Geo synthetics Engineering: In Theory and Practices
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Lecture - 17
Geo synthetics for Filtrations Drainages and Erosion Control Systems

Welcome to lecture 17, my name is Professor J. N. Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India, the name of the course Geo synthetics Engineering in Theory and Practice. Now, this module 4, lecture 17, Geo synthetics for Filtration Drainage and Erosion Control System.

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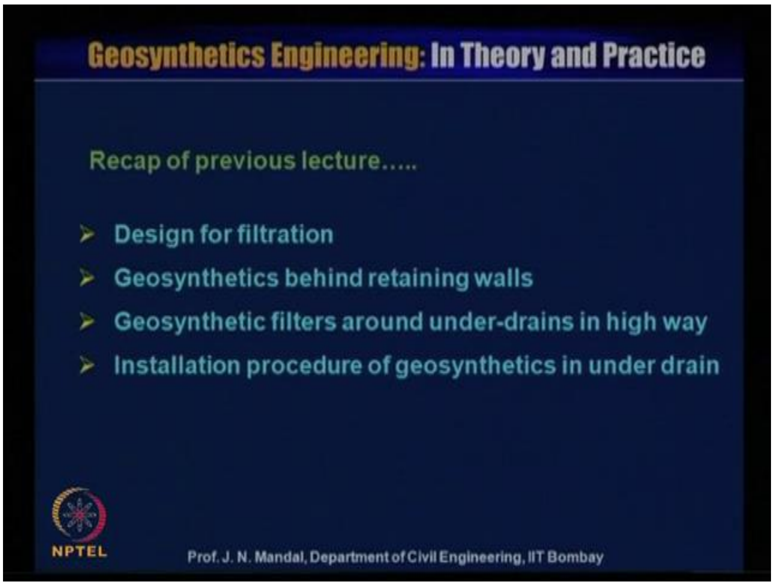

Now, I will explain recap of the previous lecture, the design for the filtration, geo synthetics behind retaining wall, geo synthetics filter around under drain in highway and installation procedure of geo synthetics in under drain. I have also given many example for the use of geo synthetics behind the retaining wall or highway and so on.

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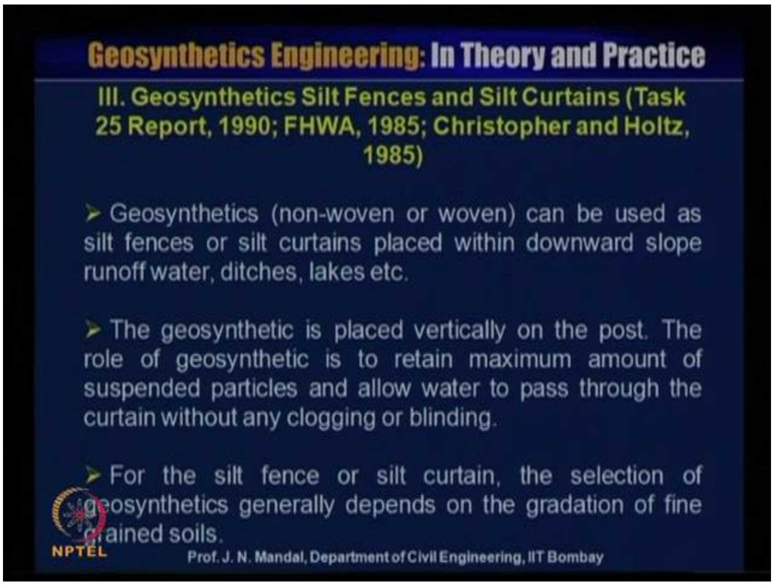

Next we will discuss geo synthetic silt fences and silt curtain that is task 25 report, 1990; FHWA 1985; Christopher and Holtz, 1985 geo synthetics nonwoven or woven can be used as silt fence or silt curtain placed within downward slope runoff water, ditches lake etcetera. The geo synthetics is placed vertically on the post. The role of geo synthetics is to retain maximum amount of suspended particle and allow the water to pass through the curtain without any clogging or blinding, for the silt fences or silt curtain, the selection of geo synthetics generally depend on the gradation of the fine grained soil.

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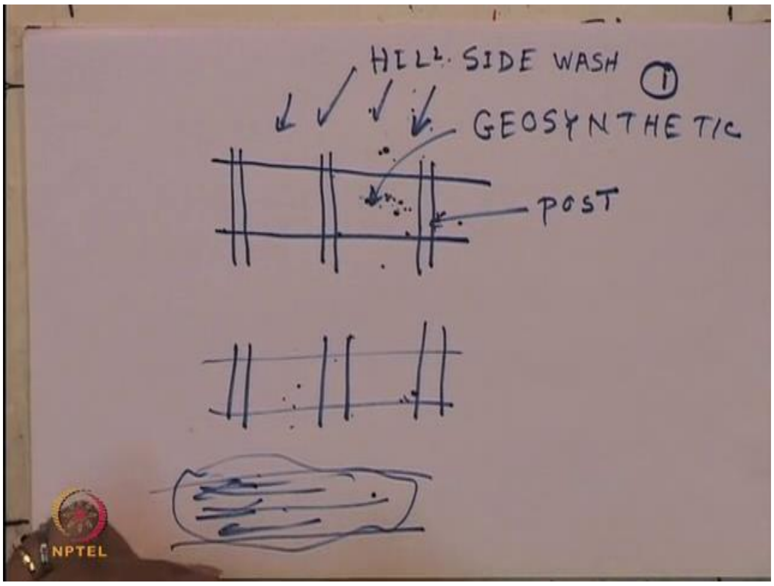

For example, if this is like a curtain and these are the post and this is the geo synthetics material and these are the post and like this, this is a what I can say that, hill side wash or any construction site where there is a slope. And all the precipitation to this slope, how we can minimize, the flow velocity you can provide another also this curtain, which you call the silt fence or the curtain, it is nothing but a combination of post and the geo textile material that whatever the suspended material will flow, along this geo synthetics material.

So, you have to minimize the flow velocity and what should be the maximum permissible fence height, it should be. So, this is a kind of the layout of the silt fences, the main objective is to how, slow down the downward velocity of the water on the slope and also at the same time removing as much as of the transported particles, as is practicable. In fact, it act as a kind of reservoir, contaminated structure for a large portion of the precipitation at any given slope.

So, total amount of the precipitation while need, is to be retained at any particular layout. So, whatever the precipitation blocked here, water can pass then gradually you can see that how it can be reduced. So, for example, any construction site is there, road slope is there and due to road there is a possibility for the rain water, can pass through these and muddy water suspension material pass to this, then this all the curve may be the block, construction may be the block. So, you can provide this kind of the silt fences. So, this kind of the silt fence can protect.

So, here we have to be select that, what kind of the geo synthetics material you should be select, what should be the height of the post and what should be the depth of the post and what should be the spacing between the post.

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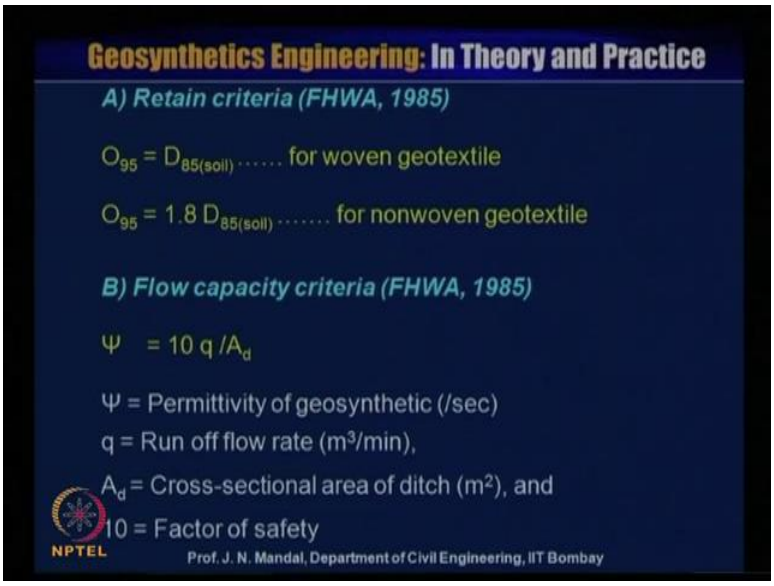

So, it should fulfill the retention criteria as per FHWA 1985 that is O 95 is equal to D 85 soil that is for woven geo textile, O 95 is equal to 1.8 D 85 soil for nonwoven geo textile material and the flow capacity criteria that is FHWA 1985, that psi is equal to 10 into q divided by A d where psi is equal to permittivity of geo synthetics per second, q run off flow rate that is meter cube per minute and A d is cross sectional area of the ditch that is meter square and 10 is the factor of the safety.

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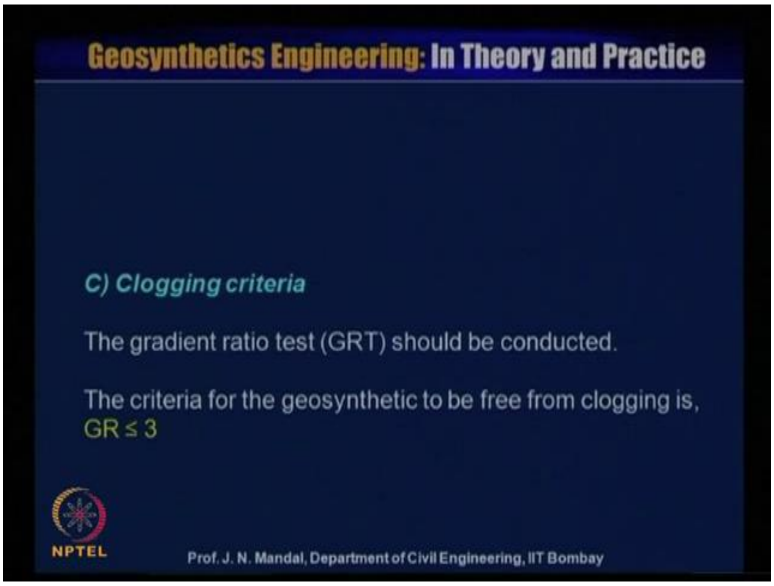

Also you should satisfy the c clogging criteria; that means, gradient ratio test have to be conducted and criteria for the geo synthetics to be free from clogging, if the gradient ratio is less then equal to 3, we have already mentioned that how to perform the gradient ratio test.

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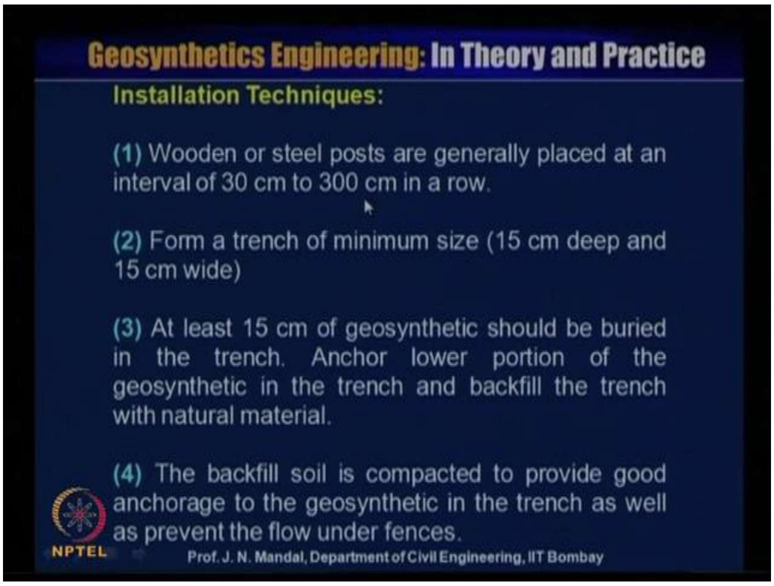

Now, how to install this system. Now, I will explains installation technique of silt fences, the wooden steel posts are generally placed at an interval of 30 centimeter to 300 centimeter in a row.

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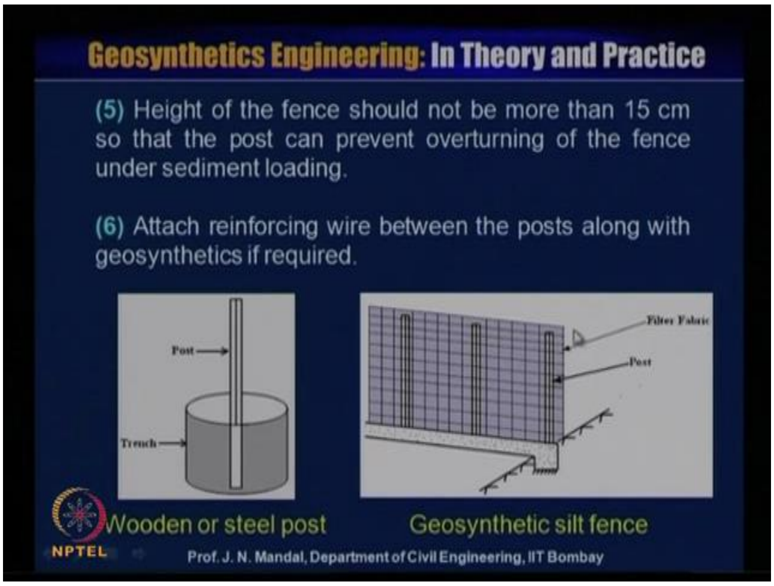

These is the wooden or the steel post can be placed at a interval of 30 to 300 centimeter in a row and this steel fence consist of geo textile plus vertically on the post to prevent the sediment and this is the wooden or steel post this is the trench.

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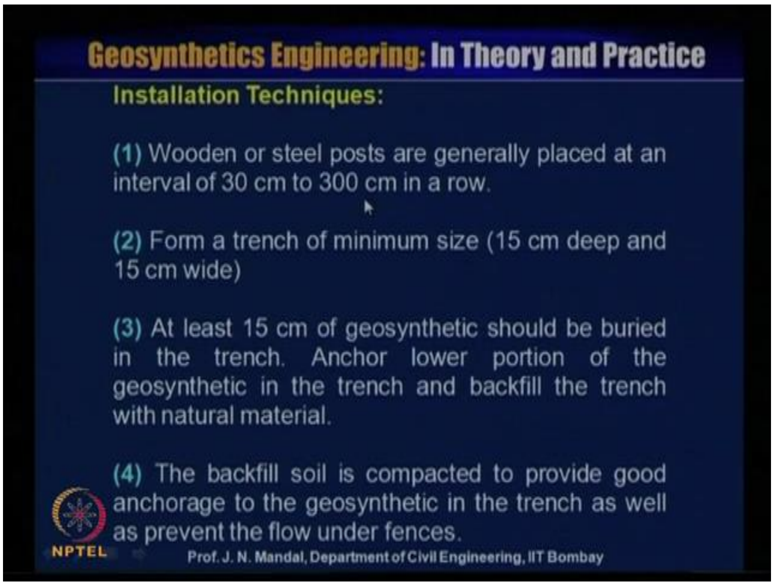

Now, form a trench of minimum size 15 centimeter deep and 15 centimeter wide.

