Technical Textiles
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Lecture No- 36
Additional Lecture on Geotextiles

Hello everyone. Today, we will discuss different strength related calculations. So during application;

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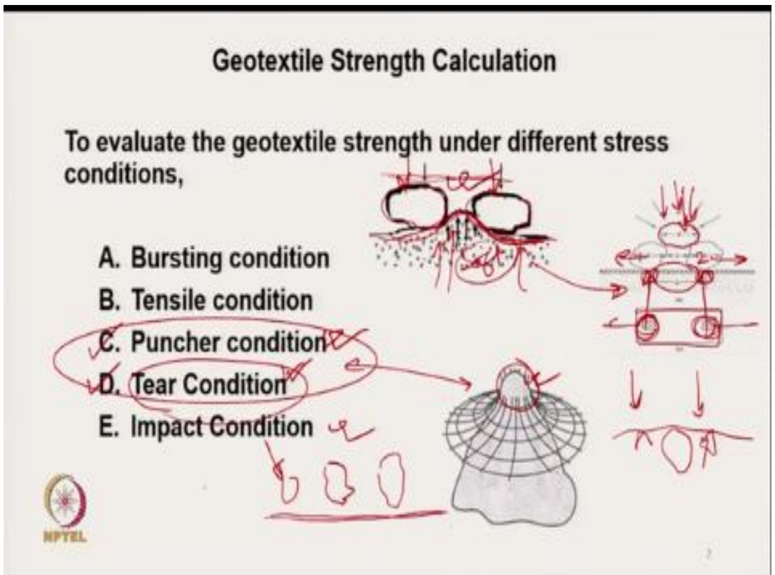

The geotextile subjected to different types of stress conditions. So to evaluate the Geotextile strength under different stress conditions, we will follow different types of empirical relationships. So these different stress conditions are; first is bursting condition where the geotextiles are placed, this is geotextile, this geotextile is placed over soft soil, this is a soft soil and the soft soil is pumped through the stones.

Here geotextile's main function is separation function and this stones are loaded with structure or may be moving vehicle. So the condition which is generated here it is similar to a bursting condition. So we will discuss all the numerical civil related to this bursting conditions. Next is the tensile condition. So along with the bursting condition, there are situations which are created where geotextiles are loaded axially or in plane.

So tensile conditions are generated and typically here tensile conditions are just like grab test grab tensile test. So, here again the soft soil is there below the geotextile, which is placed for separation purpose and the pressure is applied on the stones which are placed above the geotextiles and due to the downward pressure on this stone the other two stones, one two, this two stones will try to move laterally.

And which will create a situation like grab test where this is a textile material geotextile here, these are these two points are grabbed these are jaws, acting as jaw, so these are grabbed and this two points are actually simulating this actual condition. So due to this lateral movement, the stress will be generated, which is tensile in nature and we will see how to calculate this type of tensile stress.

Next is the puncher condition. So it may so happen that this is geotextile, and below the geotextile there is a rock or some sharp material and as the load is being applied, there will be a puncture type situation generated and this will damage the geotextile. So we must know what is the strength puncher strength required for a particular situation? So this puncture is typically associated with the tear condition.

So if we see this puncher and tear, there they work together. So we will see that the puncture strength and tear strength effectively they are same and their expressions are same. Here this tear is due to this puncture condition and this puncture is basically due to this tear. It is not due to the bursting. Bursting is totally different phenomena and the fifth tensile condition is that fifth the mechanical strength conditions is that it is impact condition.

So there may be something suppose the geotextile is placed over the ground, the rock sharp rock is falling on the geotextile and due to this impact the geotextile may get damaged. So here we will try to calculate the impact strength of geotextiles.

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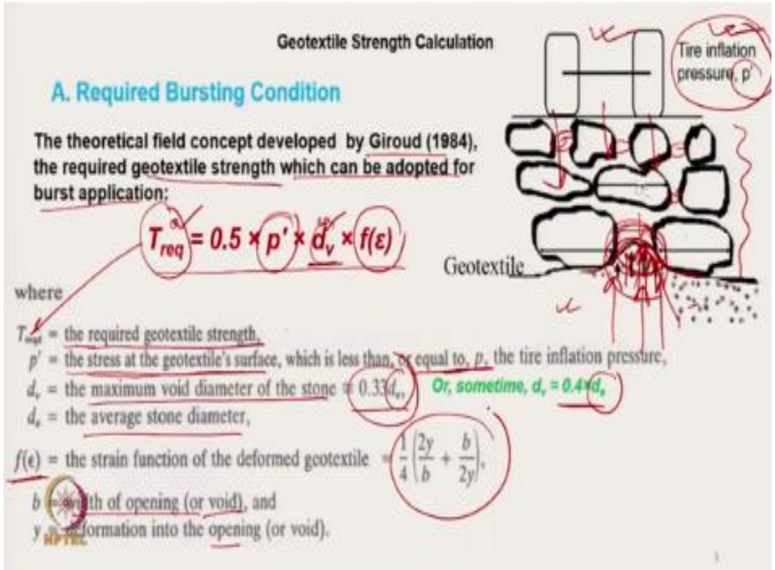

First, let us discuss the bursting condition. So as I have already mentioned that these are the rocks and the moving vehicle with the tire pressure p is moving and this is imparting downward pressure and due to this the soft soil this is these are the soft soil will try to pump upward. So this will create a bursting like situation. The theoretical field concept developed by Giroud the required geotextile strength, which can be adapted for burst applications.

