Geosynthetics Engineering: In Theory and Practices
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Lecture - 61
Designing with Geofoam

Dear student, a warm welcome to NPTEL phase two program video course on geosynthetics engineering in theory and practice. My name is Professor J.N. Mandal, department of civil engineering, Indian institute of technology, Bombay, Mumbai, India. The name of the course is geosynthetics engineering in theory and practice. This is module number 13 and lecture 61, designing with geofoam.

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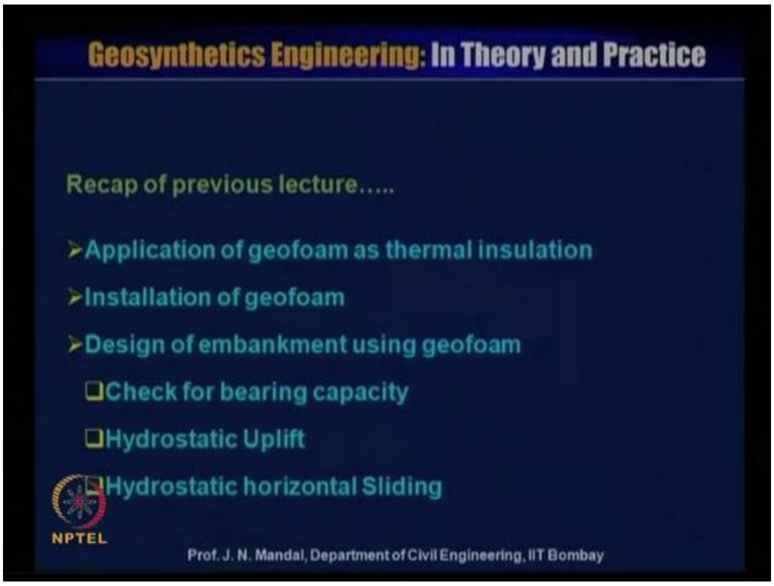

I will now focus the recap of the previous lecture. That is application of geofoam as thermal insulation, installation of geofoam, design of embankment using geofoam that is check for bearing capacity, hydrostatic uplift, hydrostatic horizontal sliding.

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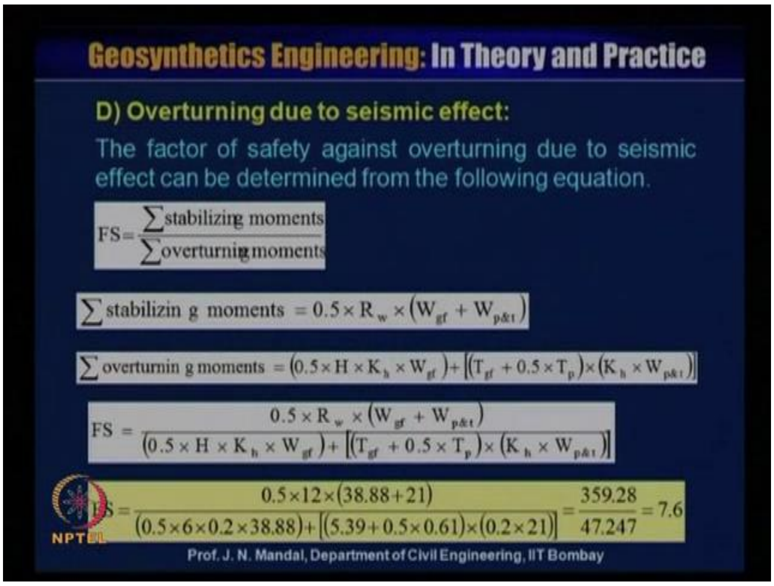

Now, I will address or continue this example that is D, overturning due to the seismic effect. The factor of safety against overturning due to seismic effect can be determined from the following equation that is factor of safety is equal to summation of the stabilizing moment by summation of overturning moment. Now, summation of stabilizing moment is equal to 0.5 into R w into W of g f plus W p and t. You know that R w is the base width of the pavement and W g f is the weight of the geofoam material and W p t is the weight of the normal pressure and the traffic load, which is given. An overturning moment is equal to 0.5 into H. H is the height of the embankment, K h into W into g of f, K h is the seismic coefficient in the horizontal direction plus T g f plus 0.5 into T p into K h into W into p and T, where T p is the thickness of the pavement. T g f is the thickness of the geofoam.

So, factor of safety can be written is equal to 0.5 into R w into W g f plus W p and T divided by 0.5 into H into K h into W of g f plus T g f plus 0.5 T p into K of h into W p and T. Now, we know that R w is equal to the 12 meters, it is given. So, 0.5 into 12 into W of g f, weight we have calculated that is 38.8 plus W of p t that is weight of the normal pressure. The traffic load that also is given 21, this divided by 0.5 into the height of the embankment 6 meter into this seismic K h value horizontally is taking 0.2 into weight of the geofoam, which we have calculated earlier that is 38.88 plus this is the thickness of the geofoam that is 5.39 plus 0.5 into this is thickness of the pavement or cover that is 0.61 into K h again is equal to 0.2 into W p t is given 21.

So, you can have 359.28 divided by 47.247. So, this will be equal to 7.6. So, factor of safety due to the seismic effect for overturning it is 7.6.

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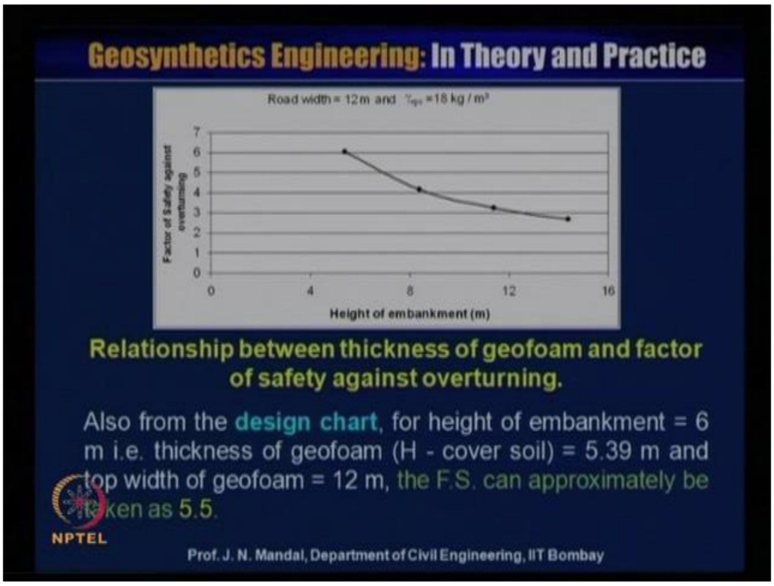

Now, here is the relationship between the thickness of the geofoam and the factor of safety against this overturning. So, this is for a particular road width is about 12 meter and the gamma of e p s is equal to 18 kilogram per meter cube. This horizontal axis is the height of the embankment and vertical axis is the factor of safety against this overturning. So, here you can see that that factor of safety due to overturning is reducing with the increasing height of the embankment.

Now, from this design chart, let us say for a height of embankment about 6 meter and thickness of the geofoam mean H minus cover soil that is 6 minus this cover soil will give 5.39 meter. Top width of the geofoam is 12 meter because that is the road width 12 meter. Then you can calculate that factor of safety from this chart let us say that the height of the embankment is 6 meter somewhere here and then you move up. Then suppose it will meet somewhere here and then you move on the left side and it will meet somewhere in between 5 and 6. So, this will about 5.5.