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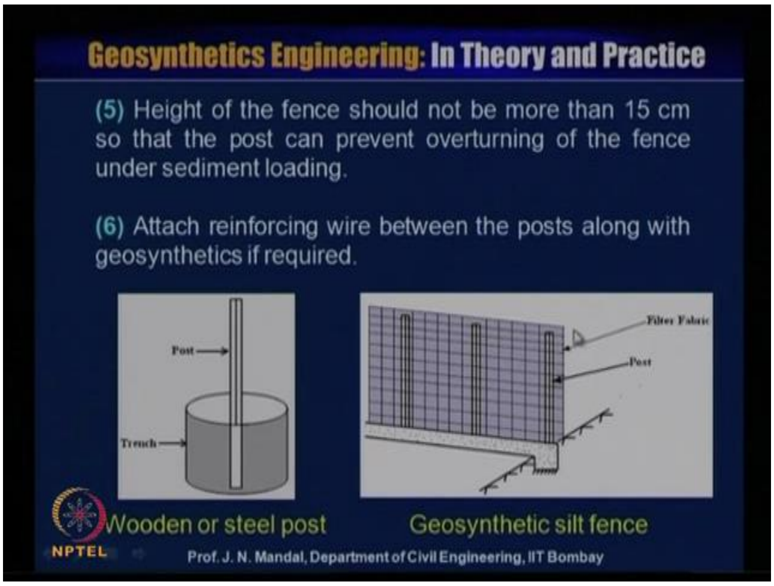

This is the trench which is 15 centimeter wide and 15 centimeter deep.

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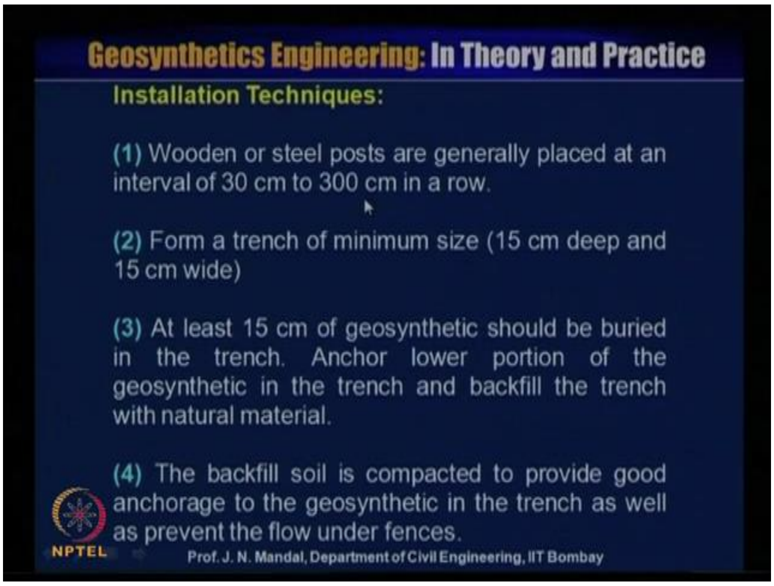

Next at least 15 centimeter geo synthetics should be buried in the trench. Anchor lower portion of the geo synthetics in the trench and backfill the trench with natural material. Here, to be buried it geo synthetics material, the backfill soil is compacted to provide good anchorage to the geo synthetics in the trench as well as prevent the flow under fences.

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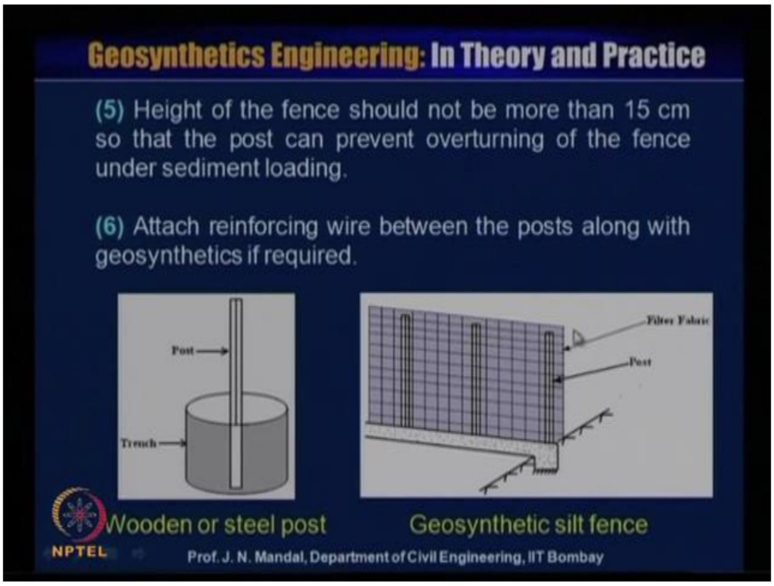

So, this backfill material provided and this you necessary for the anchoring. Next height of the fence should not be more than 15 centimeter. So, that post can prevent overturning of the fence under sediment loading. Attach reinforcement wall between the post along with the geo synthetics if require.

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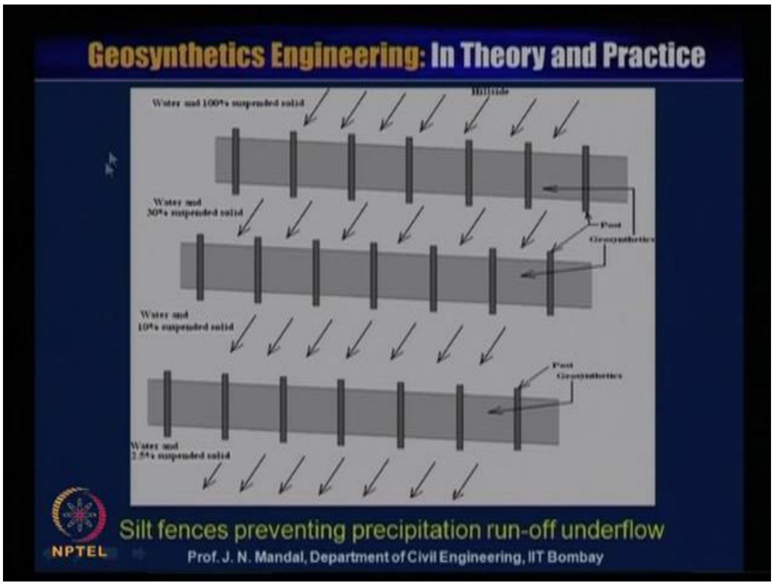

So, you can see here, that water is 100 percent suspended solid and any suppose, hill side area or any slope due to the rainfall and although water and 100 percent suspended solid material is passing through the silt fence, this silt fence which consist of the geo textile, that is placed vertically on the post to prevent the sediment. So, this is the post this is the geo synthetics material. Next, you can see that water and 30 percent suspended solid and next gradually you can see how it is decreasing, the water and the 10 percent suspension solid and like this, you can see water with 2 percent suspended solid.

So, people can work in this area, by providing that proper kind of the silt fence. So, we should know that what is silt fence, how will you design the silt fence, what should be the depth of the post and what should be the height of the post and what should be the spacing of the post.

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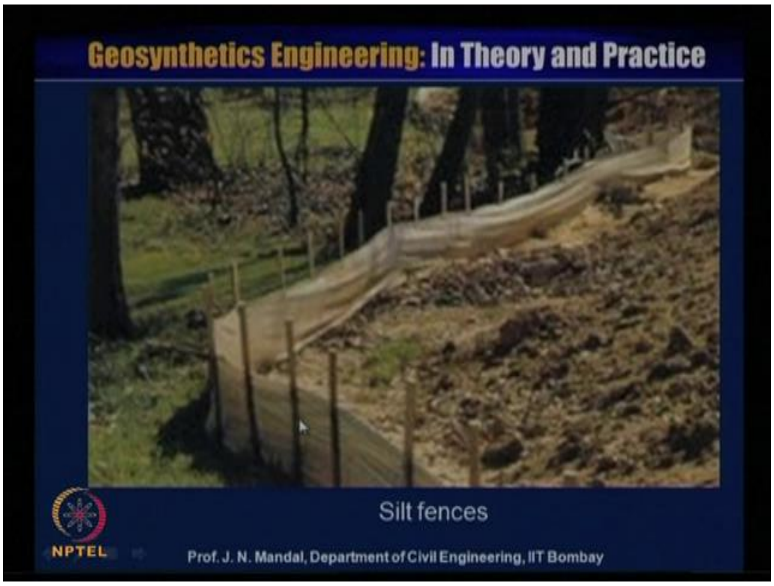

So, this is silt fence which is preventing the precipitation run off under flow. So, you can one of the silt fences here, how it has been precipitated.

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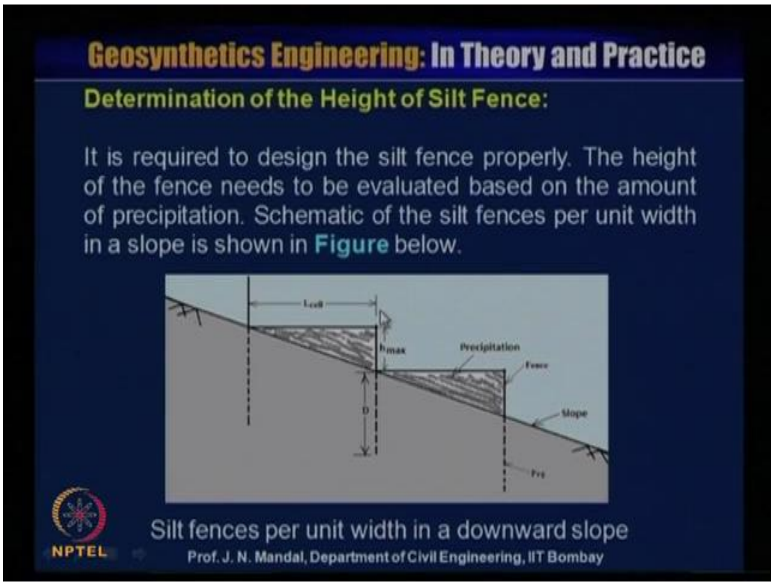

Now, we want to determine the height of the silt fence, it is required to design the silt fence properly. The height of the silt fence need to be evaluated based on the amount of the precipitation. So, this is a schematic of the silt fences, per unit width in a slope as shown. So, this is h of maximum this is L of cell and this is depth and this is the peg and this is the slope and this is the face and this is all precipitation. So, this is the silt fence per unit width in a downward slope.

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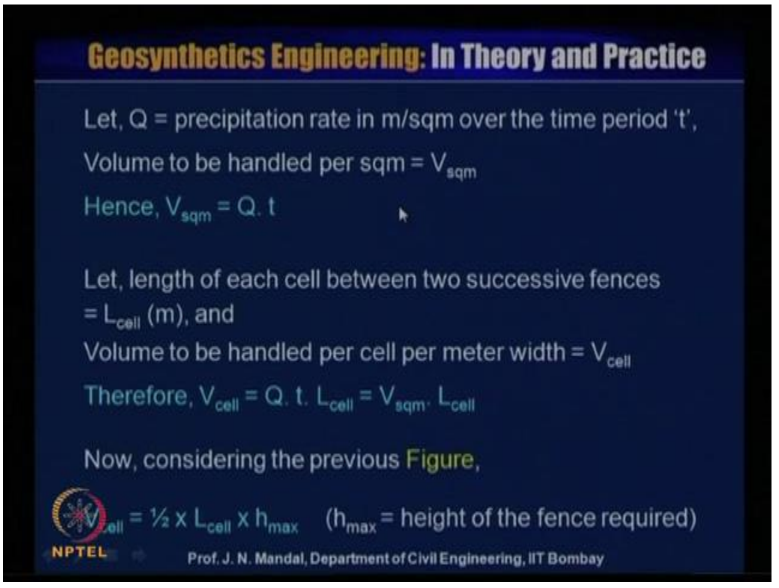

So, let Q be the precipitation rate in meter per square meter over a time period of t. So, you calculate what will be the volume to be handled per square meter, let us say V square meter. Hence V square meter you know that Q into t, let the length of each cell between the two successive fence is L cell per meter this is length between the two post this is L cell. So, volume to be handled per cell per meter which is V cell. So, therefore, V cell will be the Q into t; that means, this V square meter Q into t into L cell.

So, this will give what will be the volume of the handle per cell per meter width; that means, V square meter, this is V square meter Q t into L cell. Now, considering this earlier figure here. So, we can write that V cell will be equal to half L cell into h maximum, this is the precipitation. So, you see like a triangle. So, it will be the half into h maximum into L cell and h maximum what will be the height of the fence required therefore, V cell equal to half into L cell into h maximum.

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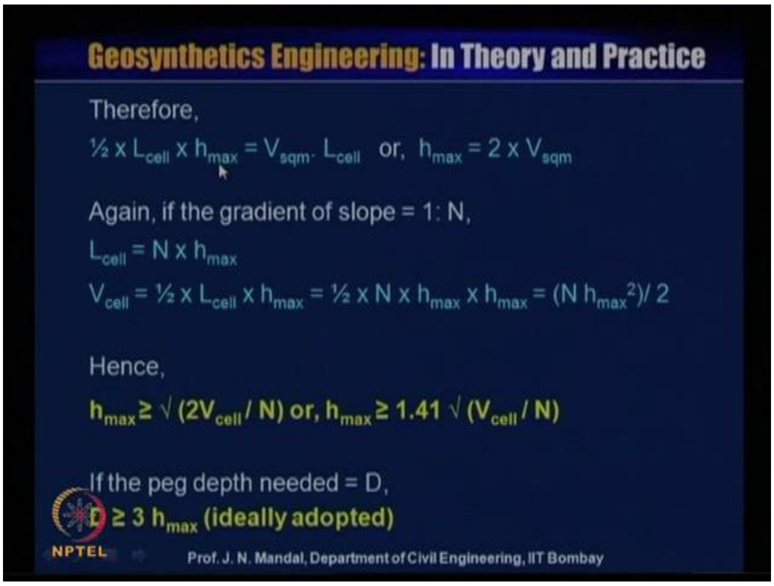

Therefore half into L cell into h maximum is equal to V square meter into L cell.

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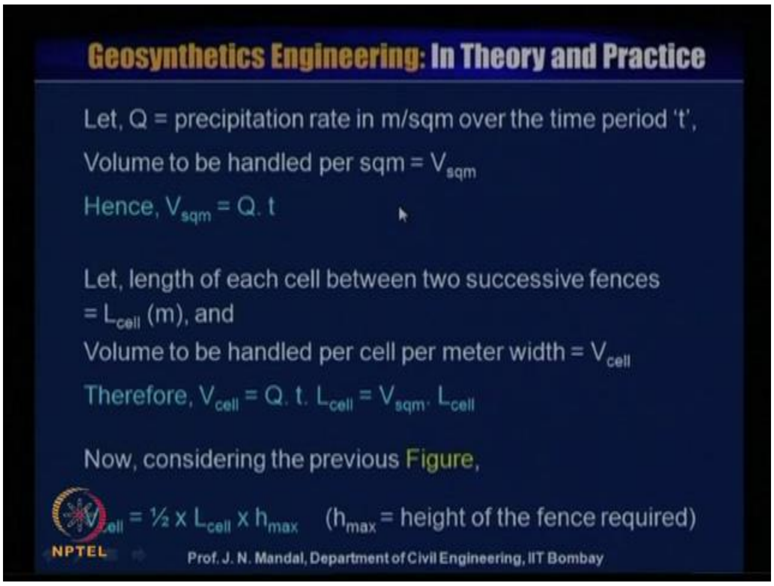

That means, this will be equal to this; that means, this will be equal to this, this is the volume to be handled per cell meter; that means, V square meter into L cell this will be equal to that what should be the V cell here half into L cell into h maximum. So, that was the area and h is the height of the fence required.

