Geosynthetics Engineering: In Theory and Practices
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Lecture - 19
Geosynthetics for Filtrations Drainages and Erosion Control Systems

My name is professor J N Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India. The name of the course Geosynthetics Engineering in Theory And Practice, this module 4, lecture 19 Geosynthetics For Filtration Drainage and Erosion Control System.

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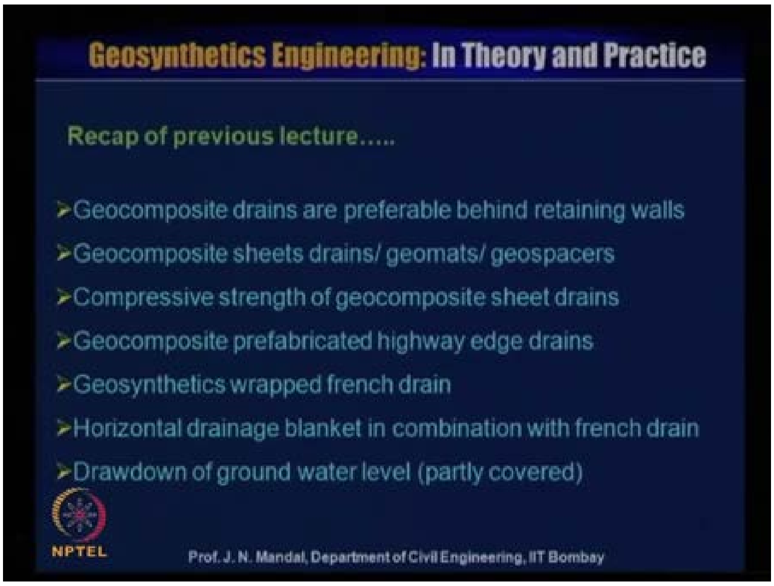

Now, I will show the recap of the previous lecture, that is geocomposite drain are preferable behind the retaining wall, geocomposite sheet drain, geomat or geospacer compressive strength of geocomposite sheet drain. Geocomposite prefabricated highway edge drain, geosynthetics wrapped french drain, horizontal drainage blanket in combination with French drain, drawdown of ground water level partly covered; and also we have covered many example using the geocomposite material geocomposite sheet drain and so on.

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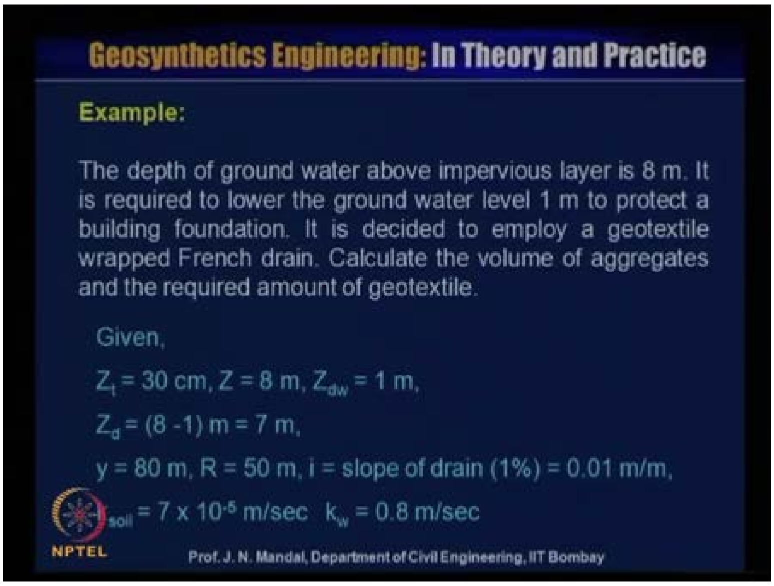

Next, I will explain the one example, the depth of the ground water above the impervious layer is 8 metre, it is required to lower the ground water level, 1 metre to protect a building foundation. It is decided to employ a geotextile wrapped French drain, calculate the volume of the aggregate and the required amount of geotextile.

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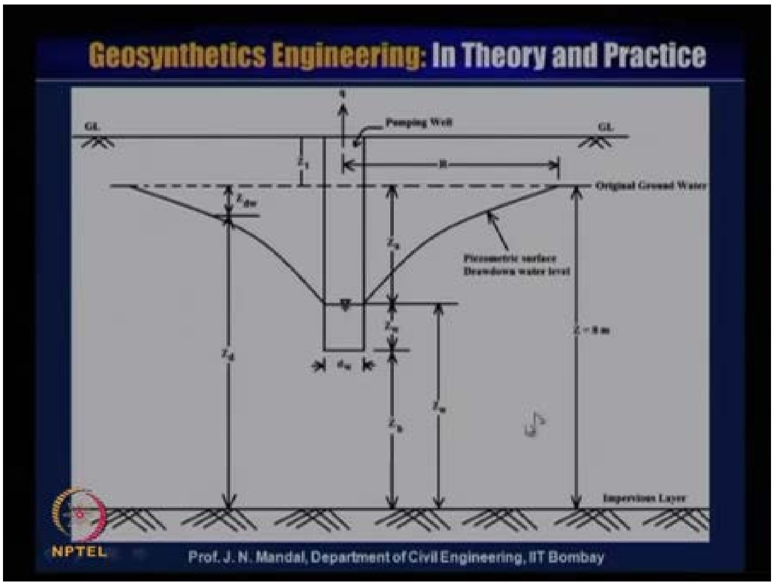

Here it is given z of t is 30 centimetre, and z this is 8 metre and z of w, so this d of z is 8 metre, and z of d w is 1 metre, so z of d here to here z of d will be equal to z 8 metre by z d w is 1 metre. So, z of d will be z 8 metre by z d w 1 metre, so z d will be equal to 8 metre by 1 metre is equal to 7 metre, and y is the length of the drainage like this y, so that is 80 metre, and here r is equal to 50 metre.

And I is equal to slope of the drain let us say 1 percentage that is 0.01 metre per metre, and coefficient of permeability of the soil is given 7 into 10 to the power minus 5 metre per second, ((Refer Slide Time: 01:35)) and coefficient of permeability of well graded aggregate k w is equal to 0.8 metre per second. So, this is the problem is given this I just showed you what is z etcetera, what is z r, z d, d w z d, how you have calculated from showing this figure.

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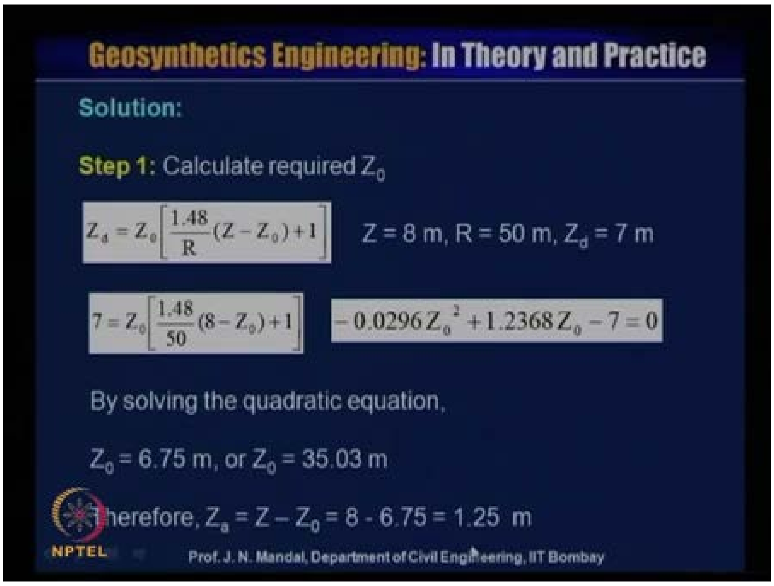

Now, solution step one calculate required z 0, so we have to use this equation z d is equal to z 0 to 1.48 by r z minus z 0 plus 1, we know z is equal to 8 metre r is equal to 50 metre z d is equal to 7 metre. So, you substitute this value that is z d which we calculated earlier that is 7 metre is equal to z 0 1.48 by r, r is 50 metre into z, z is equal to 80 metre minus z 0 plus 1.

So, then you will have this equation minus 0.0296 z 0 square plus 1.2368 z 0 minus 7 is equal to 0, now you solving this equation, quadratic equation you can obtain z 0 is equal to 6.75 metre or z 0 is equal to 35.03 metre. So, you adopt z 0 is equal to 6.75 metre, therefore z a will be equal to z minus z 0, so you calculate the z of a, so where that z of a is here, so you can calculate the z of a. So, you know z minus z 0, you have calculated z

0 is 6.75, and z this is z that is 8 metre, so z 0 z a will be equal to z minus z 0 is equal to 8 minus z 0 is 6.75 is equal to 1.25 metre, so, therefore z a is equal to 1.25 metre.

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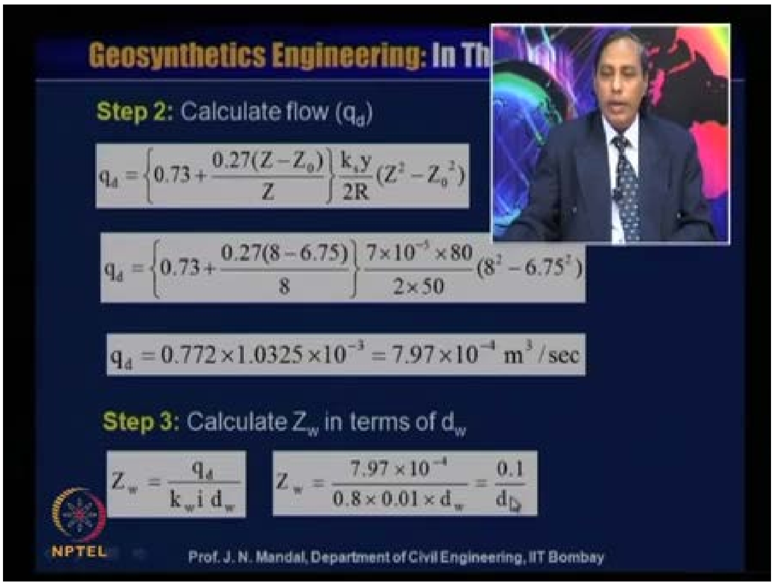

Step 2, calculate the flow q d, so this is the equation for q d, q d is equal to 0.73 plus 0.27 z minus z 0 divided by z, then k s into y this divided by 2 r into z square minus z 0 square. So, q d will equal to 0.73 plus 0.27 z you know 8 z 0 you know 6.75 and z again 8, and this is coefficient of permeability of the soil that is 7 into 10 to the power minus 5, and this y that is the length of the drain that is 80 and 2 into r r is 50 metre, so 2 into 50 this into z square 8 square minus z 0 we know 6.75 square.

