**Geosynthetics Engineering: In Theory and Practices**
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**Lecture - 39**
**Geosynthetics for Steep Slopes**

Dear student, warm welcome to NPTEL phase 2 program video course on geosynthetics engineering in theory and practice. My name is Professor J. N Mandal, department of civil engineering, Indian Institute of Technology, Bombay Mumbai, India. This lecture number 39, this module 7, lecture 39, geosynthetics for steep slopes.

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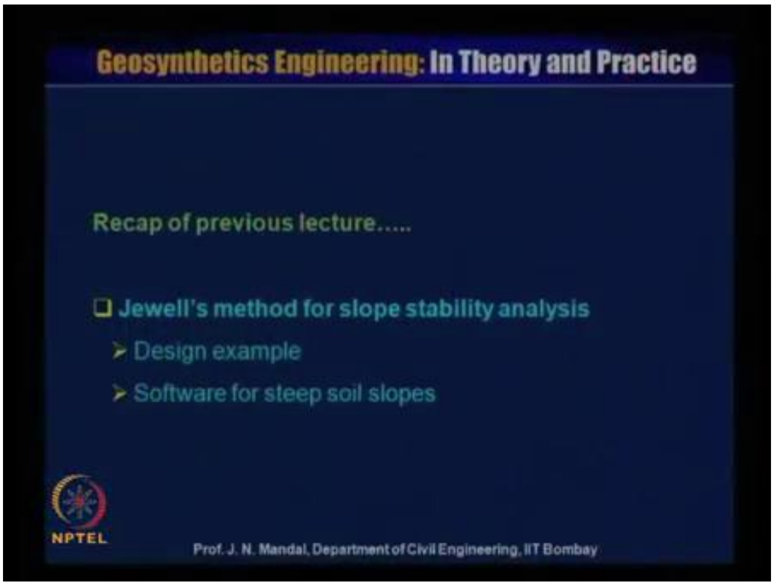


I will now address the recap of the previous lecture. I have gone through the Jewell's method for slope stability analysis. I have covered the design example and software for steep soil slope.

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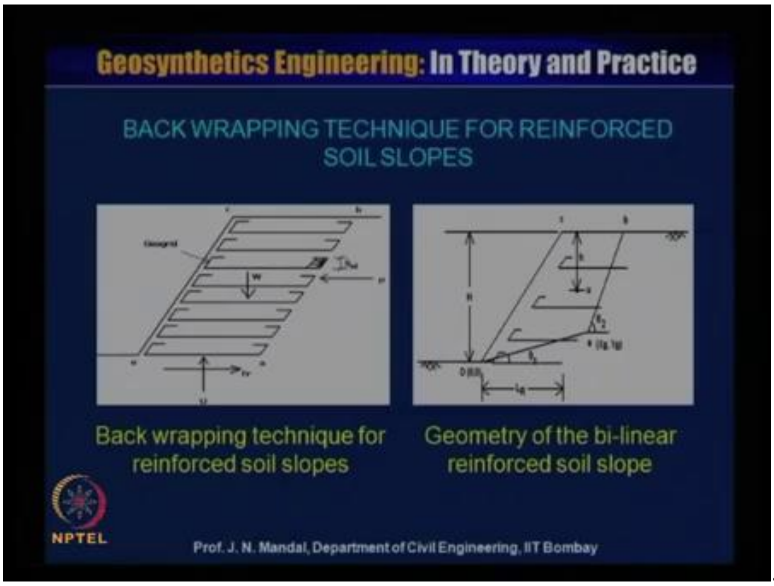


So, you now know that what is the different types of the methods? We have used for the design of reinforced steep soil slope, and we have used that Schmertmann's method, where you can change the length of the reinforcement at the bottom as well as at the top. But in case of Jewell's method, we have considered the different pore pressure ratio, and based on the pore pressure ratio, we have calculated that what will be the K required.

Based on the slope of the embankment and also the angle of friction of the soil, and also we have calculated that what will be the l by h ratio due to the sliding. And also l by h ratio due to the overturning, and then based on that we have selected that what will be the length of the geogrid and what should be the spacing. Now, I will focus on the back wrapping technique for reinforced soil slope. So, this kind of the technique is particularly suitable for the slope where space is restrained, you cannot place the reinforcement up to a certain length.