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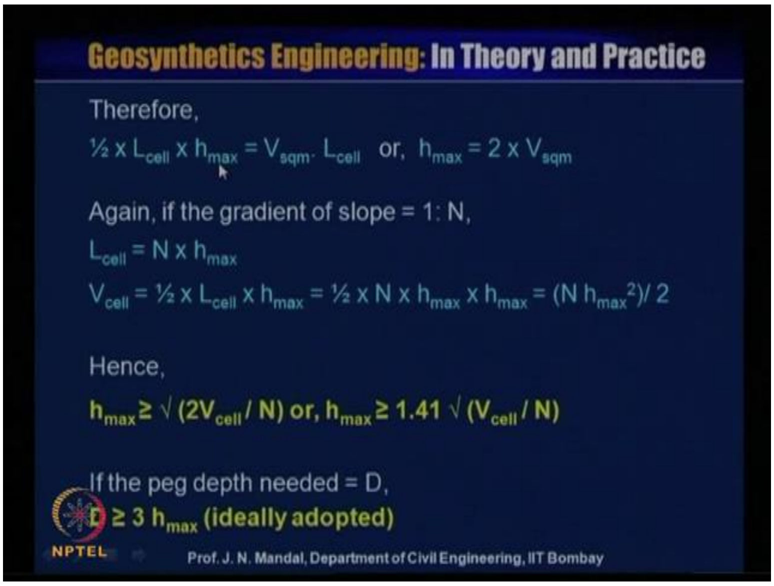

So, from that we can write half into L cell into h maximum is equal to V square meter into L cell or h maximum will be equal to 2 into V square meter. Again if the gradient slope is 1 is to N, for this is gradient slope is 1 is to N for example, if gradients of 1 is there. So, L cell will be N into h maximum. So, V cell will be equal to half into L cell into h maximum then half into N into h maximum into h maximum; that means, N into h maximum square divided by 2.

Hence h maximum should be equal to 2 into V cell root of because this h max square root of 2 into V cell divided by N or you can write h maximum should be greater than equal to this root to 1.41 root of V cell divided by N. If the peg depth needed D, then D should be greater than equal to 3 of h maximum which is ideally adopted.

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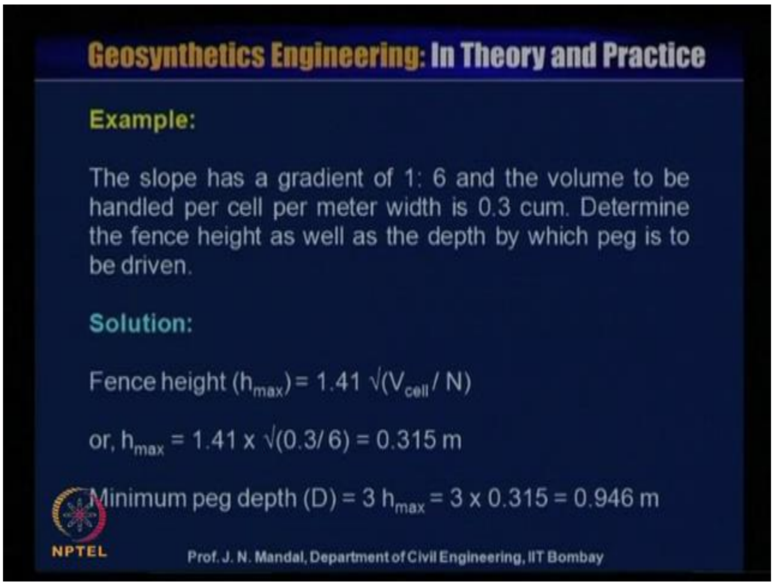

Now, we are giving one example, the slope has a gradient of 1 is to 6; that means, n value is 6 and the volume to be handled per cell per meter width is 0.3 cubic meter, determine the fence height as well as depth by which the peg is to be driven. So, we know the equation, the solution is fence height h maximum will be equal to 1.41 root V of cell divided by N. So, h maximum is equal to 1.41 and V cell is given 0.3 cubic meter. So, 0.3 and slope is N is 6. So, this is 6.3 by 0.6. So, h maximum will be equal to 0.315 meter.

Now, minimum peg depth D is 3 into h maximum, 3 into h maximum is 0.315. So, D will be the 0.946 meter. So, this way we can calculate that what should be the h maximum and what should be the peg depth.

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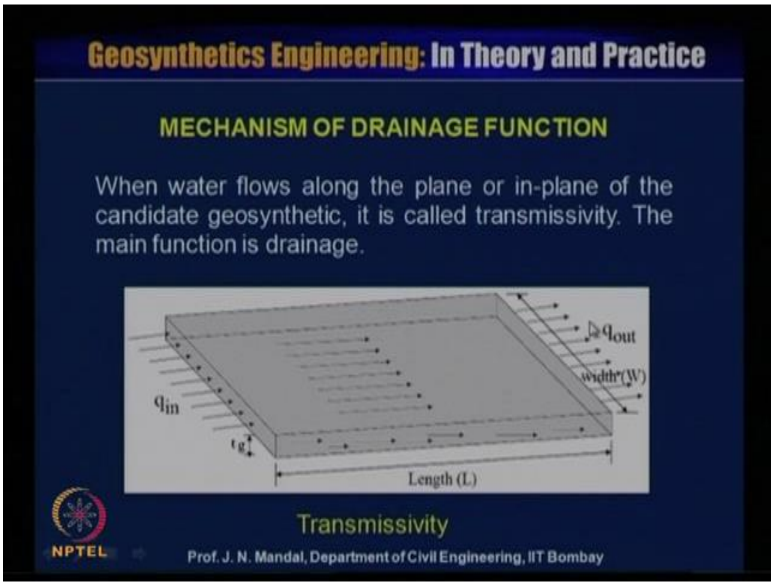

Next, mechanism of drainage function you know that, when the water flow along the plane or in-plane of the candidate geo synthetics, is called transmissivity. The main function is the drainage or which we call the transmissivity.

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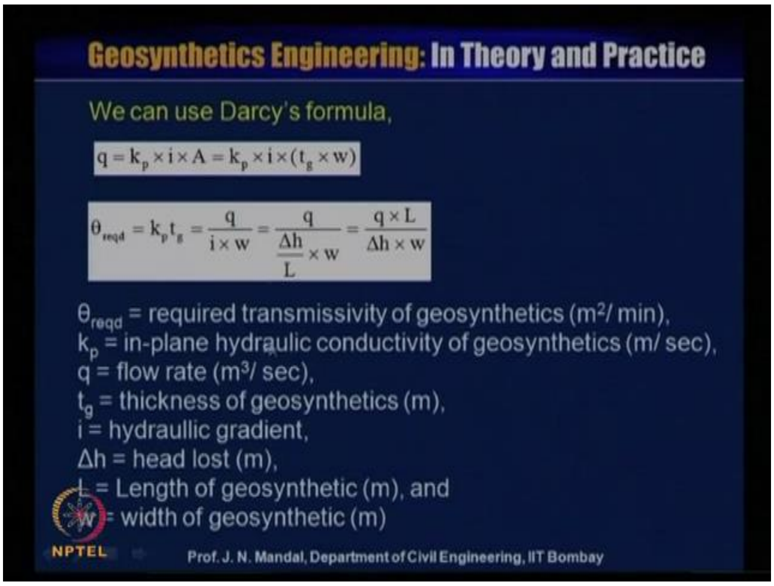

We have already cover. So, we can just for your information sake, we are giving this equation theta require will be equal to q into L by delta h into w this you know earlier already explain.

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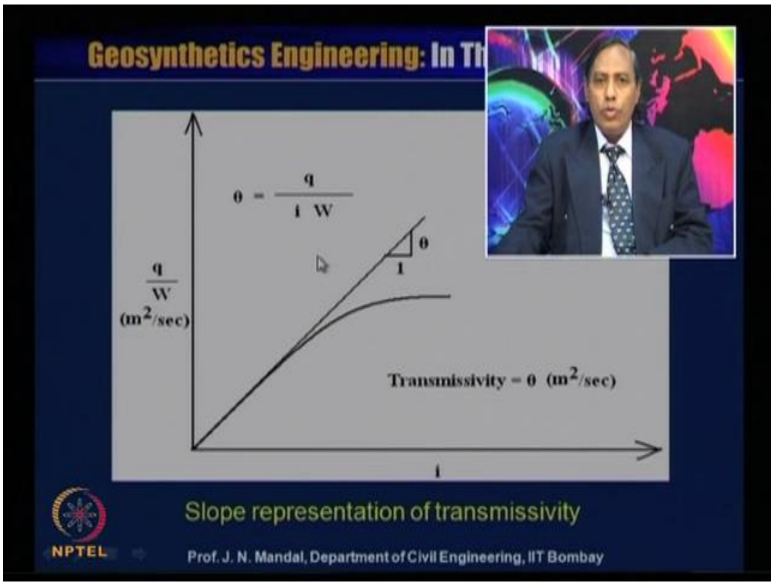

Now, also we have also shown the slope representative of the transmissivity, that is also known to you.

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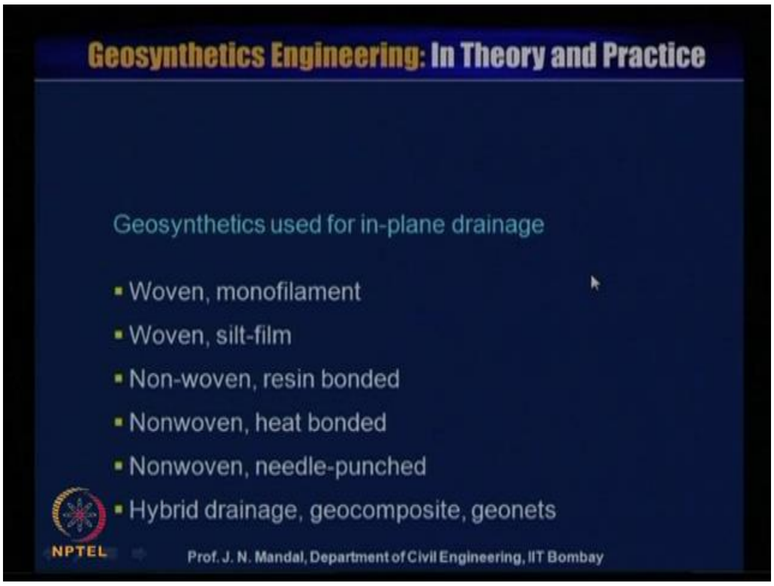

Now, geo synthetics used for in-plane drainage. So, different types of the material can be used it may be woven monofilament, woven silt film, nonwoven resin bonded, nonwoven heat bonded, nonwoven needle punched and hybrid drainage, geo composite and geo nets.

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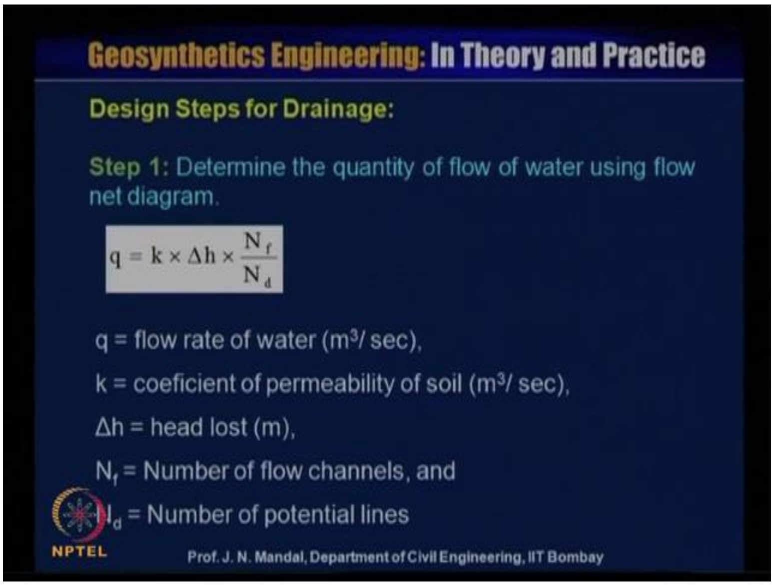

Now, what should be the design step for the drainage, first step 1 determine the quantity of flow of water using flow net diagram, you know that q is equal to k delta h N f by N d, this is also we explain earlier. So, you know that how to calculate the flow of water, by flow net diagram.

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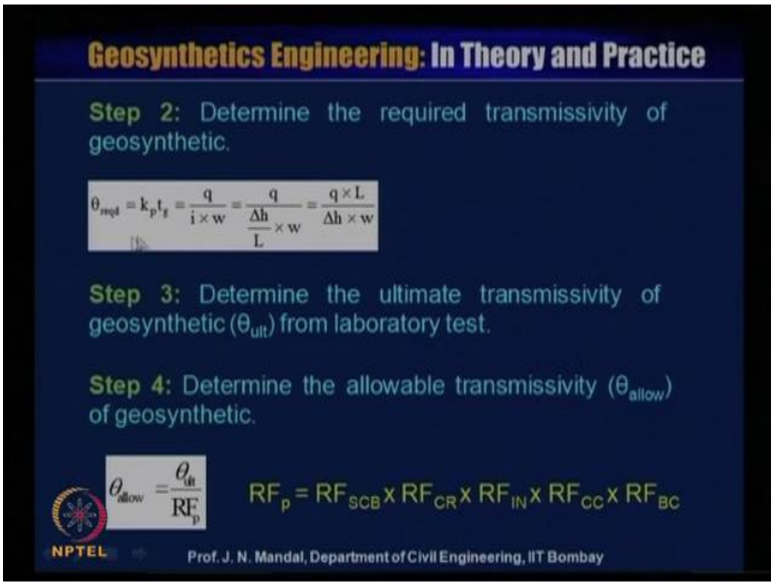

Step 2, you can determine the record transmissivity of geo synthetic. So, earlier we discussed with the permittivity now, it is transmissivity of the geo synthetics this equation also known theta require into k p into t g is equal to q L by delta h into w. Step

3, you determine the ultimate transmissivity of the geo synthetics what is from the laboratory, from the laboratory you know how to determine the ultimate transmissivity, that is theta ultimate. Step 4 determine the allowable transmissivity.

So, theta allowable will be equal to theta ultimate by cumulative reduction factor, this cumulative reduction factor this may be reduction factor for soil clogging and blinding, this is reduction factor RF CR is reduction factor for the key reduction factor of buoyed, this is RF IN that is intrusion into the buoyed, this reduction purpose intrusion into the buoyed and this is RF CC this is reduction factor for chemical clogging and RF BC is reduction factor for biological clogging.