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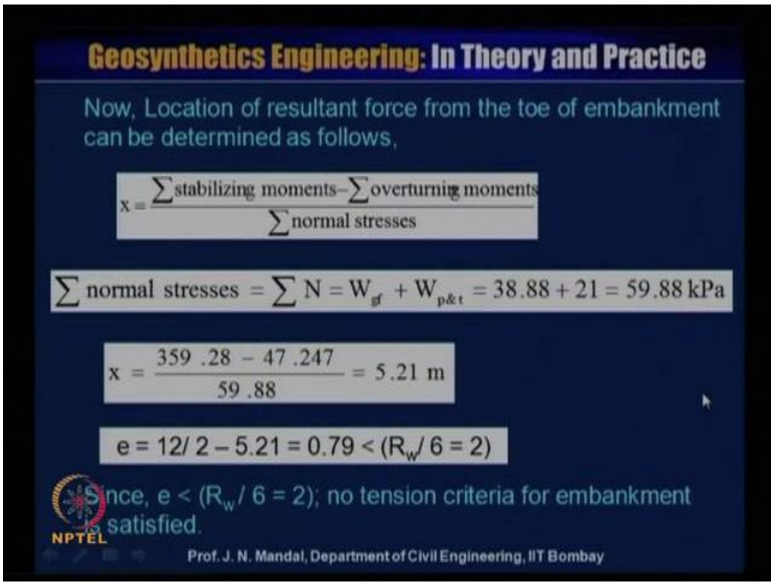

So, factor of safety can be approximated by taken as 5.5. Now, the location of the resultant force from the top of embankment can be determined as follows that if the location is distance is x, x is equal to summation of stabilizing moments minus summation of overturning moments divided by summation of normal stresses. Now, what is the summation of normal stresses that is equal to the summation of N and that is due to the W of g f plus W of p and t. We have calculated earlier W of g f 38.88 and W of p t is given 21. So, this will give that summation of normal stress is equal to 59.88kilopascal.

Now, you can calculate the x using this equation. So, x is equal to stabilizing moment, already we have calculated 359.28, overturning moment also calculated 47.247 and here the normal stress, which we calculate now 59.88. So, you can obtain the value of x is equal to 5.21meter. Now, e is the eccentricity is equal to this is 12 by 2 minus of x that means 5.21. So, this will give that eccentricity e is 0.79. This is R w is the road width that is 12 meter. So, 12 divided by 6 is equal to 2. So, this is less than 0.79. Since, e value is less than R w by 6 that is 2, so no tension criteria for the embankment is satisfied.

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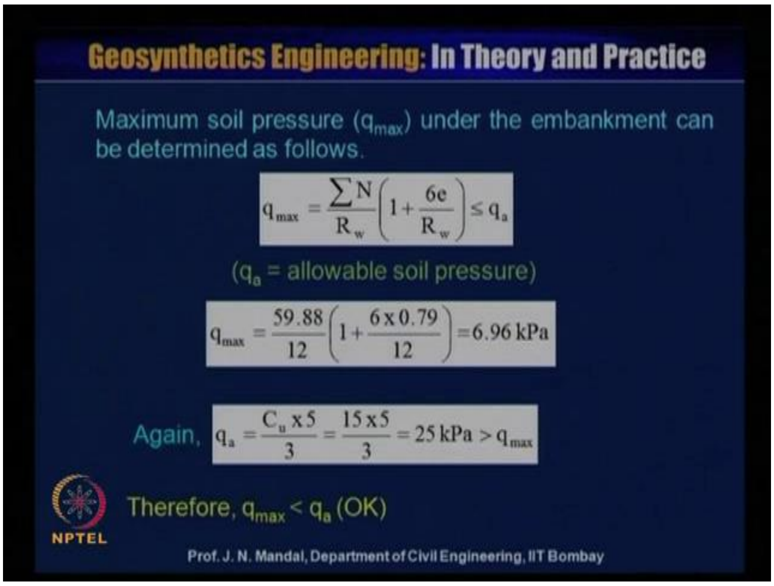

Now, what will be the maximum soil pressure q max under the embankment can be determined as follows that is q of max is equal to summation of N divided by R w into 1 plus 6 e divided by R w, which should be less than the q of a. So, we will calculate also q of a, where q a is allowable soil pressure. Now, q maximum is equal to summation of N, we calculated 59.88 divided by R w road width is 12 meter. Then 12 into 1 plus 6 e, we calculated 0.79. This is e value is 0.79. So, you put 0.79, this divided by R w again is equal to 12. So, this will give you that what will be the maximum soil pressure q maximum is equal to 6.96kilopascal.

Again, we know that allowable soil pressure that is q of a is equal to C u into 5 divided by 3. So, C u value which is given 15 into 5 divided by 3 that equal to 25kilopascal, which is greater than the q of maximum. So, you have calculated q of maximum. So, this value is greater than the q of maximum. Therefore, q maximum less than the q of a that means allowable soil pressure. That means it is ok.

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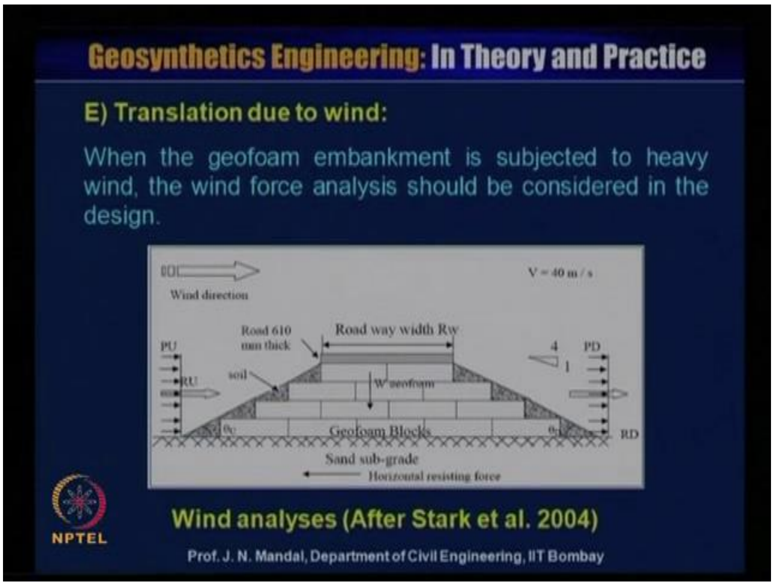

Now, E, translation due to the wind because geofoam is material is very super light material. So, you have also taken into consideration. If there is a wind and how you can design for the wind analysis, how can you do that because this is very important because when you will construct the embankment on the sub grade soil using the geofoam material and because for its light weight material, there is a possibility for the fly of the geofoam on that locality? Therefore, it is required that wind analysis, so we will consider that what will be the wind velocity in that locality and how you can calculate this design for the wind velocity.

So, here this is the wind direction you have considered and the velocity of wind about 40 meters per second. This is wind analysis after Stark et Al 2004 and this is the P of U that means this is the pressure distribution in the up wind direction, pressure distribution in the up wind direction, this is P of U. Here is the P of D that means this is pressure distribution in the downward wind direction.

This slope is the 1 vertical to 4 horizontal. This is the theta of U, this angle that means the half wind slope angle that theta of U. Here is the theta of D that means this is downward slope angle theta of D. This is the geofoam material and it has a weight is W of geofoam. This is the roadway width, which is called R of w. This is the horizontal resistance force because wind force is acting along this direction with the velocity of 40 meter per second. So, this is R of U, I say this is the upward upwind force. This is R of U upwind force and this side is R of D, which you call the downwind force. This is the downwind force. So, now we will analyze. When the geofoam embankment is subjected to the heavy wind, the wind force analysis should be considered in the design.