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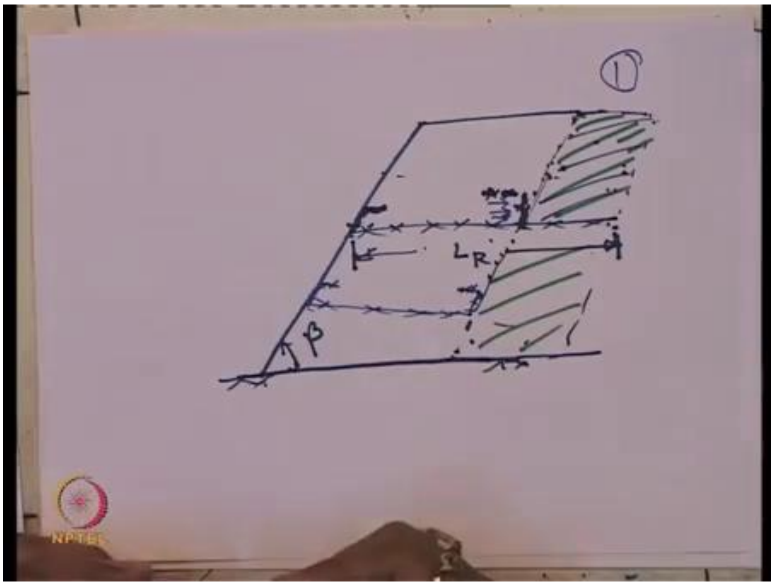


For an example I want to construct a steep slope. So, this is the slope whose angle is equal to beta and you can see that sometimes you cannot go beyond this length. Suppose, if the length is required more so you can place a one layer of the geogrid material here. And there is no space, you cannot use this space like let us say any Konkan railway where is a steep slope, and you cannot go beyond this line. But as per your design you require the length of the geogrid from here to here. So, if the length of the geogrid is here to here. So, if you want to place the reinforcement up to this length so it is required to excavate this portion of the soil. Entire portion of the soil you have to be this portion of the soil have to be excavate, and then you can place this length of the geogrid up to this portion.

Now, instead of this you are not require to excavate this portion. You can provide a back wrapping, you can back it the reinforcement like this, and you can also facing element you can back wrap like this. So, this is what is back wrapping. Instead of this length you can back wrap this geogrid material like this. So, there will be a development of the passive resistance. Here like this you can place the another geogrid material like this. You are giving the back wrapping technique. So, this is what we call the back wrap technique for reinforced soil slope. So, you can save the cost, you can save the geogrid, and it will give very good passive resistance. So, we can reduce the length of the geogrid.

So, this is what we call the back wrapping technique apart from that instead of the geogrid also you can place the geocell as a layer of reinforcement material. So, it will give the geocell material is a very good confinement effect so that way also the length of the geogrid can be reduced. So, this back wrapping technique has been used, and some design chart has also been made, and also we have adopted that 2 wedge systems here.

You know that what is two wedge systems. The dual method is based on the 2 wedge system, and this is the figure that back wrap technique for reinforced soil slope. You can see here, and this is the geometry of the bilinear reinforced soil slope. So, you know what is this height of the reinforced slope. This is the length of the reinforcement and this is the 2 wedge system.

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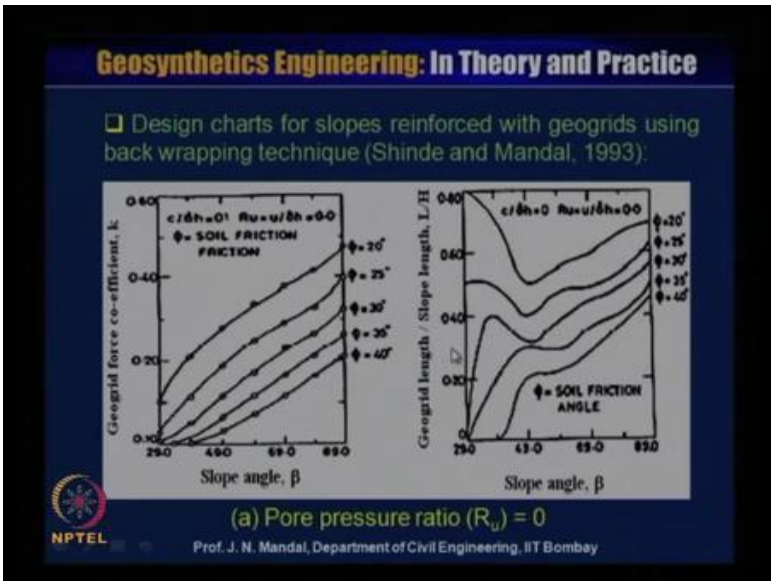