Is given by this equation, here T required, this T required is the required geotextile strength, ok, that is the strength required in geotextile is given by half into p dash, p dash is the stress at the geotextile surface. This is the stress, whatever stress is generated on the geotextile surface that means this is the stress generated in the geotextile surface and this stress it is typically we can assume it is equal to the tire inflation pressure.

That is the downward pressure applied by the tire on the ground and sometimes if the depth is very high depth of placement of geotextile is very high in that case it will be little bit less than p, but for normal calculation we can assume this pressure, stress on geotextile, this stress is equal to the tire inflation pressure for our normal practical application we can assume, dv is the maximum void diameter of stone.

So this is the maximum void diameter, so maximum void diameter it is basically where the diameters of void are different at different places. But the damage will occur at the maximum diameter places keeping all other parameters same. So that is why in this calculation we take dv as maximum void diameter which we can assume typically around 0.33 multiplied by average diameter of stone.

So this void diameter typically 0.33 multiplied by diameter of stone, so if we know the average diameter of stone then we can calculate the diameter of void or sometime we can use 0.4 into diameter of stone and if epsilon is the strain function of the deformed geotextile. Here the geotextile is being deformed and this strain function here strain function is denoted by f epsilon which is a related with the width of the opening or void.

So this is the width of void and the deformation into opening. So this is the y, so if we know this b and y we can calculate the strain function. So from this we can get the value of the required strength during bursting condition.

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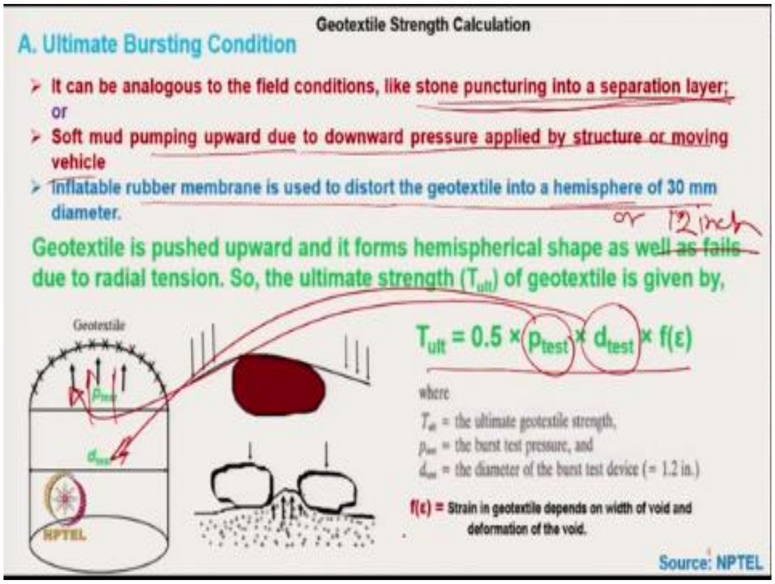

So, ultimate bursting condition is that it is analogous to the field condition like stone puncturing into a separation layer. So from this diagram we can see the load is being applied from the top and this tone is puncturing. So stone is puncturing into the separating layer of geotextile. This is the separating layer or there will be another situation where soft mud pumping upward due to downward pressure applied by the structure or moving vehicle, that I have already explained in last slide.

So these two conditions may generate the condition this fast condition normally generates where the geotextile is placed over hard rocks, that is the stone puncturing into the separation layer or geotextile is placed over the soft soil. It may so happen also that, this is a rock this is pushed downward and this is the geotextile separating land, this type of situation may also appear. So to test the bursting strength.

So inflatable rubber membrane is used to distort the geotextile into hemisphere of 30 mm diameter or 1.2 inch, 1.2 inch diameter. So, this is the bursting strength testing, here hemispherical shape is generated and this is the diameter of test which is 30 millimeter standard or 1.2 inch and this is the pressure applied on the geotextile during test. This situation is the laboratory situation where we can test the bursting strength of geotextile.

And we would like to correlate with the field condition. So geotextile is pushed upward and it forms hemispherical shape as well as fails during radial tension. So we apply the pressure but it fails due to tension. So we must know along with the pressure must know the ultimate strength the ultimate tensile strength the Tult of geotextile, which is given by the similar expression, which we have seen earlier.

Here in earlier case the diameter was the void diameter here, this diameter is the diameter of the test rig. Ptest is the pressure applied at which geotextile burst and the f epsilon is the strain on geotextile. So what we have derived here, we have calculated the ultimate stress on geotextile.