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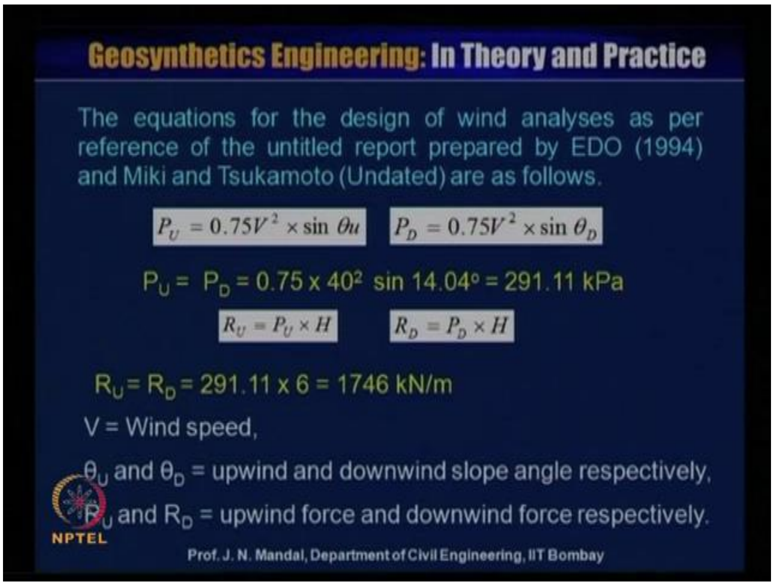

Now, the equation of the design for the wind analysis as per reference for the untitled report prepared by EDO 1994 and Miki and the Tsukamoto, undated are as follows. So, this is the P of U that means this is the pressure distribution in the upwind direction. P of U is equal to 0.75 into V square that is this velocity of the wind into sin of theta U and theta U you know that what is called upwind that slope angle. P of D is the pressure distribution, pressure distribution in downwind direction that is also equal to 0.75 V square into sin of theta D. Theta D is downwind slope angle.

Now, P U is equal to P D is equal to 0.75 into this is wind velocity 40 meter per second that is 40 square into sin of theta U or theta D, which angle is equal to 14.04 degree. So, this will give P U or P D is equal to 291.11kilopascal. Again that R of U that is the upwind force, so upwind force is equal to P U into H and R D is equal to downwind force.

So, R D is equal to P D into H. So, R U is equal to R D will be equal to this is P U or P D, which will give you this value 291.11 kilopascal. So, you have 291.11kilopascal into H. H is equal to height of embankment is 6 meter. So, this will give you the R U and R D that means upwind force and the downwind force respectively is 1746 kilo Newton per meter. V here is the wind speed and theta U, theta D, upwind and the downwind slope angle respectively, R U and R D, upwind force and downwind force respectively.

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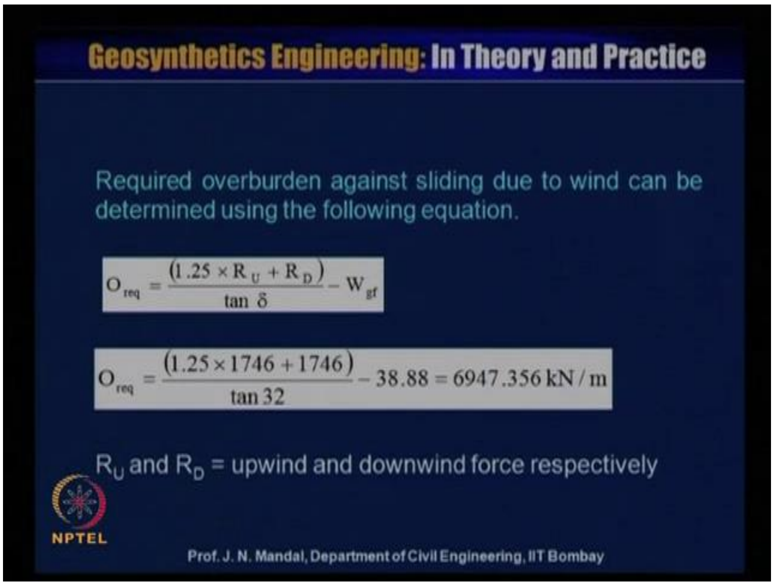

Now, required overturning against the sliding due to wind can be determined using this following equation that is O require is 1.25 into R U plus R D divided by tan delta minus W of g f. So, O required is equal to 1.25 and we calculated the R U and R D that is 1746 from here 1746. So, 1746 plus R D also same plus 1746 divided by delta value is given 32 degree. So, tan 32 degree minus this is weight of geofoam 38.88. So, this will give O require 6947.356kilo Newton per meter where R U and R D are the upwind and downwind force respectively.

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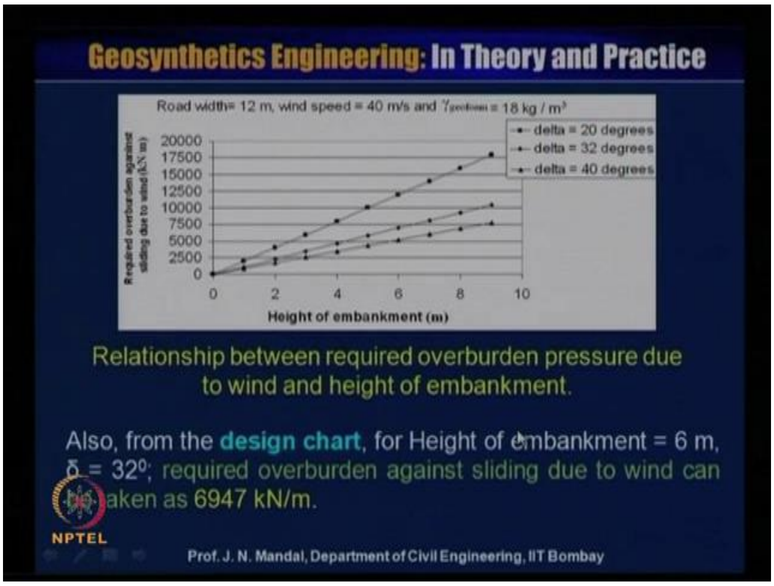

So, here this figure shows the relationship between the required overburden pressure due to wind and height of the embankment. Here, the road width is about 12 meter and wind speed is 40 meter per second. The gamma geofoam is 18 kilogram per meter cube and this is with the different delta value. Delta value is 20 degree, 32 degree and also 40 degree. This x axis indicates the height of the embankment in meter and this y axis, what will be the required that overburden against the sliding due to the wind load.

So, now from this figure, you can calculate what will be the required overburden against sliding due to the wind. Now, from this design chart, let us say that height of the embankment is 6 meter and delta value is 32 degree. So, this is here 32 degree. So, here is the height of the embankment 6 meter, you go up. This is delta value is equal to 32. Then you move the horizontal here. So, this is the required overburden against the sliding due to the wind. This is lying between 5000 and 7500. So, it will be around 6947 kilo Newton per meter.

So, required overburden against sliding due to wind can be taken as 6947 kilo Newton per meter from this design chart. So, you can see that we have also; they calculated earlier that what will be the required overburden against sliding due to the wind. It is about 6947.356 kilo Newton per meter and from this design chart, also you can calculate that what should be the required overburden against the sliding due to wind that is 6947 kilo Newton per meter. Now, again you have to calculate that what will be the O required.

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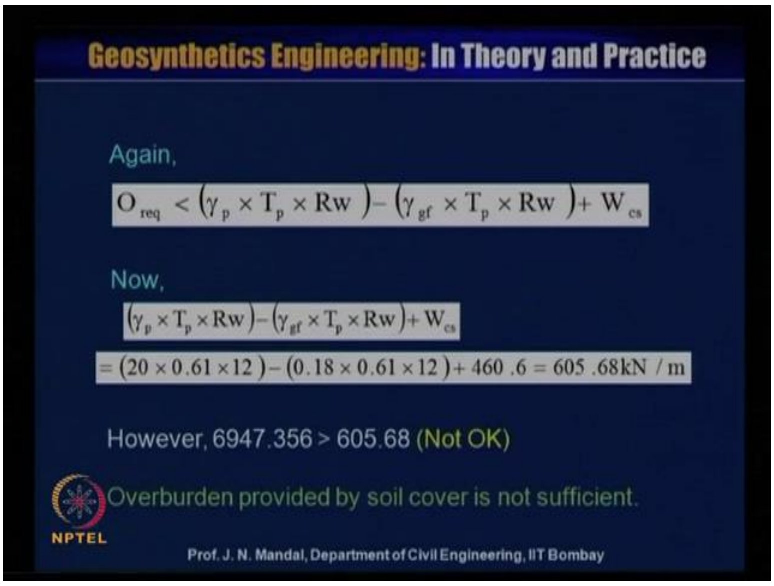

So, O required should be less than gamma in p into T p into R w minus gamma of g f into T p into R w plus W of c of s that means weight of cover soil. Now, gamma p into T p into R w minus gamma g f into T p into R w plus W of c s, so this portion gamma p you know that what will be the unit weight of the pavement that is 20. Thickness of the pavement 0.61, R w that road width is about 12 meter minus this is gamma g f for this geofoam that is 0.18 into T p that thickness of the pavement 0.61 into again R w is equal to 12 plus; we have calculated earlier what will be the weight of cover soil that is 460.6.