So, if you solve then q d will be equal to 0.772 into 0.0325 into 10 to the power minus 3 or 7.97 into 10 to the power minus 4 metre cube per second, step 3 calculate z w in terms of d w. So, z w is equal to q d by k w i into d w, so z w will be equal to q d you calculated, that is 7.97 10 to the power minus 4 divided by k w is 0.8 against this coefficient of permeability of well graded aggregate, and i is equal to we know 0.01 into d w. So, this will give 0.1 divided by d w, so we know the equation z w equal to 0.1 by d w, now we can make a correlation between the z w and d w.

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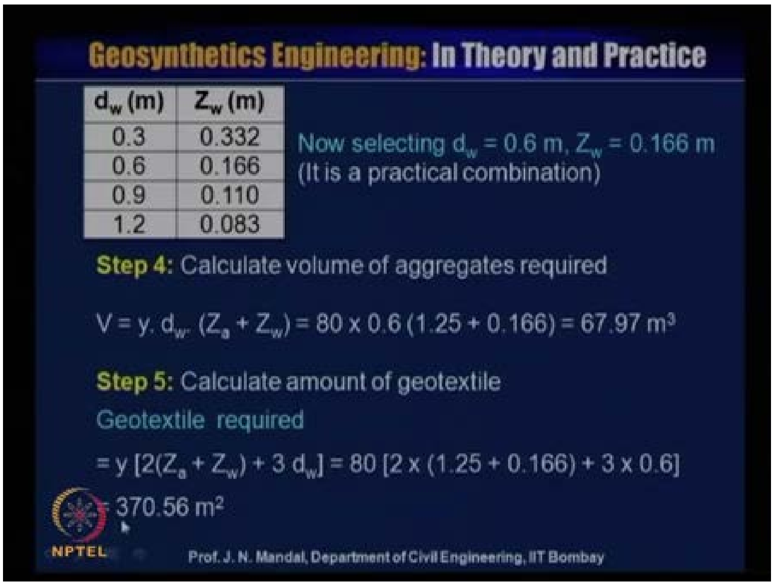

So, you can assume that different value of d w, it may be 0.3, 0.6, 0.9, and 1.2 and on the right hand side then you can calculate the z w 0.332, 0.166, 0.110, 0.083. Now, you have to select the proper d w value, so now, select d w value is equal to 0.6 metre, and then corresponding then z w will be equal to 0.166 metre. Step 4 calculate volume of the aggregate required, so volume of the aggregate will be v, y is equal to length of the drain, d w into z a plus z w, is equal to 80 into 0.6, d w is 0.6 into z a, z a we know 1.25 and z w is 0.166, so this will give the volume of the aggregate is 67.97 metre cube.

Step 5 calculate amount of geotextile, so geotextile required you know the equation earlier y is equal to 2 into z a plus z w plus 3 d w. So, here z a and z w you can calculate, I can show you that what is this figure, this is the z of a, and this is the z of w, this is two side, so 2 of z a plus z w plus this is d w top and bottom, and then overlap that is why 3 w and y is equal to length.

So, y is equal to 80 2 into z a, we calculated 1.25 plus z w you know 0.166 plus 3 into d w is 0.6, so this you can have geotextile required is 370.56 metre square, thus that is geotextile required, next we will address the geosynthetics erosion control. So, geosynthetics can be effectively used as a replacement of the well graded or the open graded aggregate, typically use beneath the riprap or the armour stone in the river bank type of the erosion control problem. And it has been also used for the coastal shore line lake or any other kind of the erosion control related area, climate change population growth and soil erosion are the greatest problem in the world.

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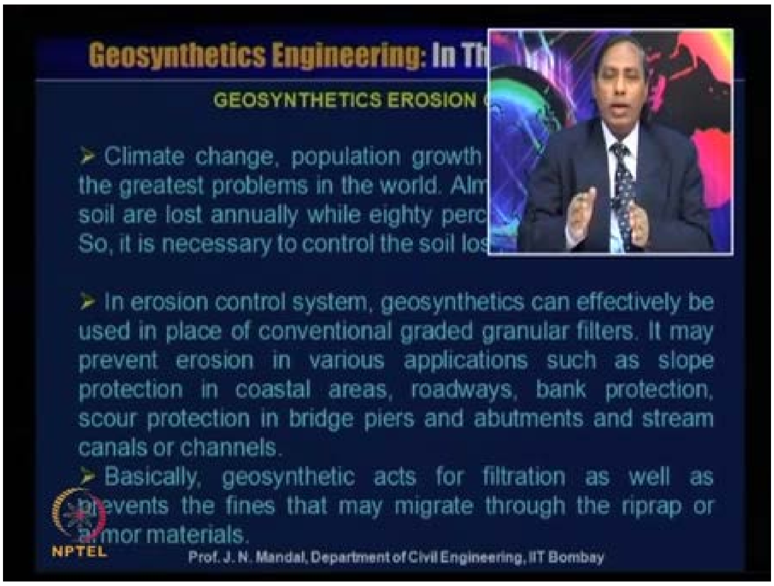

Almost, 75 billion tons of soil are lost annually while 80 percentage of the land is eroded, so it is necessary to control the soil loss from erosion in erosion control system, geosynthetic can effectively be used in place of conventional graded granular filter. It may prevent erosion in various application, such as slope protection in the coastal area roadway bank protection, scour protection, in bridge piers and abutment and stream canal or channel. Basically, geosynthetics act for filtration as well as prevent the fine that may migrate through the riprap or armour material.

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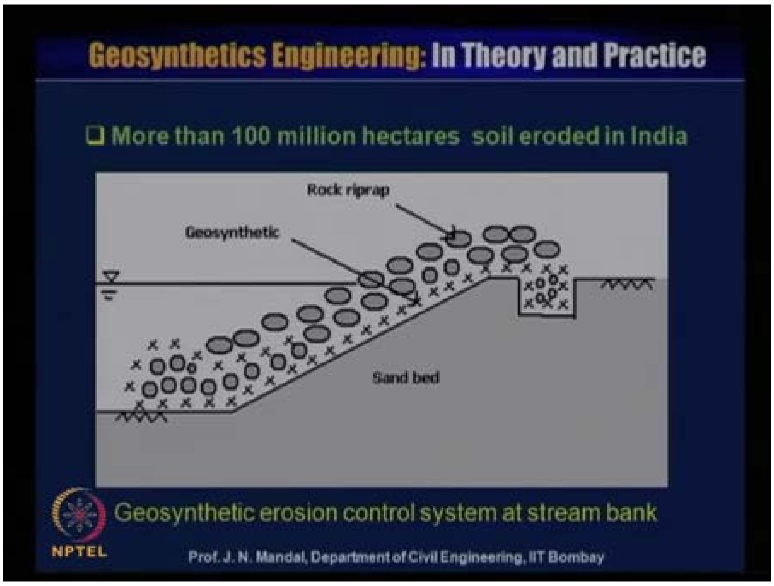

You can see here geosynthetics erosion control system at a stream blanket, where this geosynthetics material has been placed, this is the sand bed geosynthetics material has been placed. And this is the rap, and this is the rock riprap material placed on the top of the geosynthetics material, and more than hundred million hectare of soil eroded in India, you think about that quantity of the soil is eroded in India.

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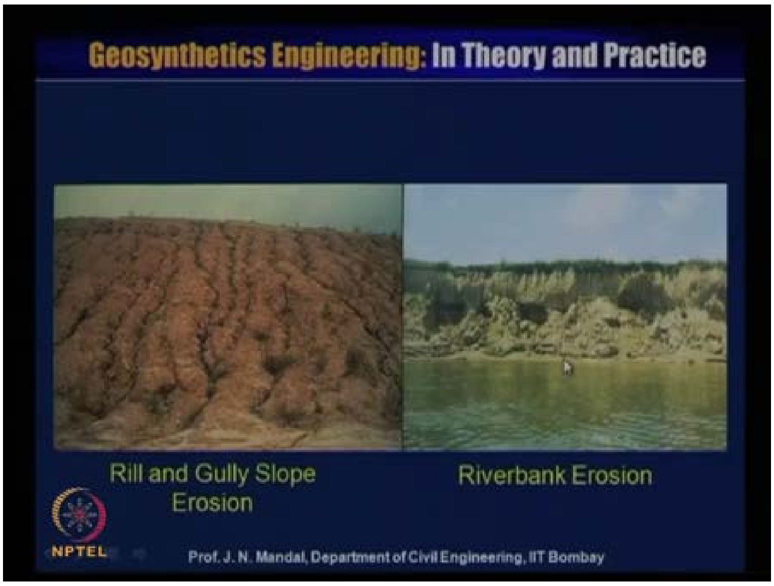

Here some pictures shown that how the rill and gully slope is eroded, here you can see that some river bank, that erosion you can see how it is eroded, and many place in the eastern zone also is eroded like this, so we can see that what kind of the problem, we are facing.

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You can see some places slope or channel, where it has been used that prefabricated block, but you can see how it fell, you can use also the hard armour near to the sea shore to protect the sea from the erosion. And at the base of these armour stone we should provide proper kind of the geosynthetics material, because there is a development of the excess pore water pressure, and that was the major reason that this kind of the structure fell.

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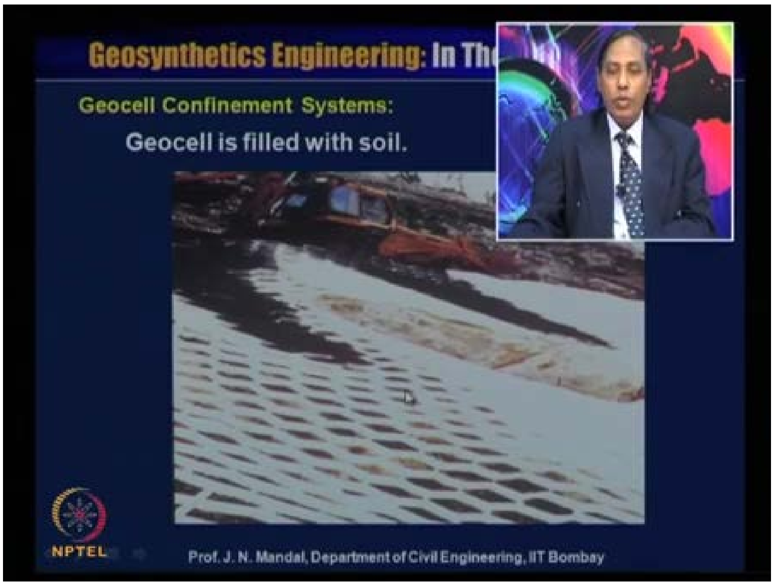

Also you can use the geocell material for erosion control, you can use the natural material jute geotextile or coir geotextile for the erosion control, you can use also the cellular material geowave or the geocell material. It give very good confinement effect, and also the grass can grow, you can see here some of the kind of the geocell, this is filled with the fertilizer soil and then grass can grow, and then this slope will be the stable, so it act as a very good confinement effect.

