothing but the diameter of the stone and also this dn, average diameter of hole, this is the average diameter hole.

This average diameter of hole is this one. So if I draw here, this is the hole diameter. This again will be equal to da. So dn is equal to da and hn again equal to da. So the hole diameter is equal to diameter of stone and this height, propagation height is again equal to diameter of stone because the propagation and the penetration are basically due to the stone. So if we assume dn equal to da and hn equal to da in that case this portion will be da into da it will be da square.

So if we use this, it will, this formula will become so Fv the total vertical force is equal to pi da square, P dash and S dash. So propagation height and average diameter of hole are typically equal to the diameter of aggregate or stone. So here we are getting Fv value. So pressure exerted on geotextile it is equal to the tire pressure and S dash, here S dash is shape factor. Shape factor of stone, which is equal to 1-S, 1-S is the sphericity.

What is sphericity? It is a ratio of projected area of the particle and the area of smallest circumscribing circle around the particle, that smallest circumscribing circle around the particle. So that ap by ac is the sphericity and S value it is given 0.7 to 0.8 for sand at the standard value given. 0.4 to 0.6 for crushed rock and 0.3 for shot rock. Now for round shape its shape factor is equal to 0 or blunt.

For sharp object it is 1. Now, let us see this is a sharp object suppose, this is a sharp object. So here a projected area is, say here this is the projected area you can see Ap is equal to 0. So here S will be zero by something Ac, will be zero. So S is zero. So for sharp object if S is zero, so 1-S =1. So that is the for sharp object. For totally blunt object it will be equal to, S will be equal to 1 where Ap equal to Ac for blunt object AP equal to AC, so S will be equal to 1.

So if S is equal to 1 then it will be zero S dash will be zero. So for blunt objects sphericity is 1, for sharp object sphericity is 0. So accordingly the shape factor will get adjusted. So from there, we get the shape factor and using this shape factor we can calculate the vertical force imposed on geotextile fabric.

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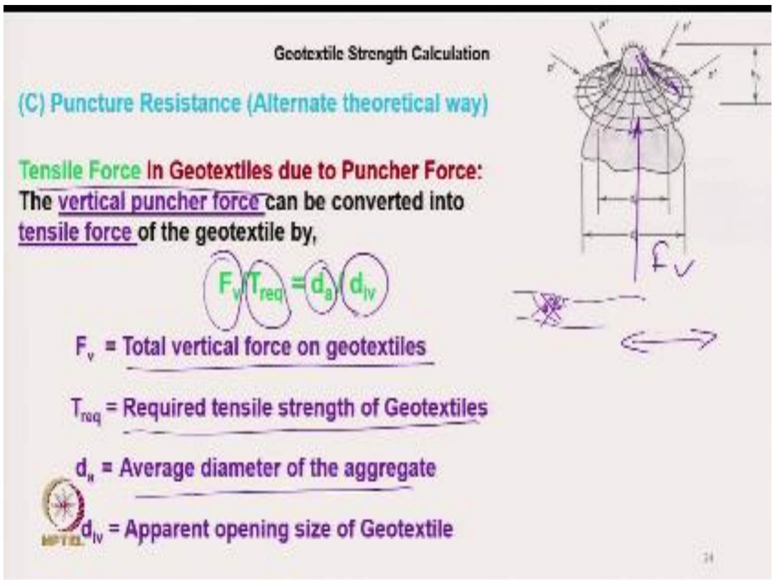

Now the tensile force in geotextile due to puncture force is the vertical puncture force that can be converted into tensile force of geotextile by this formula. So by this assumption we can calculate the tensile force on the geotextile. From the vertical forces, Fv is the vertical puncture force and t required is the tensile force on the geotextile which is given by da, diameter of the stone and div is the initial void diameter of the fabric that is the diameter of openness.

Opening diameter of the fabric, so Fv is the total vertical force on geotextile, T required is the total tensile strength of geotextile. So Fv is acting in this fashion and tensile force will be in this fashion, tensile force. da is the average diameter of the aggregate and div the apparent opening size of geotextiles. That is the opening size of geotextiles which is very small.

