Geosynthetics Engineering: In Theory and Practice
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Lecture - 36
Geosynthetics for Steep Slopes

Dear students, warm welcome to NPTEL phase two video course on geosynthetics engineering in theory and practice. My name is Professor J N Mandal, Department of Civil engineering, Indian Institute of Technology, Bombay, Mumbai, India. The name of the course is geosynthetics engineering in theory and practice, this lecture number 36. Now, this is module 7 and lecture number 36 Geosynthetics for Steep Slope.

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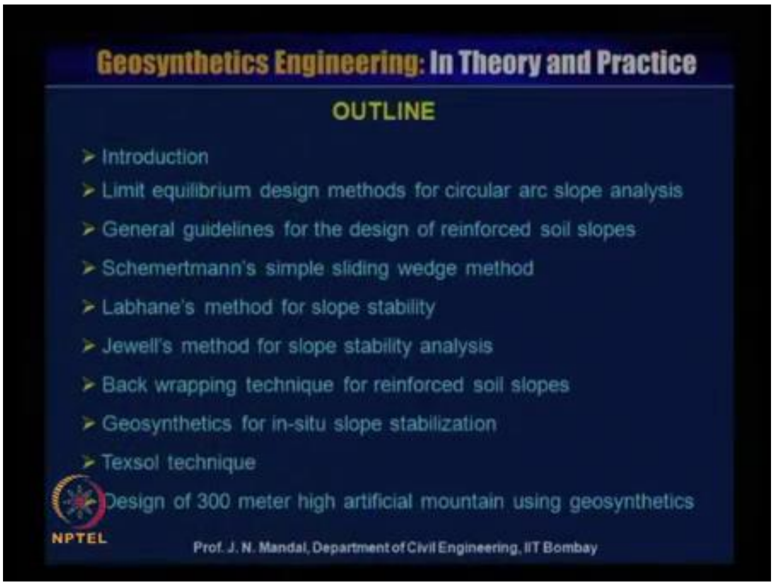

The outline of this course is introduction, limit equilibrium design method for circular arc slope analysis. General guidelines for the design of reinforced soil slope, Schemertmann's simple sliding wedge method, Labhane's method for slope stability, Jewell's method for slope stability analysis, back wrapping technique for reinforced soil slope, geosynthetics for in-situ slope stabilization, texsol technique and design of 300 meter high artificial mountain using geosynthetics.

So, regarding this steep slope stability there are use of the geosynthetics material to reinforce the steep slope or the embankment are very common. In general, if the slope angle is less than 70 degree, we can consider it is as a steep slope. And we will use the limit equilibrium method by a circular arc failure plain. This kind of the steep stability problem also can be applied for the reconstruction of the failure slope, which can add in compaction at the face of the slope. Also there is a possibility to reduce the surface erosion.

Now, a days the lot of NH1 project are going on where it is required to reconstruct a major highway also gaining of additional slope at both at the toe as well as top of the slope, where you require; what will be the length of the reinforcement, what will be the spacing between the two geogrid layer? So, detail slope stability method are nicely adopted by various computer modeling. I will show you some of the design chart, where the number of the explain design chart also are available in which, we can use and we can solve the various problem related with the slope stability.

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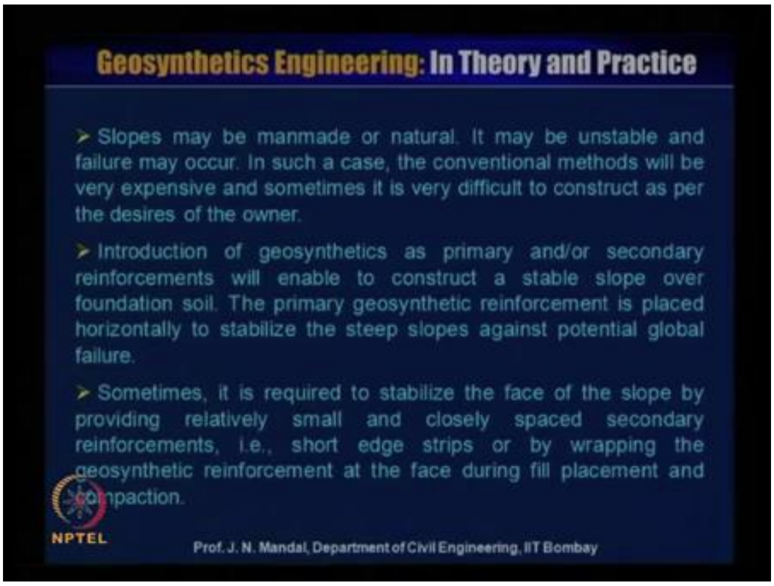

Now, you know slope may be manmade or the natural. It may be unstable and failure may occur in such a case the conventional method will be very expensive. Sometimes, it is very difficult to construct as per the desire of the owner introduction of geosynthetics as primarily and or secondary reinforcement will enable to construct a stable slope over foundation soil. The primary geosynthetics reinforcement is placed horizontally to stabilize the steep slope against the potential global failure.

Sometimes, it is required to stabilize the face of the slope by providing relatively small and closely spaced secondary reinforcement, I will show later what is the secondary reinforcement? How you can place the secondary reinforcement in a slope and why it is required to introduce, the secondary reinforcement along with the primary reinforcement along the facing of the slope? So, this is a short edge strip or by wrapping the geosynthetics reinforcement at the phase during fill placement and the compaction.

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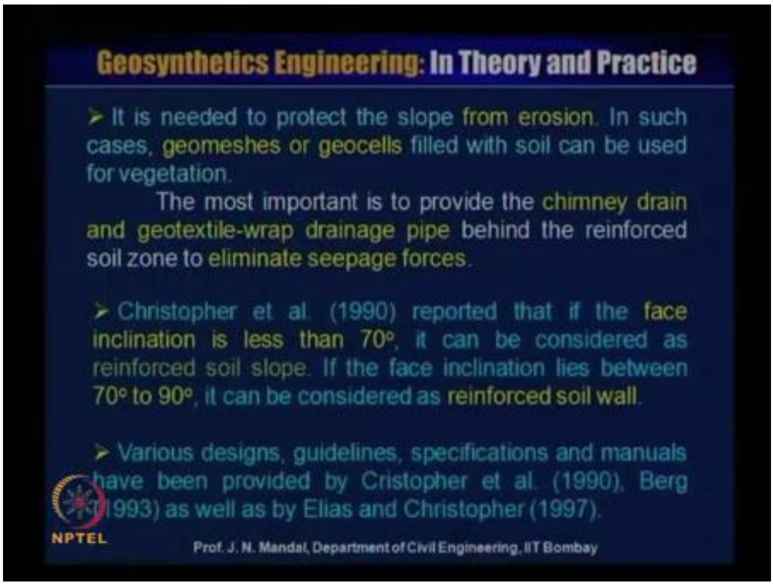

So, this it is needed to protect the slope from the erosion in such case geomeshes or geocell filled with the soil can be also used for vegetation. The most important is to provide the chimney drain and the geotextile wrap drainage pipe behind the reinforced soil z 1 to eliminate the seepage forces. It is also very important as in the case of the reinforced soil retaining wall. You have to provide with the drainage at the back of the geogrid reinforced soil retaining wall.

Similarly, for in the case of the reinforced soil slope you should also provide proper kind of the drainage behind the reinforced soil z 1 and that will eliminate the seepage forces. Christopher Et Al 1990 reported that if the face inclination is less than 70 degree, it can be considered as reinforced soil slope. If the face inclines lies between the 70 to 90 degrees, it can be considered as reinforced soil wall. Various design guideline specification and the manual have been provided by Christopher Et Al 1990, Berg 1993 as well as by Elias and Christopher 1997.

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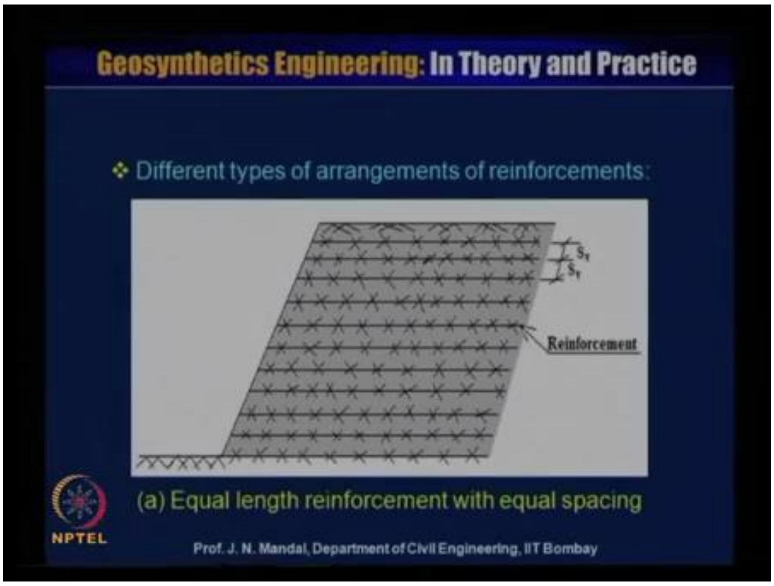

So, various geosynthetic reinforced soil specification and design also are available, so you have to know that how to design the reinforced soil steep slope and also you have to remember it should be the less than 70 degree. It may be 60 degree, it may be 50, 40, so then you can consider it is as a reinforced soil slope. If it is more than 70 degree, 80, 90 degree, then you can design on the base of the vertical reinforced soil retaining wall, which we have already covered earlier. Also, we have to be careful at the facing of the slope and facing of the slope sometimes you require for the secondary reinforcement.