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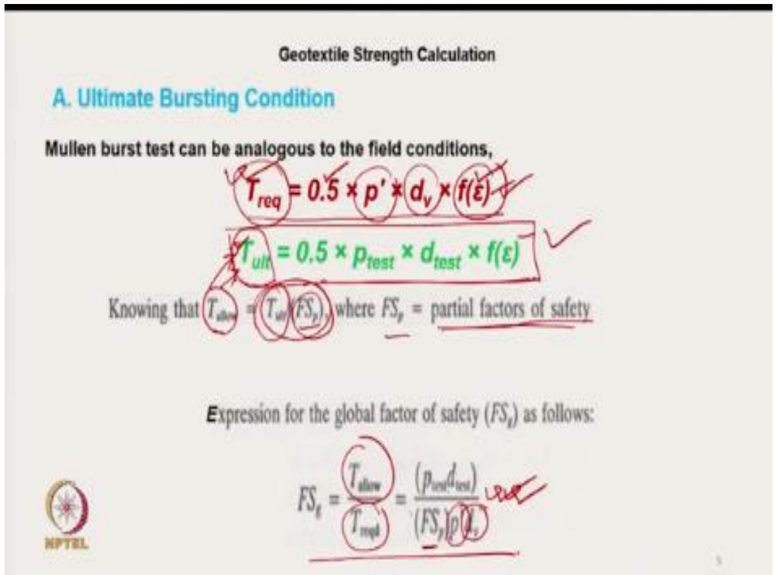

So, this is the basically Mullen burst test and which can be correlated with the field condition. So T required it is a related to the field condition and T ultimate it is a test during the laboratory testing. So we know the ultimate stress, ultimate strength of the geotextile and during application we know the required stress. If we have if we know the diameter of void and the pressure applied on the geotextile, this is the minimum required stress.

And we know that allowable strength is equal to ultimate strength divided by partial factor of safety. Typically, we assume this particular partial factor of safety as 1.5 and if we assume as 1 that means this ultimate's strength is equal to allowable strength but allowable strength we never go up to ultimate strength, so it is a factor of some partial factor of safety we always try to keep for variability in material.

The material is geotextile is normally variable in nature to absorb that variability or other factors we use partial factor of safety, so if we divide the ultimate stress by partial factor of safety that stress is allowed stress, allowed strength and the expression for the global factor of safety is. T allowed by T required. This is the global factor of safety and from these two equations, what we get T allowed equal to T ultimate this is the T ultimate by FSp that is partial factor of safety divided by this.

So 0.5 and function of epsilon that is strain will get cancelled so ultimately we get the equation is Ptest multiplied by dtest divided by partial factor of safety multiplied by pressure on geotextile, that is tire inflation pressure and diameter of void. So this is the typical relationship for factor of safety which is global factor of safety.

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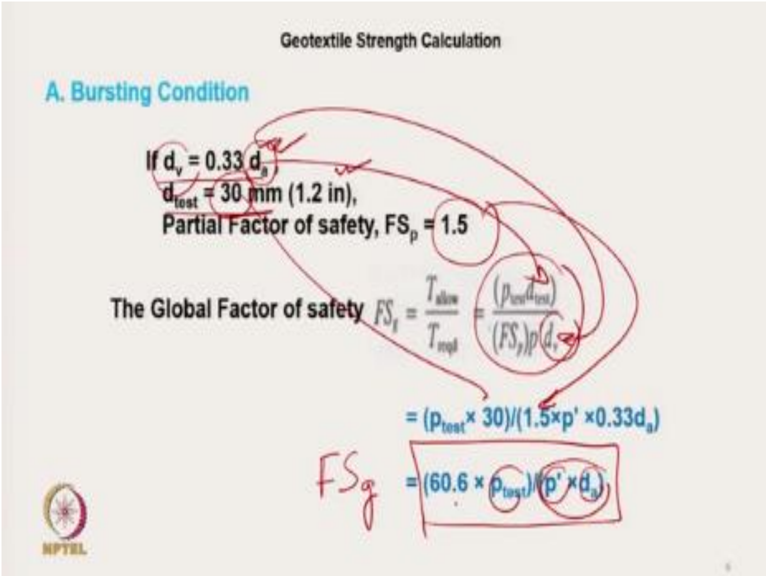

So from the earlier equation, which you have seen here earlier equation, if we use the standard values some standard relationship, we get a standard equation. So the relationship here if some assumptions we can make here void diameter equal to 0.33 into average diameter of stone, which is we can measurable we can measure here da we can measure here, so from there with the assumption that it is a 0.33 time of the diameter of stone.

So we can get the void diameter. So this void dv we can replace here, this is the dv, d test is known it is 30 millimeter or 1.2 inch. So this 30 millimeter we can use here as dtest and partial factor of safety here we can assume 1.5, if we assume 1.5 this is partial factor of safety, finally we get one relationship of global factor of safety equal to 60.6 multiplied by test pressure divided by the tyre inflation pressure multiplied by the diameter of the stone. So this relationship is actually used for quick calculation of global factor of safety.

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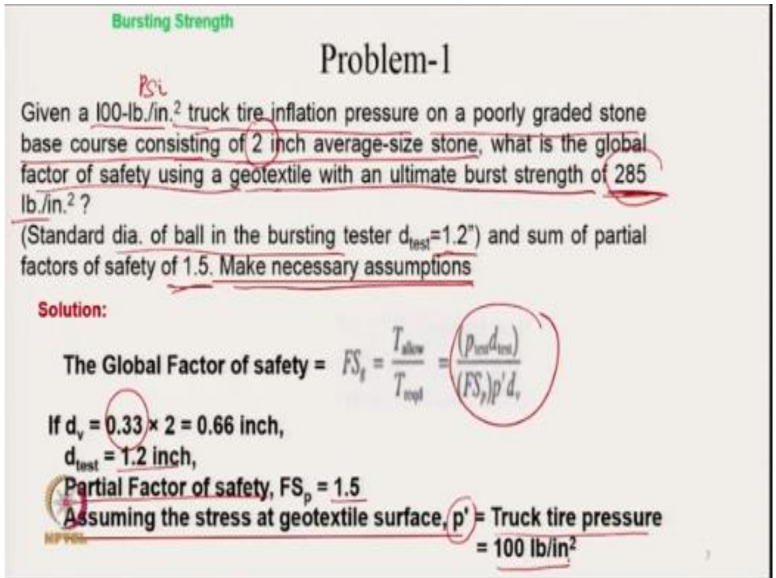

Now let us try with some numerical. So in problem 1, it is given that a 100 pound per square inch, 100 psi pressure truck tire inflation pressure, so tire truck tire inflation pressure is 100 psi on a poorly graded stone base which has actually having 2 inch average diameter of stone. So this is the poorly graded stone, here the question is what is the global factor of safety using a geotextile with ultimate bursting strength of 285 psi.