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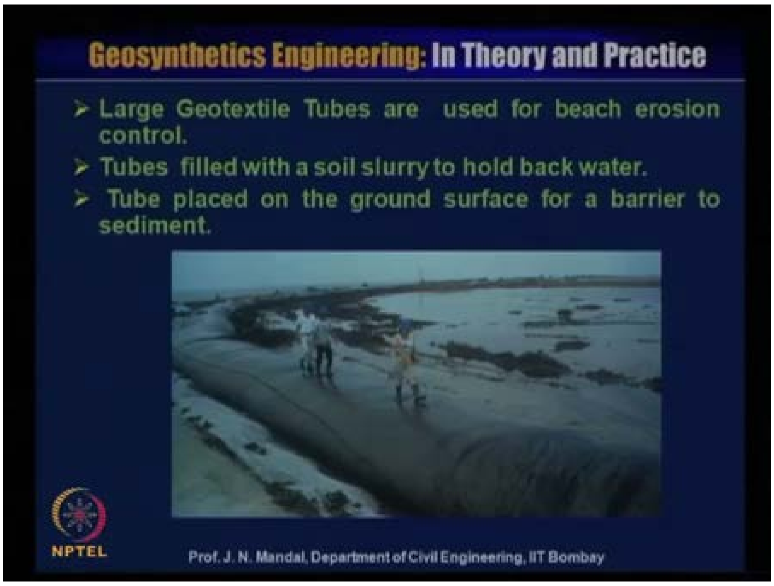

You can see that this is the large geotextile tube, which are used for the beach erosion control when that beach there is a possibility for the erosion, so you can use geotextile tube huge like a look. It is a very large geotextile tube, which you can use near to the beach to control the erosion, and most of the cases this kind of the geotextile tube you can fill up with the slurry to hold back this water. So, you can use that local material itself, which we can insert it into the geotextile tube, we can pump and insert it into the geotextile tube and can place which will control the erosion, so this geotextile tube placed on the ground surface for a barrier to sediment.

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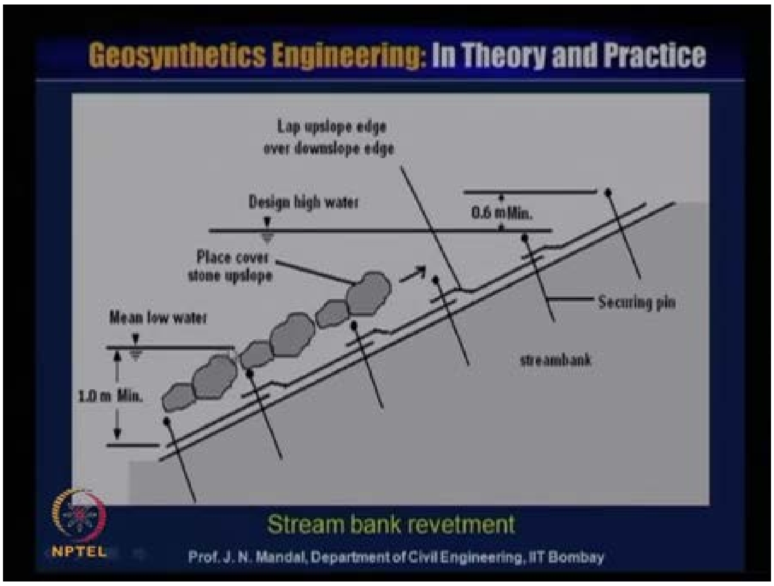

Here, also stream bank revetment you can see this is geotextile you should place the stone upslope, and also you can join with the some securing pin. So, you can place it this is the high water level, and how you can protect the stream bank revetment by using this geosynthetics material.

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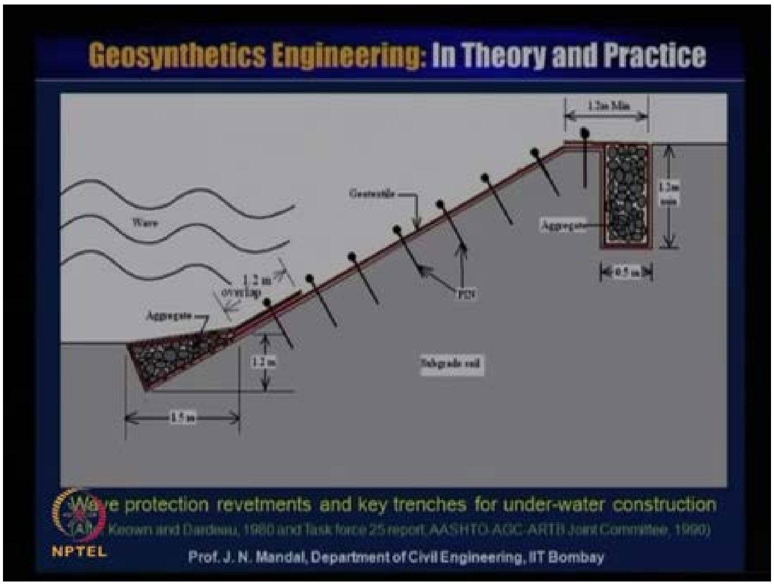

So, this is the wave protection revetment, and key trenches for underwater construction, so here sometime both the riprap also precast concrete block was replaced, sometimes with the armour or sometimes with the concrete block. And geotextile material here act as a two major contribution, one contribution is that it protect from the impact damage, the other contribution that during the installation a abrasion damage, that also happen due to the wave.

So, you have to take care for this proper selection of the geosynthetics material, so here you can see that red colour, this is geosynthetics material, this is the trench whose height is a 1.2 metre, width is 0.5 metre. And then it inside is the aggregate and wrapped with then, this geosynthetic material placed along the slope, and then you can wrap it and filling with the aggregate.

And then this geotextile material is pinned at a certain interval and this is the overlap length about 1.2 metre, and this trench is about 1.2 metre, this is 1.5 metre, and this is the pin at a particular spacing has been placed. So, this is wave protection revetment and key trench for underwater construction, this is given in task force 25 AASHTO AGC ARTB Joint Committee, 1990.

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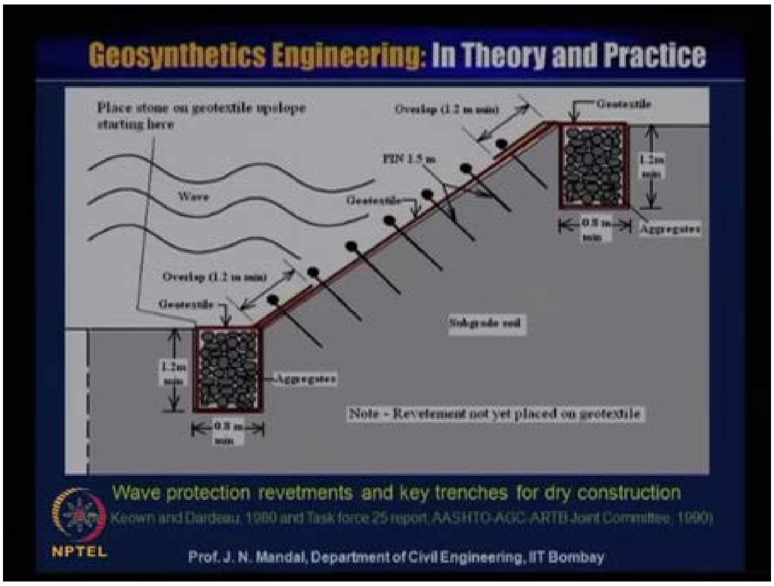

This is another wave protection revetment and key trench on the dry construction, see dry you can see that you can form a trench 0.8 metre, minimum this is 1.2 metre and then this is wrapping, then you place like this, it passes along the slope. And then make a another trench whose size is 0.8 metre, and 1.2 metre height minimum, and then wrap and then overlap 1.2 metre minimum, and then you have to place the pin whose length is about 1.5 metre, and here overlap length is about 1.5 metre minimum. So, this then place the stone on the geotextile upslope starting from here, so this kind of the system for wave protection revetment and key trenches for the dry construction can be made, so here revetment not yet placed on the geotextile.

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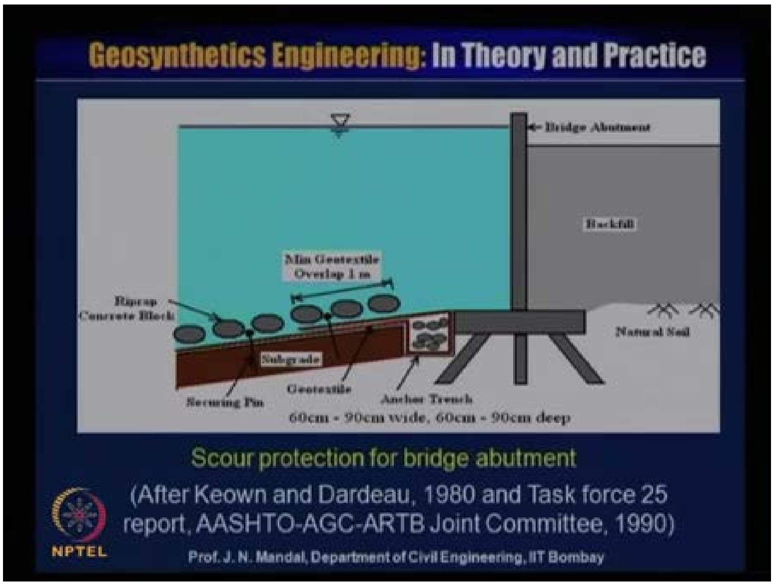

Now, you can see that this is the bridge abutment this is backfill soil, this is natural soil, and there is a curve protection for bridge abutment, and you can provide with a geotextile material, this is like a anchored trench. And then filled with the aggregate and then on the top of this you can provide with the riprap or concrete block, and this overlap of the geotextile material is about 1 metre. And you provide with the securing pin and this is about 60 centimetre to 90 centimetre wide, and 60 centimetre to 90 centimetre depth. So, this system can use for cross protection for bridge abutment after Keown and Dardeau, 1980 and task force 25 report, and AASHTO AGC ARTB Joint Committee 1990.

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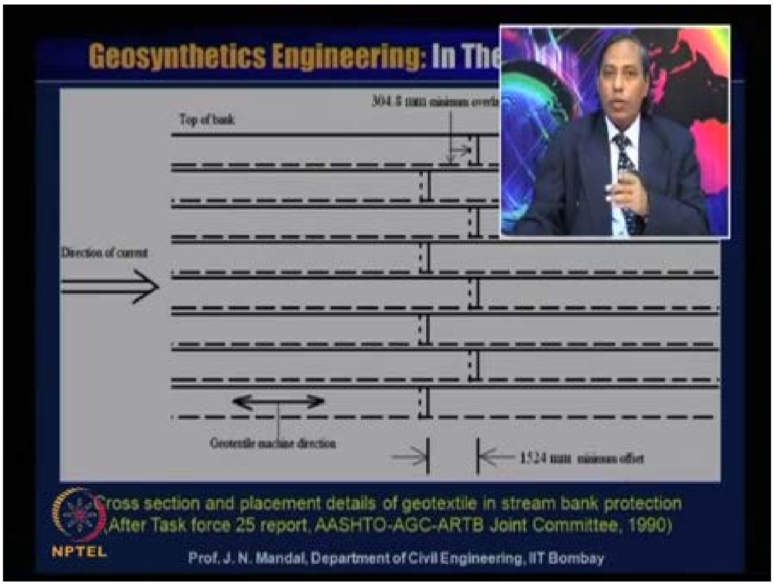

Here, same that cross section and placement detail of geotextile in stream bank protection, this is as per a task force 25 report or AASHTO-AGC-ARTB Joint Committee 1990. This is geotextile in the machine direction and this is that minimum that offset, that is 1524 millimetre, this is the minimum offset is required, and this is 304.8 millimetre minimum is offset is required, this is the top block and direction of the current in the direction, and geotextile machine direction should be this direction. So, you remember that what should be the direction of the placement of the geotextile material, for the erosion control, so whether it is the machine direction or cross machine direction.