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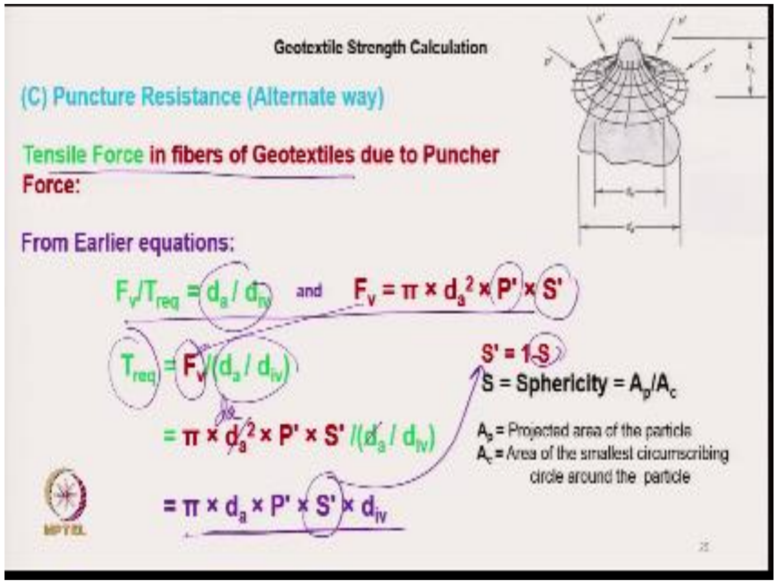

Now from this relationship what we get here, tensile force in fiber of geotextile, that means tensile force exerted on geotextile due to puncher in is that we have seen this two relationships Fv by T required equal to da by div that we know and also we have seen that Fv equal to pi da square, P dash is the pressure, S dash is the shape factor. So from there, if we see we can calculate the T required which is Fv by Fv by da by dv and by just putting the value replacing the value of Fv we get the relationship is this, where da will cancel out, one da will cancel out.

So pi da, P dash, S dash, div. So again here S dash is the sphericity, S is the sphericity and S dash is the shape factor of the stone. So from this we can calculate the tensile force generated in the geotextile due to puncture due to the upward puncturing force.

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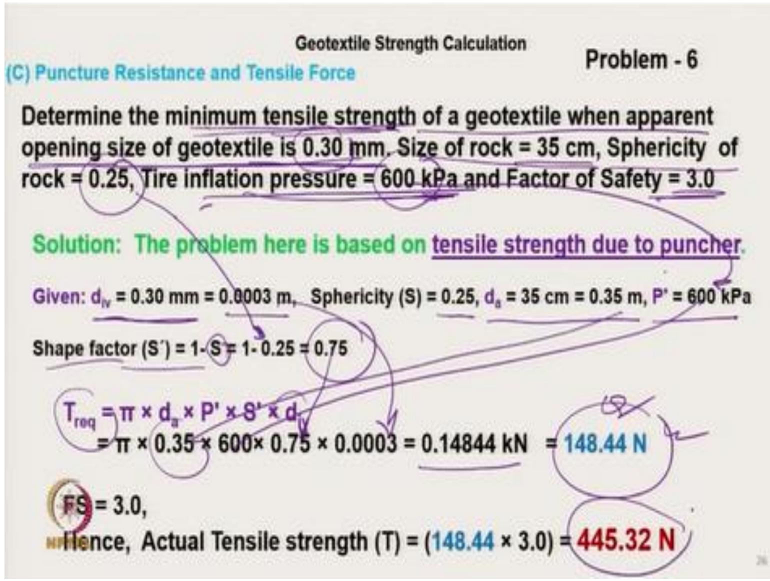

Now, let us try to solve one numerical here, determine the minimum tensile strength of geotextile, when apparent opening size of geotextile is 0.3 millimeters. So 0.3 millimeters is the opening size of geotextile, so in a suppose, this is a non-oven geotextile, so average opening size will be 0.3 millimeter, size of rock is given 35 centimeters the size of rock, very big size rock, sphericity of rock which is S equal to 0.25, as we have seen, tire inflation pressure 600 kPa, and factor of safety is given 3.

So here we have to calculate the minimum tensile strength, let us see, so the problem here is based on tensile strength due to puncher, so here we have created a puncture type situation but we want to know the tensile strength, ok, because we know the geotextile opening size and size of rock, so from there and pressure is important. So that puncture like situation is created but we want to calculate the tensile strength.