So standard diameter of ball bursting strength is 1.2 inch that we can use here and partial factor of safety is 1.5, here it is written make necessary assumptions, so what we will do will try to make some necessary assumptions which are actual reported in the literature. The assumptions are I will discuss so global factor of safety is will use this equation, which we have discussed earlier.

Here we know that the dv equal to 0.33 into 2, 2 is the 2 inches is the average diameter, so this is the assumption we will use here 0.33 multiplied by 2 and test diameter is given 1.2 inch, partial factor of safety is also given 1.5, here another assumption is that the stress of geotextile surface is equal to p dash if nothing is given, if it is given it is a say 0.9 times of p dash then we can use but if it is not given then we can assume that stress on geotextile surface is equal to track tire pressure.

Which is 100 psi here, it is given 100 psi that we will use. So using all this data in this equation we can calculate the global factor of safety.

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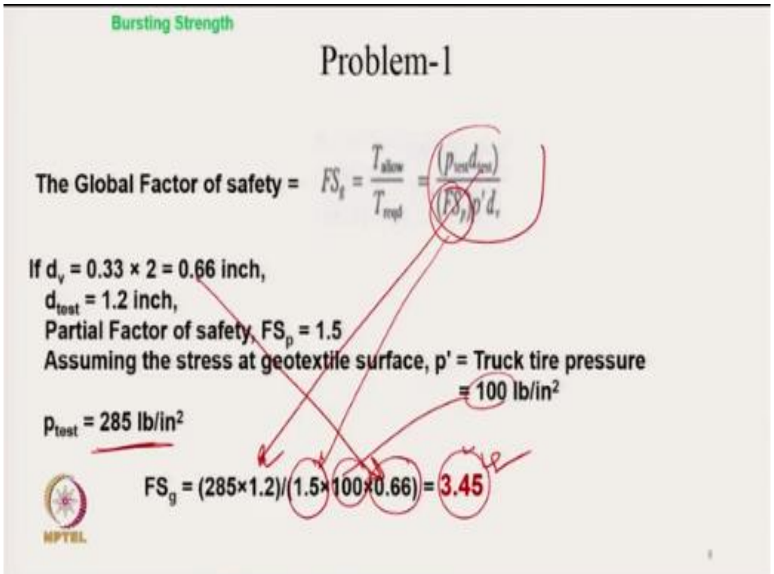

So here the global factor of safety is use this equation and we will get the value here 3.45 is the global factor of safety because ptest is given 285 multiplied by 1.2 inch, 1.5 is the partial factor of safety, 100 psi is the tire pressure and 0.66 is the dv void diameter. So from there we can calculate the bursting strength, so that is a global factor of safety.

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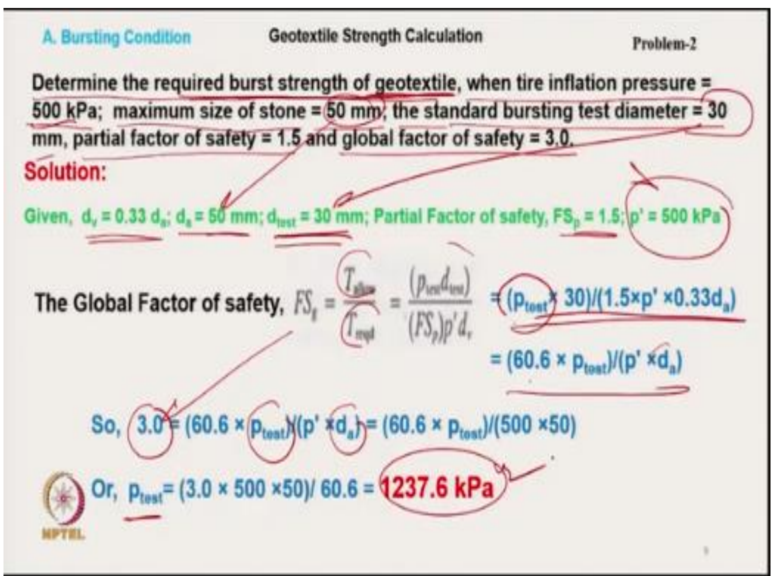

Now another problem here the problem is that the determine the required bursting strength of geotextile when tire inflation pressure is 500 kPa; maximum size of stone is 50 mm; the standard bursting test diameter is 30 millimeter, partial factor of safety is 1.5 and global factor of safety is 3. Here what we have to measure the required burst strength. This is using the same formula. Here what is given here, this is the assumption we will use dv = 0.33 into da.