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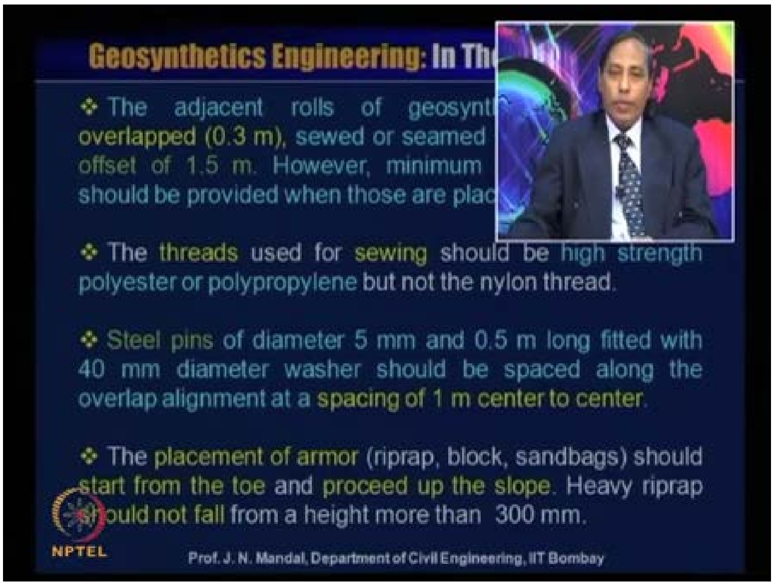

The adjacent role of the geosynthetics should be overlapped, let us say 0.3 metre sewed or seamed keeping a minimum offset of 1.5 metre; however, minimum 1 metre overlap should be provided, when those are placed under water. The thread used for sewing should be high strength polyester or polypropylene, but not the nylon thread, steel pins of diameter 5 millimetre, and 0.5 metre long fitted with the 40 millimetre diameter washer should be spaced along the overlapped alignment at a spacing of 1 metre centre to centre. The placement of armour the riprap block or sandbag should start from the toe, and process up the slope, heavy riprap should not fall from a height more than 300 millimetre, otherwise geotextile may tear it up.

The bedding layer is to be placed within 2 weeks to protect the geosynthetics from ultraviolet light it also act as a cushion, to avoid the tearing or puncturing of the geosynthetics material. So, you cannot keep the geosynthetic for a long time, because then geosynthetics material may spoil due to the vandalism or ultraviolet light, and you also provide that some sand layer at the subgrade to prevent the geotextile from the tearing. So, you can provide a, it will act as a cushion in case of geocell or jute or coir geotextile sheets can be placed for new vegetation, it is root structure provide strength to the soil to hold in place. The vegetation provide shelter from the wind and rain over the long term, as the vegetation mature it degrade leaving completely natural environment.

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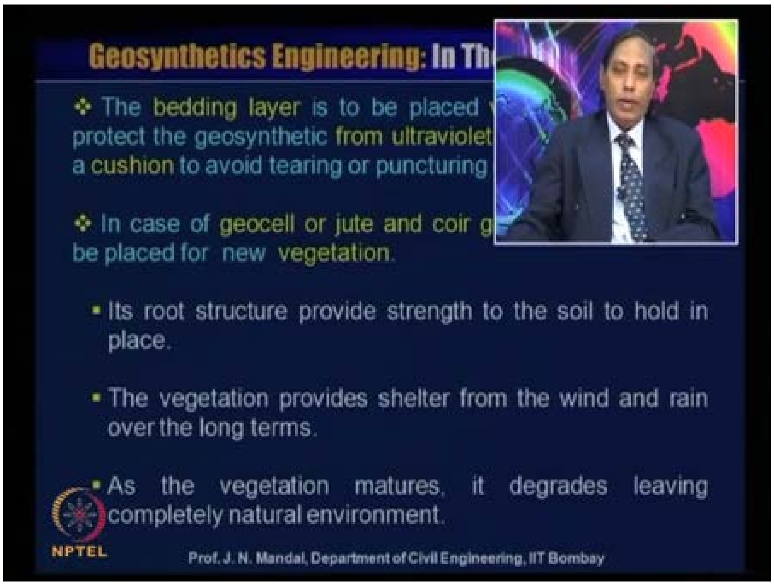

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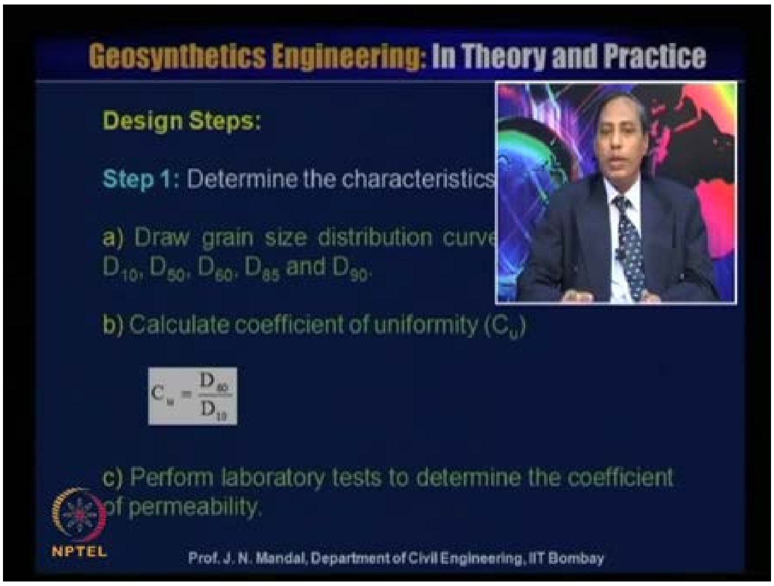

So, you can make a grain, so some design step, step 1 determine the characteristics of the field soil a draw the grain size distribution curve, and calculate all this D 10, D 50, D 60, D 85, D 90. Calculate coefficient of uniformity, that is C u is equal to D 60 by D 10 c perform laboratory test to determine the coefficient of permeability.

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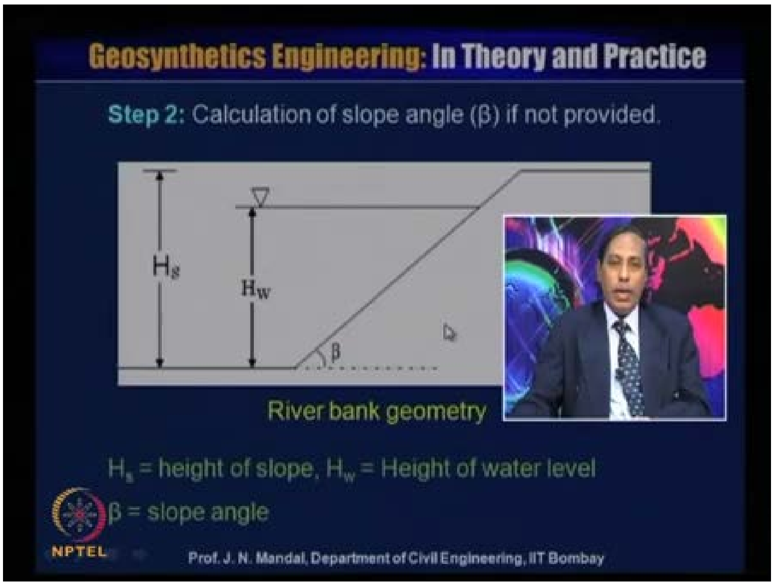

Then step 2 calculation of slope angle this is beta you have not provided, so this is a 1 river bank geometry, and this is the height of the slope, and this is the height of the water level and this angle is beta.

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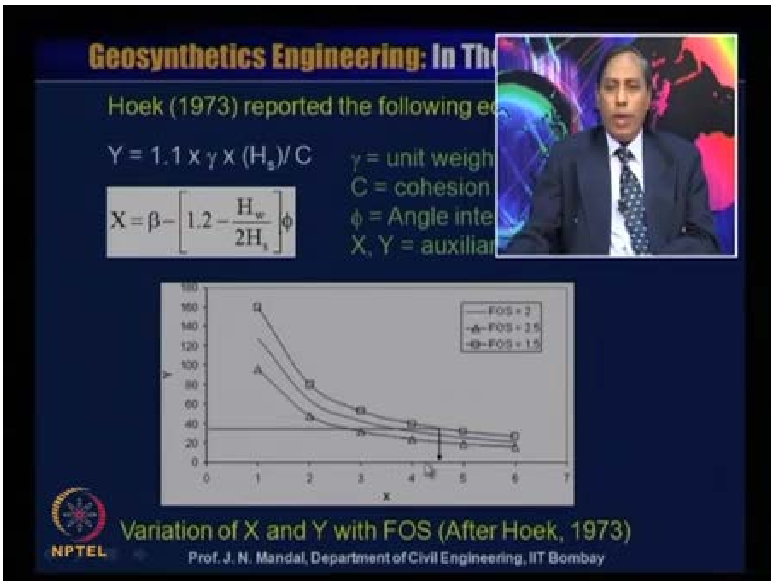

So, you have to calculate what will be the slope angle, now Hoek 1973 reported the following equation, that is y is equal to 1.1 into gamma into H s by C, gamma is equal to unit weight of soil, C is equal to cohesion of the soil, phi is equal to angle of internal friction of the soil. And X is equal to beta minus 1.2 minus H w by 2 H s into phi, for this phi is equal to angle of internal friction of the soil, and X and the Y are the auxiliary factors, and C is the cohesion of the soil. So, here this figure shows the variation of X and Y with different factor of safety, this is given after Hoek 1973, here you have drawn the curve in between the X and Y under different factor of safety, that is 1.5, 2.5 and 2, so you can see these are the curve 1.5 to 2.5 etcetera.