That also will help you for the proper compaction near to the near to the slope of the face and as well as it is, will also eliminate the surface erosion. Sometimes, also along the slope you can provide with the geocell material, which can provide you can grass can also grow and also it will stable and you can have a very greenery slope. There are also the other kind of the system, where you can use that fiber with the soil and also the grass can grow, so this kind of the system also have been applied. So, now here you can see different types of the arrangement of the reinforcement. So, the arrangement and spacing of the reinforcement has a very important role you can see here that equal length reinforcement with equal spacing is the same, but it is the equal length. So, you have to optimize the design sometimes it is required to optimize the design.

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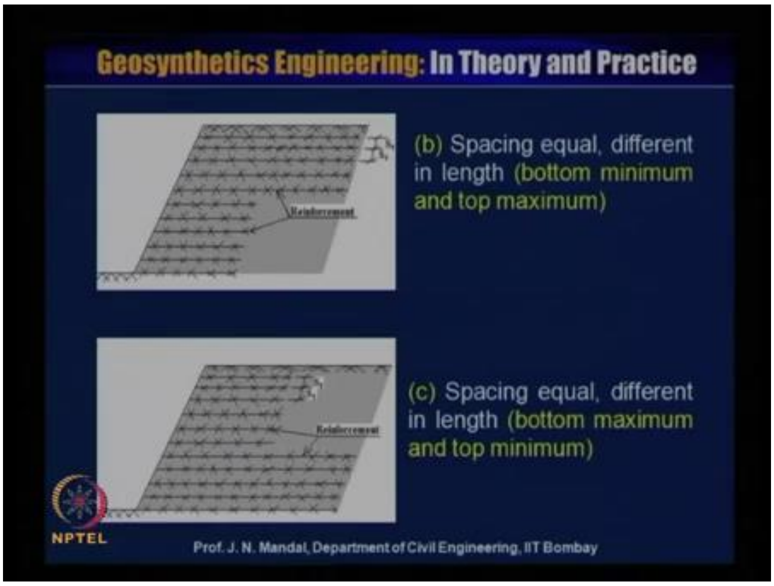

You can see that you can make a spacing is equal for different in length that bottom is minimum and top is maximum. On the other hand you can see here in the spacing is equal, but difference in the length that bottom is minimum and top is maximum. On the other hand, you can see here in the spacing is equal, but difference in length that bottom is maximum and top is minimum. So, you have to optimize you have to check, which one will be the much more stable reinforced soil slope. You can see equal spacing with the 1 layer secondary reinforcement.

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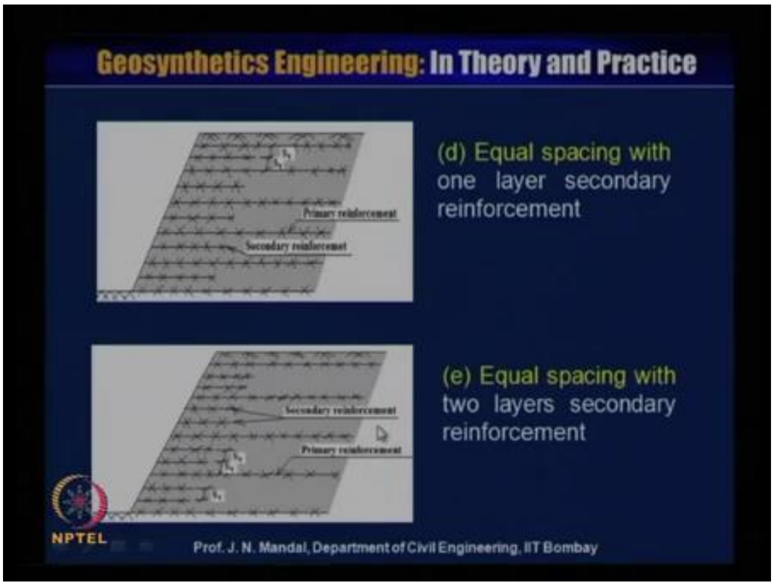

This is the larger one is the primary reinforcement, this is primary reinforcement. You can see in between there one small length of the reinforcement or the short length of the reinforcement, which you call the secondary reinforcement, but spacing is the same, but you can provide with some secondary reinforcement. So, it is equal spacing one layer with the secondary reinforcement or equal spacing with two layer of the secondary reinforcement. Sometimes, I can say that if the spacing between the two primary reinforcement is 1 meter or more than 1 meter, then it is necessary to provide with the secondary reinforcement. Sometimes, it is that one layer of the reinforcement as a secondary reinforcement and sometimes it is required two layer for secondary reinforcement.

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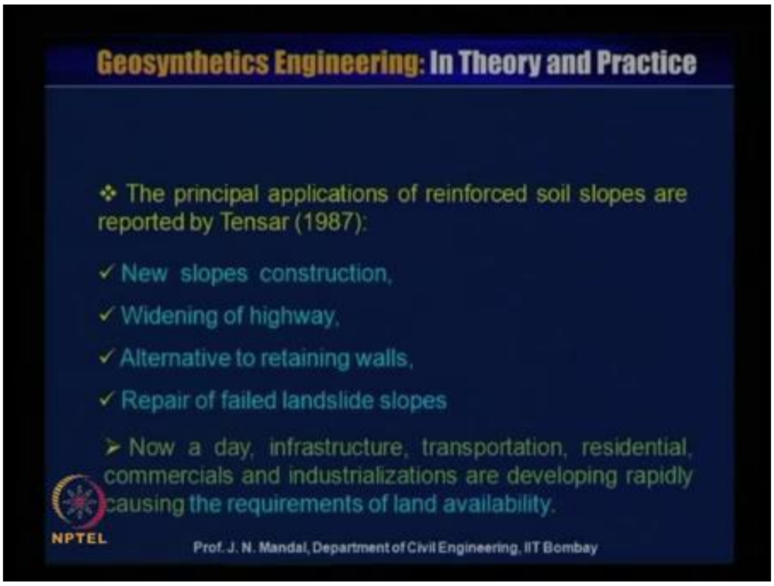

So, principal application of reinforced soil slope are reported by Tensar 1987 very new slope construction widening of the highway alternative to retaining wall repair or failed landslide slope. Now a day’s infrastructure transportation residential commercial and industrialization are developing rapidly causing the requirement of land availability.

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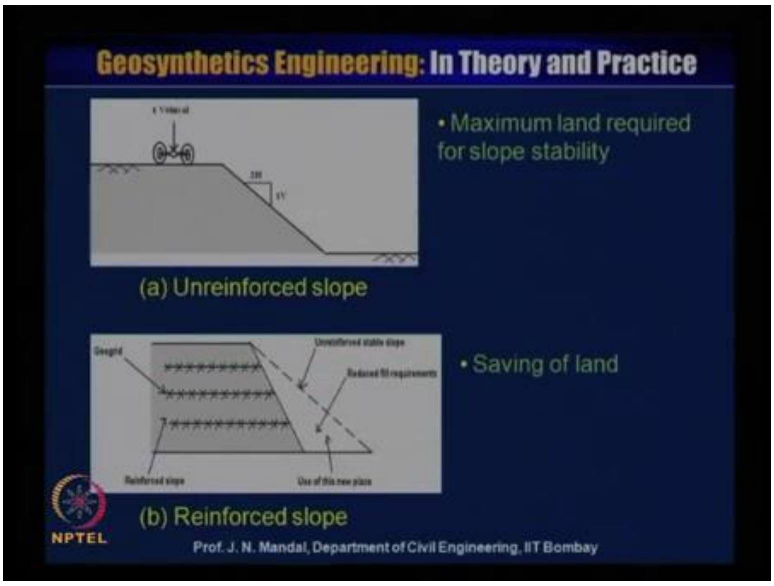

I will show you some of the figure where you can see that how you can make use of the land and how you can save the land in first. In case, that it is an unreinforced soil and for this is the vehicle can pass through this. This is a certain slope to horizontal to one vertical. So, maximum length required for the slope stability when you want to construct you have an unreinforced slope, on the other hand you can you can you can deploy the geosynthetics material, which can save this land. So, you can provide with this number of the layer of the geogrid material and construct a very steeper slope. So, this is the unreinforced stable slope, but you do not require this is unreinforced case, you can provide with the reinforced steep reinforced soil slope. So, this reduce fill is requirement, so you can this new places. This is the new places where you can use. So, you are saving a land, so by the introduction of the geosynthetics material, so you can we can see here that how you can save the land and you know that land is very expensive.