And from this that Shinde and Mandal 1993 that various design chart for slope reinforce with geogrid using back wrapping technique has been developed under different pore water pressure when the pore water pressure R u is equal to 0. So, from this chart this is the slope angle beta. This is the phi angle of friction, and this is R u that is gamma by delta h is equal to 0, and this is the geogrid force coefficient. So, this is K so knowing the value of the beta, and the soil friction angle phi. So, you can calculate the geogrid force coefficient that is K required.

So, you will be knowing K required. So, you can be knowing what will be the T related with the K, and can determine what will be the strength of the geogrid material from the right side, also this is the correlation between the slope angle, and the geogrid length to slope length at A L by h. So, knowing the angle of the beta, and the soil friction angle so then you can calculate what will be the L by h. So, that ratio you can determine. So, if you know the what will be the height of the reinforcement. So, you know the what then you can calculate what will be the length of the geogrid. So, you know the length of the geogrid, you assume some value of the spacing between the two geogrid material, and then you can design this back wrapping technique system using this chart.

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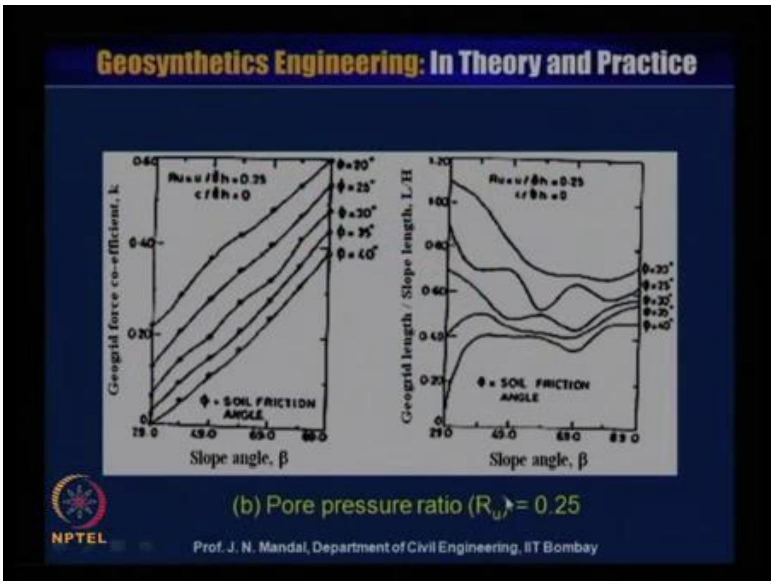


So, this is one chart when pore water pressure R u is equal to the 0. Similarly, when the pore pressure ratio change, R u is 0.25. This is also curve relation between the slope angle, and geogrid force coefficient and this also slope angle with the geogrid length to the height ratio.

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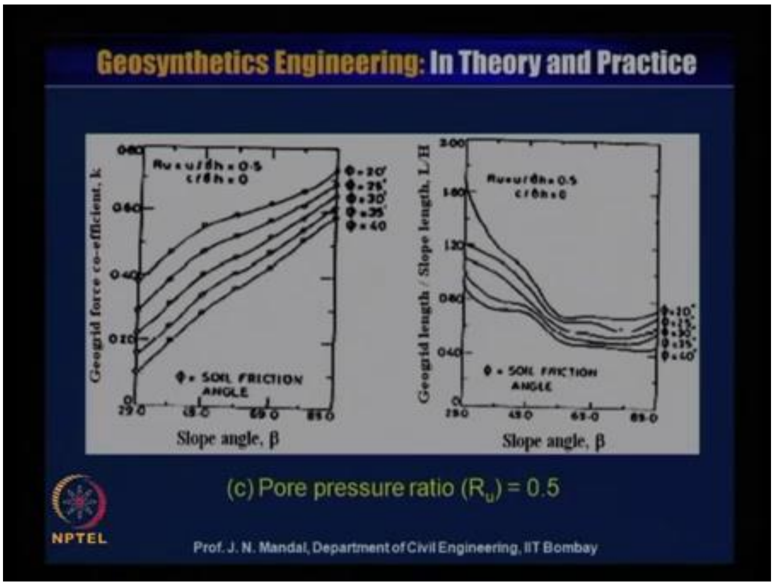