So da is given, diameter of stone is given and dtest is given here diameter of test, which is again if it is not given then we can also assume normally it is a standard is 30 millimeter or 1.2 inch, partial factor of safety is given 1.5 and p dash that is the tire inflation pressure is given. So global factor of safety, we know it is T allowed by T required. So, this is the equation we know the global factor of safety.

So here we have to calculate the ptest. So required the so ptest if we want to calculate this is the formula we know we have seen earlier also. So from here, we can calculate the ptest. So 3 is the global factor of safety, 60.6 from earlier equation we get and da is given here. So from using this equation, we get the test pressure that bursting strength which is 1237.6 kPa. This is the bursting strength of the geotextile.

So given different conditions we can calculate the characteristics of mechanical characteristics of geotextile material.

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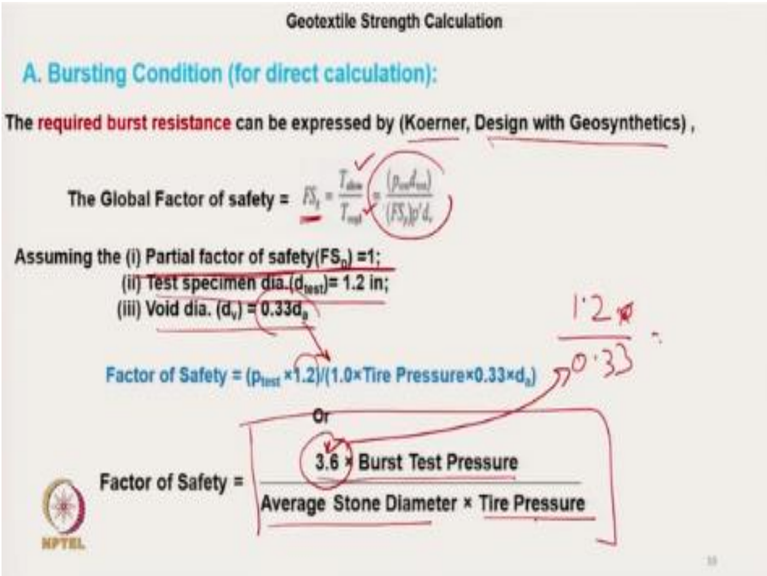

Now coming to the next slide, so from all these Koerner in his book design with geotextile geosynthetics, he has given one simplified formula to calculate the factor of safety knowing the bursting strength of geotextile, average stone diameter and tire pressure. So if we know this we can calculate roughly the factor of safety required, ok. What is the factor of safety? So from this equation global factor of safety is equal to T allowed by T required as we have seen earlier.

Here partial factor of safety is assumed to be 1. So in the Koerner equation this is for simplified or easy calculation of factor of safety, he has assumed the partial factor of safety is 1 and test specimen diameter is the standard 1.2 inch and void diameter is 0.33 into da and using the same equation we can get this value. So, this is the standard equation, which is used widely is basically 3.6 multiplied by bursting strength by average stone diameter

And tire pressure this 3.6 came from 1.2 divided by 0.33 this will come out to be 3.6. So we can use this formula directly to calculate the factor of safety.

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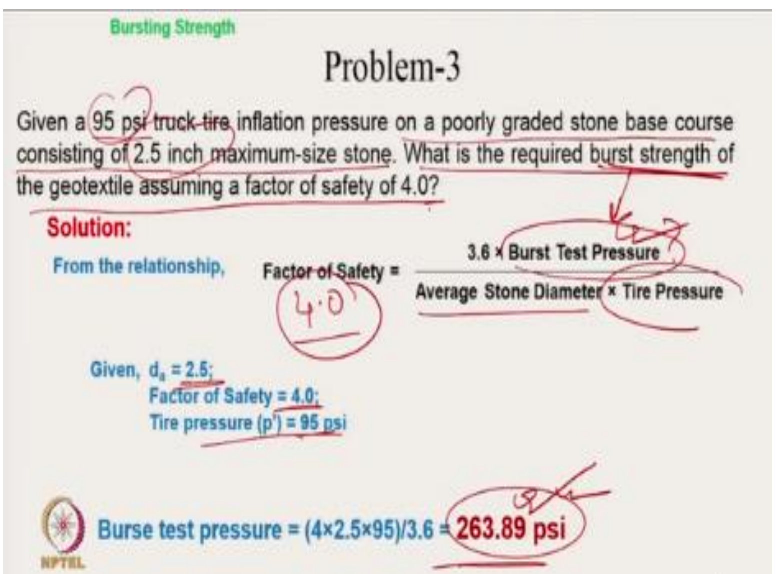

Let us see how to calculate the factor of safety quickly. So, given a truck tire inflation pressure 95 psi which is that tire inflation pressure on a poorly graded stone base course consisting 2.5 inch maximum diameter of stone, what is the required burst strength of geotextile assuming the factor of safety of 4, if nothing is given no other thing is given so factor of partial factor of safety is not given so from there we can simply use this Koerner equation.

This equation here burst test pressure factor of safety, what is the required burst strength? This we have to calculate average stone diameter is given a 2.5 inch and tire pressure is given here and factor of safety is given 4.0 and using this equation we can quickly calculate the burst test pressure of geotextile. The factor of safety is here, tire pressure is 95 at diameter of stone is 2.5 inch and from there we can we get the burst test pressure is so from different situation we can predict the burst test pressure required.