So, this portion will give you is about 605.68 kilo Newton per meter. However, 6947.356 is greater than the 605.68. So, it is not; so overburden provided by the soil cover is not sufficient. So, you have to take care for that. So, this way you have to design the embankment using the geofoam material. You have to calculate that what will be the wind forces what will be the sliding, what will be the overturning and you have to be provided with proper kind of the cover soil. If cover soil does not satisfy, you have to change the design the dimension or the thickness of the cover soil can be increased. The slope can be the decreased or geometrical shape of the embankment also can be redesigned if it does not satisfy all those criteria.

Now, we will discuss the some of the important that testing of the expanded polystyrene geofoam material, it is very interesting. This is the first time seen in India. We have been performed number of the various kinds of the tests on the expanded polystyrene geofoam material. We have taken the various densities and we will observe that what kind of density will be the suitable for the construction of the embankment, what kind of the thickness of the geofoam is required to reduce the lateral pressure of the retaining wall and how also you have to calculate.

So, for all the calculation, you have to know about that performance test and how you are to perform the different types of the testing of the expanded polystyrene material. So, we will now discuss that some of the test as per ATM and also some IS code specification. So, we will follow up that American society for testing material specification for conducting the different types of the geofoam with different densities.

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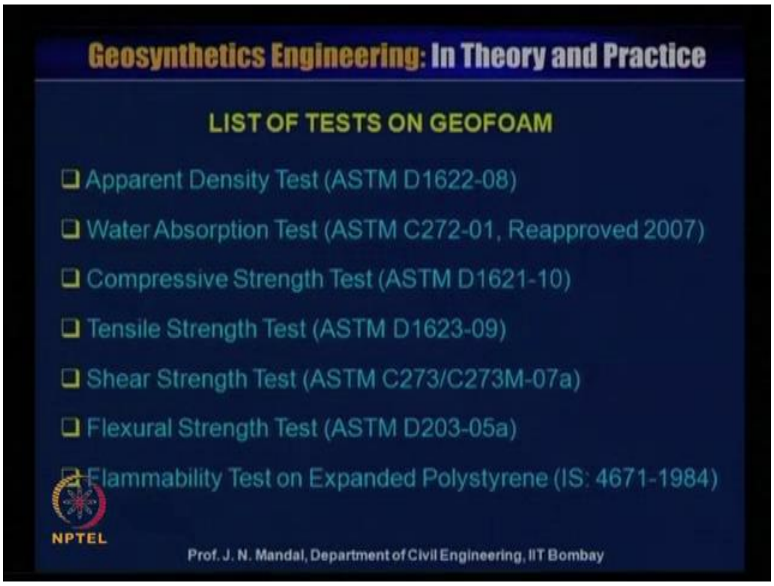

So, here I will now discuss this apparent density test ASTM D 1622 dash 08, water absorption test. As you know that geofoam material may absorb the water and it has a certain limitation of the water, it should observe otherwise you cannot use this material for the infrastructure. So, water absorption test also is very important. This is as per ASTM C272 dash 01 2, reapproved 2007. Compressive strength test that is ASTM D1621 dash10, tensile strength test ASTM D1623 dash 09, shear strength test ASTM

C273, C273M-07a, flexural strength test ASTM D203 dash 05a, and flammability test on expanded polystyrene as per IS 4671, 1984.

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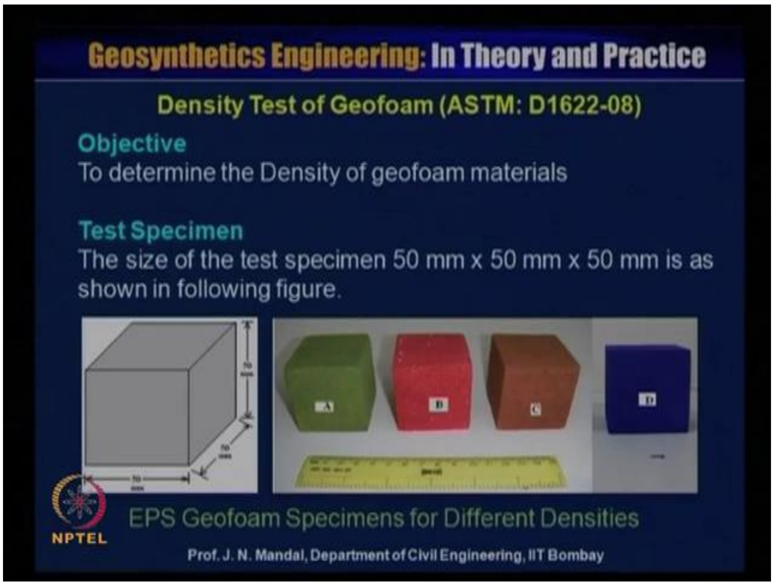

So, these are the some of the tests, which we performed. It has been performed in this institute in geosynthetic testing and research laboratory. So, we have to perform that what will be the density test of the geofoam as per ASTM D1622 08. So, objective of this test is to determine the density of the geofoam material. So, here is the test specimen. Size of the test specimen, generally it is 50 millimeter into 50 millimeter into 50 millimeter centimeter. This is as shown here. This is the different color of the geofoam because it will indicate what should be the density of this material. Let us say this is material A, this is the B, this is the C and this is the D material. Each and individual material have a different density and we wanted to calculate that what will be the density of this geofoam material. So, this is the EPS geofoam specimen for different density.

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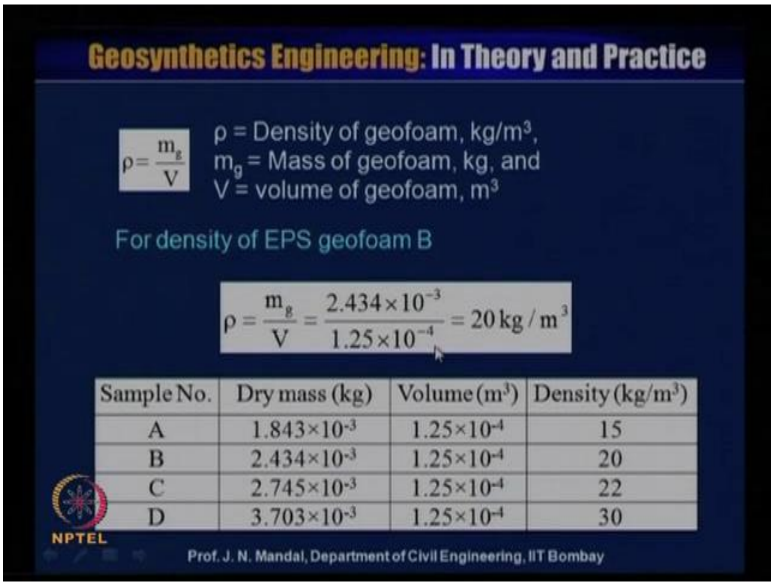

Now, we know that density of the geofoam rho kilogram per meter cube is equal to m g divided by V. m g is equal to mass of the geofoam in kilogram and V is equal to volume of the geofoam in meter cube. For the density of the expanded polystyrene in geofoam B, let us say we are considering as B sample and then rho density will be equal to m g divided by V. You can take the weight in a weight box and measure this is 2.434 into 10 to the power minus 3. This divided by that volume of the expanded polystyrene geofoam is 1.25 into 10 to the power minus 4 that is in meter cube. So, this will give 20 kilogram per meter cube that means density of the expanded polystyrene geofoam V is 20 kg per meter cube.