Similarly, for the pore pressure ratio R u is 0.5. So, from left side curve we can chart, you can determine what is geogrid force coefficient K required and the right side you can determine what is L by h. So, I have already solved this related kind of the problem earlier by the Jewell's method. So, here I am just presenting these three chart for the back wrapping technique with the three different pore pressure ratio which you can use.

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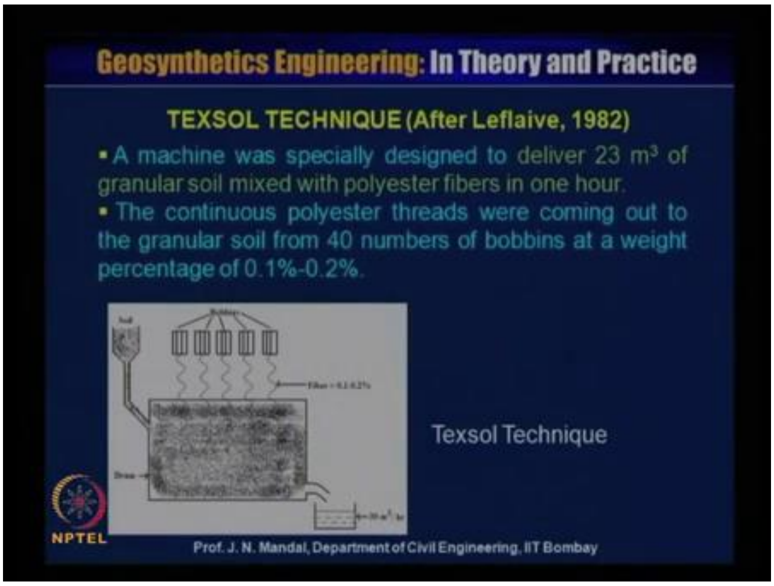


Next, I will talk about Texsol technique, this chapter leflaive 1982. So, this is a machine was specially designed to deliver 23 meter cube of granular soil mixed with polyester fiber in 1 hour. So, and this continuous polyester thread were coming out to the granular soil from 40 number of bobbins at a weight of percentage of 0.1 to 0.2 percentage. So, this is a kind of the system this is a drum and the soil is inserted into this drum and this is the bobbins, this is a machine and from this continuous polyester in the form of thread and that is 0.1 to 0.2 percentage is out and then mix up with the soil. This is a kind of the thread, it is very popular in France, and I have seen this kind of the machine also in the France.

And then how they had been used in for slope stabilization in their country, and then you have to spread near to the slope. So, it is a mixture of the soil and the thread and then you are placed any kind of the slope, and after sometimes there will be a green grass, will grow, and it looks very greenery. It has been used exclusively in the France and you can see bobbins at a weight of percentage only 0.1 to 2 percentage.

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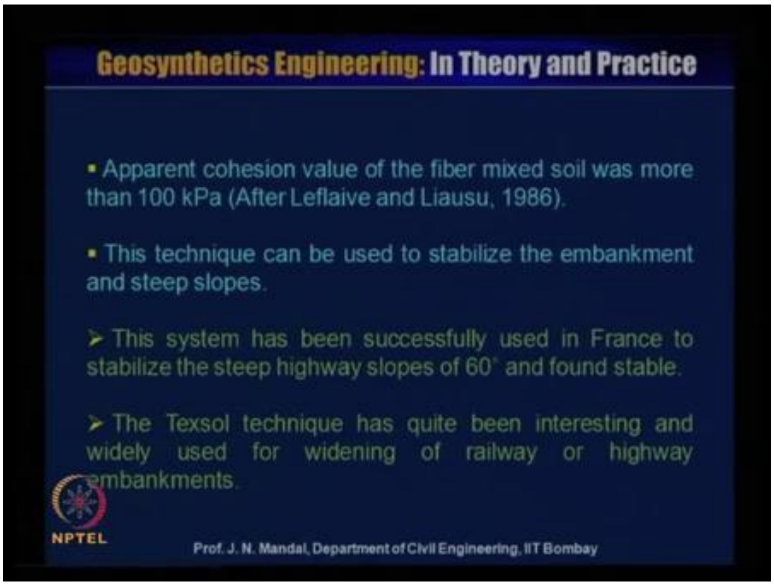