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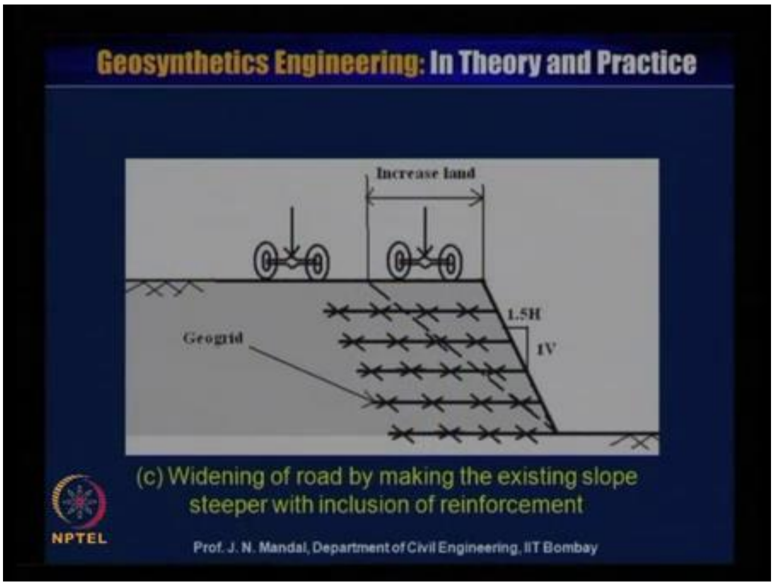

So, with respect to the conventional method if you can adopt the alternative geogrid reinforced soil slopes, if slope, then you can see how we can save the land. Also, you can widening of the road by making the existing slope much more steeper. For example, that this is the here widening of the road by making the existing slope steeper with the inclusion of the reinforcement. So, you require the steeper slope it is… For example, this is the existing road where here, where the vehicle is passing here and you want to do widening of the road in our lot of any type project, where it is required for the widening of the road.

So, if it is a widening of the road, you can see that you can introduce this number of layer of the geogrid reinforcement, you can make a slope of 1.5 horizontal to 1 at the vertical and you can increase the land. So, vehicle can pass through this. So, it is also sometimes required that widening of the road by the existing slope steeper with the inclusion of the reinforcement material, so you when it is required to increase the land. Yes, you can use the steep slope steeper slope and when it is required that you want to save the land. Yes, you can do that by introducing the geogrid reinforced steep slope. Now, instead of conventional retaining wall you can use geogrid reinforced soil wall can be constructed.

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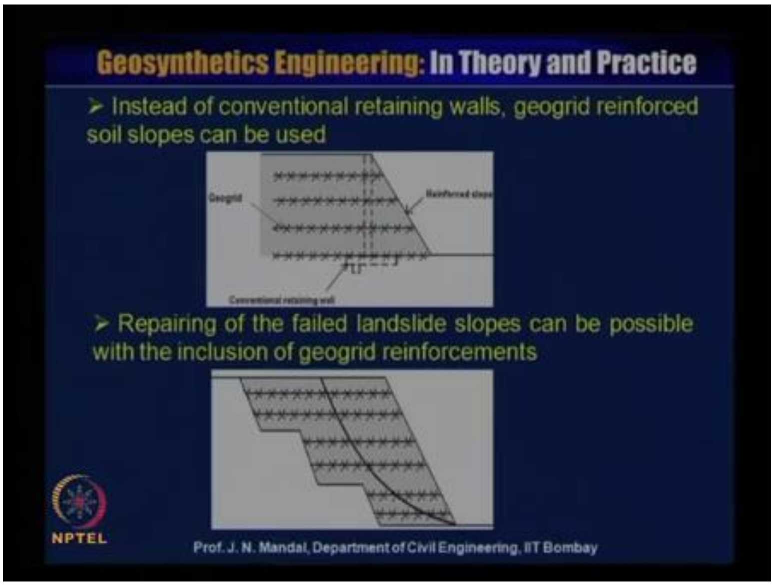

So, for example, this is the road and you are using the conventional retaining wall here conventional retaining wall, which will be the very expensive. So, instead of that you can use the geogrid reinforced slope. Why it is required you can use, so it will be much more economical. Also, repairing of the failed of any landslide slope can be possible with the inclusion of the geogrid reinforcement. Most of the landslide you can save, because proper you know design and proper you know drainage kind of the system has been applied. So, you can use this geogrid material to protect the landslide slope by the introduction of the geosynthetics material.

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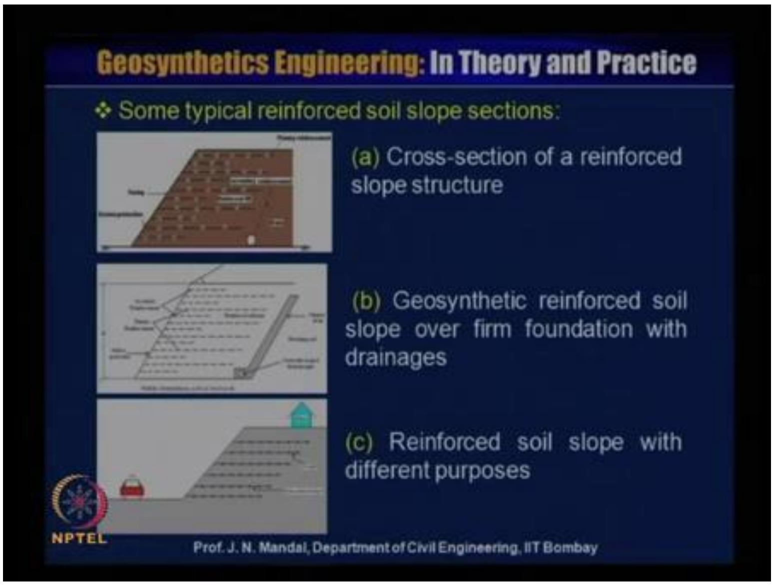

Some type of typical reinforced soil slope section is shown here. This is the cross section of the reinforced slope structure. This is the geosynthetics reinforced soil slope over the firm foundation with the drainage I am showing you here. So, this is a stable foundation of the soil or form or the foundation is a bed rock. This is the slope steep slope and this is the number of the layer of the reinforcement and this larger length of the reinforcement you consider as a primary reinforcement. This smaller or short length of the reinforcement, we considered as a secondary reinforcement and at the back of this slope. You should provide with the proper kind of the drainage system.

So, here it is the chimney drain and then you can provide with the geotextile wrapped drainage pipe here. It is geotextile wrapped drainage pipe, so this geosynthetic reinforced slope over the firm foundation with the drainage, so drainage is very important. So, most of the time if you do not provide with the drainage and there is a possibility for the failure of the structure, so you should provide the drainage. Similarly, also the reinforced soil slope also for different purpose also you can use. So, for an example that you can you can want to construct a house near to the slope, and at the bottom of the slope where the vehicle are the passing and then the house may collapse.

So, you can provide with this kind of the system, you can see here that you can make a steep reinforced slope and also you can construct a house here, also in the find some places also in the hilly area, where there is building and this portion almost is going to be collapsed. So, this it is provided with a wrap around geotextile reinforced slide slope, so that way you can protect the house in the sloping step.

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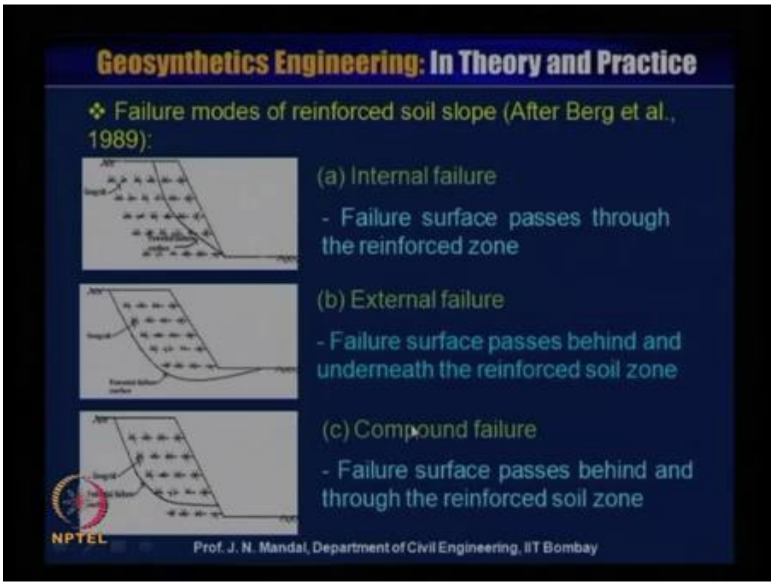

So, failure mode of the reinforced soil slope after Berg Et Al 1989 and there is a possibility for internal failure external failure and compound failure. So, this is the internal failure means failure surface passes through the reinforced z 1. This is the external failure that failure surface passes behind and underneath the reinforced soil z 1 and compound failure. The failure surface passes behind and through the reinforced soil z 1. So, there are different types of the failure it may the internal failure, external failure and compound failure, so we have to check that in terms of the factor of safety.