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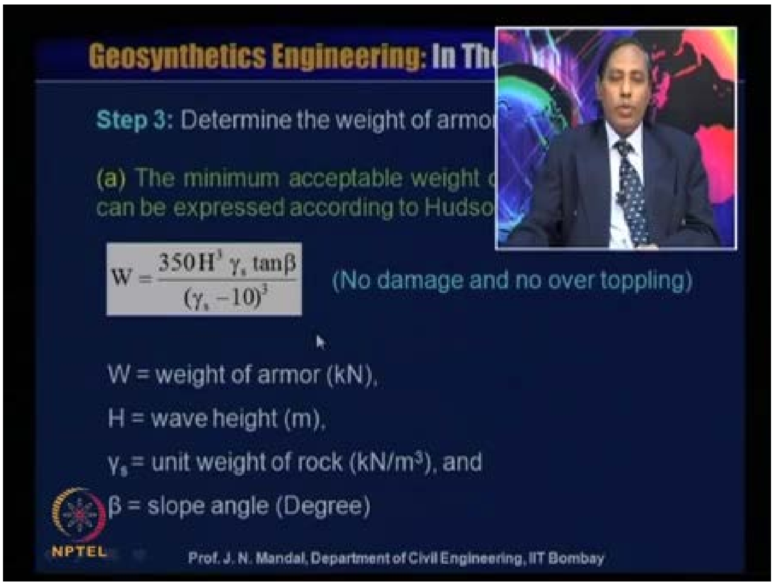

Now, step 3 determine the weight of the armour, a the minimum acceptable weight of the armour stone W can be expressed according to Hudson formula 1959, that is W is equal to 550 H cube gamma s tan beta divided by gamma s into 10 whole to the power cube. And here, no damage and no over toppling has been considered, where W is equal to weight of the armour is kilo Newton, H is the wavelength metre gamma is unit weight of the rock that is kilo Newton per metre cube, and beta is slope angle. So, from this equation you can also calculate what should be the weight of the armour.

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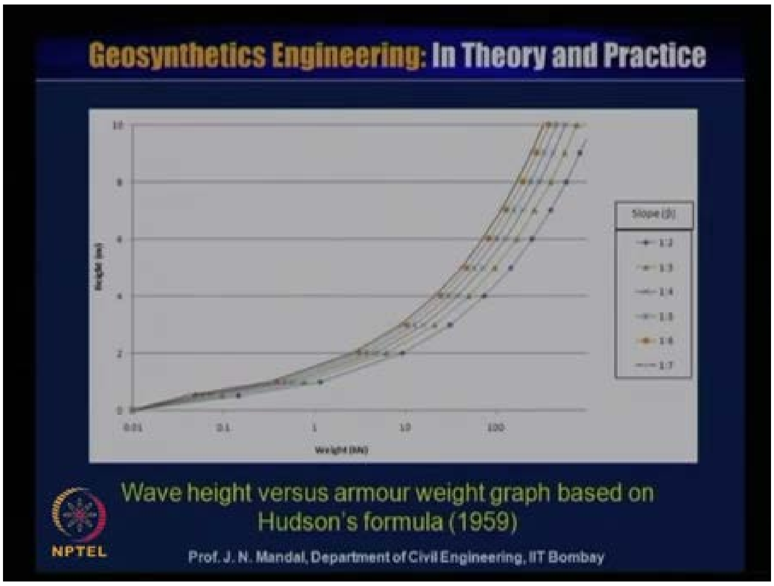

Now, in this figure shows the wave height versus the armour weight graph based on the Hudson formula, so this is for different slope, 1 is to 2, 1 is to 3, 1 is to 4, 1 is to 5, 1 is to 6, 1 is to 7. So, you can see that what will be the nature of the curve between the weight, this is in kilo Newton, and the height is metre, so if you know that what kind of the wave height. It is a 1 metre, 2 metre, 3 metre, 4 metre, 5 metre, 8 metre, and what should be the slope, you know what should be the slope whether it is 1.2 1.3, 1.4, 1.5, 1.6, 1 is to 6, 1 is to 7, then you can calculate, what should be the weight, whether it is a 1 kilo Newton, 10 kilo Newton, 100 kilo Newton, etcetera.

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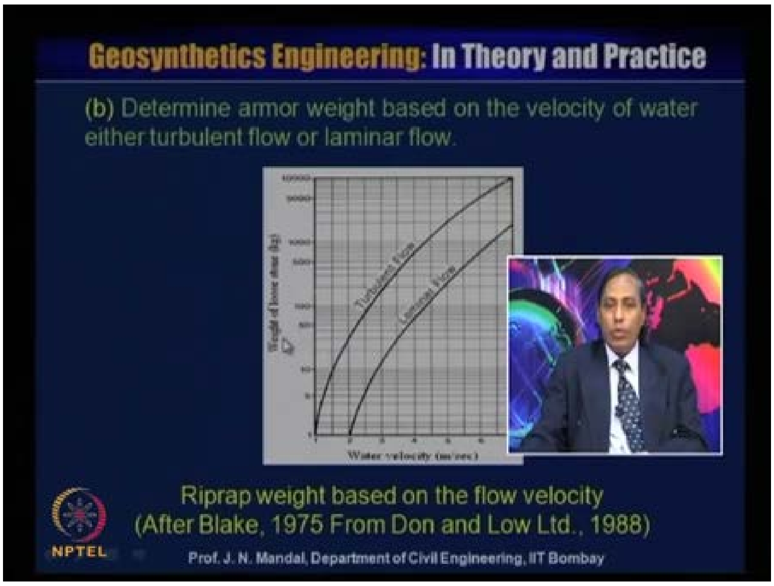

So, from this curve you can calculate that what should be the weight, this is also be determine the armour weight based on the velocity of water, either turbulent flow or laminar flow. Here, Blake in 1975, and Don and Low, 1988. So, the both the curve whether it is a laminar flow, whether it is a turbulent flow, this curve is between the what will be the water velocity metre per second, and the weight of the loose stone is k g. So, if you know that what will be the water velocity, and if you know whether it is a laminar flow or the turbulent flow, then correspondingly we can calculate that what will be the weight of the loose stone from this figure.

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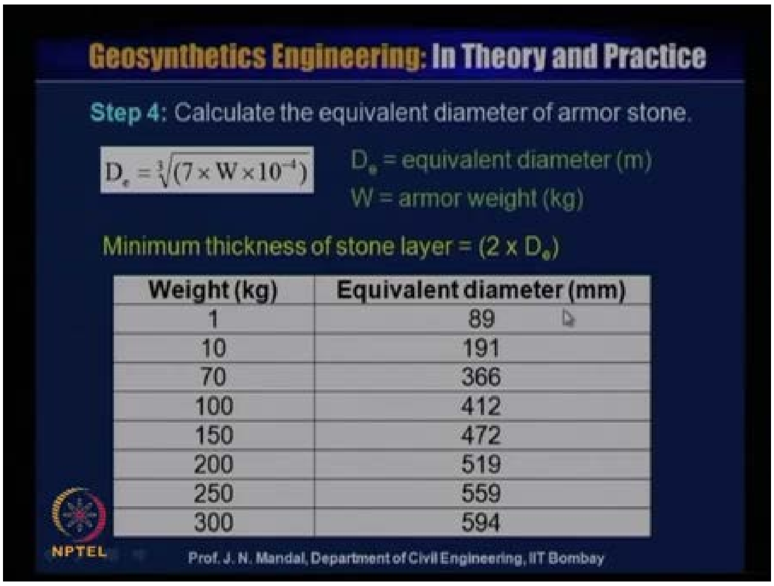

Weight (kg)	Equivalent diameter (mm)
1	89
10	191
70	366
100	412
150	472
200	519
250	559
300	594

Step 5 also calculate the equivalent diameter of the armour stone, so this the equation D e is equal to root 3 7 W into 10 to the power minus 4, which D e is expressed as equivalent diameter in metre, and W is the armour weight in k g. So, here table have been tabulated, that what should be the different weight, and corresponding the equivalent diameter in millimetre. If weight is 10, then equivalent diameter of the stone will be 191 millimetre, it was a 70 366, 100 412 millimetre, like the 200 519 millimetre, 300 594 millimetre, like this. So, from this table also you can take that what should be the equivalent diameter for that weight, and minimum thickness of the stone layer should be 2 into D, this you remember that minimum thickness of the stone layer always will be 2 into d e; that means, equivalent diameter of the stone.

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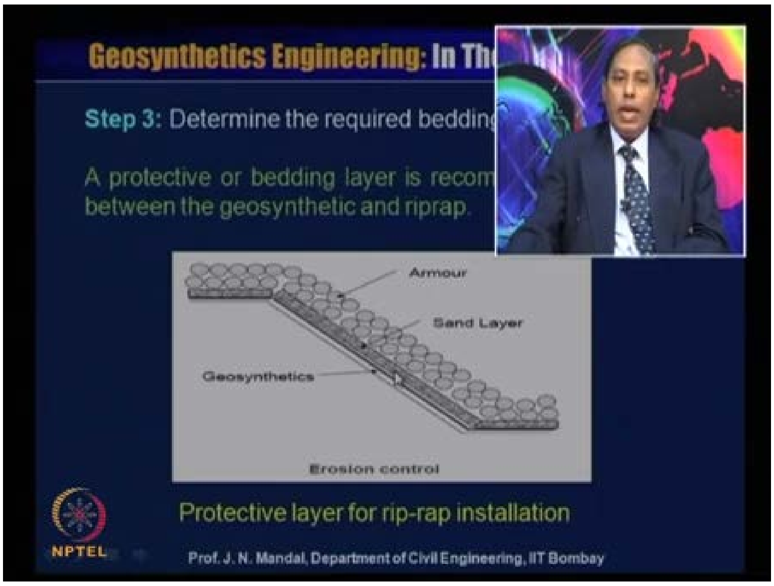

Step 3 determine the required bedding, so if this is the subgrade this is the erosion control let it problem, we are placing this geosynthetics material here, so you need a protective layer between the geosynthetics and the riprap. Otherwise, the geosynthetics material if you place directly, the stone armour stone on the geosynthetic material then geosynthetics material may tear up or damage.

So, that is why it was required a protective layer or bedding layer, this is recommended to provide between the geosynthetics and the riprap. And because when you are dumping this geosynthetics material, there is a possibility for the impact damage during the installation, and also there is a possibility for abrasion damage due to the wave. So, it will be direct contact with the armour or the aggregate with geotextile, and there is a possibility for the abrasion damage due to the wave action, so it is recommended to provide a bedding layer in between geosynthetics and the armour stone material.