Similarly, we have been performed for other sample; sample number A, sample number B, sample number C and sample number D whose dry mass for sample number A is 1.843 into 10 to the power minus 3, volume is 1.25 into 10 to the power minus 4. That will give the density is about 15 kilogram per meter cube. For sample number B, the dry mass is 2.434 into 10 to the power minus 3 kilogram. The volume is 1.25 into 10 to the power minus 4 meter cube and density gives 20 kilogram per meter cube. We have shown this calculation only for V that is 20 kilogram per meter cube.

Similarly, for sample number C, the dry mass is 2.745 into 10 to the power minus 3 kilogram and volume is 1.25 into 10 to the power minus 4 meter cube. So, this will give density about 22 kilogram per meter cube. For sample number D, the dry mass is 3.703

into 10 to the power minus 3 kilogram and volume 1.25 into 10 to the power minus 4 meter cube. This will give density 30 kilogram per meter cube. So, we have performed the all density, all kinds of the density, and the other kind of the test for 15, 20, 22 and the 30 as per it is available in India.

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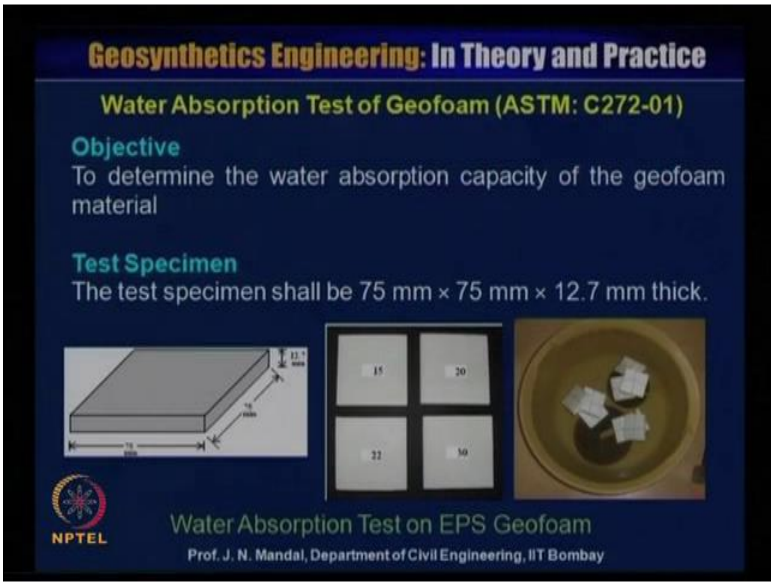

So, after the density test, we have also performed that water absorption test for geofoam that is as per ASTM C272 01. So, objective of this test is to determine the water absorption capacity of the geofoam material. This test specimen shall be 75 millimeter into 75 millimeter and this thickness is 12.7 millimeter. So, you can see that this is the different sample that is for that, density is 15, this is 20, and this is 22 and the 30. This is the equipment in which the water absorption test has been performed on the EPS geofoam.

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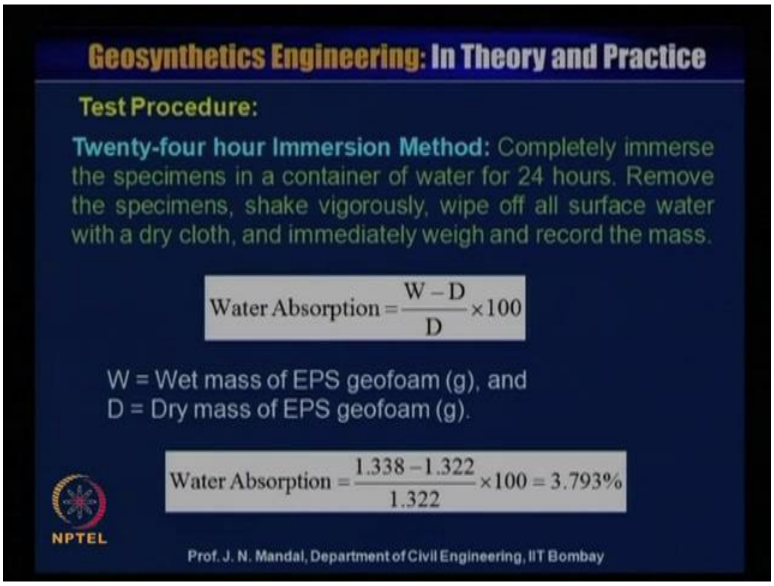

This form, this test we are showing you about the test procedure, 24 hour immersion method. This is completely immersing the specimen in a container of water for 24 hours. Remove the specimen, shake vigorously, wipe off all surface water with the dry cloth, and immediately weight and record the mass. Then you can calculate what will be the water absorption.

So, water absorption is equal to W minus D divided by D into 100, where W is equal to wet mass of the expanded polystyrene geofoam in gram. D is the dry mass of the expanded polystyrene geofoam in gram. So, here water absorption is equal to wet is wet mass of EPS geofoam 1.338 minus D that mean dry mass of EPS geofoam 1.332, this divided by dry mass of EPS geofoam is 1.332 into 100. So, water absorption is 3.793percentage. So, you can observe that this geofoam material has a water absorption capacity and water absorption capacity is about 3.793water. Now, I will just now show you the table for the different kind of the density of the geofoam material. What will be the water absorption capacity?

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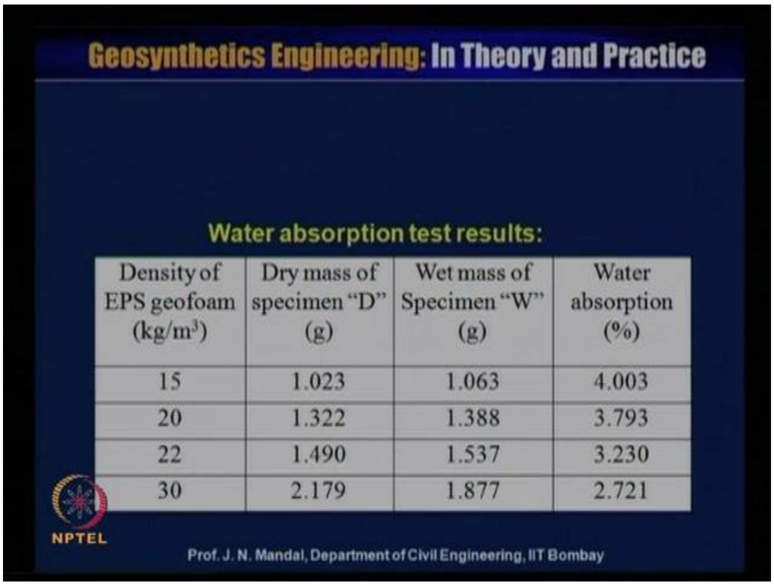

Density of EPS geofoam (kg/m^3)	Dry mass of specimen "D" (g)	Wet mass of Specimen "W" (g)	Water absorption (%)
15	1.023	1.063	4.003
20	1.322	1.388	3.793
22	1.490	1.537	3.230
30	2.179	1.877	2.721

So, here from this table, you can see we have performed the density of the geofoam that is kilogram per meter cube. When it is 15, the dry mass of the specimen D is 1.023 gram and wet mass of the specimen W is equal to 1.063 gram. So, water absorption in terms of the percentage is 4.003. Now, when the density of the EPS geofoam is 20 kilogram per meter cube, the dry mass of the specimen D is 1.322 gram. The wet mass of the specimen W is 1.338 gram. So, water absorption is 3.793percentage, which we have shown you for the density of the density of the EPS geofoam that in 1 calculation that is only for the 20 kilogram meter cube density of the geofoam.

Similarly, that density of the EPS geofoam is 22 kilogram per meter cube, dry mass of the specimen D is 1.490 gram and wet mass of the specimen W is 1.537 gram. So, water absorption is 3.230percentage. Now, density of the EPS geofoam is 30 kilogram per meter cube and dry mass of the specimen D 2.179 gram and wet mass of the specimen W is 1.877 gram. So, water absorption is 2.721percentage. So, you can observe from this table that most of that various kind of the density and water absorption capacity is quite reasonable and acceptable. This value is generally lies between 2 to 4percentage. So, geofoam material is also suitable for the use of the different infrastructure project in India and abroad. So, now another very interesting test and that is on the compressive strength of the expanded polystyrene geofoam material that compressive property of the geofoam as per ASTM D1621 dash 10.