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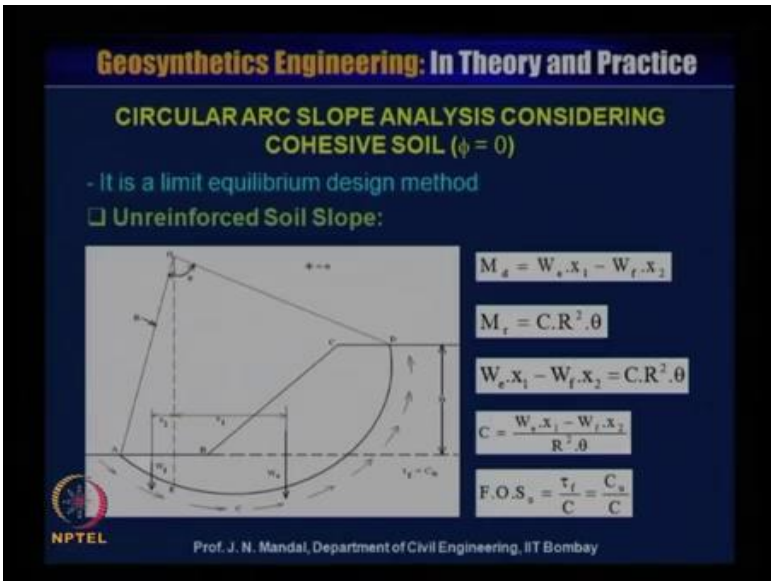

Now, what theory we will adopt for different types of the soil? So, initially I will now discuss about the conventional method, and what will be the limit equilibrium method for the design of the slope. So, if we will use the surface arc slope analysis considering the cohesive soil when phi is equal to the 0, so it is a limit equilibrium design method. So for example, that this is the stability analysis of a slope in a homogeneous clay soil, where phi is equal to the 0.

This is the foundation and this is the embankment the embankment, this is the slope here and this embankment has its own weight, which we designated as W of e that means weight of the embankment. Similarly, this part is the foundation, so this foundation also has its weight, which we call the weight of the foundation, which is designated as W of W of f.

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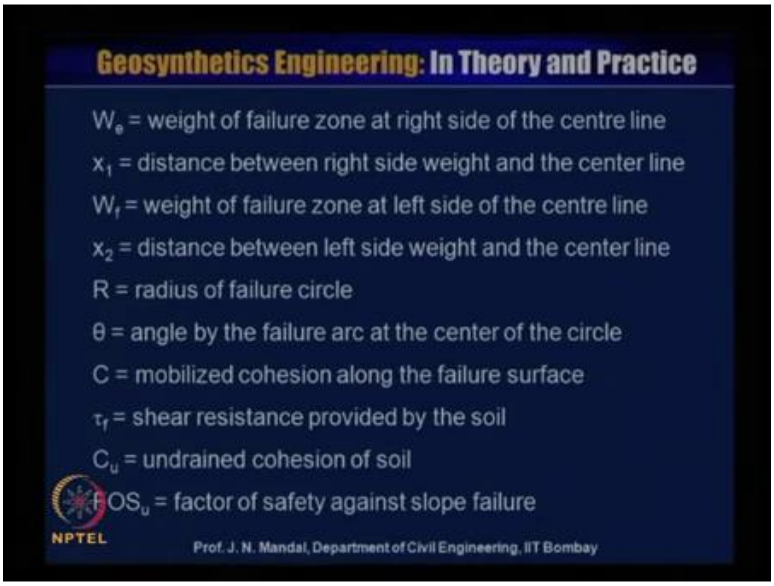

So, this W of e here this W of e is the weight of the failure z 1 at the right side of the center of the circle this is the failure z 1. This is the origin and which making at an angle of theta and this is the radius is R and this x 1 distance between the right side weight and the center line this is the x 1. This is the W F is the weight of the failure z 1 at the left side of the center line and this is the x 2 is the distance between the left side weight and the center line and arc. As I said, it is the radius of the failure circle and theta here is the angle by the failure arc at the center of the circle and this is the C.

So, C is mobilized coefficient along the failure surface and the tower is equal to shear strength of the soil which we call the C of u. C u is the un drained cohesion of the soil and you have to check what will be the factor of safety against the slope failure. So, you have to check what will be the factor of safety against the slope failure, when phi is equal to the 0? So, we have to calculate what will be the driving moment and what should be the resisting moment? So, driving moment that means this is the weight W of e, when the weight of this part embankment. So, W e it take a moment this is the o, so then W e into x 1 minus this is the weight of the foundation here.

So, W F into x 2 because it is lying on the left hand side for the center line, so we can write that driving moment will be equal to W e into x 1 minus W F into x 2 and what is the resisting moment? This is the resisting moment along this arc. So, this is the C is the cohesion, which is acting along this surface. So, R is the radius theta is the angle, so C into this arc that means a e and d, so this resisting moment will be equal to C into R theta into R.

That means C into R square into theta, so resisting moment C R square into theta, so for the equilibrium… Then this resisting moment will be equal to the driving moment. So, here it is shown that resisting moment is equal to the driving moment, so this is the driving moment W e into x 1 minus W F into x 2 is equal to C R square into theta. So, from this you can calculate the C. So, C will be equal to W e into x 1 minus W F into x 2 divided by R square theta.

Now, you have to calculate what will be the factor of safety against this sliding? So, factor of safety will be tau F by C. So, tau F means C of u, because this is tau F is equal to C of u, so C u divided by C. Now, this C u by C that means that if the circular surface is this one for u is the ratio that that means C u by C is a minimum when, where, when the C is the maximum. So, you have find out what should be the circular surface for the sliding, so a number of the tall arc are to be made for the different tall circle. You have to go for the different tall circle so minimum value of factor of safety you can obtain. That minimum factor of safety will give you what will be the factor of safety against the sliding for the slope and the corresponding circle is the critical circle. So, you have to check, so this is the case of the unreinforced soil slope and how you can calculate the factor of safety? So, you can calculate the, what will be the driving moment, also you can calculate what will be the resisting moment. You can take the ratio and check up that what will be the factor of safety against this sliding.

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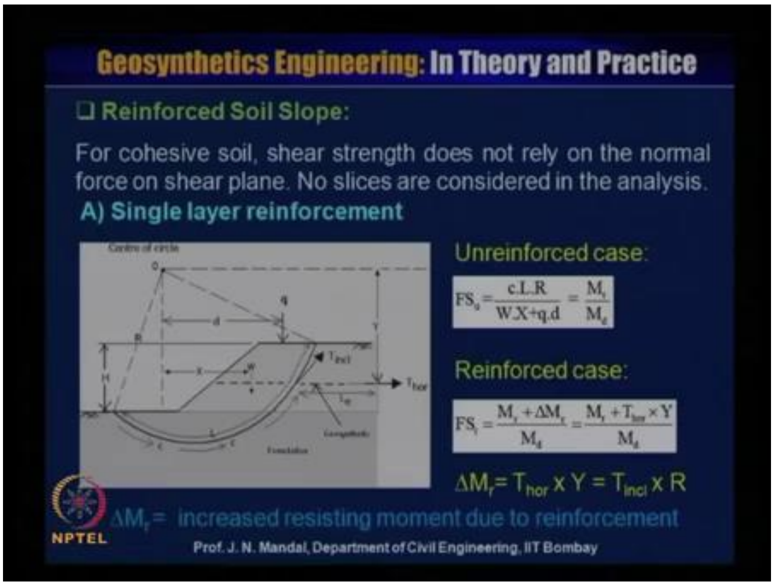

So, now if it is a reinforced soil slope, so what will happen so in case of the reinforced soil slope you are considering for cohesive soil and shear strength does not rely on the normal force on the shear plain. So, no slices are considered in the analysis, so initially we are showing on a single layer of the reinforcement. So, we know that in case of the unreinforced soil, what is the factor of safety against sliding that means you know that C into l into R that divided by W into x plus q d. Let us consider that if we consider the one layer of the reinforcement here, this is the reinforced soil slope you are providing, let us say one layer of the reinforcement. This is the slope and there is also M e load, which it is designated as q and the height of the slope is h. This is the steep circle and this is the center of the circle is o. This arc length is l.