So, what is the most important here is that it has been observed that apparent cohesion value of the fiber mixed soil was more than 100 kilo Pascal after Leflaive and Liausu, 1986. The technique can be used to stabilize the embankment and steep slope. This system has been successfully used in France to stabilize the steep highway slope of 60 degree, and it has been found that it is stable. The Texsol technique has quite been interesting, and widely used for widening for the railway and the highway embankment.

Only by we find that this is a kind of the huge equipment where you require for proper kind of the mixing because this fiber should be mixed with the soil, and there will be no segregation. And then you directly place the mixture of the fiber and the soil along the slope, and then you can find that grass can grow and it looks very greenery, and it has been mentioned that it is also this steep highway that in slope of 60 degree, and it is very useful. So, this is a one kind of the Texsol which is developed by Leflaive, and also that if you wanted to widen of the highway or railway embankment by applying the same technique that is Texsol technique.

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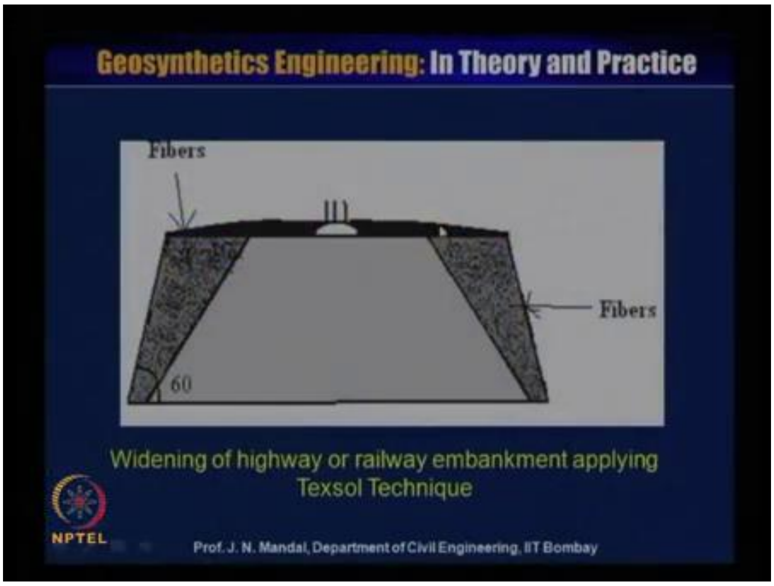


Suppose this is the embankment highway or the railway, and you wanted to extend this portion. We have observed that you can use the number of the layer of the geogrid material. You use can also use that kind of the geocell material. Also you can use that geofoam material apart from that you can use this kind of the fiber soil mixture, and you can place it and you can widening the road. It is also very stable.

We have been performed many laboratory test using the different percentage of the fiber element, and we found also it is very encouraging result and we have also used in a centrifuge modeling. I will show you later that how this system also has been used in the centrifuge modeling, and what kind of the failure may occurs and how it is stable and also we have compared the both with the fiber mix soil as well as the geogrid as a reinforcement. So, this is very interesting. We can have more information the later on in my next lecture. Now, I will talk about the design of 300 meter. It is about 305 meter high artificial mountain using geosynthetics.