So, all this factor depending upon type of application, can be selected and then you can calculate that, what will be the cumulative reduction factor and ultimately you can calculate it what will be the theta of allowable.

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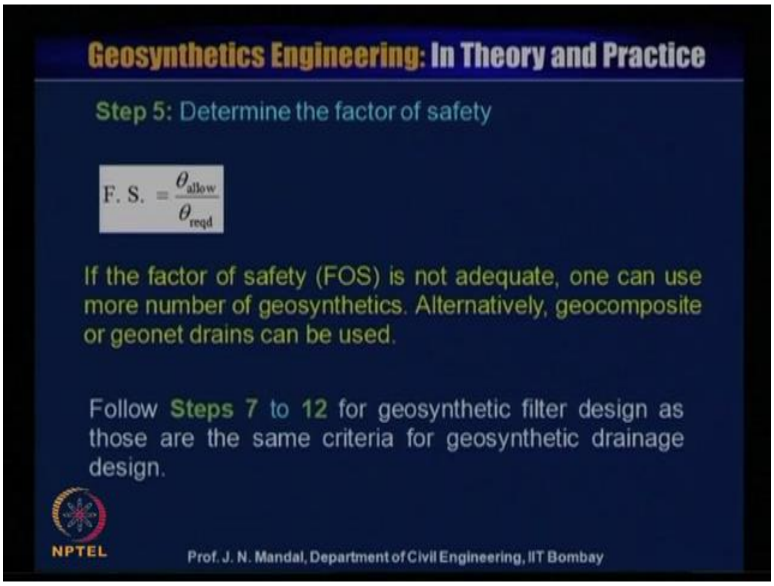

Step 5, determine the factor of safety. So, factor of safety will be equal to theta allowable by theta require, if the factor of safety is not adequate, one can use more number of the geo synthetic material, alternatively geo composite or geo net drain can be used. So, in our permittivity problem, filtration problem you can follow the step 7 to 12 geo synthetic filter design, as those are the same criteria for geo synthetic drainage design.

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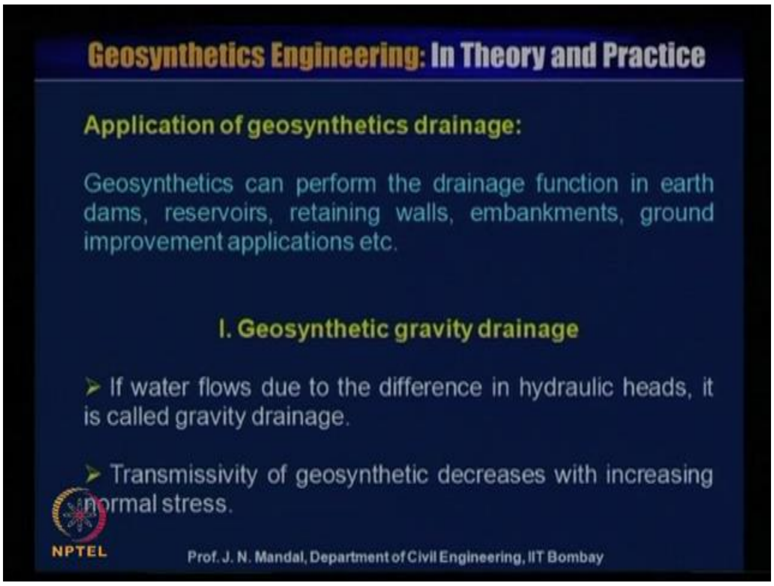

So, application of geo synthetic drainage. Geo synthetic can perform the drainage function in earth dam, reservoir, retaining wall, embankment, ground improvement application etcetera. Now, first I am expressing the geo synthetics gravity drainage. If the water flows due to the difference in the hydraulic head, it is called the gravity drainage. Transmissivity of geo synthetic decreases with increasing the normal stresses, you know this we have already discussed earlier.

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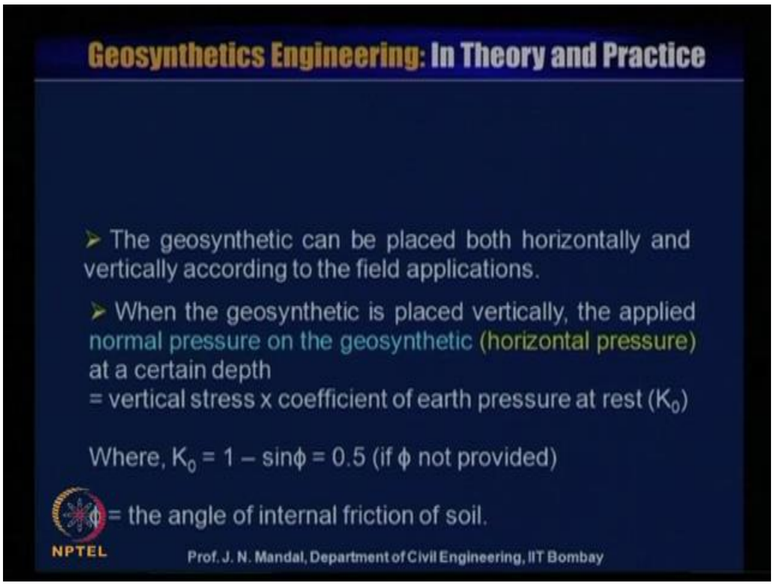

The geo synthetic can be placed both horizontally and vertically according to the field application. When the geo synthetic is placed vertically, the apply normal pressure of the geo synthetics; that means, horizontal pressure at a certain depth that horizontal pressure will be equal to the vertical stress into coefficient of earth pressure at rest, and that earth rest K 0 can be determined using the equation K 0 is equal to 1 minus sin phi that is 0.5 if phi is not provided, where phi is equal to angle of internal friction of the soil.

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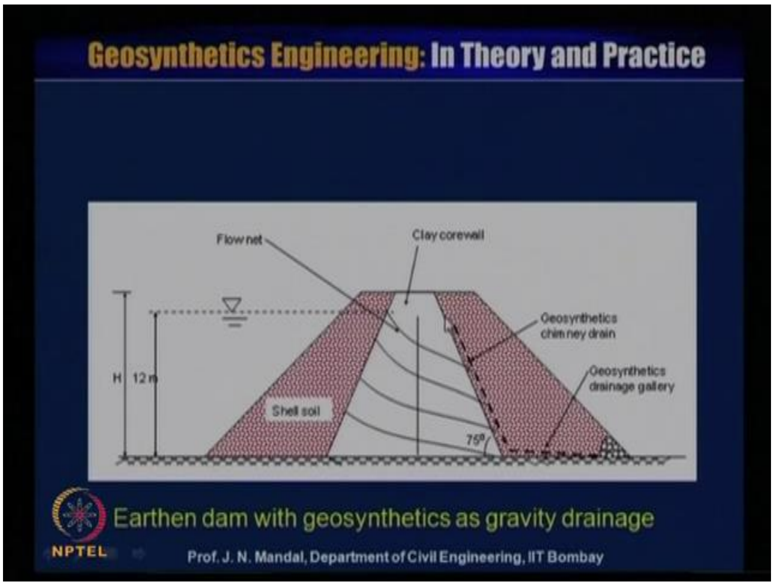

You can see this is an earth dam geo synthetics as a gravity drain, here the geo synthetics as a chimney drain, here geo synthetic drain as a gallery and this is the clay core and you in the clay core you can draw the flow net and you can determine what should be the number of the flow lines and equipotential line and this angle also is known to you suppose, here is 75 degree, this height of the dam is h and this water level is about 12 meter, this is as showing one of the example like that.

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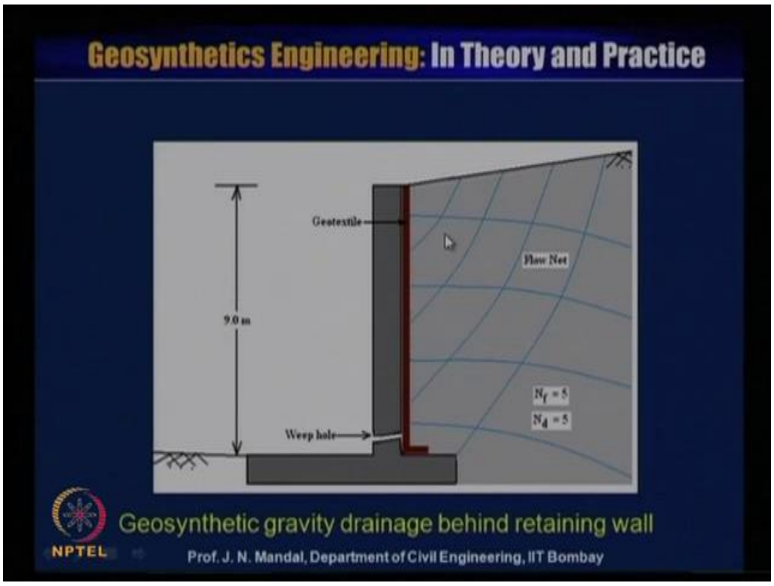

Similarly, geo synthetic gravity drainage behind the retaining wall, what you can use, you can see this is the retaining wall there is a weep hole and geo textile material is placed, just behind the retaining wall. So, whatever water will flow this will go vertically downwards and then passes through the weep hole.

So, here we go for one design, for this wall is height may be the 9 meter, then what quantity of water flow through this then that also it can be determined, by drawing the flow net diagram and from the flow net diagram you can estimate that, what will be the number of flow line N f is equal to 5, what will be the number of potential line N d also will be the equal to the 5. Now, one example that design the geo textile drainage.

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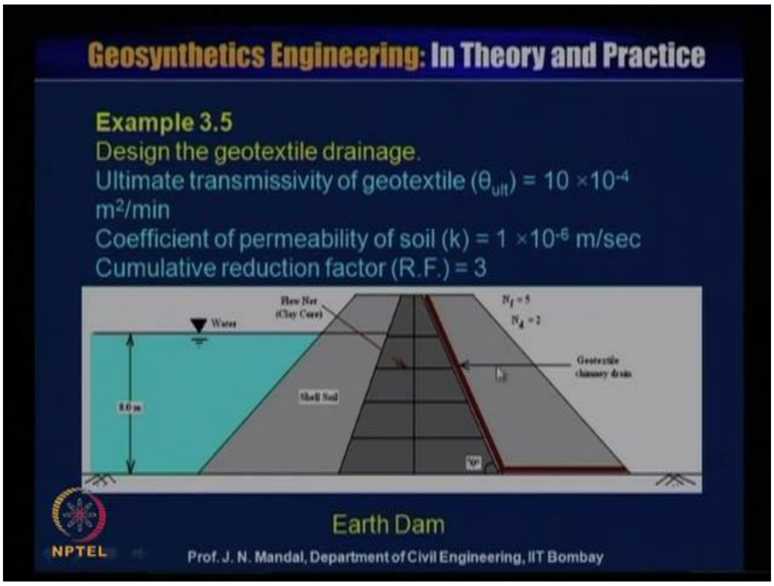

So, this is a earth dam and ultimate transmissivity of this geo synthetics material given 10 into 10 to the power minus 4 meter square per minute and coefficient of permeability of the soil k is 1 into 10 to the minus 6 meter per second and cumulative reduction factor is 3. So, in the core, this is a clay core. So, you can draw a flow net diagram and this angle is 70 degree and this height is about 8 meter.

So, from the flow net diagram you can calculate what is the number of flow 5, and because number of the potential line 2. So, N d is equal to 2 N f is equal to 5 and this angle you remember is 70 degree and height is 8 meter.

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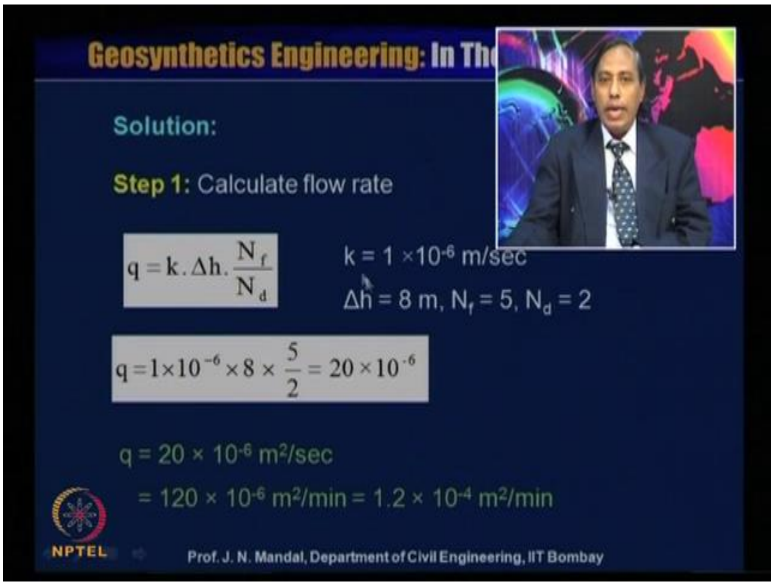

Now, solution step 1, calculate the flow rate. So, you draw the flow net diagram then you use the equation q is equal to k delta h N f by N d k value is given 1 into 10 to power minus 6 meter per second delta h is 8 meter. And then N f is equal to 5 N d is equal to 2 we have obtained from the flow net diagram, then it substitute the value k is 1.10 to the power minus 6 into delta h is equal to 8, and N f by N d is equal to 5 by 2. So, q will be equal to 20 into 10 to the power minus 6 this is the flow rate.

Now; that means, this q is 20 into 10 to the power minus 6 meter square per second and this will be 120 into 10 to the power minus 6 meter square per minute and 1. you can write 1.2 into 10 to the power minus 4 meter square per minute.

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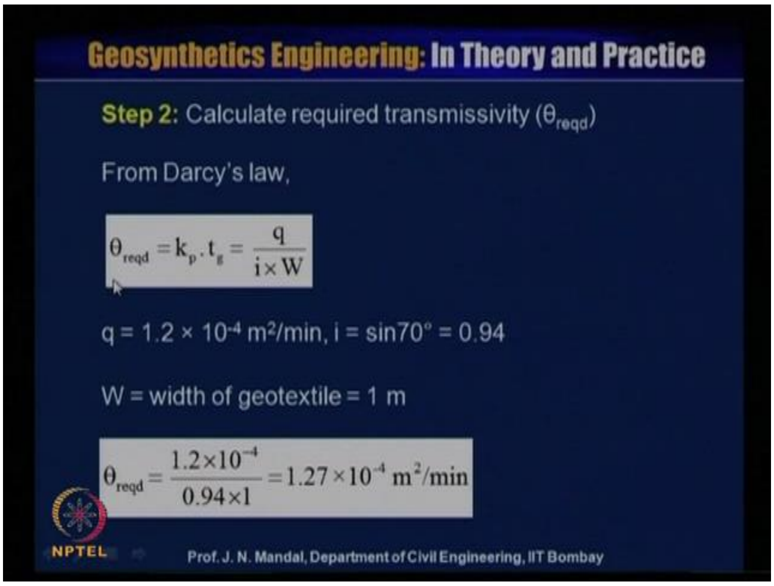

Now step 2, calculate required transmissivity theta require from the Darcy's law, we know theta require k p into t g q by i into W q is already we have calculated 1.2 10 to the power minus 4 meter square per minute and i is sin 70 degree is equal to 0.94 because this wall this is core wall this angle is 70 degree. So, this is i. So, i is equal to 70 degree is equal to 0.94 and W is equal to width of the geo textile is 1 meter.