So using this formula we can get quickly if we want to keep the factor of safety 4, so with the given situation we require one geotextile with test burst strength of 263, this is actually this helps in generating the specification of geotextile of material which is needed, so we must get one geotextile with minimum this value of burst strength bursting pressure.

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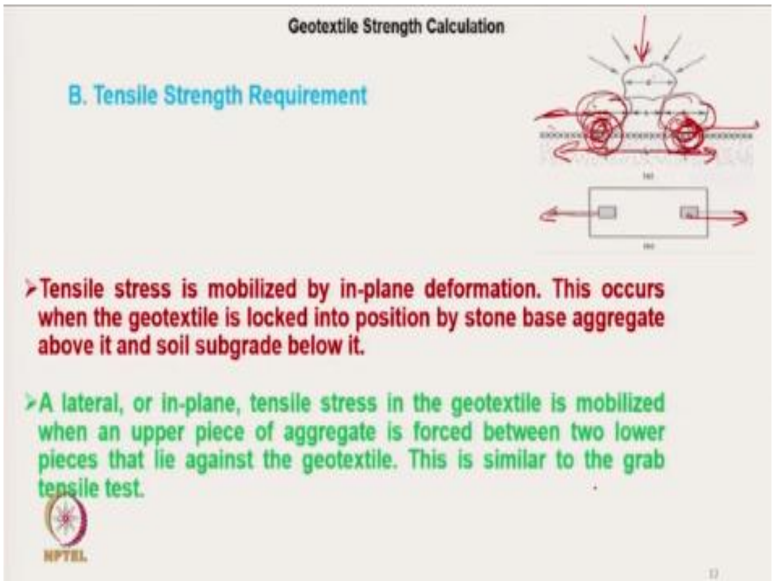

So after bursting strength our next problem is that, the tensile strength requirement. So the tensile strength requirement as I have already mentioned due to this downward pressure these two rocks will try to slide sideway and which will generate one situation like grab stress applied on the geotextile. So the tensile stress is mobilized by in-plane deformation, this is the in-plane deformation.

This occurs when the geotextile is locked into position by stone here, it is a locked but stone base aggregate above it so, this is the geotextile and these stone based aggregates are above the geotextile and here the geotextile is locked and below there is a subgrade soil. So if it is not locked if there is a friction is there is suppose there is no friction then simply this will slide then there is no stress, tensile stress generated on the geotextile but effectively there is a locking.

Here there is a locking. So there will be the stress generated. So this locking is acting as a jaw, A lateral or in plane tensile strain, so tensile stress is generated on geotextiles when upper piece of aggregate is forced between two lower pieces as I have already mentioned, this is similar to the grab tensile test.

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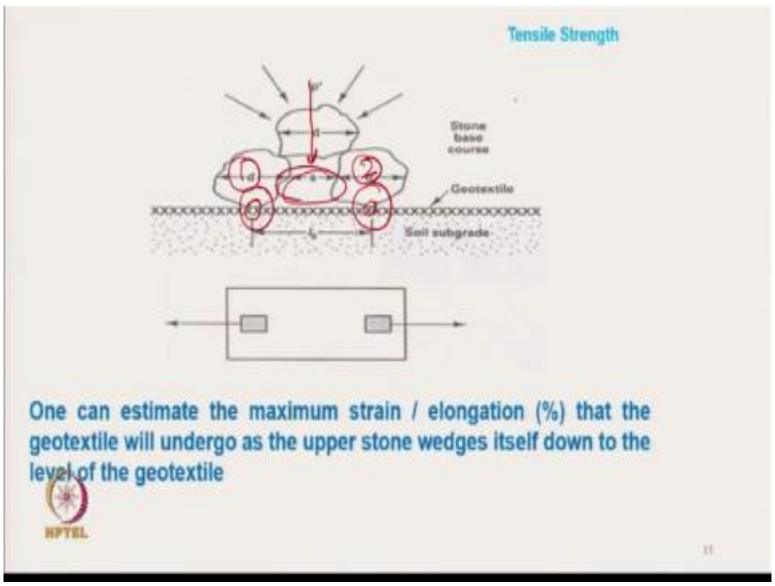

One can estimate the maximum strain or maximum elongation that the geotextile will undergo. As the upper stone this wedge upper stone wedge itself down to the level of geotextile. So at this stage, this is the initial stage, so if it comes down at this stage here, then we can calculate the maximum strain or maximum elongation. So when the maximum elongation condition generates? When the condition is that between this geotextile and the stone.

If this the bottom stones here at this contact point if there is no slippage that means very high friction in that case, there will be maximum strength generated on the geotextile. So we can calculate the condition that maximum strain condition.

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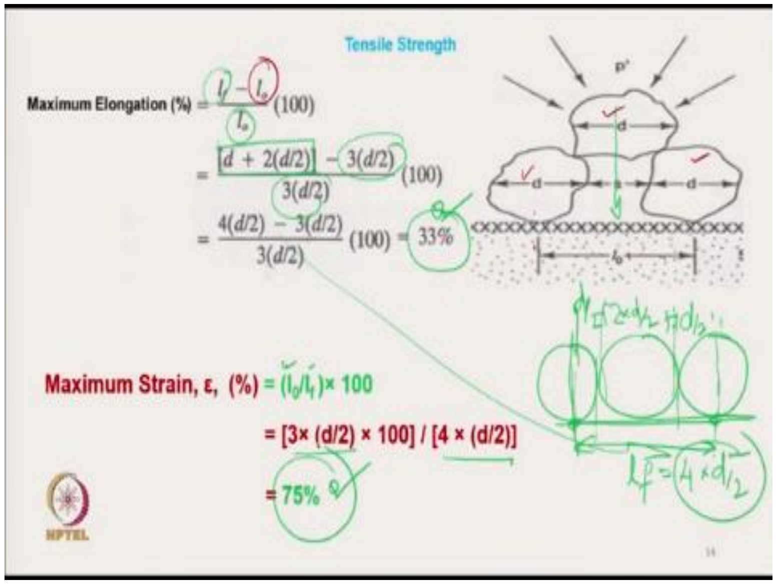