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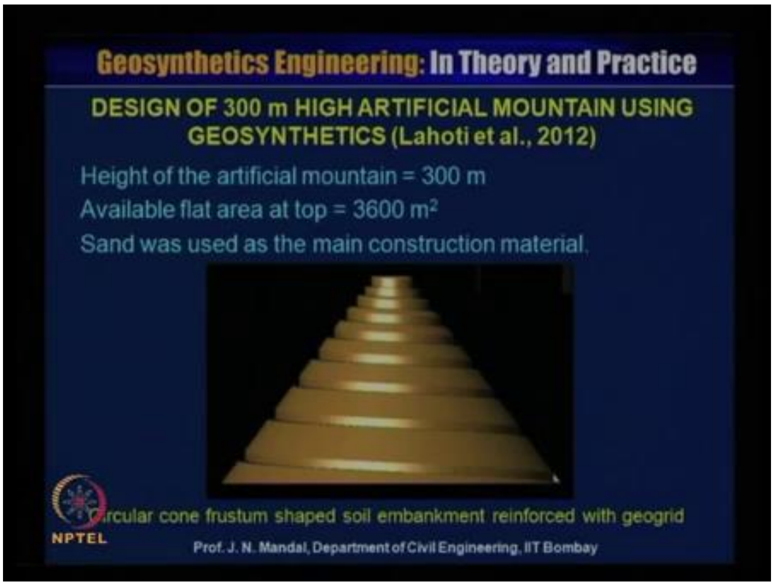


This is Lahoti and Mandal and 2012. This is the project, it has come from some middle east country to our department to design a 300 meter high artificial mountain, and this king wants that it should be made of only sand. But it came to structural my colleague, and they started working with this steel as a material and it found that it will be very expensive. But the client want that it should be locally available material and that is the sand because huge quantity of sand is been available and as you know that he wants that it should be artificial.

So, two of my student have worked out and designed this 300 meter high artificial mountain using geosynthetics. You can also have details of this paper which has published in ASC. So, here available flat area at top about 3600 meter square and as I said that sand was used as the main construction material and you can see this is a circular cone frustum shaped soil embankment reinforced with the geogrid and it is a that is a three road.

So, looking one from the bottom with the car and it will go like this and on the top. So, you can have a very magnificent view at the top and this about 70 meter. The top diameter about 70 meter and bottom diameter about the 600 meter and height is about 305. There is three road, the vehicle can pass go up and one vehicle can go down if there is any accident. That is why it has been provided with another road. So, see road also has been designed.

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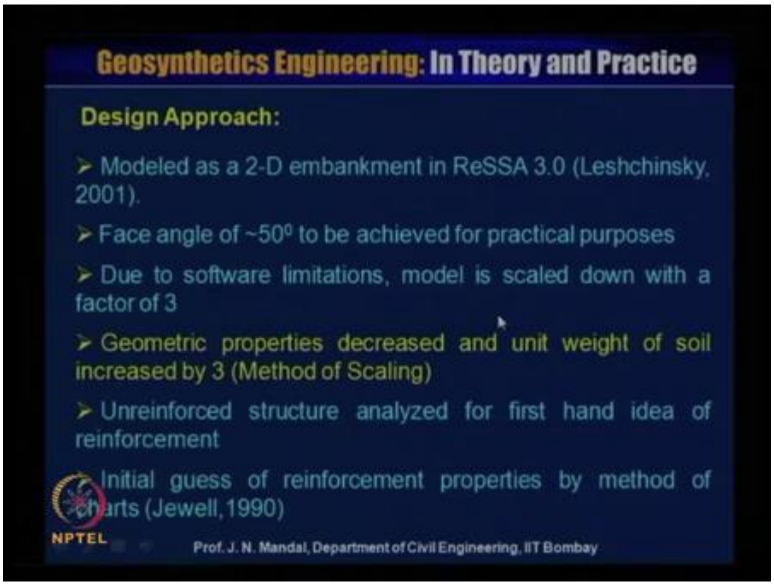


So, here I will just focus how it has been designed, what is the design approach for this. So, this is modeled as a 2 dimensional embankment in ReSSA 3.0, that software which is developed by Leshchinsky in 2001 and facing angle of 50 degree to be achieved for practical purpose. Now, there is a limitation of the software. So, model is scaled down with a factor of 3.

So, geometric property decreases and unit weight of the soil increases by 3, this is what we call the method of scaling without the measure of scaling then this software will not accept. So, that is why we have to bound to scaled down this method. So, unreinforced structure analyzed for first hand idea of reinforcement. So, initial guess of the reinforcement property by the method of the chart given by Jewell 1990, which I have described the different types of the Jewell chart or method.