So, theta require will be q, q is equal to 1.2 10 to the power minus 4 this divided by i, i value is equal to 0.94 this is 0.94 and W is equal to 1. So, this theta require will be equal to 1.27 into 10 to the power minus 4 meter square per minute.

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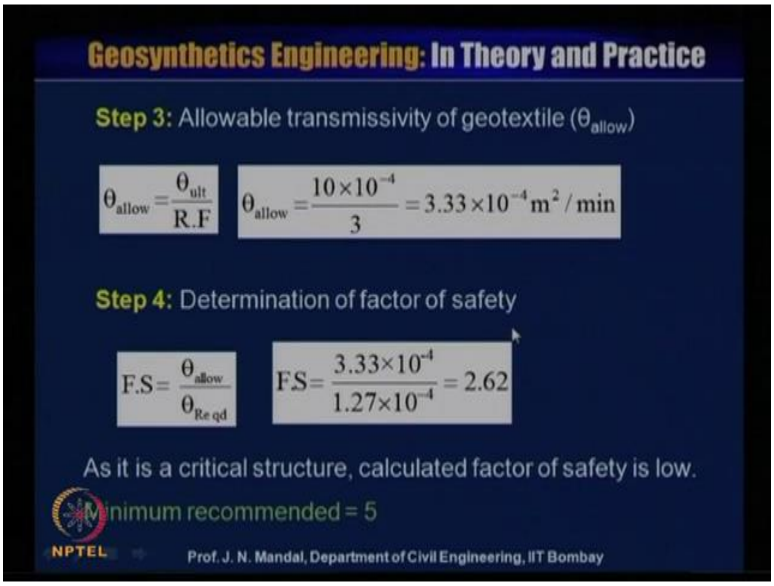

Now, step 3 allowable transmissivity of geo textile that is theta allowable. So, theta allowable will be theta ultimate by reduction factor. So, theta allowable you know that theta ultimate value 10 into 10 to the power minus 4 and reduction factor is given 3. So, theta allowable will be equal to 3.3 into 10 to the power minus 4 meter square per minute.

Step 4, determine the factor of safety. So, factor of safety is the ratio of theta allowable by theta required and what is theta allowable 3.3 into 10 to the power minus 4 and theta required we have calculated 1.27 into 10 to the power minus 4 this is theta required 1.27 into 10 to the power minus 4. So, this is theta required is 1.27 into 10 to the power minus 4. So, we will have the factor safety 2.62. So, as it is a critical structure, calculate the factor of safety is low. So, therefore, it is recommended that minimum factor of safety is 5 then what we will do.

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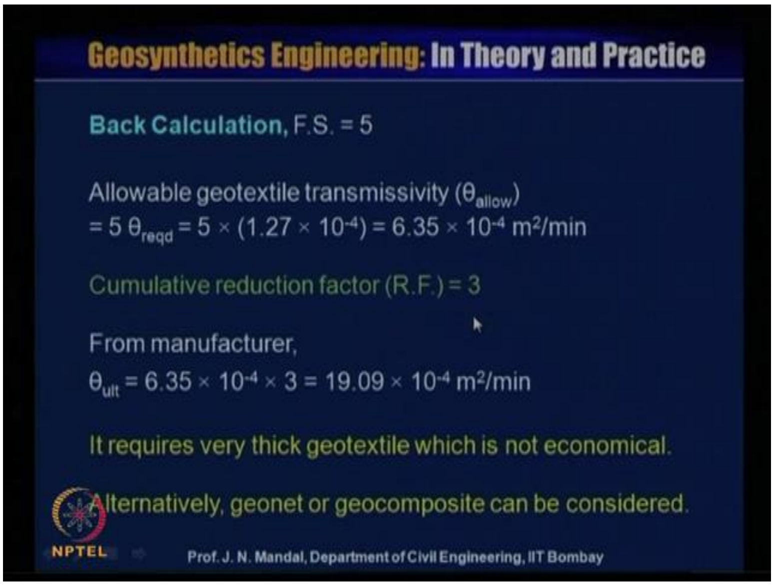

So, we do some back calculation assuming factor of safety is equal to 5, allowable geo textile transmissivity theta allowable will be equal to 5 into theta required; that means, 5 into theta required you know 1.27 into 10 to the power minus 4 that is equal to 6.35 into 10 to the power minus 4 meter square per minute. Now, considering cumulative reduction factor that is 3.

So, from the manufacturer side theta ultimate is 6.35 into 10 to the power minus 4 into cumulative reduction factor 3 is 19.09 into 10 to the power minus 4 meter square per minute therefore, it is require very thick geo textile, which is not economical. So, alternatively geo net or geo composite can be considered.

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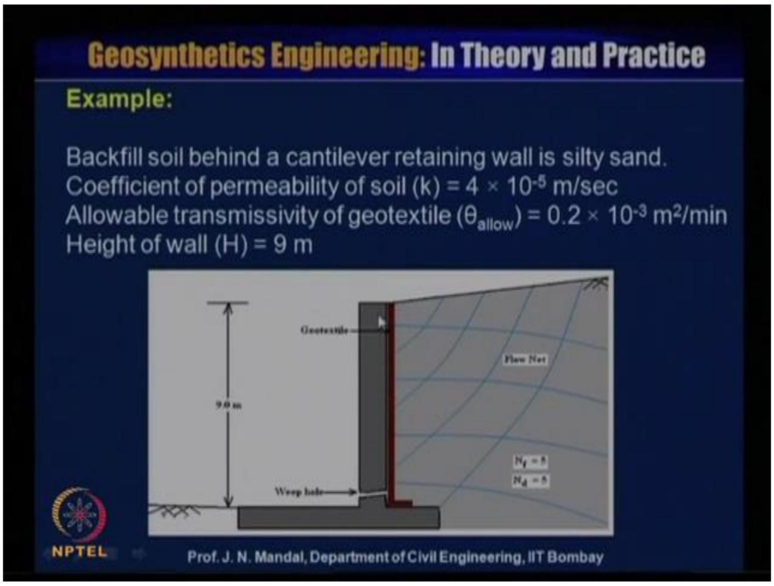

Now, this is another example, this is the backfill soil behind a cantilever retaining wall is silty sand and coefficient of permeability of the soil is 4 into 10 to the power minus 5 meter per second, allowable transmissivity of geo textile theta allowable is given 0.2 into 10 to the power minus 3 meter square per minute, height of the wall is 9 meter. So, here you can see that again you can draw the flow net diagram you find out what is N f and N d that is equal to the 5.

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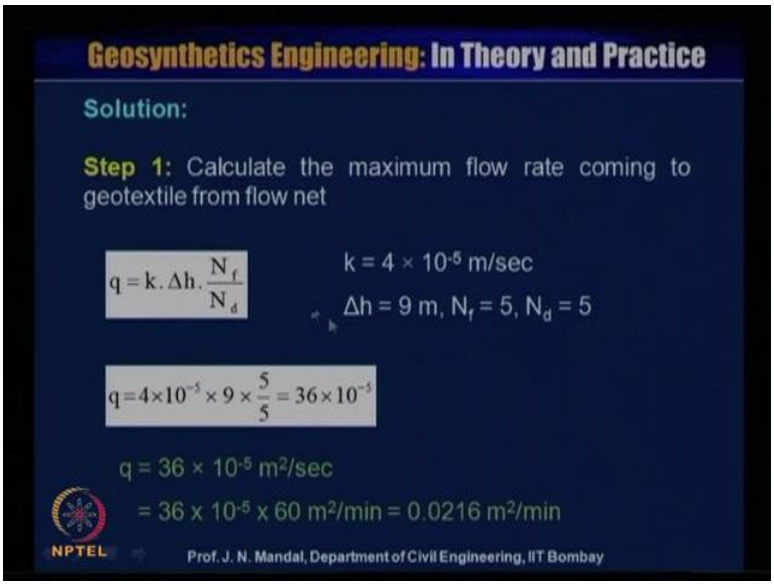

Now, the solution step 1, calculate the maximum flow rate coming to the geo textile from flow net, that is you know the equation q k delta h N f by N d k is equal to 4 into 10 to the power minus 5 meter per second delta h 9 meter N f is equal to 5 N d is equal to 5. So, q will equal to k is 4 into 10 to the power minus 5 into delta h is 9 and N f by N d 5 by 5 you can have q is equal to 36 into 10 to the power minus 5. So, this is meter square per second. So, this you can write again 36 into 10 to the power minus 5 into 60 that is meter square per minute, that is equal to 0.0216 meter square per minute.

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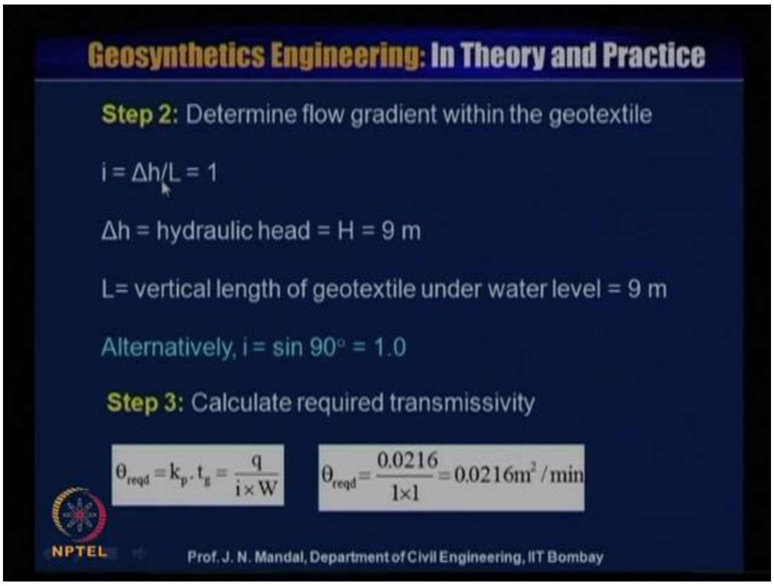

Now, step 2 determine the flow gradient within the geo textile here, i is equal to delta h by L; that means, it will be 1 and delta h is equal to hydraulic head H is equal to 9 meter, L is equal to vertical length of the geo textile under water level is equal to 9 meter. Now, alternatively we can also write i is equal to sin 90 degree is equal to 1.0.

Step 3, calculate the required transmissivity, then theta required you know k p into t g q by i into W; that means, q is known that is 0.0216 which we have calculated 0.0216. So, this is 0.0216, i is equal to you know 1, W is equal to 1. So, theta required will be 0.0216 meter square per minute.

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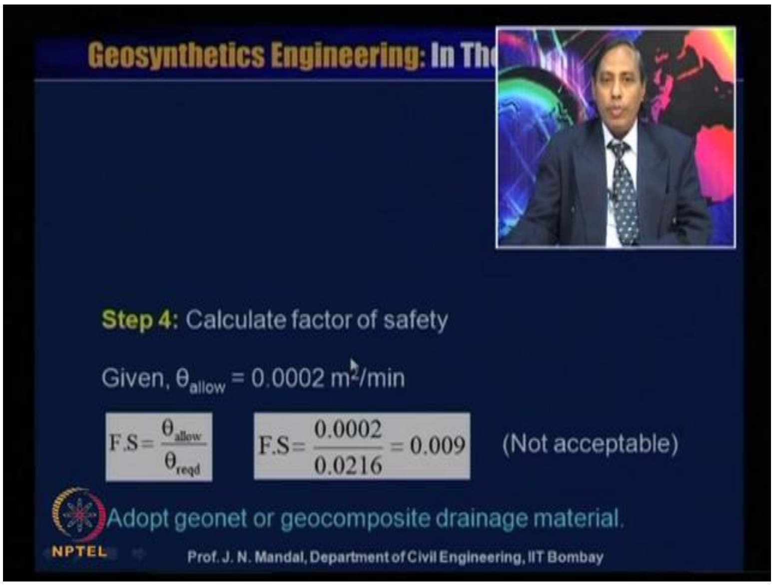

Now, step 4 calculate the factor of the safety, it is given theta allowable 0.0002 meter square per minute. So, factor of safety will be theta allowable by theta required, that mean factor of safety will be equal to 0.0002 divided by 0.0216 is equal to 0.009. So, we can see factor of safety is very, very less, so not acceptable. So, in that case we can adopt the geo net or geo composite drainage material.

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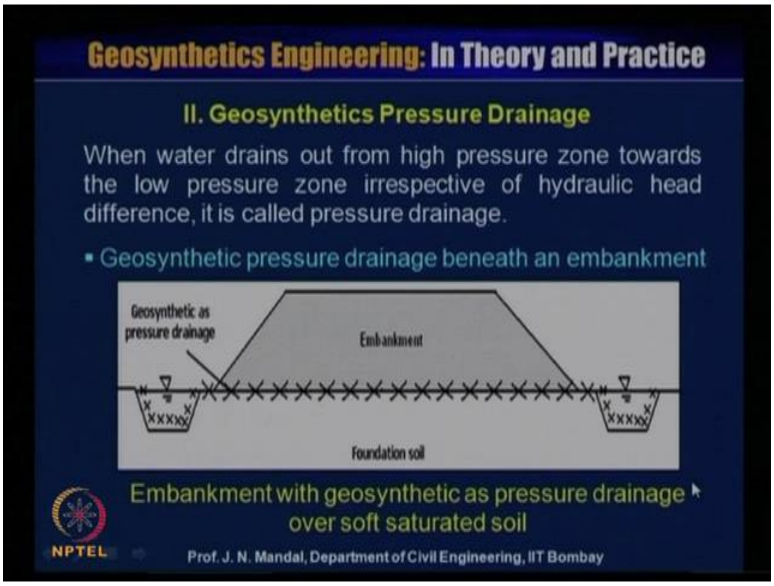

Now, we discuss geo synthetics pressure drainage, when water drains out from high pressure zone towards the low pressure zone irrespective of hydraulic head difference, it is called the pressure drainage. So, geo synthetic pressure drainage beneath an embankment, here you can see that this is one embankment and geo synthetic is placed between the foundation soil and the embankment. So, embankment with geo synthetics as a pressure drain over, this is a soft saturated soil and this is the both side is the drainage.

So, I will give you one of the example also, how we can solve this problem geo synthetics for the pressure drainage.