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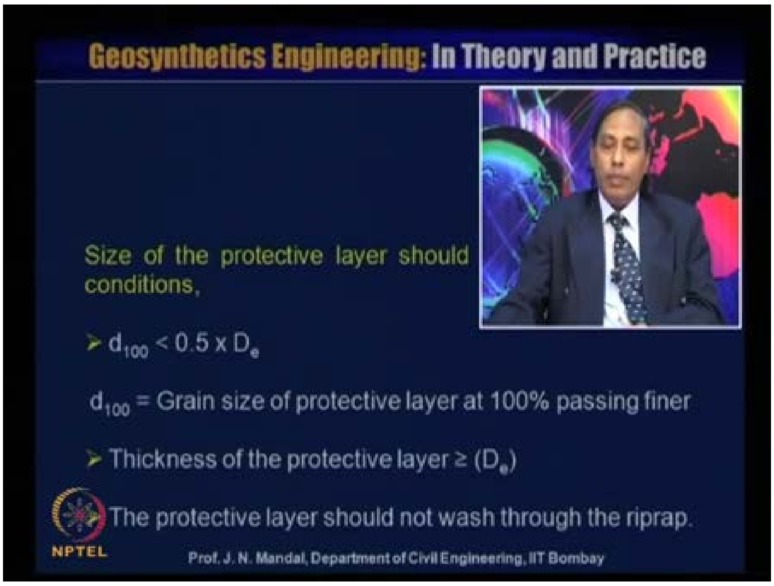

So, this will act as a protective layer for riprap installation, it is also important the size of the protective layer, should satisfy the following condition that is d 100 should be less than 0.5 into D e. D 100 is the grain size protective layer at 100 percent passing finer, and thickness of the protective layer should be greater than equal to D e, so protective layer should not wash through the riprap.

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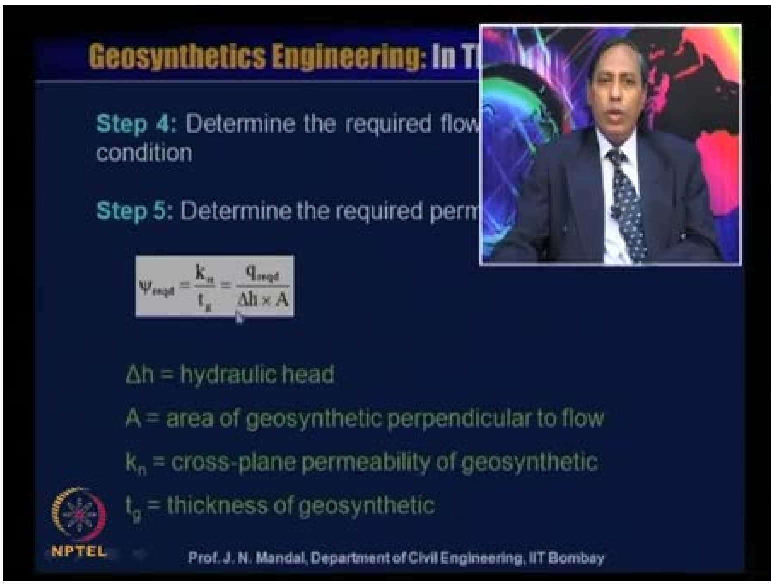

Step 4 determine required flow rate, q require in the field condition, step 5 determine the required permittivity psi required, so psi required you know the equation that is k n by t g q required by delta h into A. So, you know that what is the delta h hydraulic head, and A area of geosynthetic perpendicular to the flow, k is cross plane permeability of geosynthetics t g is equal to thickness of the geosynthetic material.

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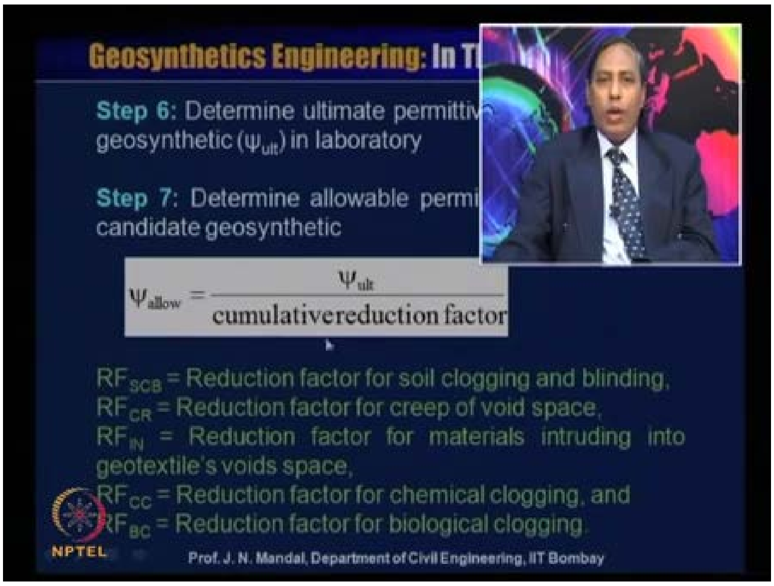

Step 6 determine the ultimate permittivity of the candidate geosynthetics, psi ultimate in laboratory, step 7 determine the allowable permittivity of the candidate geosynthetics, so psi allowable will be equal to psi ultimate by cumulative reduction factor. So, this cumulative reduction factor, it may be due to reduction factor for SCB; that means, reduction factor for soil clogging and blinding.

Then reduction RF CR that is reduction factor for creep of void space, RF IN reduction factor for material intruding into the geotextile void space, RF CC reduction factor for chemical clogging, and RF BC reduction factor for biological clogging. This is also given by the professor Koerner, and then for this erosion control application, so what this reduction factor, you should consider. And then based on that you can calculate that what will be the cumulative reduction factor, then you can determine that what will be the allowable permittivity of the candidate geosynthetics.

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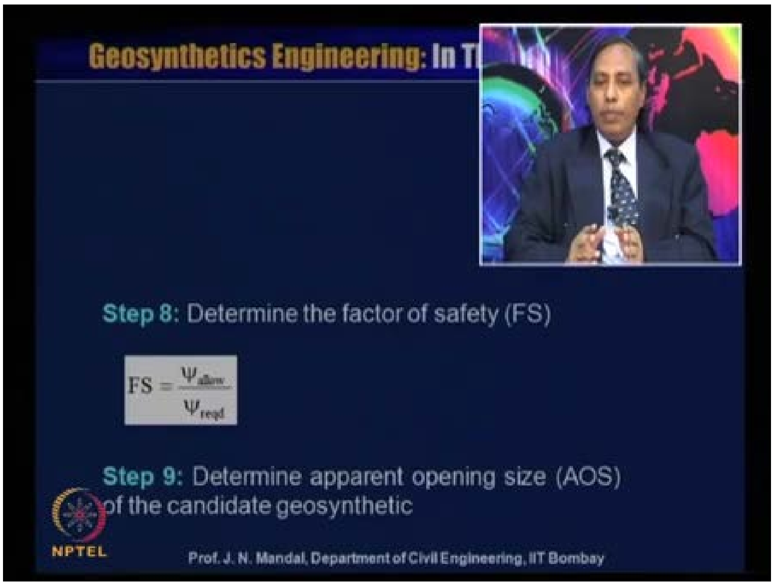

Step 8 determine the factor of safety, so factor of safety will be equal to psi allowable by psi required, step 9 determine apparent opening size that mean AOS of the candidate geosynthetics. So, this we require for the design, so when you will design you should follow up all the step, you have take care about the flow related problem, you have to take consideration of the apparent opening size of the geosynthetics material or the equivalent opening size of the geotextile material.

And we have to be taken care for that there should may not be any damage, when the riprap or stone are installation directly on the geotextile material. So, you require proper kind of the bedding system, so that bedding system will act as a cushion, now universal soil loss equation that is USLE for the slope erosion, now universal soil loss equation that is Wischmeier and Smith 1960 reported.

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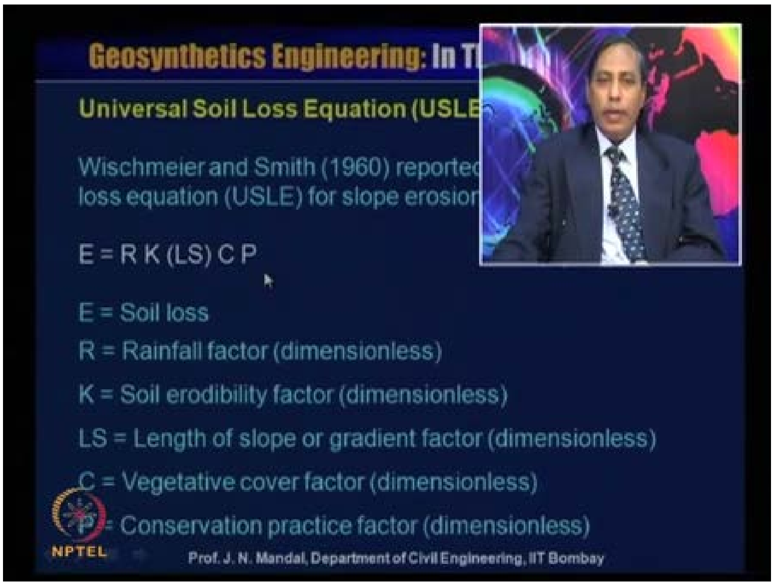

The universal soil loss equation that is USLE for slope erosion, so he has given this equation that is E is equal to R into K LS C P, where E is equal to soil loss, R is equal to rainfall factor that is dimensionless. And K is equal to soil erodibility factor that is also dimensionless, and LS the length of the slope or gradient factor that is dimensionless, and C is vegetative cover factor that dimensionless, and P is conservation practice factor that dimensionless. So, from this equation also you can calculate that what should be the soil erosion.

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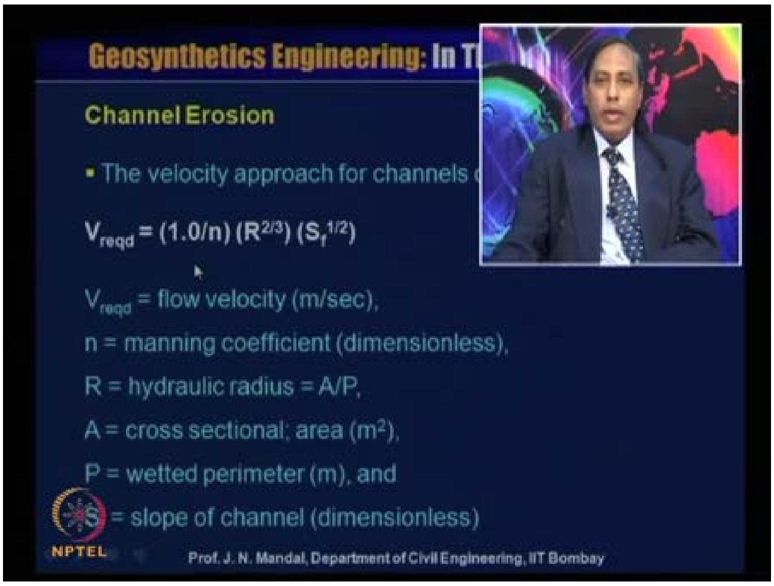

Now, for channel erosion the velocity approach of channel can be expressed as, V required is equal to 1.0 by n R to the power 2 by 3 into S f to the power half, where V required is the flow velocity, that is metre per second. And n you know manning's coefficient which is dimensionless, R is equal to hydraulic radius; that means, that is A by P, and A is equal to cross sectional area metre square, and P is wetted perimeter metre and S f is the slope of the channel, which is dimensionless. So, for the channel erosion you can also calculate the velocity, so what is required for the channel.