So we have to use the formula which we have already discussed, here it is given that diameter of opening that is geotextile opening diameter that is apparent opening size that means geotextile pore size is 0.3 millimeter and it is given kPa. So we have to convert it to in meters, so it is 0.0003 meter sphericity is given S 0.25, diameter of stone is 0.35 centimeter that is 0.35 meter, tire inflation pressure is 600 kPa.

Here, it is given 600 kPa and shape factors, shape factor is nothing but 1 minus sphericity and sphericity is given here it is a 0.25, so safe factor of the rock is 0.75. So we can use this equation directly to get the required tensile strength, so this is the, so pi 0.35; 0.35, 600, 0.75 and div is 0.0003 meter, so we get the value 0.14844 kilo newton and which is nothing but 148.44 newton and we know this factor of safety.

This is the required, this is the value which we get which will be required to sustain in this conditions in the field condition, so in the field condition minimum value required is 148.44, otherwise we will not be able to survive and the product which we get the with the specification that factor of safety required is 3. So it will be definitely 3 times to that of this so the factor of safety is 3.

So actual tensile strength required is 445.32 that is the minimum tensile strength we require in the geotextile to get that minimum 3 factor of safety with the following conditions. So first we will require from the given condition we will calculate the required tensile strength for survival under this condition and then we will get the value of the actual tensile strength of the product. So this is the actual tensile strength.

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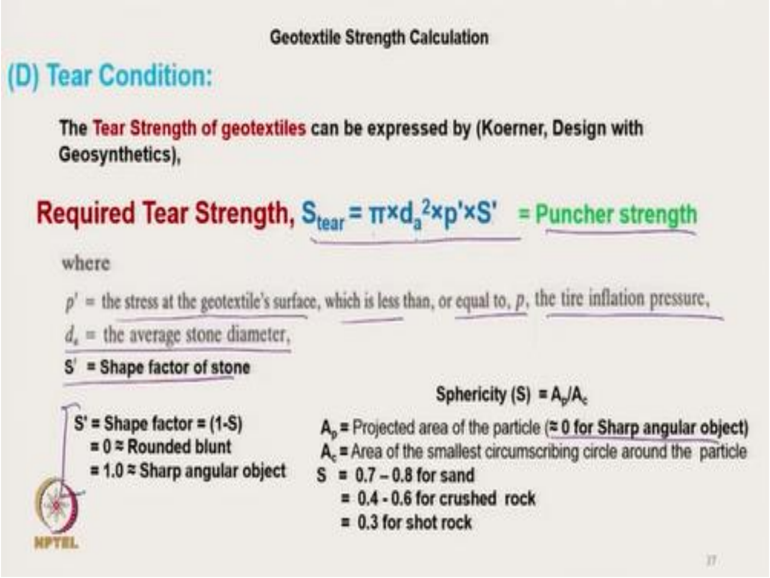

Now the tear condition as I have mentioned it is exactly similar to puncher condition, so basically the tear in a geotextile occurs during the just after the puncture. So there are tear strength of geotextile can be expressed by Koerner using the same equation is S tear directly pi d a square p dash and S dash, S is dash is the shape factor here ok, which is nothing but a punchers strength as I have already mentioned, p dash is the stress at the geotextile surface.

Which is less than or equal to the tire inflation pressure and da is the average stone diameter is this S dash the shape factor of the stone has already been mentioned here so, these are the parameters, which has already been explained. So sphericity Ap by Ac, so same shape factor we can use here.

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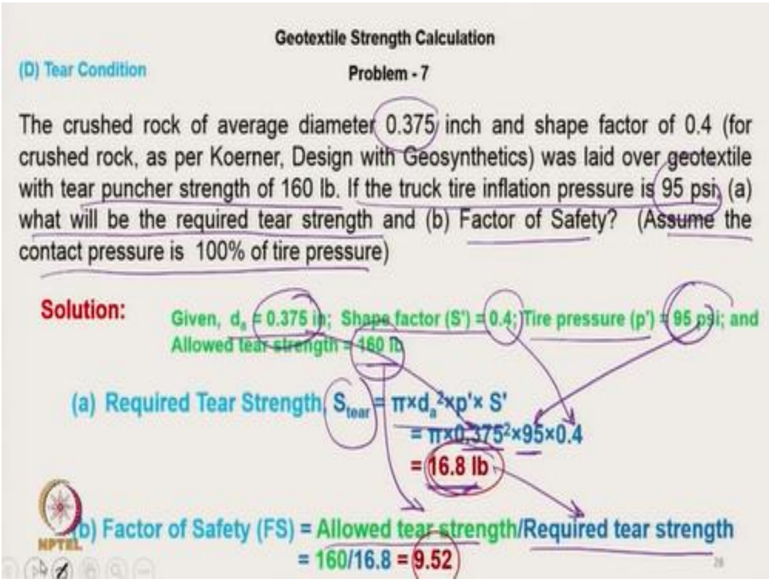