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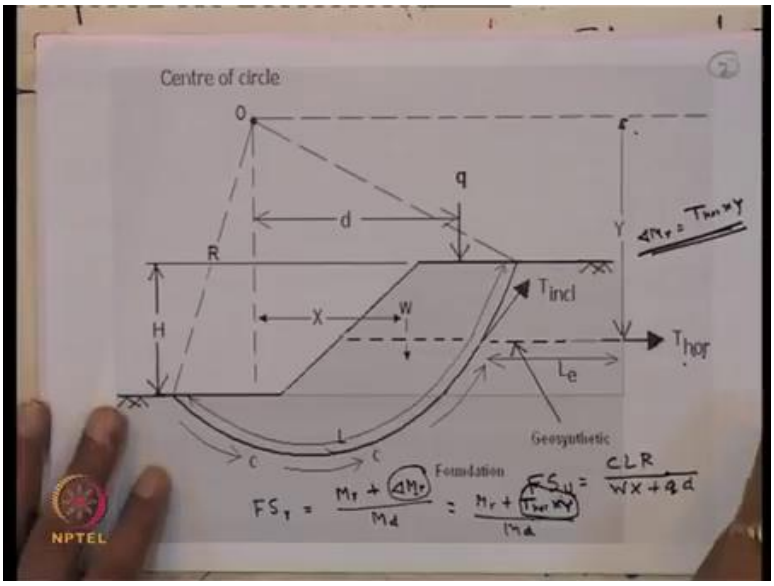

Let us say there is no reinforcement in the beginning, so this embankment has a weight let us say this is the weight W and which is located at the from the center of the circle at a distance of x. So, when there will be the no reinforcement you have to check what will be the factor of safety for unreinforced soil. So, factor of safety for unreinforced soil if I say F of s u this will be equal to this is the C and this arc length is l this is l. So, that means C into l into R that means C into l into R this is what you call the resisting moment divided by driving moment. Driving moment is due to the weight of the embankment. So, this is W into x plus due to this surcharge load q that means q, which is located at a distance d from the center of the circle, so q into d, so this will be q into d.

So, first of all you have to calculate what is the factor of safety for unreinforced case? So, you know the C you know the l you know the R, you know the W and where it is located you know the surcharge load. So, you can calculate what will be the factor of safety for unreinforced case. Now, if you introduce for example, in case of the unreinforced soil, if it fail if this factor of safety is less than 1 then it is required for the deployment of geogrid material along the slope. Now, if we introduce this 1 layer of the reinforcement here which will give some horizontal forces that is T of horizontal, now in the reinforced case. So, let us say that factor of safety for reinforced.

So, there is a resisting moment and also the driving moment, so this resisting moment 1 is m R you know unreinforced case plus this resisting moment due to the introduction of the geosynthetics material. Let us say this resisting moment is increasing and that resisting moment. Let us say delta of m of R this divided by driving moment is equal to m of d. So, this factor of safety will b equal to m of R plus for this increment is due to the introduction of geosynthetics material. Now, this resisting moment will be equal to this is the T horizontal, which is the geogrid tensile strength this into this distance if you take moment in origin. So, T horizontal into y, so this delta m R mean T horizontal into Y this divided by m d.

So, you see that this part this part is increment that means delta of m R is T horizontal into Y and that is the reason there is a increasing the factor of safety due to introduction of the geogrid material. Because, this part will be on the higher value and this is constant, so this factor of safety will be on the higher side, if in the unreinforced case if the factor of safety value is less than 1, then you can introduce the geogrid material.

So, you can introduce the even then number of geogrid material, if you place at the one layer of the geogrid material in between the foundation and embankment. If it is does not satisfy you can give two layer, three layer, four layer and see that what layer it will satisfy this factor of safety even. Then sometimes, if it is required for the construction of the embankment very high strength of the geogrid, which also can fail to you to stable the structure.

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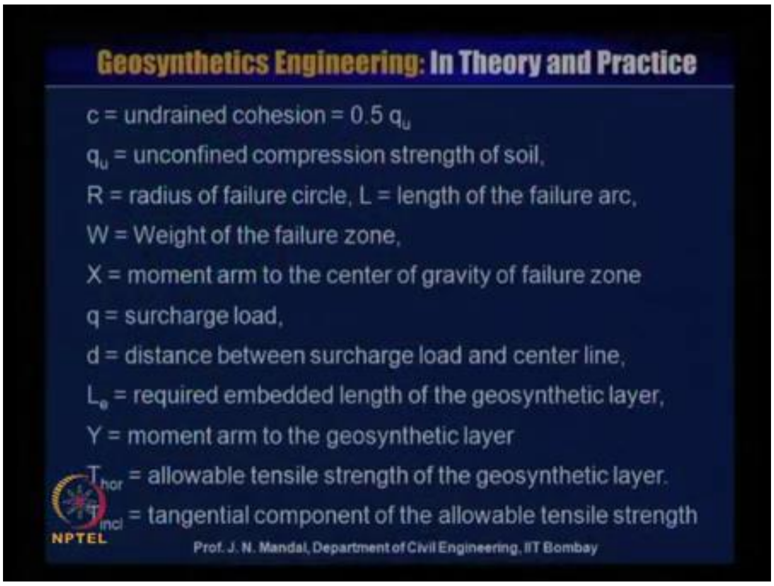

So, here also by just mentioned here that where that C is the un drained cohesion. Sometimes, this C un drained cohesion you can take 0.5 times of q of u where q u is equal to unconfined compression strength of the soil. Also, when you are introducing the geogrid material this part is the l of e, what you call the required that embedment length of the geosynthetics layer. So, what should be the length of the geogrid behind this failure surface that also is important to ask. Here you can see that when you are introducing the geosynthetics material there will be a allowable tensile strength of the geosynthetics layer in this direction. Also, there will be a inclined that means tangent component of the allowable tensile strength. That is T of incline here is also the question that sometimes this geotextile material may be failure line it may not be like this.

So, it may be tangent to the failure surface T incline or it may be in between this angle it may be that T incline and also this any angle you can optimize. Also, can be calculated, but in horizontal it can give the more value, but T inclined it may give the less value also you have to optimize. Also, you can find out what will be the tensile strength of the geogrid material is required for the stable slope. So, this also is to be taken care for design.

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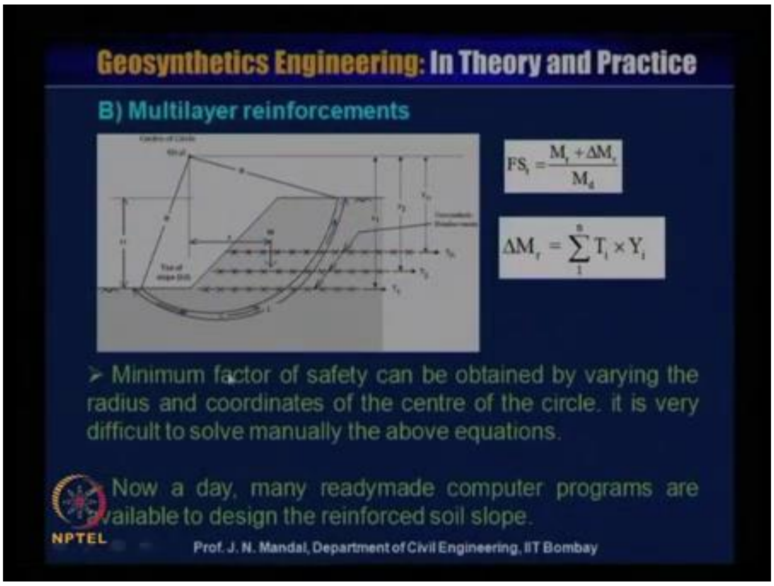

Now, I just said that you can do the number of the layer of the reinforcement. Now, you can see here that this is the slope the height of the slope h. This is the radius and this is the center of the circle and this is o, which is x and Y and you provide the number of the layer of the reinforcement. So, for example, that you can see here this is the one layer of the reinforcement whose strength is T 1 another layer of the reinforcement, whose tensile strength is T 2 like that n number of reinforcement with tensile strength is T n.

So, you are introducing number of the layer of the reinforcement and this reinforcement is located at a distance of Y 1 from the center of the circle. This T 2 is located at a distance Y 2 from the center of the circle this T n also located Y n distance from the center of the circle. This is the weight of the embankment, which is located at a distance of x and this is the toe of the slope this is 0. This I say the cohesion that is C and this arc length is which we call the l and this is the height of the wall. So, what you have to calculate that what will be the minimum factor of safety can be obtained by varying the radius and the coordinate of the center of the circle.

So, it is very difficult sometimes to solve the manually, so that is why there are many readymade computer program also is available. So, you can make use of that for the reinforced soil slope. So, We know that what will be the factor of safety for the reinforced case multilayer reinforced case for example, the factor of safety you have calculated the resisting moment divided by this is delta m R divided by driving moment. Now, this delta m R is due to introduction of the reinforcement

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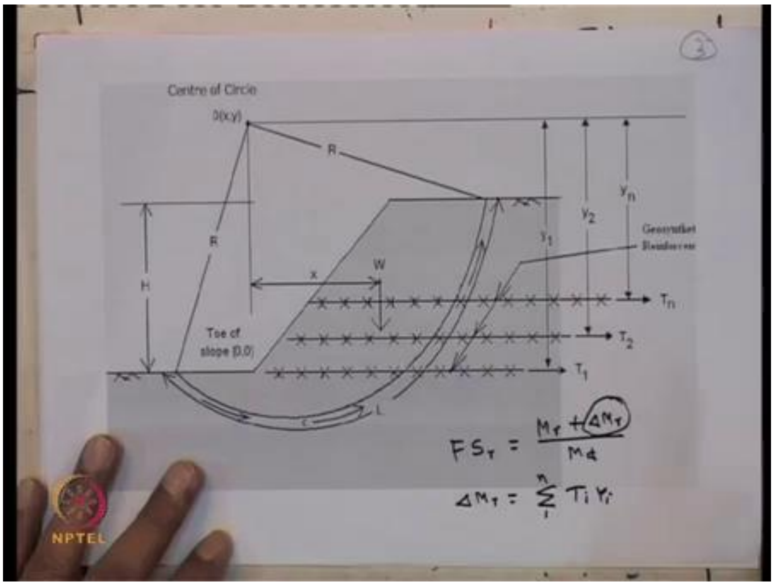

Now, if you use the number of the layer of the reinforcement that means, this delta of m R will b equal to summation of 1 to n that means T i into Y i. So, you can take this value

T 1 into Y 1 plus T 2 into Y 2 plus like that T 2 into Y 2. You can give the spacing also you can vary 0.5 or 0.1 meter and check that when the factor of safety in reinforced case will be the stable or this value will be equal to greater than equal to 1.3 or 1.5 for slope stability problem? So, you can do the number of the reinforcement layer.