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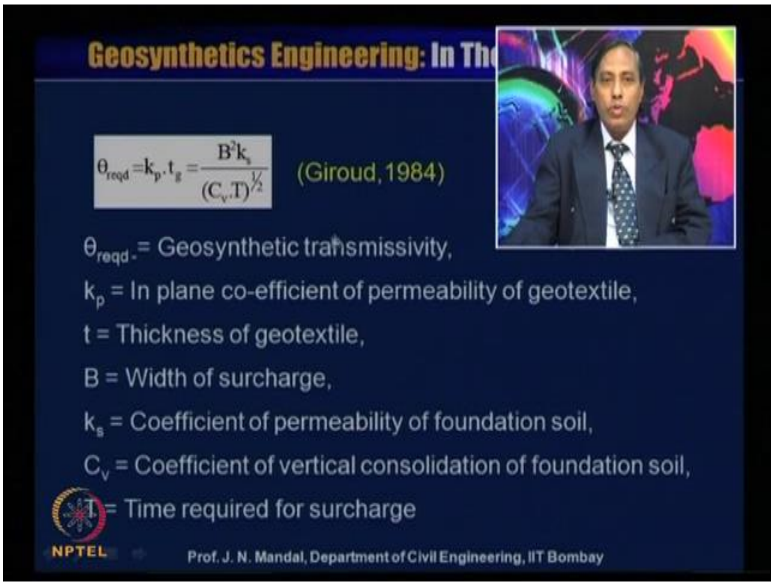

So, giroud 1984 give this equation, that is theta required is equal to k p into t g is equal to B square k s by C v into T whole to the power half, this theta required is the geo synthetic transmissivity, k p is known to in-place coefficient of permeability of geo textile, this is t g is the thickness of the geo synthetics material, and B is the width of the surcharge, k s is the coefficient of permeability of the foundation soil and C v is equal to coefficient of vertical consolidation of foundation soil and T is time required for surcharge. So, you should remember this equation.

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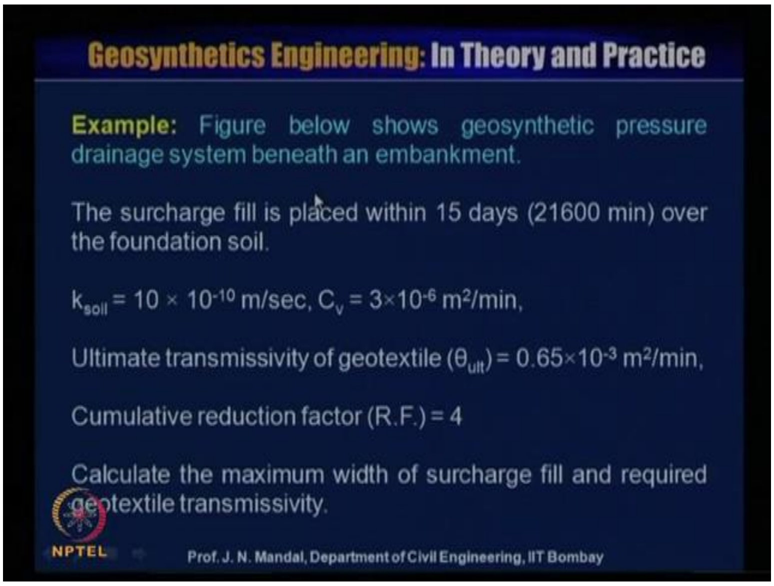

So, let us one example this is show that geo synthetics pressure drainage system beneath that embankment.

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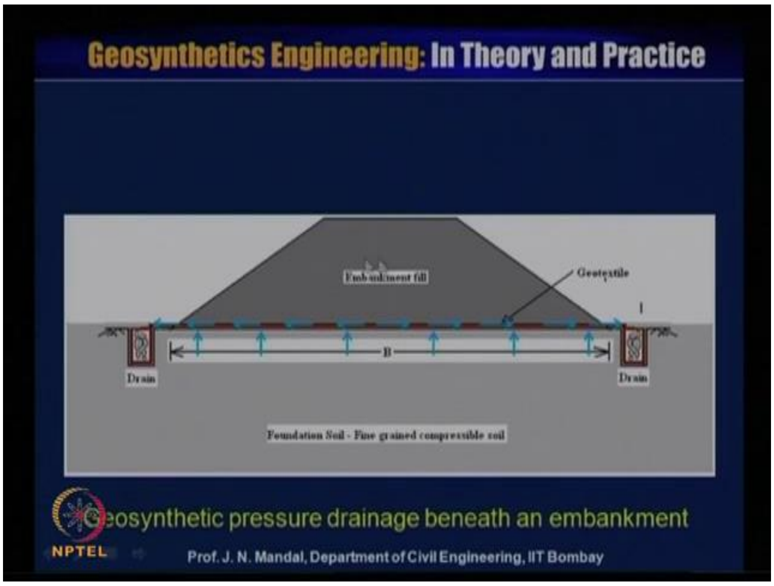

This is the embankment and geo synthetic is placed, here and this is the B and this is the foundation soil fine grained, compressible soil. So, there is a development of the pressure on the geo synthetic material and this is the drain, you can see that how the water is passing along the plane of the geo synthetic material through the drainage.

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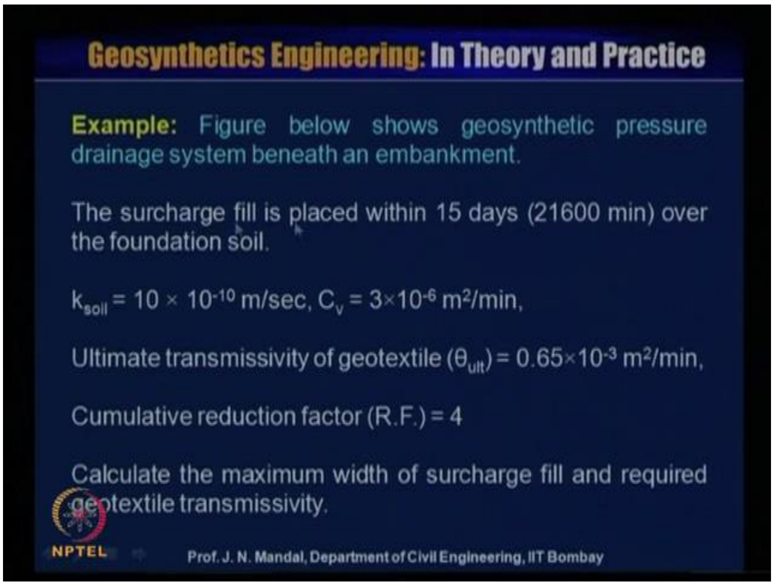

So, in this problem the surcharge fill is placed within 15 days; that means, 21600 minute over the foundation soil and coefficient of permeability soil is given, 10 into 10 to the power of minus 10 minute per second. And coefficient of consolidation C v is given equal to 3 into 10 to the power minus 6 meter square per minute, ultimate transmissivity of the geo textile is given theta ultimate is equal to 0.65 10 to the power minus 3 meter square per minute.

Let us consider cumulative reduction factor is equal to 4, you have to calculate what will be the maximum width of the surcharge fill required geo textile transmissivity, we have to find out maximum width of the surcharge this what should be the maximum width of the surcharge. So, this is an example of geo synthetics pressure drainage beneath an embankment.

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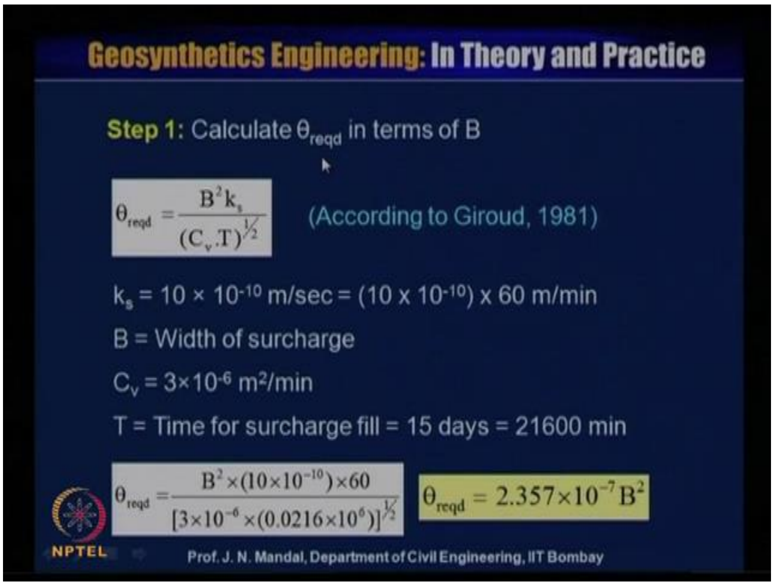

Now, the solution step 1, you calculate theta require in terms of B. So, we know according to the giroud 1981 theta required is equal to B square k s divided by C v into T whole to the power half, k s is given is 10 into 10 to the power minus 10 meter per second; that means, 10 into 10 to the power minus 10 into 60 meter per minute and B is the width of the surcharge. And C v coefficient of consolidation also given 3 into 10 to the power minus 6 meter square per minute and time T for surcharge fill it is for 15 days; that means, 21600 minute.

So, now, theta required you can write B square into k s, k s is this 10 into 10 to the power minus 10 into 60 this divided by C v, C v is equal to 3 into 10 to the power minus 6 into capital T that is equal to this; that means, this you can write 0.0216 into 10 to the power 6 and this whole to the power half. So, if you calculate this, you can have a relationship between theta required and B square. So, theta required will be equal to 2.357 10 to the power minus 7 B square.

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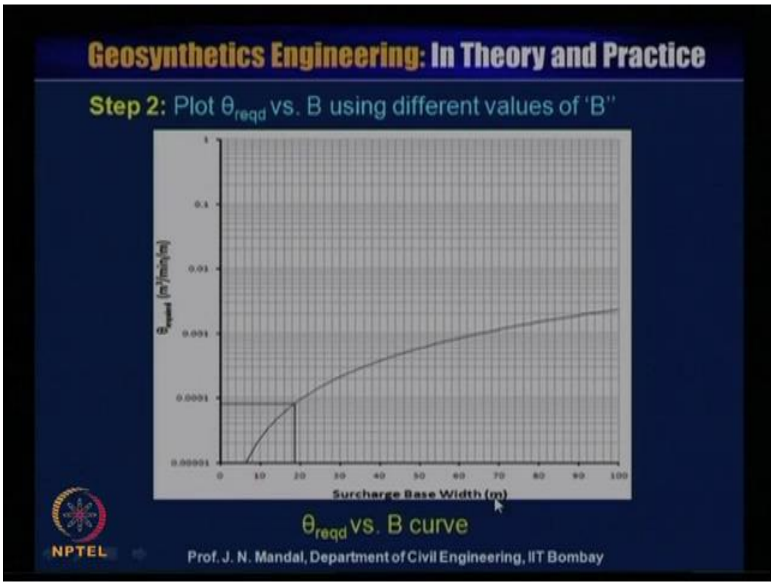

So, now, you have to plot the theta required versus B that will be the surcharge base width in meter. So, you assume the different values of B and then you calculate what will be the theta required. So, here assume the different value 5, 10, 20, 30, 40, 60 meter width of the surcharge base width and then accordingly, we can calculate the what will be the theta require because you know this equation theta required is equal to in terms of B square, so knowing assuming the different values of B. So, you can calculate theta require and you can draw a curve line this.

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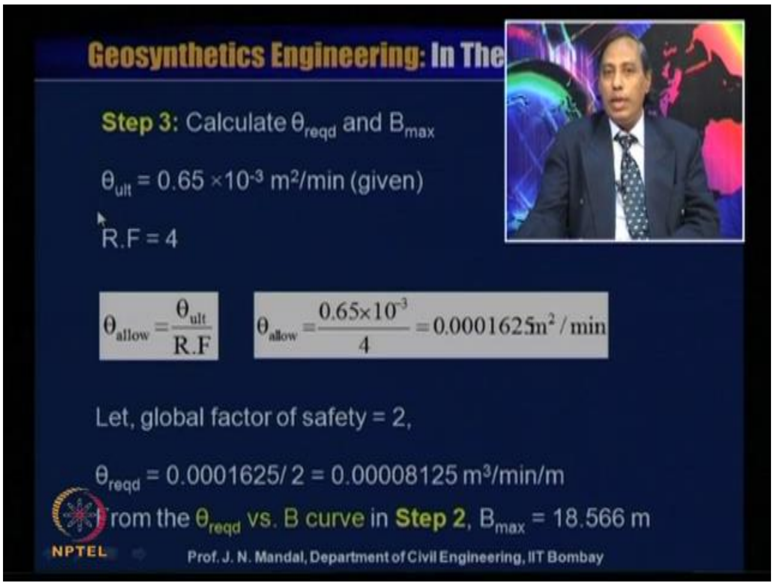

So, from this curve step 3, that calculate theta required B maximum you can obtain that theta of ultimate value given is 0.65 into 10 to the power minus 3 meter square per minute, it is given and considering the reduction factor is equal to 4. So, theta allowable is equal to theta ultimate divided by reduction factor. That mean theta allowable will be equal to 0.65 10 to the power minus 3 divided by 4 is equal to 0.000162 meter square per minute. Let the global factor of safety 2. So, theta required will be equal to 0.0001625 divided by 2 is equal to 0.00008125 meter cube per minute per meter.

So, from the theta require an B curve, but I have shown in the step 2. So, you can calculate what will be the B maximum that will come B maximum 18.566 meter. So, you know that what will be the theta required.

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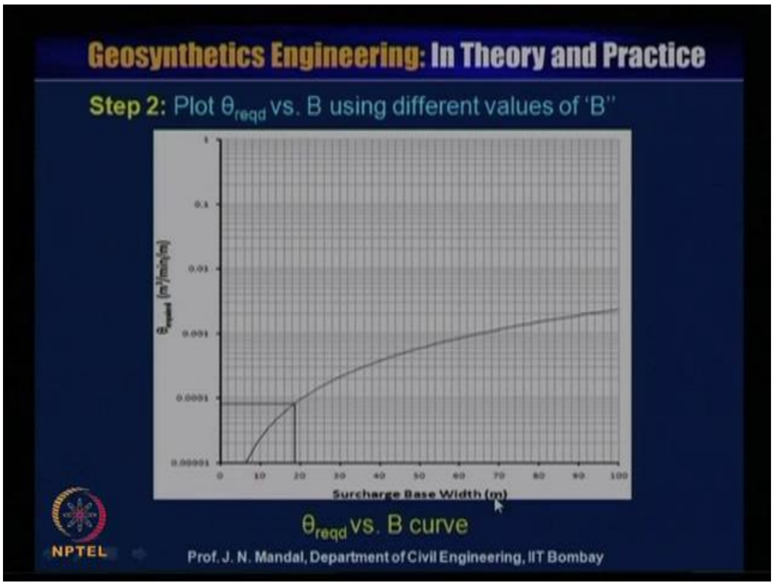

So, you know this value. So, you can draw horizontally and then vertically downward you can see, you can have what should be the B what will be the surcharge base width in meter. So, it is less than in between 10 to 20 this is 18. Something this is 18.566 meter. So, this here calculated what is B maxima?