Suppose all the, this stones are of having similar dimensions. Say it is a d and here the assumption is that this is d, this is d, this is d and if we assume so average it is a d by 2 it is a gap. So that this is d by 2, ok. In this condition and here this is gripped with the geotextile. So effective length initial length, this l 0. What is the this l 0? Here it is a half at this stage it is d by 2 here d by 2 so d by 2 + d by 2 + d by 2.

So, this is, this d by 2, here it is at this d by 2 this distance and here it is this d by 2. So we get 3 d by 2 is the initial length of grip so, this is the initial length, l 0. Now, when this upper stone is pushed downward so it is coming here. Let us see the situation, so l 0 is clear. Now, let us see the other condition this is it has been pushed here. Now, this is the condition it is a final condition lf, the maximum it has been stretched so, these are the grippings here.

Now finally it has become this is d by 2 this distance is d by 2 and here it is a d that means 2 into d by 2. So effectively it becomes 4 into this + this + this 4 into d by 2, 4 multiplied by d by 2. So, that is the, final lf, so this is 4 d by 2 - 3 d by 2 divided by l 0 it is a 3 d divided by 2. So that means maximum elongation, which we get here it is the 4 - 3 by 3, that is 1 by 3 multiplied by 100 it is a 33 %.

33% is the maximum elongation of geotextile that can take place during this condition, and if we convert it to strain%, it will be l0 by lf, l0 is 3 d by 2, lf is 4 d by 2 multiplied by 100 it is a 75%.

So 75% is the maximum strain and 33% is the maximum elongation that can take this during this tensile or grab condition.

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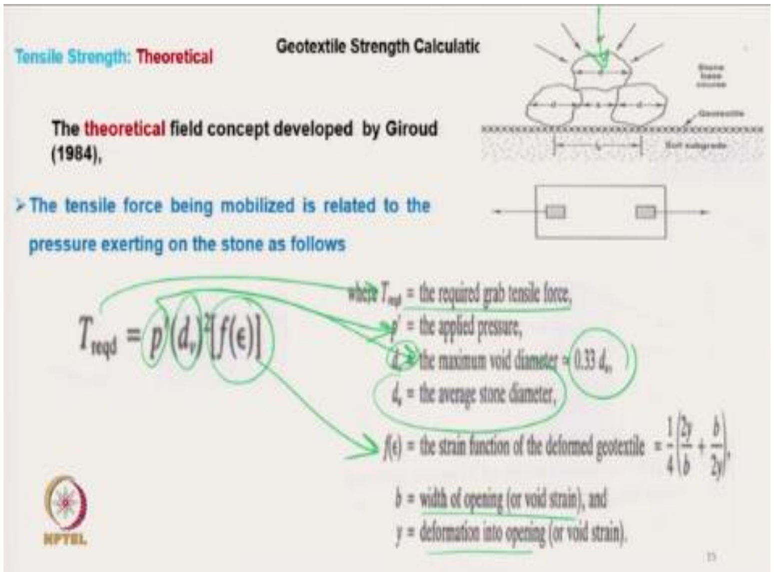

So again Giroud has proposed a relationship to calculate the tensile force on geotextiles. The tensile force being mobilized is related to the pressure exerted by the stone on geotextile, which is given by the relationship T required equal to p dash dv square multiplied by function of epsilon, that is the strain function where T required is the grab test, required p dash again is the applied pressure that is we can assume it is equal to the tire inflation pressure, dv is the maximum void diameter, which is equal to approximately equal to 0.33 of diameter of stone.

And strain function, which we have already discussed. Which is actually function of the width of opening and deformation into opening that is the how much it is being deformed during this when it is pushed in that is the total strain.

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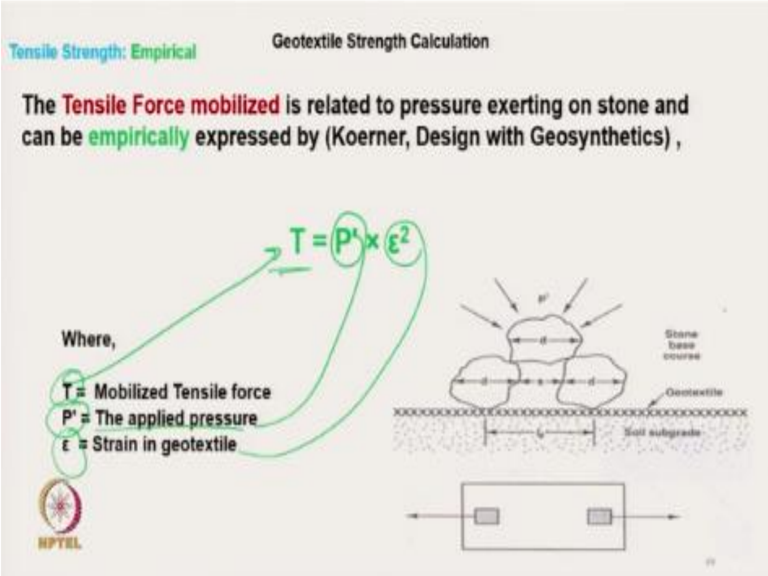

So the tensile force mobilized is related to pressure, so earlier, what was that this tensile force required theoretically given by proposed by Giroud. So and Koerner again as proposed a tensile force mobilization value by giving that empirical relationship. What is that relationship? He has given a simplified relationship, which is T that is tensile force mobilized equal to p dash multiplied by epsilon square but T is that mobilized tensile force, p dash is the applied pressure.