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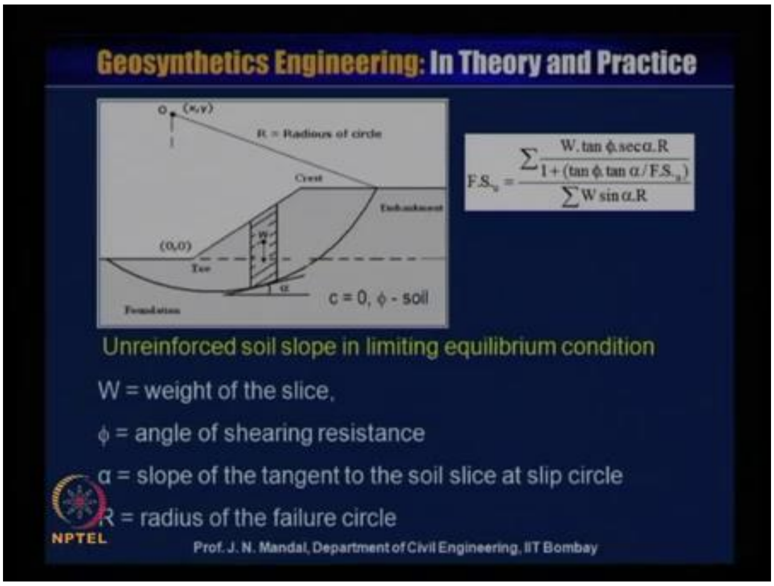

For this unreinforced soil slope in the limit equilibrium condition, so here you can see this is the soil where C is equal to the 0 and this is the phi soil this is the embankment and this is the foundation. This is the center of the circle, which coordinate is x and Y and R is the radius of the circle. This is the toe and this is the crest, so first of all we are considering it is a unreinforced soil slope in limiting equilibrium condition, which take that strip and this is the W weight of the slice. You take one slice here.

So, this is the weight of the slice W and you know phi is equal to angle of shearing resistance of the soil and this is the alpha, you can see tangent to this horizontal which is alpha. This is the slope of the tangent to the circle of the slice at the strip circle and R is the radius. So, we know that how to calculate the factor of safety with this equation it is also known to you, you know that method. So, this is W into tan of phi into sec alpha into R divided by 1 plus tan phi into tan alpha divided by factor of safety, this divided by summation of W into sin alpha into R.

So, this is what factor of safety required, so you assume some factor of safety and you know all these value you know what will be the weight, you know the what will be the alpha value, you know the R value. So, you so you substitute this value and check that. What will be the factor of safety required and what will be the factor of safety you assume? So, this is by like a trial and error check up that what will be the factor of safety in case of the unreinforced soil slope. So, this is for C is equal to 0 and phi soil

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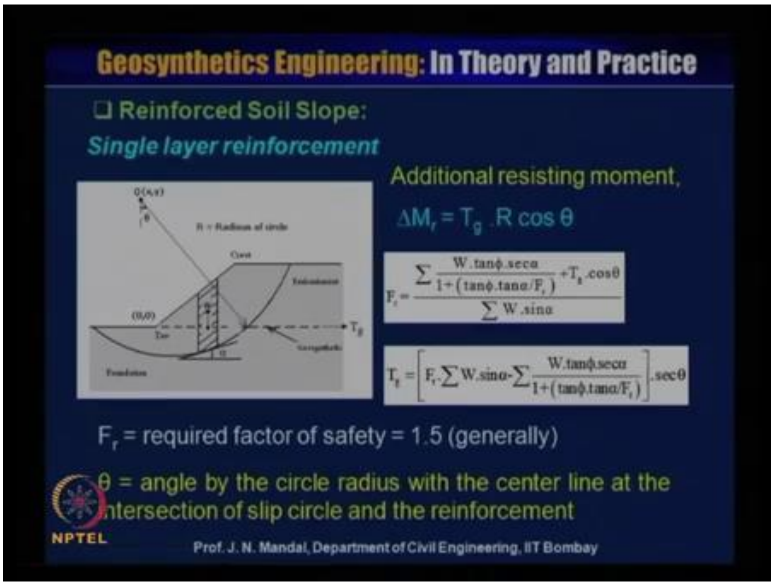

Now, in case of the reinforced soil slope single layer reinforcement only single layer reinforcement, which has been placed at the embankment and the foundation soil. This is a single layer reinforcement whose tensile strength is equal to T g. This is the center of the circle x y, which is making at an angle to the vertical theta and this is the toe 0. This is the crest and this is the R is the radius of the circle and this is the failure surface only, here we introduced one layer of the reinforcement whose tensile strength is T g here, weight of the slide W g and alpha. You know what you are making at an, to the horizontal to this tangent is theta.

So, you can calculate that what will be the additional resisting moment due to the introduction of this reinforcement that is T g into R cos theta. So, this theta angle by the circle radius with the center line add the intersection of the strip circle and the reinforcement. So, this additional resisting moment that due to the reinforcement, if it is a delta m R will be equal to this is T g into R into cos theta. Now, you can see this is the equation, which I have shown you earlier that factor of safety for unreinforced case, but due to the introduction of the reinforcement, this required factor of safety will be equal to this is for unreinforced case, plus if you add this, that is delta M r additional resisting force that is T g into R cos theta, R is cancelled. So, this is T g cos theta, so this is the additional part due to the introduction of the reinforcement.

So, here again you can calculate what will be the factor of safety and this factor of safety required is 1.5 in generally. So, from this equation also you can write the equation like this that is T g is equal to F R summation W sin alpha into summation of W tan phi sec alpha 1 plus tan phi by tan alpha divided by F R into sec theta. So, you can directly determine what will be the tensile strength of the geogrid material, once if you assume some value of factor of safety, you find out what will be the required factor of safety when you know the required factor of safety is 1.5 generally then it is okay.

So, with the introduction of the geosynthetics material if you find the F R factor of safety is 1.5. So, if you know that what will be the factor of safety suppose 1.5, then you can calculate what will be the tensile strength of the geogrid material, so you can calculate. So, if the unreinforced case if the factor of safety is less than 1 then only you can introduce the geosynthetics material as reinforcement for stability analysis. Now, we will discuss the circular slope analysis considering C phi soil.

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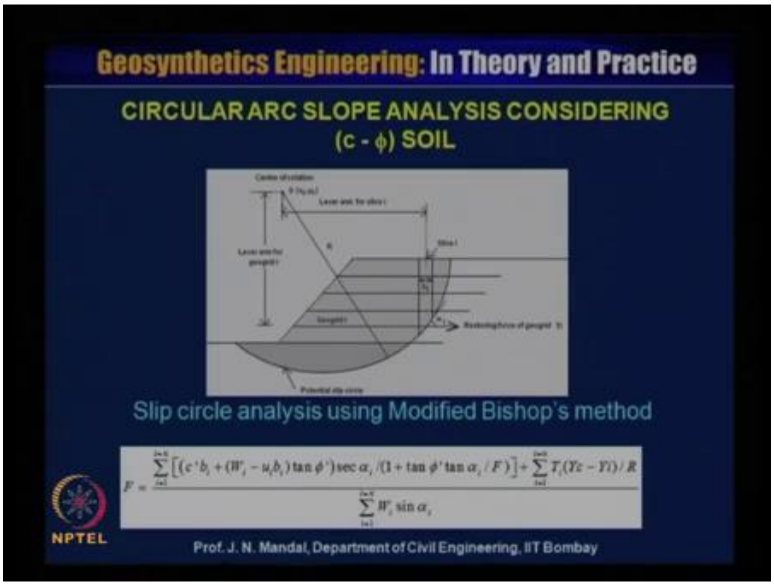

Now, we considered C soil we considered phi soil now if it is a C phi soil. So, in case of the C phi soil we will consider slip circle analysis using the modified Bishop’s method. So, we will consider that modified Bishop’s method, so you have to take this is you can see in this slope and this is the b of I that means this is width of the slice i b i is the width of the slice. It has also has a weight that means weight of the slice it solves as a weight. The weight of the slice let us say W of i we are considering the C phi soil and this is the lever arm for this slice i and this one and the center of the rotation x C and y C x C and the y C and that is the coordinate.