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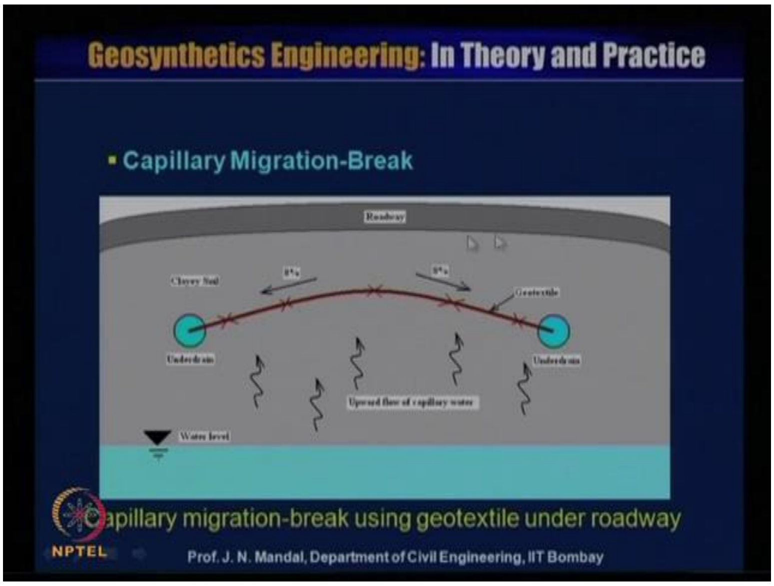

Next, the capillary migration break, we can see that most of the time in the roadway, you can see it is a clay soil and this water level is here and there is a upward flow of capillary water, sometime water can move beyond the roadway and water is stagnant that is due to the upward flow of the capillary water. So, what we do in general, we provide with the drainage somewhere here.

So, if you can provide with the drainage, some conventional system, drainage we can provide here and because this upward flow of capillary water is more, than it will be very difficult to control the flow with the conventional system therefore, it is required to provide a geo synthetics material and then under drainage from both the side and then you can provide with the some slope that is 8 percent say slope.

So, whatever the water or capillary or pass through the geo textile material, it should be going down to the drainage even then some water what is come from the top from the rainfall, that also can pass through this slope and then to the drainage. So, this is one of the very important, that capillary migration break kind of the problem and how you can solve the problem using geo synthetics material.

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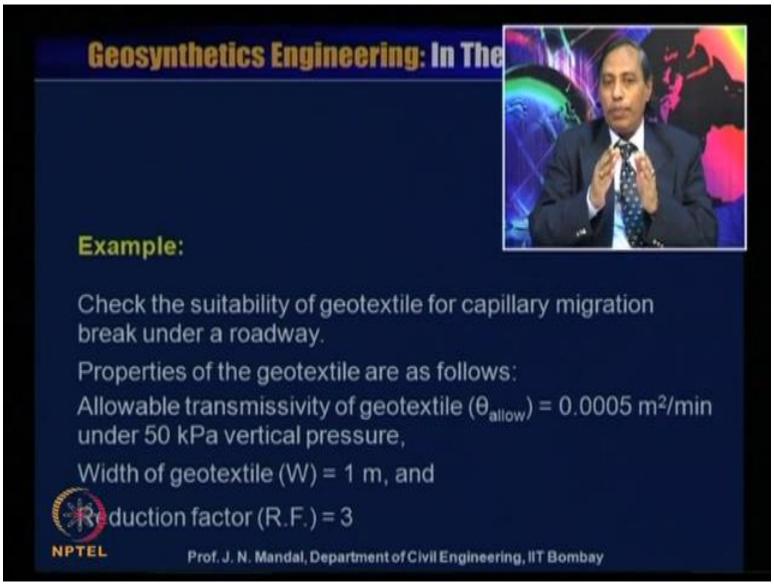

Here, I am giving one simple example, check the suitability of the geo textile for capillary migration break under a roadway. So, properties of the geo textile is given, let us say allowable transmissivity of the geo textile theta allowable is equal to 0.0005 meter square per minute, are under a 50 kilopascal vertical pressure, width of the geo textile W is equal to 1 meter and reduction factor is equal to 3.

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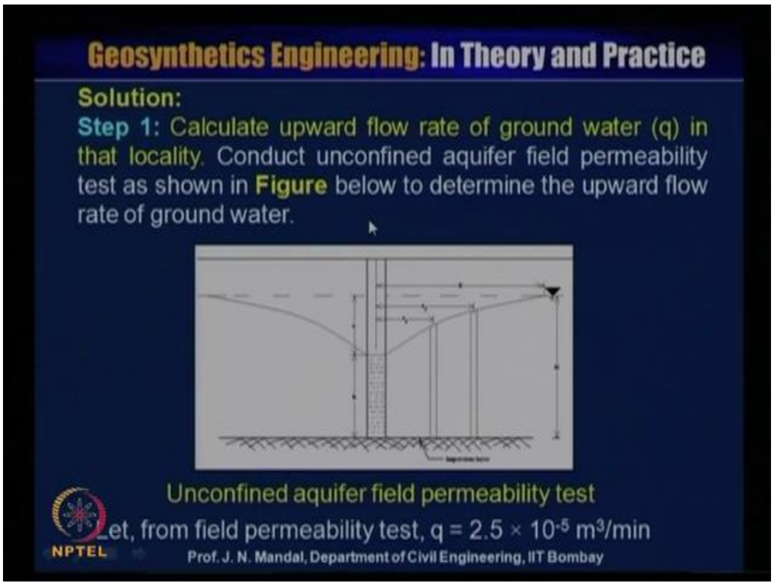

Now, the same I say the capillary migration break using geo textile under roadway and first of all that step 1, you have to calculate the upward flow water of ground water in the locality. So, you should know what will be the upward flow of water in this locality. So, to calculate the upward flow of ground water in the locality, you have to conduct the unconfined aquifer field permeability test.

You know that, what is unconfined aquifer field permeability test and from this test, you can calculate that what will be the upward flow rate of ground water, let from this field permeability test you calculate that q is equal to 2.5 into 10 to the power minus 5 meter cube per minute. So, in that locality you should know, what will be the flow rate of that water. So, that is very important wherever when you design for the filtration and the drainage for any road etcetera.

So, you should know that what will be the quantity of water flow in that area, you should know what will be the intensity of the rainfall in that area, most of the time design has not made as for the quantity of water flow in that locality. So, one has to be very careful for the design of geo synthetics material for the filtration and drainage. So, you should know exactly, that what is the quantity of water flow in the locality and accordingly, you can design for the filtration and the drainage for the geo textile material.

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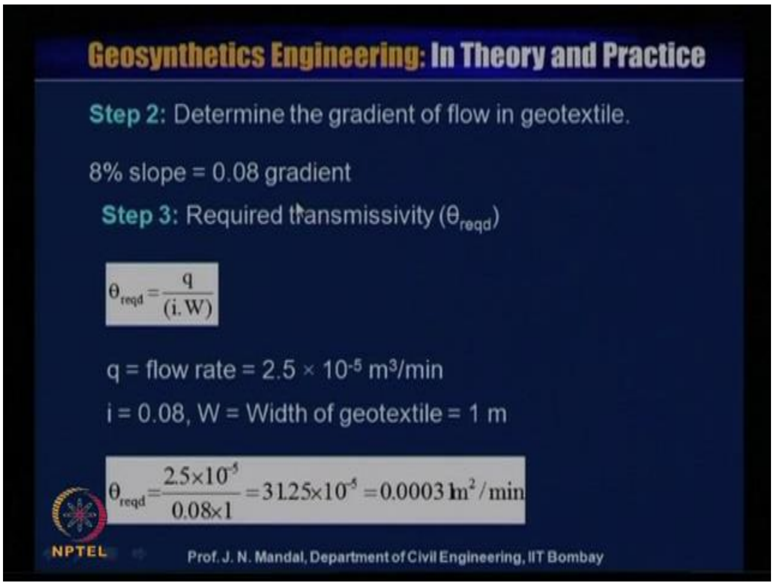

Now step 2, determine the gradient of flow in the geo textile, here it is given the 8 percent slope that is equal to 0.08 gradient. Step 3, required transmissivity that is theta required, theta required will be q by i W and q is equal to flow rate which we calculated here q 2.5 into 10 to the power minus 5 meter cube per minute.

So, you write q is equal to 2.5 10 to the power minus meter cube per minute and i is equal to this is slope 0.08 and W is equal to width of the geo textile here 1 meter. So, if you substitute this value. So, you can determine theta required is equal to 2.5 into 10 to the power minus 5 q divided by i is 0.08 and W is equal to 1 meter. So, this theta require 31.25 into 10 to the power minus 5; that means, is equal to 0.0003 meter square per minute.

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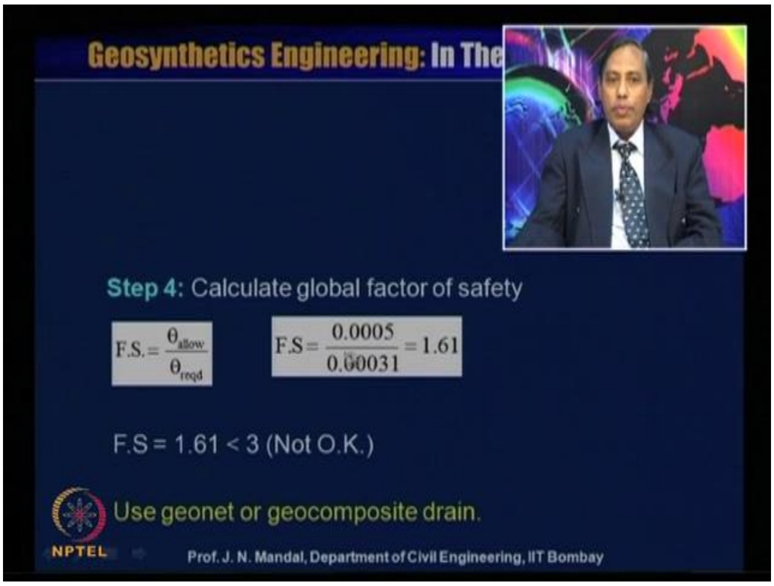

Step 4, calculate the global factor of safety, that mean factor of safety is equal to theta allowable by theta required. So, factor of safety you know what is theta allowable 0.0005 and this divided by theta require 0.00031 which we know earlier, what is theta require. So, you can calculate the factor of safety this is 1.61. So, factor of safety is equal to 1.61 on the lower side, it is less than three. So, it is not ok.

So, therefore, you have to select some alternative material either you can select the geo net or you can select the geo composite material. So, you can see most of the cases if you do not select, the proper kind of the geo synthetics material and how, it is not satisfying all the criteria, it is not satisfying the factor of safety, it is not satisfying the flow criteria, it is not satisfying the permittivity or the transmissivity criteria.

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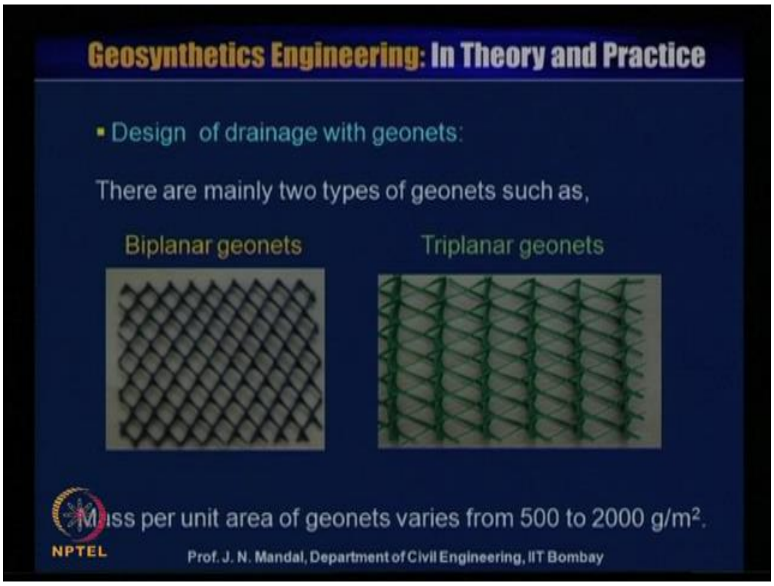

Next design of drainage with the geonets. So, let us discuss that design of drainage with geo net, there are mainly two type of the geo net, that is one is the bi planar geo net and another is the tri planar geo net. So, you can see this is a kind of the bi planar geo net material, you can see this is rhombus in shape and if there is any flow quantity is more then you can use the bi planar geo net material or if the quantity of more and more then you can use tri planar geo net.

So, mass per unit area of this kind of the geonets are varies from 500 to 2000 gram per meter square. So, we observe that, what is the type of the bi planar geo net and what is the type of the tri planar geo net.

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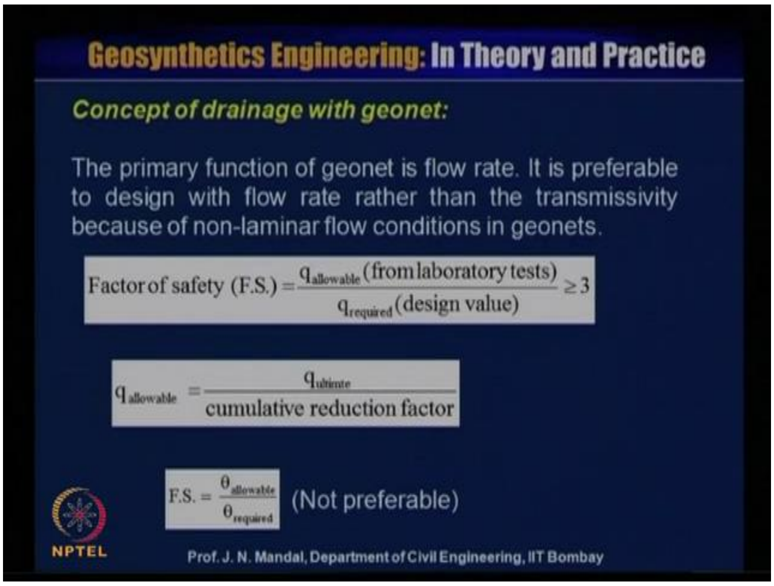

Now, concept of drainage with geo net, very simple the primary function of geo net is flow rate, it is preferable to design with the flow rate rather than transmissivity, because of non laminar flow condition in geo net. So, it will not obey the Darcy's law. So, therefore, when you will design then you should think about whether it is a laminar flow or the non laminar flow, if it is a non laminar flow then you have to consider that what should be the quantity of flow of water passes through that area.

So, here factor of safety can be determined by q allowable, which we can determine from the laboratory test and q required what is the design value and that factor of safety should be greater than equal to 3 and q allowable is equal to q ultimate by cumulative reduction factor, you know what is cumulative reduction factor and then you have to calculate the what will be the factor of safety, that is theta allowable by theta required.

But, theta allowable by theta required not preferable because of non laminar flow condition. So, we have to deal with the flow related problem, flow not the theta allowable and theta required, this is geo composite drainage.