That is the equal to the tire inflation pressure and strain in the geotextile is given by epsilon. That is epsilon square, so p dash multiplied by epsilon square if we can get all these values, so we can calculate the tensile force mobilized in the geotextiles.

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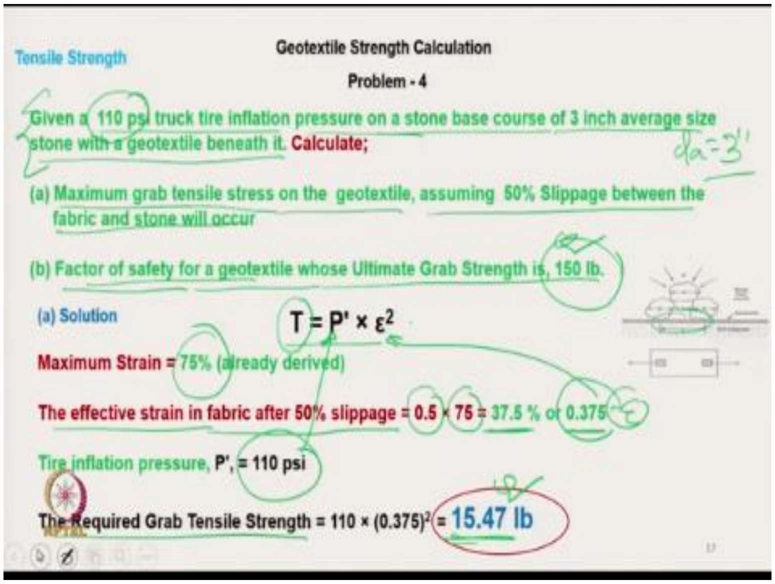

So let us see how to calculate the tensile strength here. So the problem here is that given a 110 psi truck tire pressure. So truck tire pressure is given as 110 psi on a stone base course of 3 inch average diameter. So the stone diameter is, da is 3 inch so with geotextile beneath it. Calculate the maximum grab tensile stress on geotextiles assuming that 50% slippage between the fabric and the stone.

So, that is the assumption, normally earlier the calculation what we have seen here, here the elongation and or strain percent here the assumption was that there is no slippage but in case there is a slippage, so it is not holding properly, there will be little bit slippage and in the problem given here it is a 50% slippage. So let us see so 50% slippage and also next we have to calculate the factor of safety for a geotextile whose ultimate grab strength is 150 pound.

So first thing is that we have to calculate the maximum grab stress with 50% slippage and next we have to calculate the factor of safety. So we will use the formula relationship proposed by Koerner. So, this is the condition here T is the grab tensile stress, so the maximum strain here is 75% that we have already seen. So maximum strain we can get 75% or maximum elongation we can get 33%.

So that we have already derived. The effective strain in fabric after 50% slippage is that 0.5 multiplied by 75, 37.5% which is in factor it is a 0.375. This is epsilon and tire inflation pressure is 110 psi. 110 psi is the tire inflation here assumption is that, that tire inflation pressure is directly being applied on the on this geotextile, there is no reduction, so p dash we can assume. So the required grab strain, grab tensile strength is 100 multiplied by 0.375 square that is 15.47 pound is the required grab tensile strength.

So that is the minimum grab tensile strength required which that will be generated during this condition, but what we have got? We have got a material with grab strength of 150 pound, so but in this in the given condition we need a material with a grab strength of 15.47 pound, but now we have to calculate the factor of safety we need a material with grab strength of 15.47, but we have a material of grab strength of 150 pound. So the ratio of this two will be effectively the factor of safety.

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So factor of safety on the basis of ultimate grab strength is that, so factor of safety is ultimate graph strength by required grab strength, so here we will be using ultimate grab strength because the partial factor of safety we are assuming as 1. So if partial factor safety was given then the allowed grab strength would be the ultimate strength by partial factor of safety but it is not given. So let us assume here as 1.

So that is global factor of safety will be ultimate grab strength by required grab strength, so ultimate grab strength is given 150 and required we have calculated. So it will be 9.7, 9.7 is the global factor of safety. Suppose the, it is given that partial factor of safety was 1.5, in that case it would have been that is 150 by 1.5. 10 was the allowed that is the strength allowed, ultimate the allowed grab strength.

So then it would have been 10 by 15.47 or 150 by 1.5, 100, so 100 by 15.47. That would be so if it was given in that partial factor of safety of 1.5. So we will stop here, other that mechanical characteristics we will discuss in the next class, so the next class we will discuss that puncture, tear and impact related characteristics mechanical characteristics of on geotextiles. So till then thank you.