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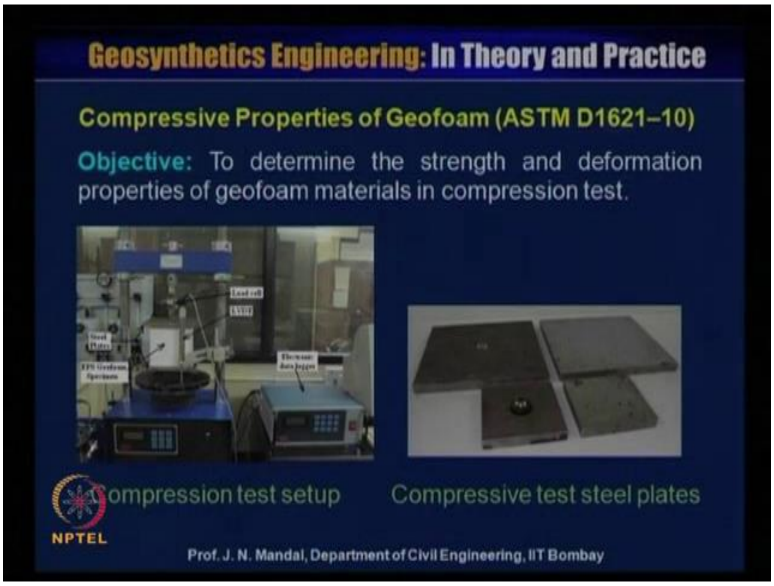

The objective is to determine the strength and the deformation property of the geofoam material in compression test. This is very important test because for any structure, there you require what will be the strength of the geofoam, what will be the deformation of the geofoam. So, you should know when you will design for any structure; use the expanded polystyrene geofoam material. This is the experimental setup in our institute and this is the compression test setup. This is the load sell this is the l v d t and this is the steel plate. This white color this is the EPS geofoam as a specimen and this is the electronic that is the data logger and the form this compressive test. This is the geofoam specimen and you have to place the compressive test steel plate. So, this is the compressive test steel plate, which you have to place at the bottom and the top of the expanded polystyrene geofoam material for uniformly apply the load.

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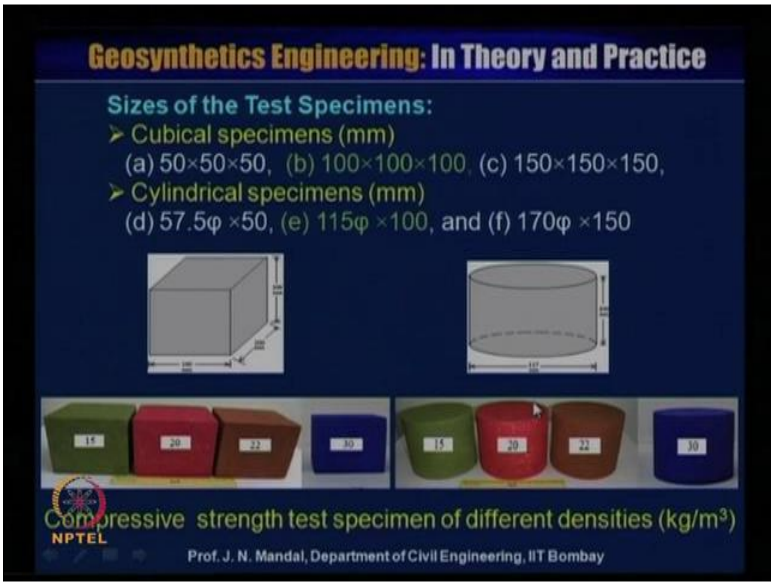

Now, for this test, there are different sizes of the test specimen. So, it may be the cubical specimen. If it is a cubical specimen that is that a is 50 millimeter into 50 millimeter into 50 millimeter. For b, it is 100 millimeter into 100 millimeter into 100 millimeter. This is a cubical specimen and c 100 and 50 millimeter into 100 and 50 millimeter into 100 and 50 millimeter.

Also, you can perform this test as a cylindrical specimen test. So, it is this 1, the cubical specimen this is 100, 100, 100, let us say and this is the cylindrical specimen. So, this is 57.5 the diameter of the specimen and this is the 50 millimeter in the height or it may be the 100 and 15 diameter into 100 millimeter is the height of the cylinder. It may be 170 millimeter diameter and the 150 millimeter of the height of the cylinder. So, you can see here that different types of cubical specimen and with the density, this is 15, this is the 20, this is the 22, and this is the 30. This is all are in cubical specimen and this right hand side here is the cylindrical specimen. This is density is 15, this is 20, 22 and 30 kilogram per meter cube.

So, we have performed this compressive strength test specimen of the different density. So, from this test, you can obtain that what will be the stress strain behavior of the geofoam under the compressive strength because that you require when you apply for the construction of the retaining wall. You wanted to use the geofoam at the back of the retaining wall. So, what will be the compressive strength, what will be the deformation and how you can calculate that and what should be the thickness of the geofoam material is required at a particular density.

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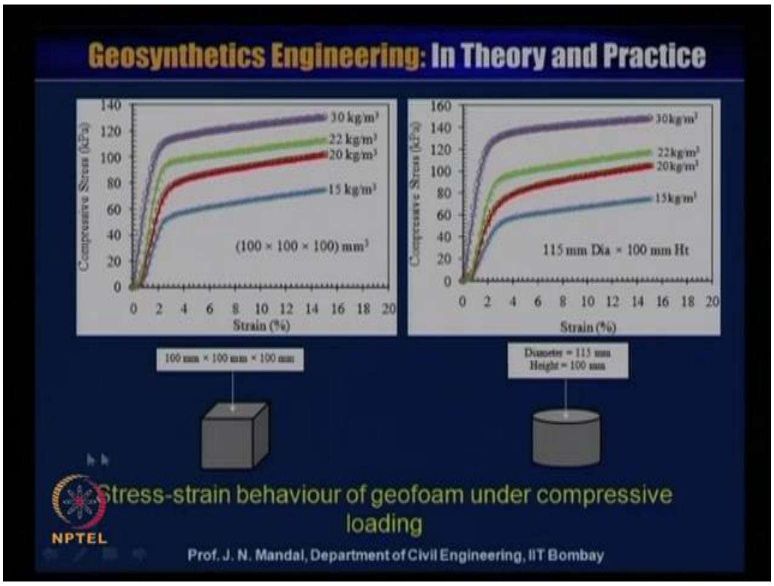

So, here this curve shows that this is the 100 millimeter by 100 millimeter by 100 millimeter. This is the specimen and you have performed the number of the test. I am just showing that 1 of the sample whose size is about 100 millimeter by 100 millimeter 100 millimeter with the different density that is 15 kilogram per meter cube, 20 kilogram per meter cube, 22 kilogram per meter cube and 30 kilogram per meter cube.

So, this is the compressive stress in kilopascal in y axis and the x axis is the strain. You can see that nature of the stress strain behavior of the geofoam under the compressive strength. So, it is that initially it is moving little bit the horizontal; it is some strain, but no stress. Then the compressive stress is increasing. Then it is increasing like this. You can see in all under, all that different density, the nature of the curve is similar. Also, it has been noted that there is a increasing density of the expanded polystyrene geofoam and the compressive stress also are increasing.

So, when you have performed in a cubical specimen 100 and 100 millimeter per meter square per second, you can observe the nature of the curve. It is also noted that that density is increasing and compressive strength of geofoam also is increasing, but when also you can use this cylindrical specimen like this cylindrical specimen whose diameter is 100 and 15 millimeter and height is 100 millimeter, this is the test, this between the compressive stress in kilopascal. This is the strain in percentage and the sample as I say that diameter is 100 and 15 millimeter and 100 millimeter is height. So, under different density, you can see 15, 20, 22, 30 kilogram per meter cube even then when you are using the cylindrical specimen, the nature of the curve is almost the same.