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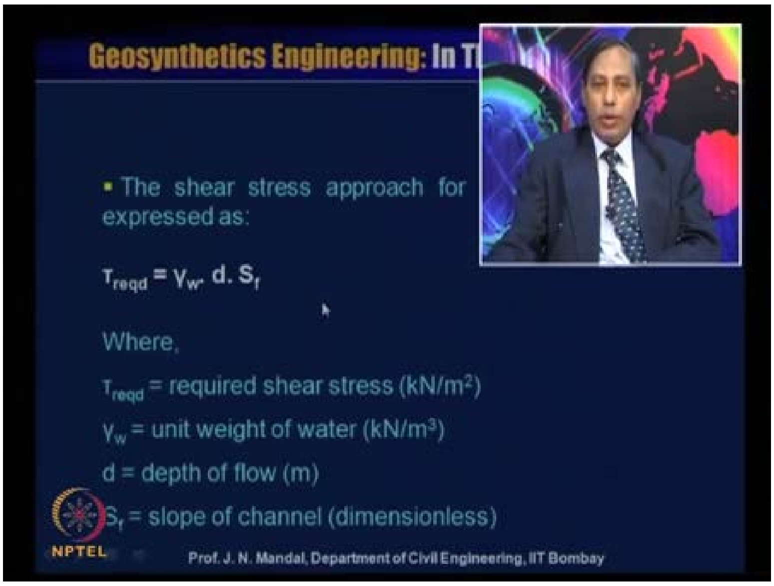

Now, there is a development of shear stress approach for channel, can be also expressed as t required is equal to this is gamma w into d into S f, where T required is equal to required shear stress that is kilo Newton per metre square. Gamma w is unit weight of water kilo Newton per metre cube, and d is the depth of flow in metre, S f is slope of channel is dimensionless, so you can calculate what will be the required shear stress using this equation.

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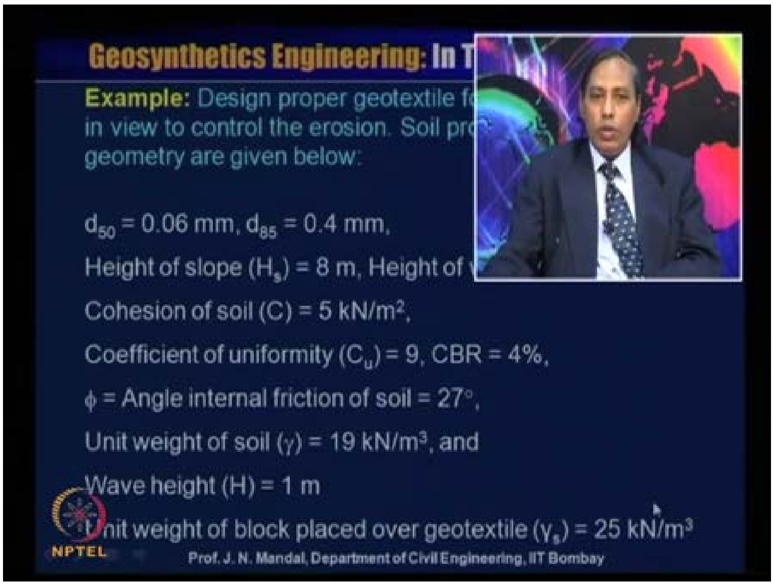

This one example design proper geotextile for placing at a river bank in view to control the erosion, soil properties and the river bank geometry are given, and these are the data is given D 50 is 0.06, millimetre, D 85 0.4 millimetre. This we can have grain size distribution curve of the soil, height of the slope let us say H s is equal to 8 metre, height of the water level H w is equal to 5 metre.

Cohesion of the soil C is equal to 5 kilo Newton per metre square, coefficient of uniformity C u is equal to 9, and CBR value is equal to 4 percent, phi angle of internal friction of the soil is equal to 27 degree. Unit weight of soil gamma 19 kilo Newton per metre cube, and the wave height H is 1 metre, and unit weight of block placed over the geotextile gamma S is 25 kilo Newton per metre cube, this is the unit weight of the block.

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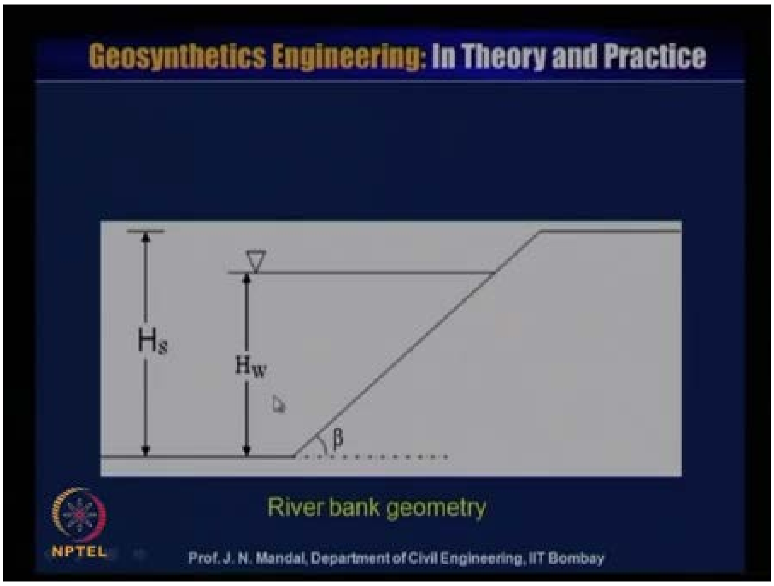

Now, we can see here river bank geometry, this is height of the slope H s, this is angle beta this is the water level height is H w and this is the solution.

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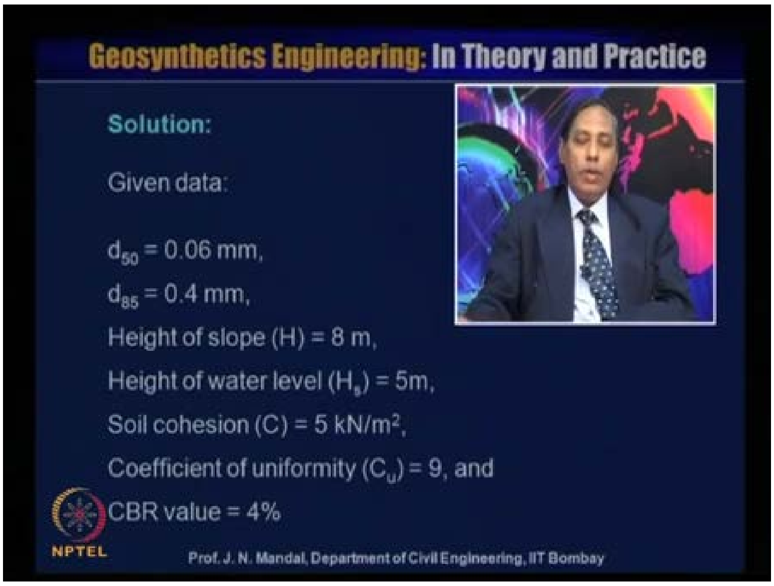

So, these are the data given D 50 is 0.06 millimetre, D 85 0.4 millimetre, height of the slope H is 8 metre, height of the water level H s is 5 metre soil cohesion C is equal to 5 kilo Newton per metre square, and coefficient of uniformity C u is 9, and CBR value is equal to 4 percentage.

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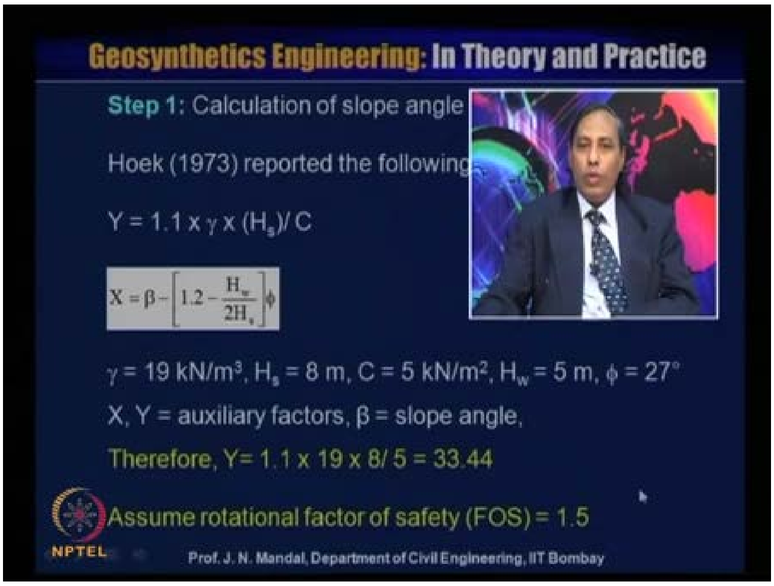

Now, step 1 we calculate of the slope angle; that means, Hoek 1973 reported the following equation that is y is equal to 1.1 into gamma into H s by C, and x is equal to beta into 1.2 minus H w by 2, H s into phi. And we know gamma is equal to 19 kilo Newton per metre cube, H s is equal to 8 metre, C is equal to 5 kilo Newton per metre square, H w is equal to 5 metre, phi is equal to 27 degree. So, you substitute this value into this equation, where X and Y is the auxiliary factor and beta is equal to slope angle. So, you can have y is equal to 1.1 into gamma, gamma is 19 into H s, your H s is 8 metre this divided by C, C is 5, so you can have y value is equal to 33.4, so if you assume the rotational factor of safety FOS is equal to 1.5.

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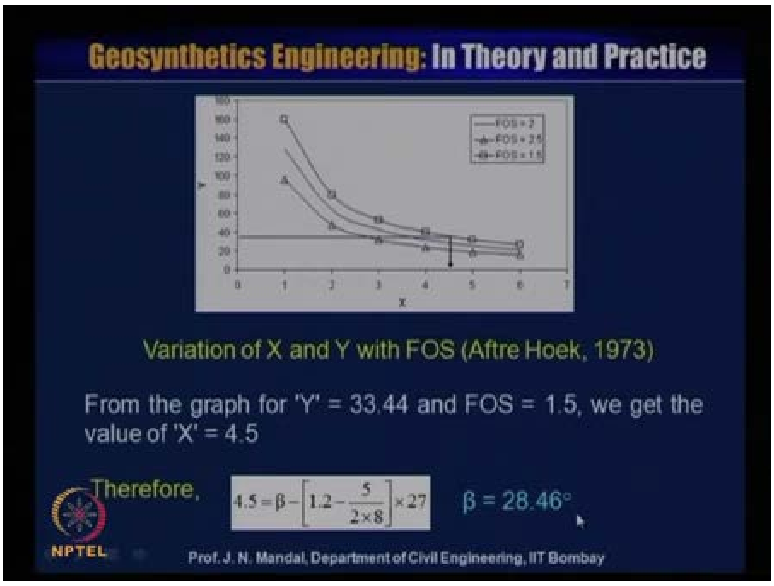

Now, you can draw the variation of X and the Y factor, this is after Hoek, 1973 for the different factor of safety value, so we have shown you also, earlier from this curve when you know that Y value is equal to 33.44. So, you know that Y value is 33.44, and you have considered this factor of safety 1.5; that means, this is factor of safety 1.5 for this curve. So, knowing this Y value 33.4, and the factor of safety 1.5, so you get the value of X, and this X value is about 4.5, so that is why this X value is 4.5.