Now let us try to solve the equation, so it may be puncture strength or sometime it can we ask that tear strength, okay? The crushed rock of average diameter 0.375 inch and shape factor is 0.4 for crushed rock as per Koerner, so that is the was laid over geotextile with tear puncher strength of 160 pound, so tear strength is known if the truck tire inflation pressure is 95 psi, what will be the required tear strength? And what will be the factor of safety?

So here assumption is that contact pressure is 100% of the tire pressure. So term normally contact pressure is little bit less or less than tire pressure but for simplicity we can assume 100% of tire inflation pressure. The solution so, here given the diameter da of the average diameter 0.375 inch of the rock, shape factor is 0.4, tire inflation pressure is 95 psi, and allowed tear strength is 160, so this is the allowed tear strength.

So required tear strength is this is a nothing but a puncture strength which is equal to 16.8 pound, so pi multiplied by 0.375 is the diameter of stone and 95 is the tire inflation pressure 95 psi the tire inflation pressure, shape factor directly, it was given and diameter is 0.375, so from there, we get its a 16.8 pound. So factor of safety which is equal to allowed tear strength by required tear strength.

So allowed strength is given is 160 and the required tear strength is 16.8, so dividing 160 by 16.8, we get 9.52 as the factor of safety.

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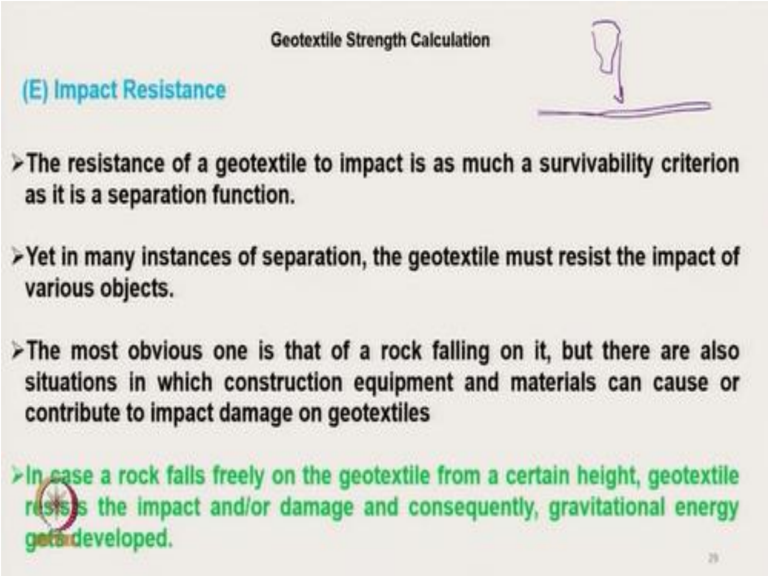

So after puncture and tear; the next strength related calculation is the impact resistance, which is very important during the application during the laying down of geotextile, but during it's application under the ground this type of situation may not arise. The resistance of geotextiles to impact is as much survivability criteria as it is a separation function, so it is a basically survivability criteria it is not basically impact is normally not we counteract during the application during the use.

So yet it may in many instances of separation, geotextile must resist the impact of various objects. So there will be different situations where geotextile will counteract the impact type of situations. The most obvious one is that of rock falling on it, but there are also situations in which construction equipment or material can cause impact and it may damage the geotextile. In case a rock falls freely on the geotextile from certain height geotextile resist the impact.

And it may sometimes get damaged, so this fall this is geotextile a rock is falling on it freely and typically this fall is due to the gravitational acceleration, so gravitational energy is generated and we measure this gravitational energy on the geotextile.