Also, there is a increasing in the density that means increasing in the compressive stress value. So, there may be the slight difference in terms of the value of the compressive strain. The strength value also it has been observed that when here is crossing at this point at a very minimum strain value, that may be the 2 to 3 percentage strain value after that it is just increasing like this way.

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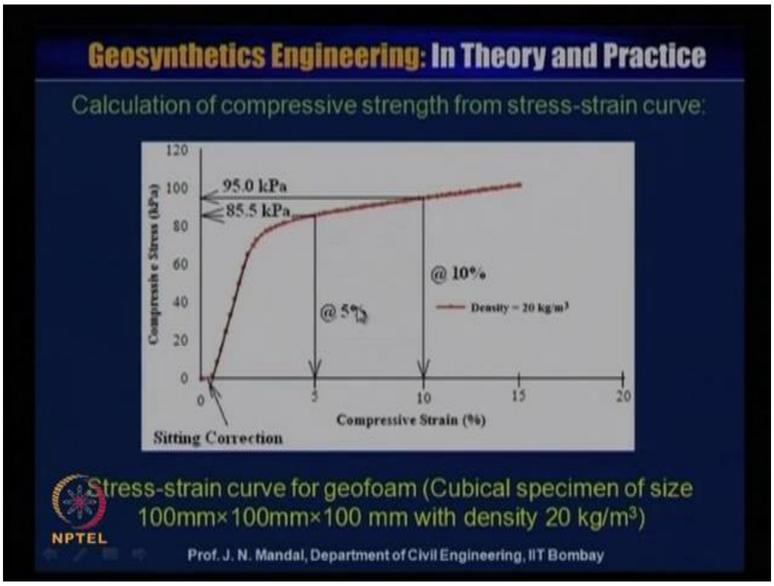

So, now you have to calculate the compressive strength from the stress strain curve. So, here is 1 typical stress strain curve of the geofoam. This is the cubical specimen that is 100 millimeter into 100 millimeter into 100 millimeter with density of 20 kilogram per meter cube. So, you can see that nature of the curve is like this. So, this portion, initially there is a requirement for the sitting correction here, some percentage of the compressive strain, you have to take into account as a sitting correction. Then it is this compressive stress is increasing and with a minimum that also strain value.

So, you can calculate what should be the compressive strain at the 5 percent strain. So, from this x axis, when the compressive strain is 5 percent, you move up and then you move the horizontally, which will meet this compressive stress value is about

85.5kilopascal. Now, you can also calculate that for the 10 percentage that compressive strain, when it is 10 percent, you move up. When you will meet this point here, then you move horizontally and you can have a compressive strain value 95 kilopascal. So, increasing the strain also increasing the compressive strain value, this is for a particular expanded polystyrene geofoam whose density is about 20 kilogram per meter cube. So, this is also very important that when we will design this geofoam material for any structure, so we will consider what should be the compressive strain for a particular strain value and particularly for the 5 percent and 10 percentage. Now, we see calculation of the yield strength from stress strain curve.

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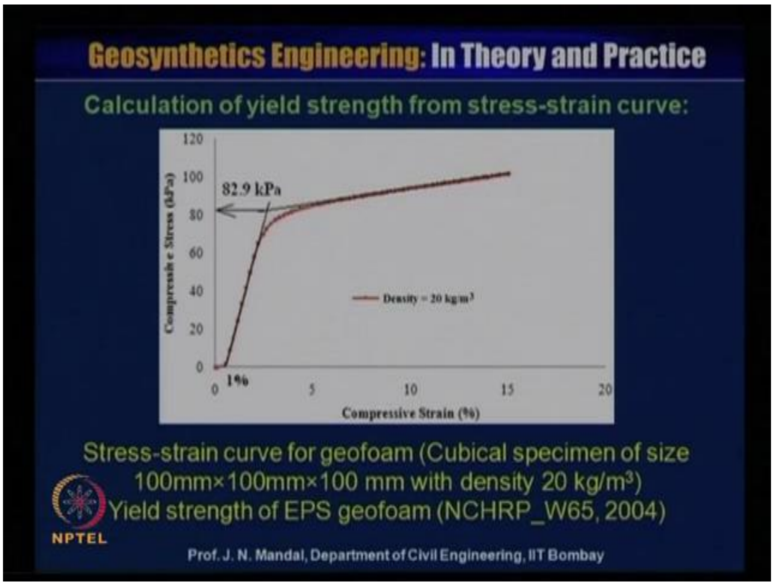

So, there is a compressive stress versus the compressive strain. This is the stress strain curve of geofoam. This is a cubical specimen of size 100 millimeter into 100 millimeter with the density of 20 kilogram per meter cube. Here, this yield strength has been calculated that is based on the EPS geofoam NCHRP W65, 2004. So, here I say that some kind of the sitting correction that here it is a 1 percentage. Then you put the tangent from here, from the 1 percent; you can put a tangent to this curve. Similarly, you can put the tangent from this curve, where it will meet here; where it will give this compressive strength value is 82.9kilopascal. So, here 82.92, so you can calculate what will be the yield strength. So, you calculate the yield strength value whose value is 82.9kilopascal. So, you should know that how to calculate the yield strength this is as per NCHRP W65, 2004.

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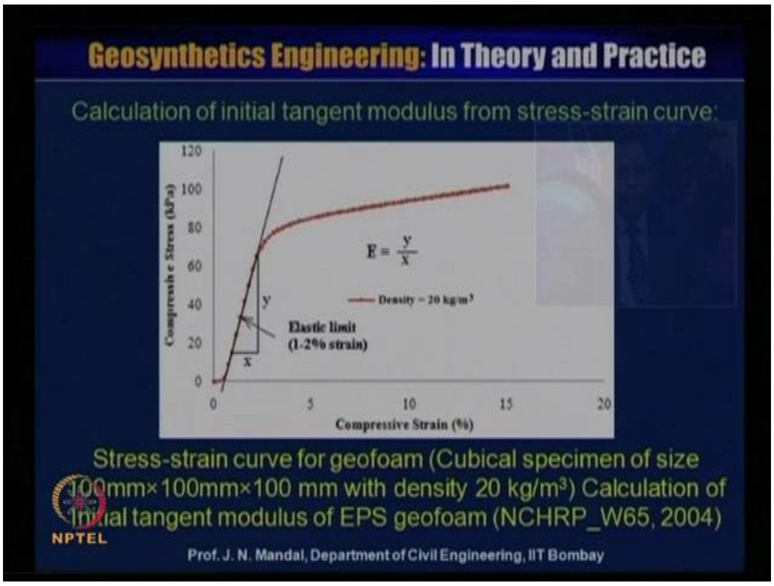

Now, calculate the initial tangent modulus from the stress strain curve. So, this is the stress strain curve for geofoam that is cubical specimen of size 100 millimeter into 100 millimeter into 100 millimeter with density 20 kilogram per meter cube and calculation of the initial tangent modulus EPS geofoam as based on the NCHRP W65, 2004. So, here you can see, we can draw the tangent here. This you know the sitting correction is 1 percentage and you can draw a tangent and you can take a slope of this curve. So, this is the y and this is x. So, this is the elastic limit. This is the elastic limit and at a strain is about 1.2percentage, so then you can calculate that what will be the initial tangent modulus that is E. E will be equal to y divided by x. So, that means slope of this curve.

So, this is the initial tangent modulus, which you can obtain from the stress strain curve of the geofoam and with the elastic limit, with the strain of 1.2percentage for a density of 20 kilogram per meter cube. So, I am just we are now showing only here for a particular specimen and for a particular density. Similarly, we have also calculated that what should be the initial tangent modulus or what will be the compressive strength for the 5 percent and as well as the 10 percent have also been performed.