So, therefore, you know this equation X is equal to beta, this equation is known to you, so then you got X is equal to 4.5 is equal to beta into 1.2, and other value H w, H s, H w also you know 5, H s also you know 8, and phi 27 degree. So, if you substitute this value here 5 2 into 8 into 27, so from this equation you can determine what will be the beta angle, so beta angle is 28.46 degree, so you can calculate what should be the beta angle.

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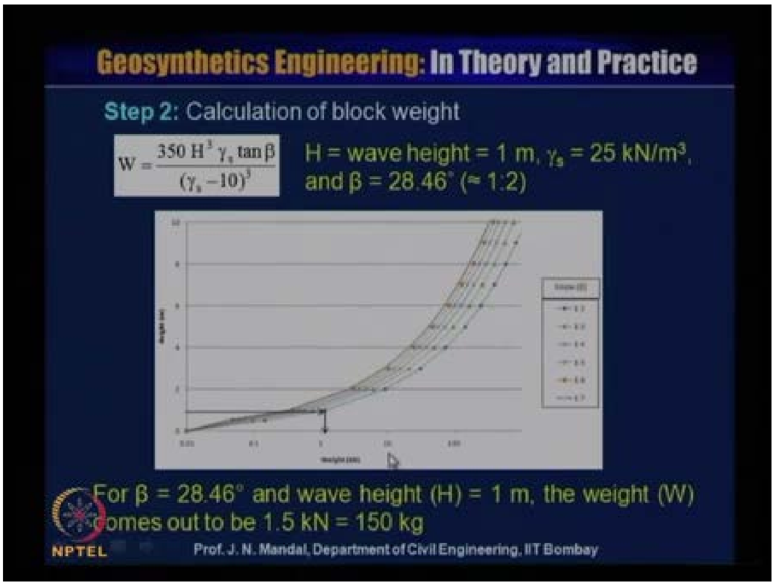

Step 2 calculation of block weight; that means, w is equal to 350 into H cube gamma S tan beta divided by gamma S minus 10 whole to the power cube, where H is equal to wave height is equal to 1 metre. And gamma S is equal to 20 kilo Newton per metre cube and beta is equal to 28.46 degree that is approximately 1 is to 2 ratio. Now, here is the figure which show the height versus the weight, for the different slope angle beta,, it may be 1 is to 2, 1 is to 3, 1 is to 4, 1 is to 5, 1 in to 6 and 1 is to 7 like this.

So, from this figure if you know that what is the wave height in that area, and the slope angle, then you can calculate what should be the weight of the armour stone, so here beta is 28.46; that means, this is the approximately 1 is to 2 ratio. So, we know that wave height H is 1 metre, so from this when height is 1 metre, you draw the horizontal line, and you see that this is the figure for the slope 1 is to 2 or 28.46 degree. Then you go vertically downward, then you can have the weight, this weight comes out to be 1.5 kilo Newton over 150 k g.

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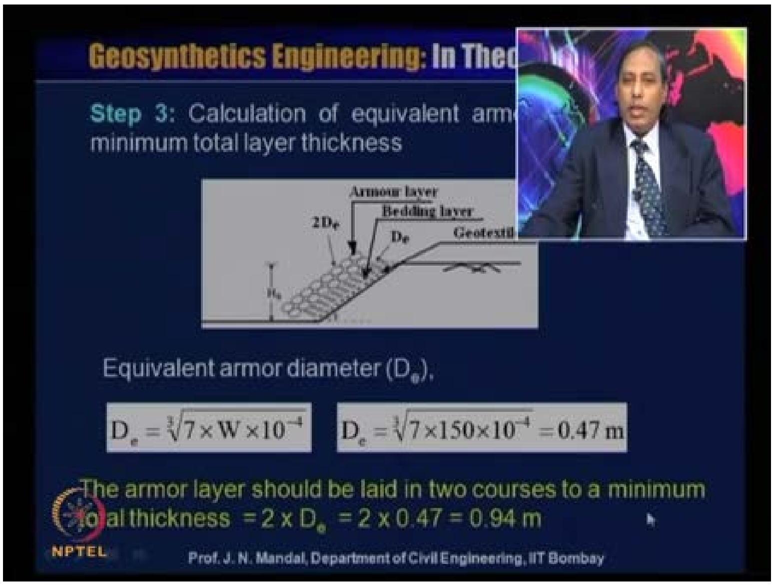

Step 3 calculation of equivalent armour diameter minimum total layer thickness, so this is the armour layer, I say that you provide with the some bedding layer between the geotextile. And the armour stone to prevent from the puncturing or damaging the geotextile material, so you have to provide that what will be the equivalent armour diameter.

So, equivalent armour diameter D e you can use this equation root over cube into 7 W 10 to the power minus 4, so from this d you can calculate root cube 7 and W you have calculated this 150 k g. So, you substitute the value of W 150 into 10 to the power minus 4 is equal to 0.47 metre, the armour layer should be laid in two courses to a minimum total thickness 2 into D e. I mention that always that two time of d to 2 into D e, so D e is 0.47 metre, so 2 into 0.47 metre means 0.94 metre, so you remember that you have to be placed of the thickness.

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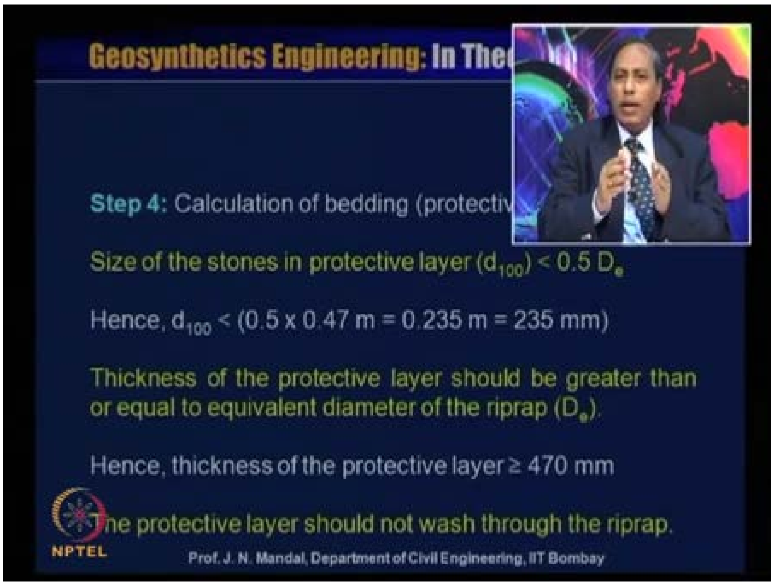

Step 4 calculation of bedding protective layer, so size of the stone in the protective layer is D 100 should be less than 0.5 into D e, hence D 100 less than 0.5 into D e of we have calculated 0.475 metre here 475 metre D. So, 0.5 into 0.47 metre is equal to 0.235 metre is equal to 235 millimetre, so thickness of the protective layer should be greater than or equal to equivalent diameter of the riprap that is D e. Hence, thickness of the protective layer should be greater than equal to 4 into 70 millimetre, so 470 millimetre, so it should be always greater the protective layer should not wash through the riprap.

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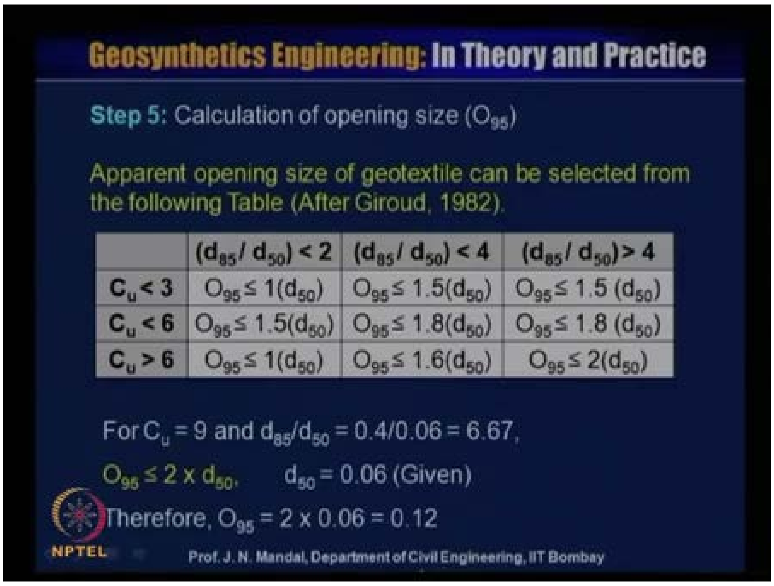

Step 5 calculate the opening size; that means, O 95 apparent opening size of the geotextile can be selected from the following table after Giroud, 1982 you know that for different value of C u and from this table. You can calculate that what should be the apparent open size of the geotextile; that means, O 95 that is very important, so here we know for C u is equal to 9 D 85 by D 50 all what we have we have from the grain size distribution curve, that is 0.4 by 0.06 is equal to 6.67.

So, you can see that C u is 9 that mean greater than 6, and D 85 by D 50 is 6.67, you see where is D 85 by D 50, D 85 D 50 is greater than 4; that means, D 85 by D 50 is 6.67 means greater than 4, and C u also greater than 6. So, you have to adopt O 95 should be less than or equal to 2 into D 50, you know C u 9 that mean greater than 6, you know D 85 by D 56.7 greater than 4. So, for this C u greater than 6, hence D 85 greater than 4. So, you have to adopt this equation; that means, O 95 should be equal to 2 into D 50, and D 50 value is given 0.06. So, therefore, O 95 should be 0.12, so you know how to calculate the apparent opening size of the geotextile material.

So, this is very important that you should know how to calculate the apparent opening size of the geotextile material, also there is also lot of hybrid material have been introduced. Where, this is very high flow capacity, which is some of the you know that about the wick drain, you know about the swift drain, you know about the highway edge drain, and these hybrid also material. This is a spectacular that application in geosynthetics engineering, and also there will be a thrilling development of the different types of the geocomposite material is coming up.

So, what you have learnt, that you know that how to control the erosion control, erosion control is very important issue to us and particularly in India, you have seen that what type of the erosion control. What type of the flood how there is a damage of the house, the people, the land, the agricultural land, how the people are being suffering, so you require proper kind of the system to control the erosion. And we are using lots of money we are spending lots of money to control the erosion, but you need proper kind of the system proper kind of the technology to adopt, then you can control the erosion control system, please let us hear from you any question thanks for hearing.