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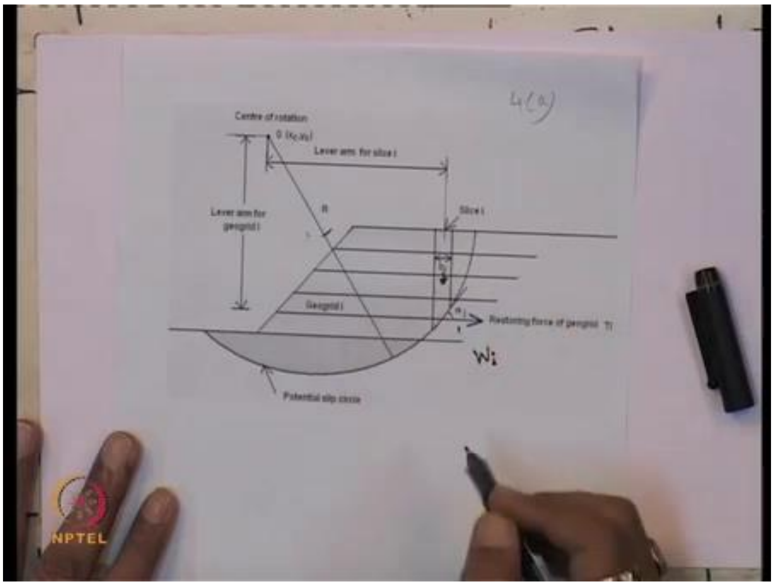

This is the lever arm for the geogrid i for this section and this is the alpha of i, which is inclination of the base from the horizontal for slice i, this is the resisting force of the geogrid. This is T of i and you know R is the radius of the potential failure surface and later consider that you n is equal to total number of the slice considered n is equal to total number of the slice considered.

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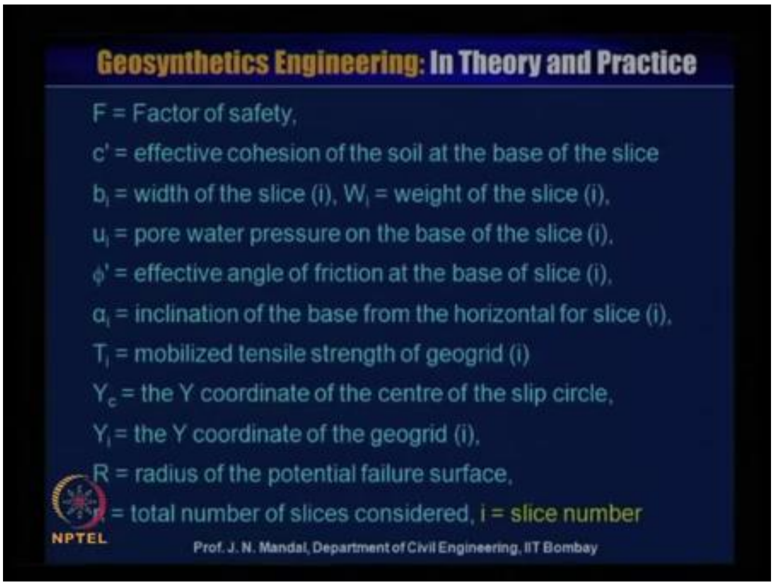

Let us say here that what I say that F factor of safety C dash is the effective cohesion of the soil at the base of the slice b i is the width of the slice i, W i is the weight of the slice i and there is a development of the pore water. So, this is also important u i is equal to pore water pressure on the base of the slice i phi dash is equal to effective angle of friction at the base of the slice alpha 1. Inclination of the base from the horizontal for slice i and T i mobilized tensile strength of the geogrid. Y c is the Y coordinate of the center of the slip circle and Y i is the Y coordinate of the geogrid i. R radius of the potential failure surface, n total number of the slice considered and i is equal to slice number.

So, from this you know that Bishop method this is the equation F is equal to summation of i is equal to 1 to n C dash into b i. This is the C dash and this is the b of i plus this is W i minus u i into b i, because due to pore pressure into tan of phi dash into sec alpha i this divided by 1, plus tan phi dash into tan alpha i divided by F plus summation of i into 1 T I, Y c minus Y i divided by R this whole divided by summation of i is equal to 1 to n W i into sin of alpha i. So, this is the modified Bishop’s method for the C phi soil, so here both the C phi soil has been considered and the pore water pressure also has been considered, so this is the equation. So, this you know the equation for the circular slope analysis for the C phi soil.

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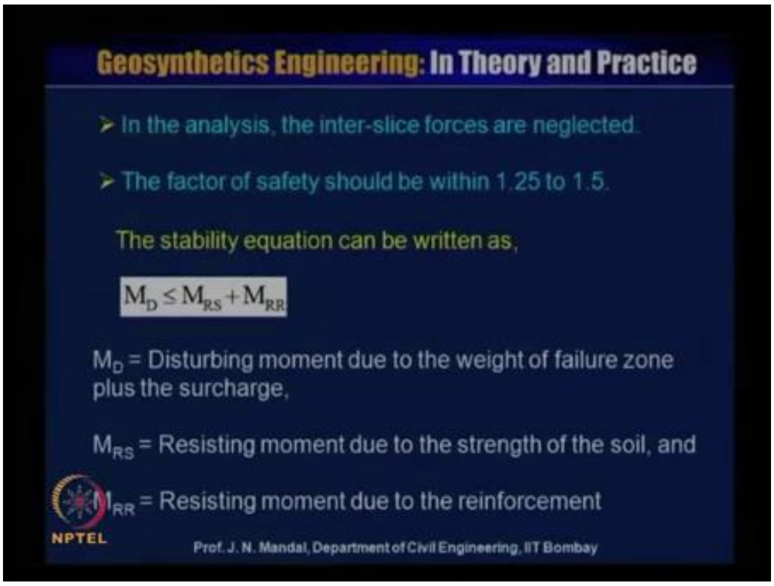

Now, in the analysis the inter slice forces are neglected the factor of safety should be within 1.25 to 1.5 for stability equation can be written as, M D should be less than equal to M R S plus M R R, where M D is equal to disturbing moment. Due to the weight of the failure z 1 plus the surcharge M R S is resisting moment due to the strength of the soil and M R R is the resisting moment due to the reinforcement. So, it should be that M D should be less or equal to M R S plus M R R.

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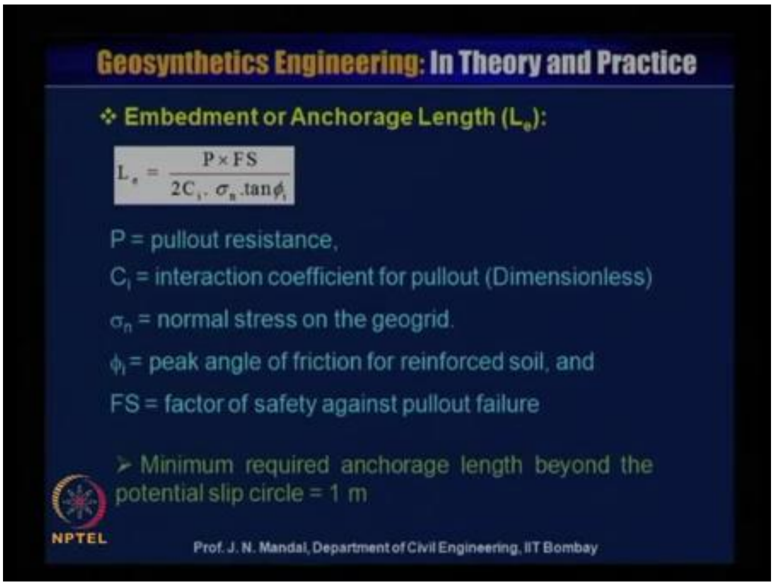

Now, you have to calculate also the embedment or what you call the anchor length l e that means what will be the length of the reinforcement beyond the failure surface 1 e. So, l e can be determined using this equation l e is equal to p into F S divided by 2 C i into sigma n tan phi i, where p is equal to pull out resistance C i is equal to interaction coefficient for pull out, which is dimensionless sigma. n is equal to normal stress on the geogrid reinforcement phi i is equal to peak angle of friction for reinforced soil and F s is factor of safety against the pullout failure. So, minimum required anchor length beyond the potential slip. Circle should be 1 meter if it is less than 1 meter then 1 d C should consider that is 1 meter.