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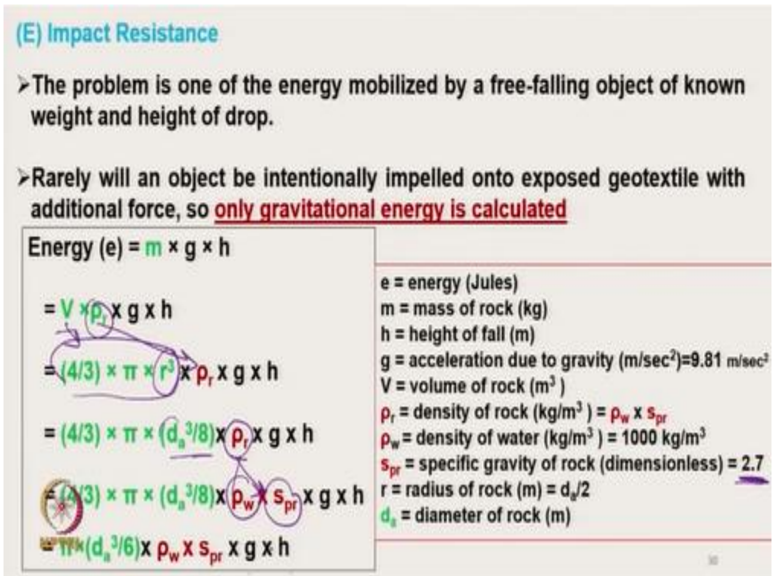

So the problem here is the free fall, so problem is one of the energy which is mobilized by free falling of object of known weight from known height, ok, that is the and rarely there will be a situation where someone is intentionally impelling on a some objects on the exposed geotextiles, this type of situation rarely happens. So some additional force is normally we do not add, so only gravitational energy is calculated for impact resistance.

So there is a normally do not apply any force, it may get dropped only during the impact type of situation, so here that is why only gravitational energy is calculated. So energy here, it is we know the potential energy is equal to m, g and h, where e is the energy in joules, m is the mass of rock in kg, h is the height of fall in meter and g is the acceleration due to gravity it is a 9.81 meter per square centimeter.

So here the v is the volume of the rock and rho r is the density of the rock, which is nothing but the specific gravity of rock multiplied by density of the water and r is the radius of rock, p w is a density of water, so radius of rock. So if we get this V if we assume it is a spherical, so 4 by 3 pi r cube is the volume, rho r is the density of rock and from there by just by rearranging we get this value r q that is the radius cube, so da by da q by d a is the diameter of rock.

And from here we can calculate so replacing rho r by specific gravity of rock and density of water, specific gravity of rock a typically 2.77 is the specific gravity and finally we get this equation pi da cube by 3 rho w specific gravity of rock g and h. So, if we know this values we can calculate the energy that is impact energy generated due to free fall of any objects sub-grade object.

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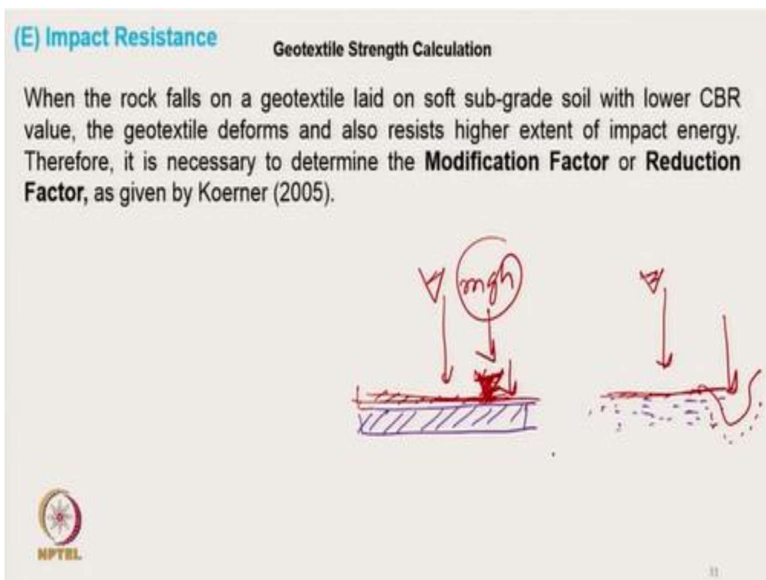

So when the rock falls on a geotextile laid on soft, soil soft, soft sub soil, so here there is a condition now, let us see it is a hard surface very hard surface another is very soft surface, very soft surface, ok, and we are laying geotextile, so this is geotextile we are laying on it this and here, suppose one sharp object is falling and here another surface is falling here, this is sharp object due to this softness this is after falling here.