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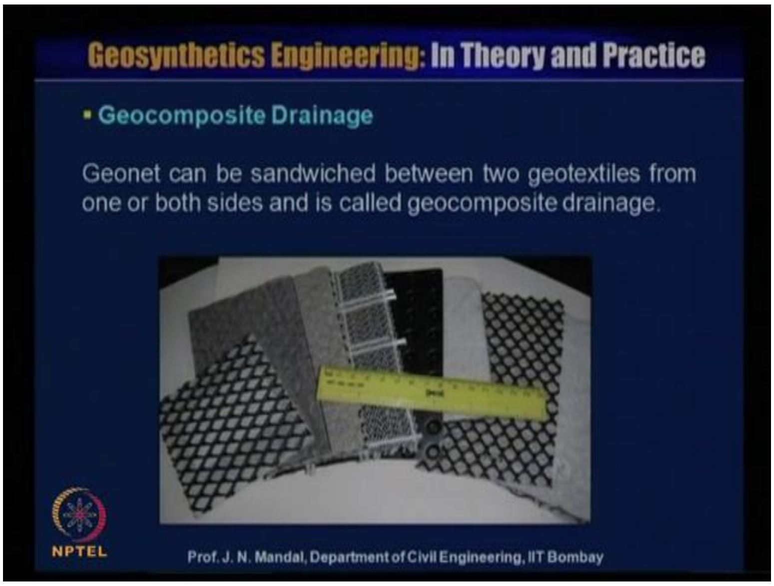

So, geo net can be sandwiched between 2 geo textile from one or both side and is called the geo composite drainage for example, this is the geo net and you can see, this is also laminated with the geo textile material, nonwoven geo textile material. So, this is on the one side and also we can have this is geo net inside you can have both the side, this top and this is also the bottom, it is like a sandwich between the two geo textile from one or both side it is called the geo composite drainage. So, you know that what is geo composite drain?

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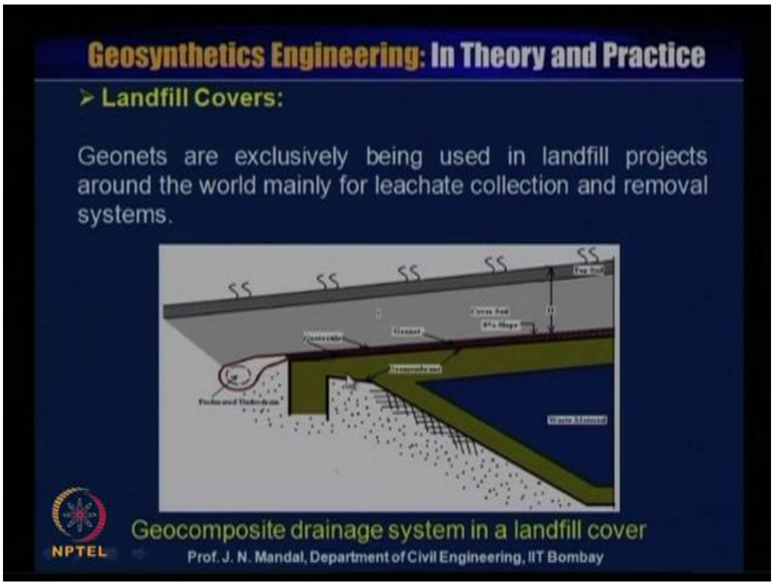

And landfill cover, this is geo net are exclusively being used in the land fill project around the world mainly for leach ate collection and removal system. So, here geo composite drainage system is shown in a landfill cover on the top, this is the landfill and this is the all waste material and on the top of that you have to provide with the geo composite material, that is geo net and then laminated with geo textile material, it is top and bottom is geo textile and this is geo net material.

So, this is a geo composite material is in cover, this is the cover soil. So, you need to design this cover soil, most of the cases you can see in India lot of landfill it is now opening there is no cover. So, you have to provide proper kind of the covering system. So, this you have to provide with the geo membrane material, which is impermeable material and then you can provide with the geo composite material, this is geo net and geo textile at the top and the bottom.

And then you fill up with the cover soil with the certain soil of 8 percentage and on the top of the soil, you can provide the top soil and then here you can grow this whole thing looks like a very greenery and this height of the covered soil is designated here as h and the whatever water, though it is a impermeable material if water can percolate most of the time there is a possibility for cracking, then rain water can pass through this and then pass through this geo textile material and then pass through the drainage.

So, then waste material will not be no formation of the leach ate. So, you have to protect the waste material, by providing the geo membrane and geo composite material. Now, you will design this cover soil, this height is equal to the h.

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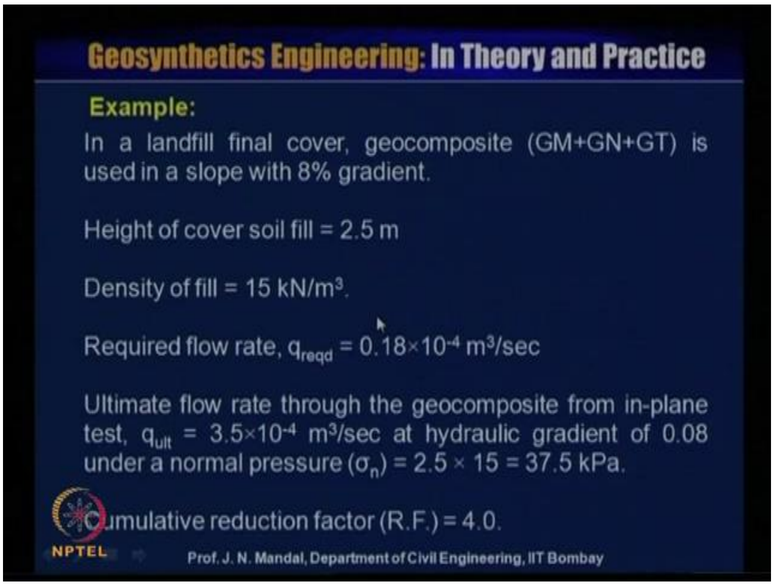

So, for an example in a landfill liner cover geo composite I say geo membrane it means geo net and geo textile material is used in a slope with the 8 percent gradient, here is the 8 percent gradient and then height of the cover soil 2.5 meter, this is height of the h is 2.5 meter and density of the fill, this is density of the fill is 15 kilo Newton per meter, this is density of the fill this is 15 kilo Newton per meter and required flow rate that is q required is 0.18 into 10 to the power minus 4 meter cube per second.

So, ultimate flow rate through the geo composite from in-plane test; that is q ultimate is 3.5 into 10 to the power minus 4 meter cube per second at a hydraulic gradient of 0.08. So, under this already you know that water can, just past through along the plane of geo synthetics that is why it is transmissivity and then it goes to the drainage and this is the height and this is the density. So, you will be knowing what will be the stress here, that vertical stress here acting on this geo composite material.

So, you can determine what will be the flow rate through the geo composite from in-plane test, let us say q ultimate value you obtain 3.5 into 10 to the power minus 4 meter cube per second, at a hydraulic gradient 0.08. Now, this is under a normal pressure that is sigma n is equal to 2.5 into 15. So, this is the 2.5 is the height of the cover soil that is meter 2.5 that height of the cover soil and density of the fill is 15 kilo Newton per meter cube, this is gamma into h; that means, this is gamma and this is h.

So, h is equal to 2.5 and gamma density of the fill is 15 kilo Newton per meter. So, this is the normal pressure sigma n will be the 22.5 into 15 is equal to 37.5 kilopascal and cumulative reduction factor consider 4.

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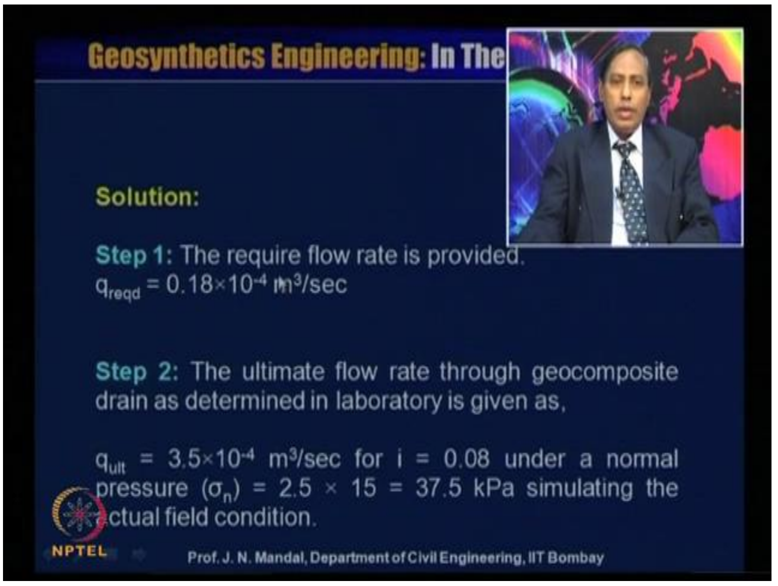

So, now the solution now step 1, we require flow rate is provided; that means, q required is 0.18 into 10 to the power minus 4 meter cube per second. Step 2, you ultimate flow rate through the geo composite drain as determine in the laboratory is given that q ultimate is equal to that is 3.5 10 to the power minus 4 meter cube per second for i is equal to 0.8 under a normal pressure sigma n is equal to 37.5 kilopascal, simulating the actual field condition.

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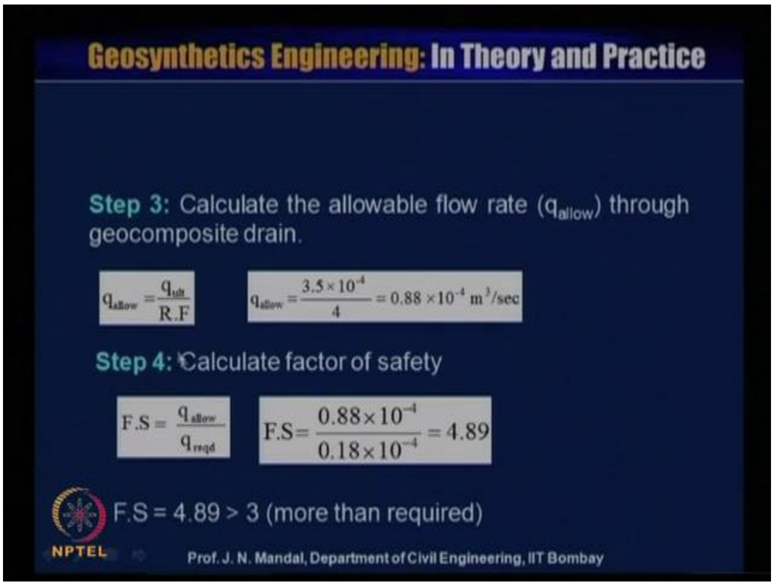

Step 3, calculate the allowable flow rate q allowable through the geo composite drain. So, q allowable will be q ultimate by reduction factor, q ultimate is 3.5 into 10 to the power minus 4. So, q ultimate 3.5 into 10 to the power minus 4 this reduction factor is 4. So, q allowable will be 0.88 into 10 to the power minus 4 meter cube per second. Step 4, calculate the factor of safety.

So, factor of safety is equal to q allowable by q required. So, factor of safety will be equal to 0.88 into 10 to the power minus 4 this divided by this is q allowable 0.8 10 the power minus 4 this divided by q required, q required we have calculated earlier 0.1 into 10 to the power minus 4.

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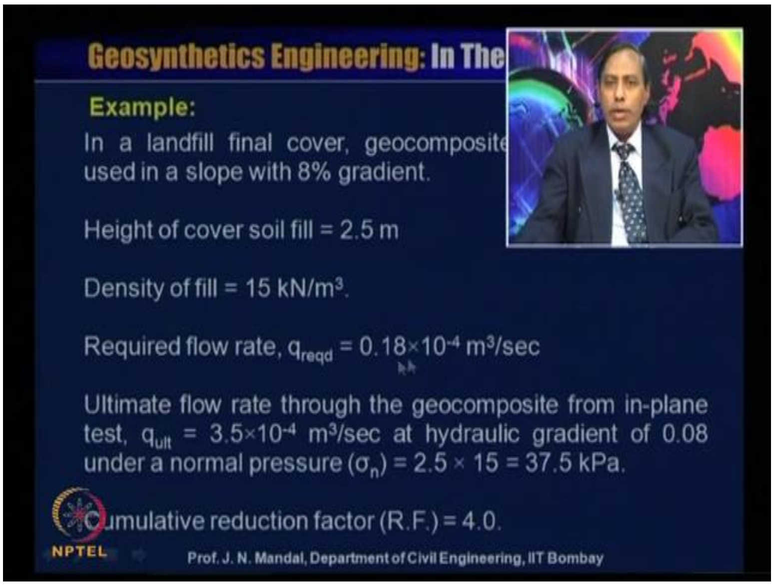

So, this also we have calculated earlier this is q required is 0.18 into 10 to the power minus 4 meter cube per second.

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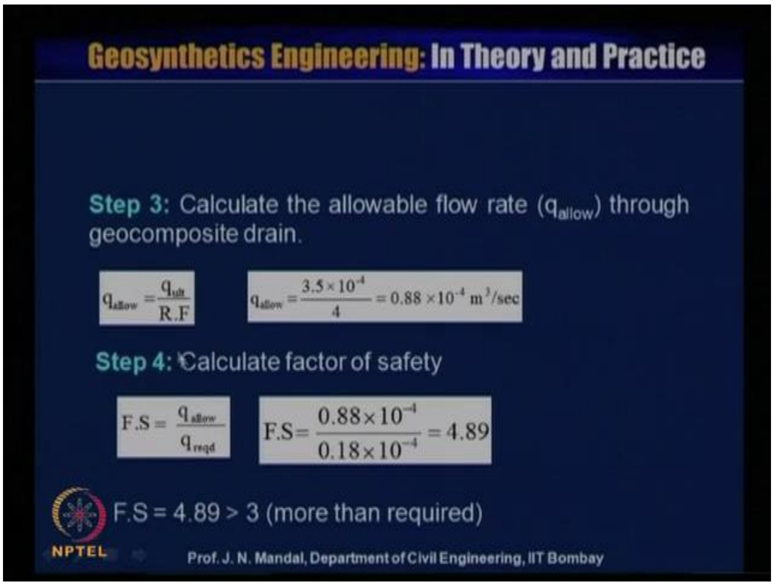

So, this is q required is 0.18 into 10 to the power minus 4. So, this will give you the factor of safety 4.89. So, factor of safety is equal to 4.89 it is greater than 3. So, it is more than required. So, it satisfy the criteria. So, here you see that how that that geo composite material have been used and it is the design is based on the flow related. So, you remember, when it is a not in the laminar flow condition, then you have to design based on the flow. So, you can check that what will be the flow related problem and you find now this material is suitable for the landfill cover system.

So, then there will be no problem, you can protect the landfill from the leach ate or contamination problem. So, you have to be careful for the select, the material. So, we deal with the woven geo textile material, nonwoven geo textile material you can see sometimes it does not satisfy the criteria, if it sometimes does not satisfy the criteria, we go for the more number of the layer of the geo textile material, either it is a woven geo textile material or it would be the nonwoven geo textile material.

If you go more number, number of geo textile material, then you will be knowing that a thick, it will be gradually thicker and thicker, it will be quite expensive. So, alternative to that you can adopt the geo composite material, you can adopt the geo net material, you can adopt the combination of the geo net and the nonwoven geo textile material, it is in a laminated form, on the one side or on the both side or you can use like a triangular type of the geo net material.

So, this kind of the material can satisfy this criteria of course, there are many, many different types of the geo composite product, are coming up which will be very much useful for the related with the drainage and the filtration problem because most of the time the structure, fail due to the drainage and the filtration. So, you have to be careful for the proper selection of the geo synthetic material with this I ended up this lecture.

Thank you.