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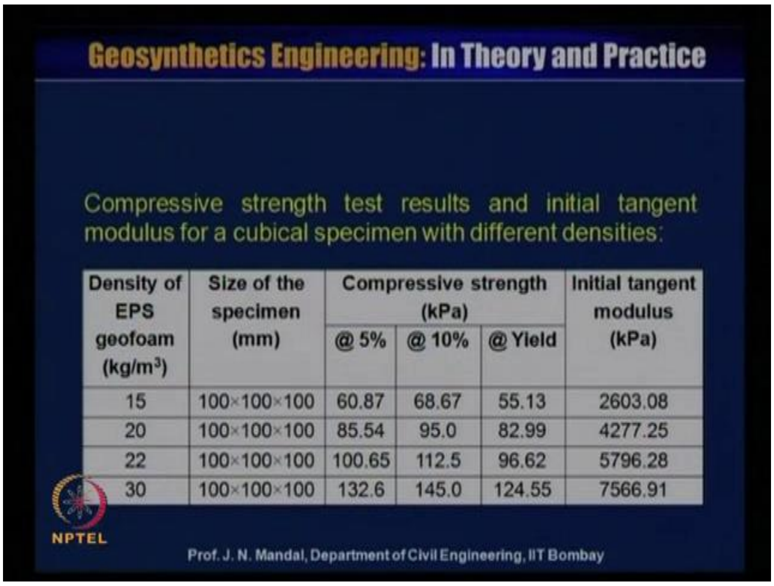

Density of EPS geofoam (kg/m^3)	Size of the specimen (mm)	Compressive strength (kPa)			Initial tangent modulus (kPa)
		@ 5%	@ 10%	@ Yield	
15	100×100×100	60.87	68.67	55.13	2603.08
20	100×100×100	85.54	95.0	82.99	4277.25
22	100×100×100	100.65	112.5	96.62	5796.28
30	100×100×100	132.6	145.0	124.55	7566.91

Now, in this table, we are showing all the test result that compressive strength test result and the initial tangent modulus for a cubical specimen with different density. So, density of the EPS geofoam that is kilogram per meter cube that is 15 kilogram per meter cube, size of the specimen 100 into 100 into 100 and compressive strength at 5 percent, 60.87kilopascal and at 10 percent, 68.67 kilopascal at yield 55.13 percentage and initial tangent modulus 2603.08.

So, these are the data is very important for the design of the expanded polystyrene geofoam and as well as also for the numerical analysis or finite element analysis. So, when the density of the EPS geofoam is 20 kilogram per meter cube and size of the specimen is 100 millimeter into 100 millimeter into 100 millimeter and compressive strength at 5 percent, strain 85.54 and at 10 percent, 95kilopascal and the yield strength value is 82.99that is kilopascal.

So, this portion, we have I have shown you in calculation and then initial tangent modulus 4277.25 kilopascal. Now, when the density of the EPS geofoam is 22 and the size of the specimen is 100 millimeter into 100 millimeter into 100 millimeter, compressive strength at 5 percent strength is 100.65kilopascal at 10 percent strength is 100 and 12.5 kilopascal and at yield’s value is 96.62kilopascal.

The initial tangent modulus is 5796.28kilopascal and density of the geofoam when is 30 kilogram per meter cube. The size of the specimen is 100 into 100 into 100 that is millimeter cube that is compressive strength at 5 percent, 132.6kilopascal and compressive strength at 10 percent is 145.0kilopascal and yield value 124.55kilopascal and initial tangent modulus is 7566.91.

It has been observed from this table that further the Indian condition and other, it has been observed that this material whose density is about to 22, this initial tangent modulus value is about 5796.28kilopascal. This will also shoot for the construction of the embankment on the soft soil or for any road construction, this will be very useful. So, this data are very important when you will design for any kind of the structure for embankment construction or if you wanted to use back of the retaining wall, like that different types of the structure can be constructed using the different density of the geofoam material.

It is very important that you should know about their yield strength value and what will be the compressive strength value at the 5 percent and the 10 percent and 10 percentage. Also, you should know what should be the initial tangent modulus value because this value also we can use for the finite element analysis. Also, when you simply design the geofoam and this value is very important to us.

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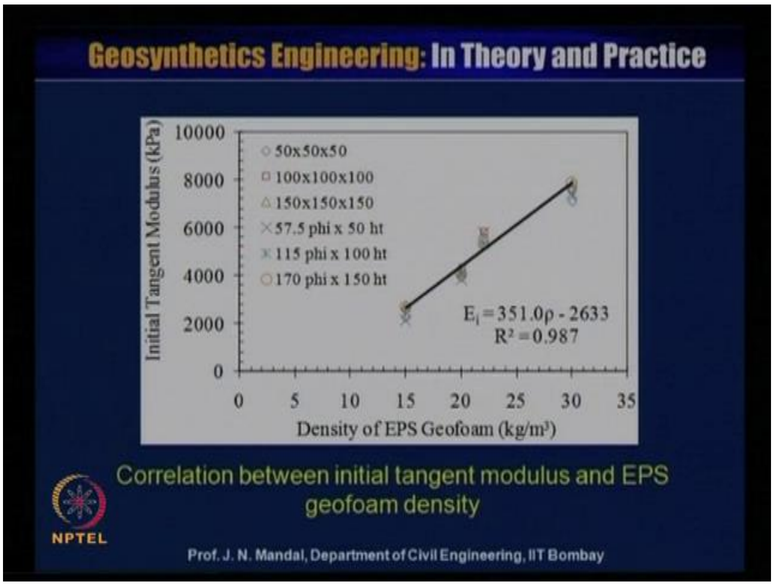

Now, we will show that correlation between the initial tangent modulus is and the expanded polystyrene geofoam density. So, here is the x axis is what will be the density of the EPS geofoam, we have taken the various density from 15 to 30. Also, this is the initial tangent modulus value in kilopascal and this of the specimen is about 50, 50, and 50. This is all millimeter 100, 100 millimeter, 100 millimeter, 100 millimeter, 150 millimeter, and 150 millimeter into 150 millimeter. This is all are in cubical shape.

Apart from that cubical shape, we have also considered what should be the cylindrical shape that is 57.5 millimeter in diameter and 50 millimeter in height and another cylindrical shape is 115 millimeter in diameter and 100 millimeter in height and another sample 170 millimeter in diameter and 150 millimeter height. So, this entire sample either it is a cylindrical in shape or it is a cubical in shape and you can have a nature of the curve is like this.

So, all this point you can see here and this here, so you can have a correlation between the initial tangent modulus and the density of the expanded polystyrene geofoam material. From this, you can establish a correlation or the equation between the density of the EPS geofoam and the initial tangent modulus that means here is the established equation is E i is equal to 351.0 into rho minus 2633. So, R square is equal to 0.987.

So, E i is equal to initial tangent modulus and rho is equal to density of the embankment. Suppose if you know what will be the density of the expanded polystyrene geofoam, then you can calculate what will be the initial tangent modulus with this equation, which can satisfy this criteria. So, this equation is also very useful when you will do any analysis or the finite element method analysis.

So, you can if you know that what will be the density of the expanded polystyrene geofoam material, then you for using this equation, you can calculate what will be the initial tangent modulus and that initial tangent modulus, you can directly use for your computation. So, this relationship is very much helpful to you. So, I think so far, we have covered the different types of the geofoam material and different types of their density of the material, how we are to perform that what should be the density of the expanded polystyrene geofoam material. Also, you have known that how you have to calculate that water absorption capacity of the EPS geofoam material. We find that this water absorption capacity also vary from 2 to the 4 percentage and which can be also considered into the design.

We have also performed that what should be the compressive strength, which is very important to us and either it is a cubical in shape or it is a cylindrical in shape. We also compile that what should be the compressive strength value at the 5 percent and the compressive strength at the 10 percentage.

Also, what should be the initial tangent modulus value and what should be the yield strength value of the expanded polystyrene geofoam material. As I also recommended for the Indian condition that 22 density of kilogram per meter cube will be the more suited because in terms of the value of the initial tangent modulus or yield strength value. So, that will be much more this applicable as far this the observation from some other also reference on the study of the expanded polystyrene geofoam material. So, with this, I finish my lecture today. Let us hear from you, any question?

Thanks for listening.