The impact energy which will be generated here is m g h as we have impact energy, it will be 100% impact energy will be absorbed by here by the geotextile will be imparted on the geotextiles, but if it is on the soft surface, this will get deformed will get deformed here and the subsoil will absorb little bit, so that is the actually it is called reduction factor or modification factor so when the rock and it has been proposed by Koerner in 2005, okay?

So that effect on softness effect will reduce the impact energy effective impact energy on the geotextiles. So when the rock falls on geotextile, late on soft subgrade soil with lower CBR value, California bearing ratio, that we have already discussed. So lower CBR value the geotextile deforms, so it due to deformation it resists higher extent of impact energy, therefore it is necessary to determine the modification factor, so which is proposed by Koerner.

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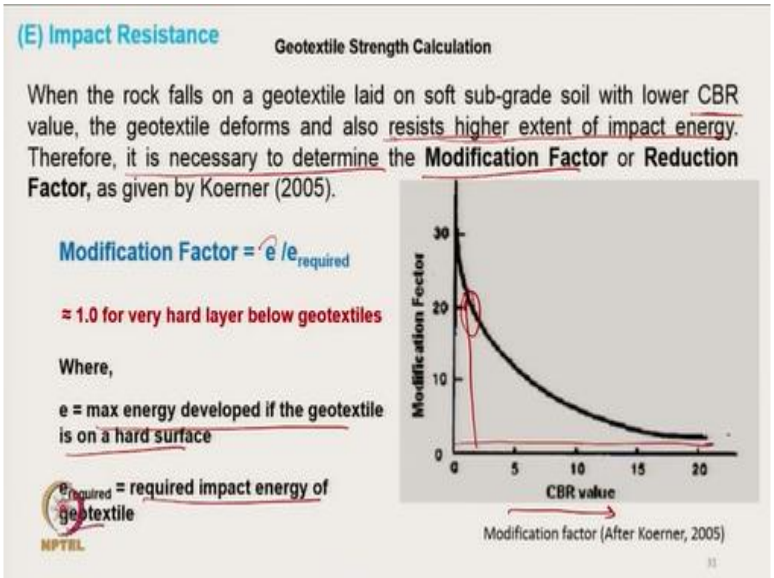

By this is the typical curve here CBR value California bearing ratio value higher the value means the harder the surface. So at lower value so modifications factor is very high that means that effective impact resistance impact energy will be reduced by that that value and it will become typically around 1 for very hard surface. So modification vector is the energy the maximum energy developed.

That we have seen in that equation, whatever we have seen that is the maximum energy developed due to gravitational that is a gravitational energy on the hard surface and e required is required impact energy of geotextiles. So that is the e by e required and here is a higher the modification factor lower will be the required energy, so for a very hard surface, it will it is typically around 1. So this is a very hard, so CBR value is 20 and above it is very hard.

So here you can see this is typically around 1, so for a very hard surface it is 1. So, in that case modification factor is 1 means, required energy impact energy is equal to maximum impact energy developed on geotextiles, okay?

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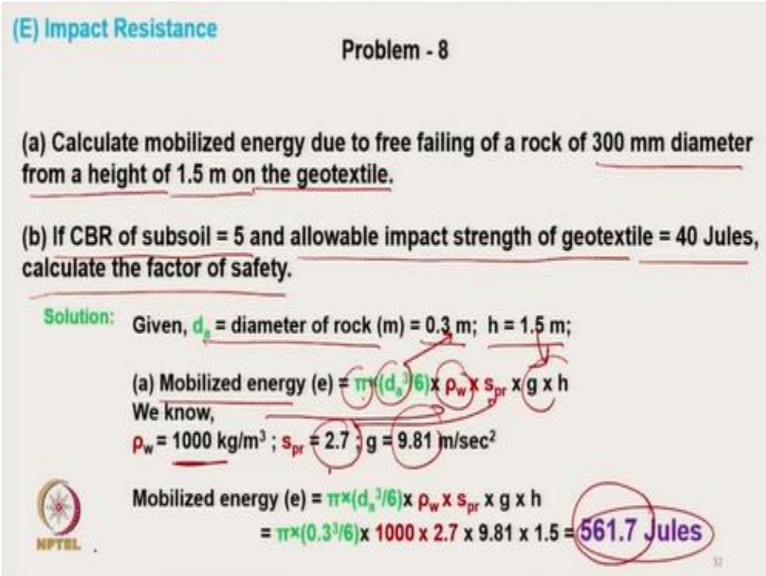