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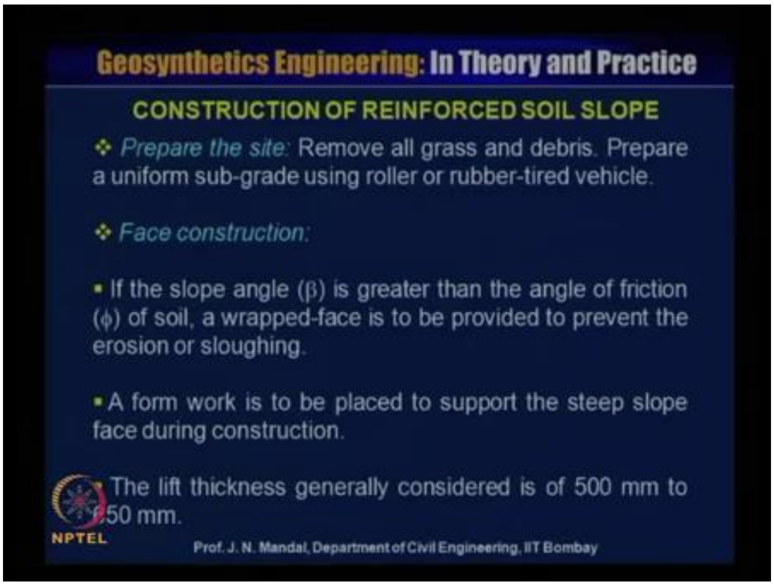

Now, construction of the reinforced soil slope, so first of all you have to prepare the site you remove all the grass and the debris and prepare a uniform sub grade using the roller or rubber tired vehicle. Now, how to construct the face construction if the slope angle beta is greater than the angle of friction phi of the soil a wrapped face is to be provided to prevent the erosion or the sloughing

So, what is required you have to provide a like this, you have to provide a form work this is the form work. So, initially you have to be clean and use the light weight compaction equipment at the base and use the ordinary compaction and then this is the primary geosynthetics material. So, this is a wrapping around ((Refer Time: 52:00)), but you have to provide a form work is to be placed to support the steep slope face during the construction. Then this slip thickness generally consider about 500 millimeter to 600 millimeter.

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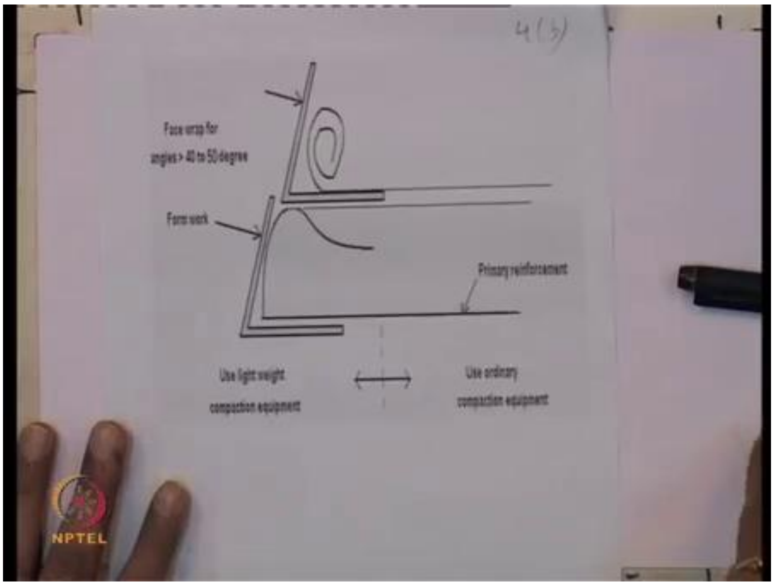

So, one has to maintain that spacing between the two reinforcement and this face wrap for the angle, which should be the greater than 40 degree to 50 degree. Then again you can remove the form work then you can place here the form work. Then the geogrid also it is in the roll wrap from, so it can be opened and can be placed like this, so you can construct this wall like this. So, this is construction step as I say that is the lift one plus reinforcement to lift two, then lift two with the face is wrapped and then the C lift two. Then it is completed like that you can construct the reinforced soil steep slope.

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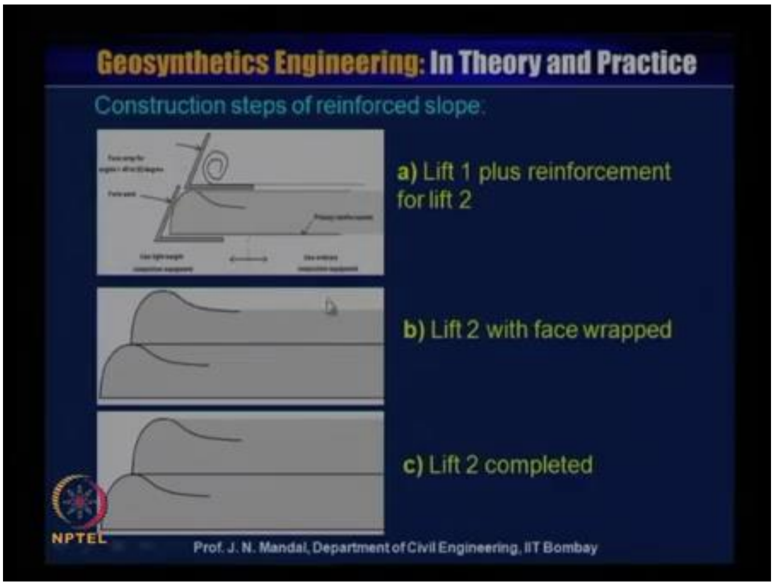

So, it can be prevented for any sloughing, there is a possibility for the sloughing to the slide slop, so that is why it is needed to provide a kind of the from work then placement of the geosynthetic higher strength is required along the width of the slope. Therefore, it is recommended to place the geosynthetic with machine direction along the width of the slope, it should not be wrinkled to protect from the wind.

The geosynthetics should be anchored with the aid of sand bag, or pins a minimum overlap length of 100 millimeter, should be provided while stitching the two geotextile material placement of the backfill. And compaction place the backfill material over the geotextile and compact it with a rubber tired vehicle for cohesive soil or using roller for granular soil a minimum 150 millimeter thickness should be maintained between the wheel of the roller.

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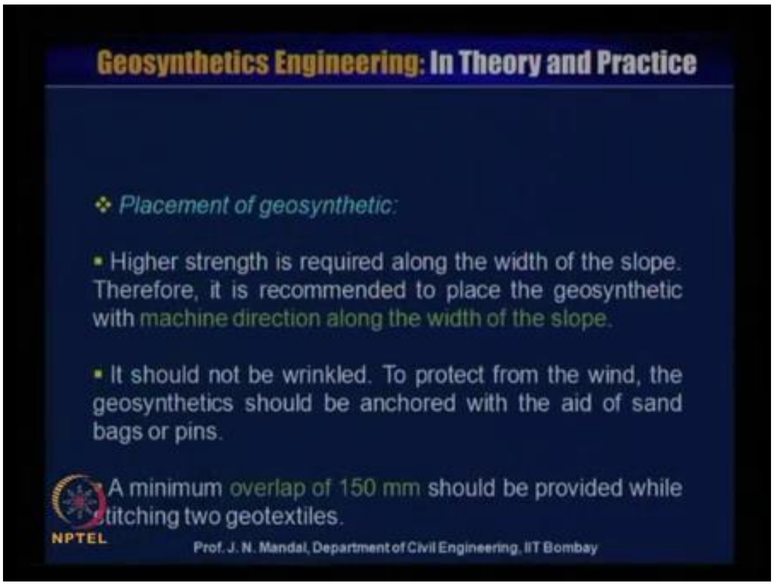

The geotextile reinforcement always light weight compaction should be used near the face of the slope. So, you should maintain the compaction should be achieved about 95 percent of standard maximum dry density within plus minus 2 percent of optimum moisture content. Then repeat the procedure with the next layer of geotextile and backfill and so on. Vegetation are to be provided at the face of the slope to prevent the soil erosion.

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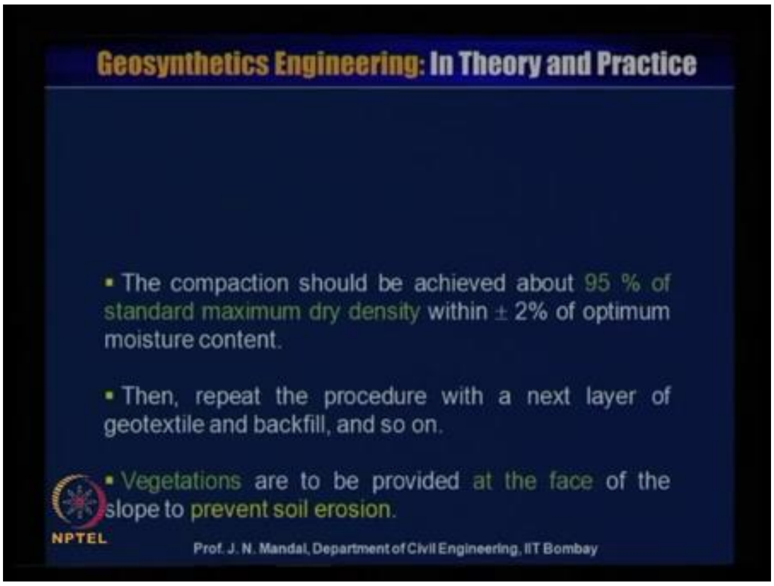

So, you can have some idea about that how you can you can place these geotextile material. And how you can construct the slope using the flexible material, how you could wrap, how you should compact, what density you should achieve in order that there should not be any sloughing, or the slope or there should not be any the erosion at the face of the slope? In addition, that there you should maintain the minimum spacing between the two reinforcement material during the compaction, otherwise that there is a possibility for the damage of the geosynthetics material. With this I finish my lecture today. Let us hear from you, any question?

Thank you for listening.