So, now let us see we have to calculate the calculate the mobilized energy due to free falling of rock of 300 millimeter diameter from a height of 1.5 meter on geotextiles, that is the requirement so and next is that if CBR value of soil is 5, the allowable impact strength of geotextile is 40 joule, calculate the factor of safety. So let us see; so da is the diameter of the rock 0.3, h is 1.5 and mobilized energy da pi, da is given here.

The rho w is a 1000 water and specific gravity of rock is 2.7, g value is known h is 1.5, from this data we can calculate the mobilized energy and it is coming out to be 561.7 joules. So, this is the mobilized energy, so which is mainly due to gravitational force.

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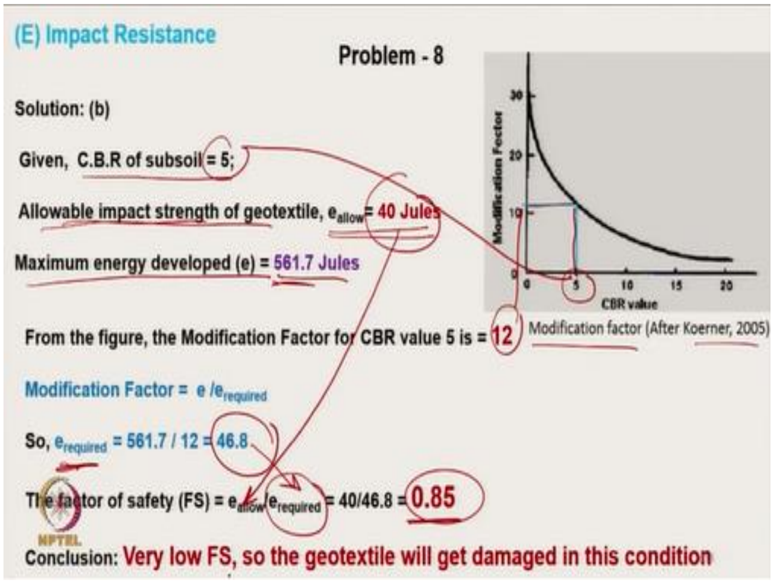

Now, we have we know that CBR value of the subsoil is 5, it is a soft subsoil, that means there will be some modification factor, allowable impact strength of geotextile is 40 joules, so 40 joules is actually it is a allowable impact strength that is the maximum impact sense allowed. So, maximum energy developed as we have seen earlier 561.7 joule that is a maximum energy, now from this modification factor curve by Koerner 2005.

So CBR value is given 5, so for 5 CBR value, we have to calculate the typical modification factor here from this curve, we have calculated this modification factor is coming out to be typically around 12 and this modification factor equal to e by e required. So e required we have got is 46.8, so maximum energy is 561.7, but due to modification factor due to soft subsoil actual the impact resistance required will be reduced to 46.8 that much that much impact is force is actually generated in the fabric.

So the factor of safety is e allowed by e required, e allowed is coming out to 40 that is the maximum allowable impact strength and required impact strength is 46.8, that is the actual it is generated. So it is coming out less than 1, impact that factor of safety is less than 1, which implies that during the given way with the given condition and given material characteristics, this is a factor of safety is very low and so the conclusion is that very low factor of safety.

So the geotextile will get damaged in this condition, so what we have tried to discuss here we have tried to understand different practical implication of geotextiles. How to calculate with a given conditions, given practical condition. How to calculate the stress generated different types of stress generated in the geotextiles and how to select geotextile based on the given or targeted factor of safety. So we will stop here, thank you.