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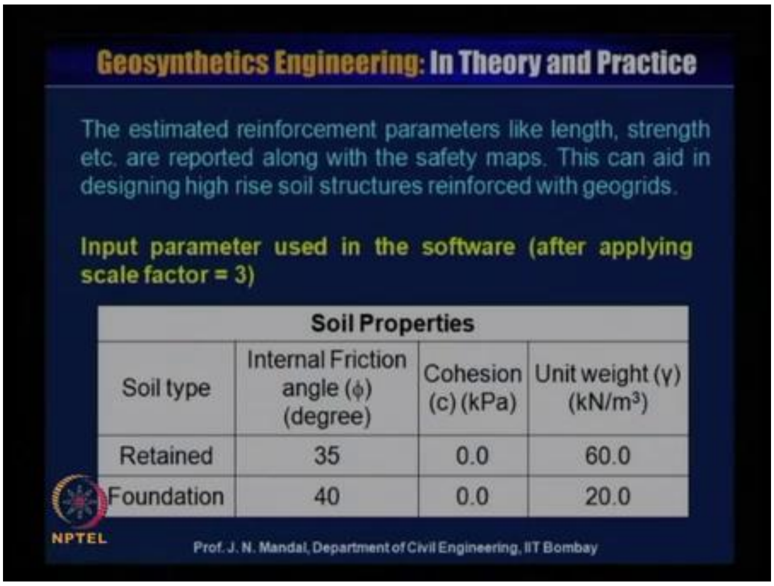


The estimated reinforcement parameter like length, strength, etcetera are reported along with the safety maps. This can aid in designing high rise soil structure reinforced with geogrid. Now, what are the input parameter used in the software after applying the scale factor of 3. So, you can see here soil property and soil type. It is in the retained and the foundation and internal friction angle phi that is for retained.

It is 35 degree for foundation. It is 40 degree cohesion c in kilo Pascal, 0 for retained and 0 for foundation and unit weight kilo Newton per meter cube, for retained soil 60 kilo Newton per meter cube and foundation 20 kilo Newton per meter cube. You can see how we have apply the scale factor to 3 times. That is why the unit weight of retained soil is 60 kilo Newton per meter cube.

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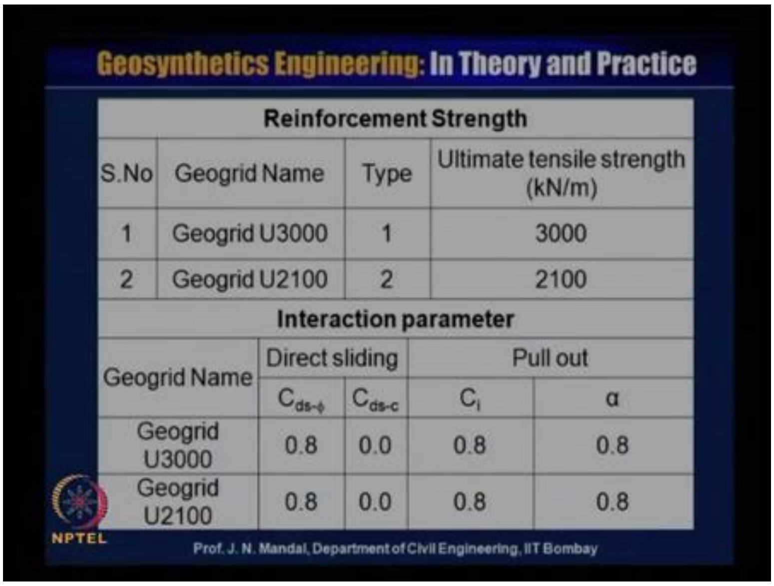


| Reinforcement Strength | | | |
|---|---|---|---|
| S.No | Geogrid Name | Type | Ultimate tensile strength (kN/m) |
| 1 | Geogrid U3000 | 1 | 3000 |
| 2 | Geogrid U2100 | 2 | 2100 |

| Interaction parameter | | | | |
|---|---|---|---|---|
| Geogrid Name | Direct sliding | | Pull out | |
| | $C_{ds-\phi}$ | $C_{ds-c}$ | $C_i$ | $\alpha$ |
| Geogrid U3000 | 0.8 | 0.0 | 0.8 | 0.8 |
| Geogrid U2100 | 0.8 | 0.0 | 0.8 | 0.8 |

Now, reinforcement strength. The two types of the reinforcement have been used that is 3000 kilo Newton per meter and 2100 kilo Newton per meter. This is very high strength of the geogrid material, most of the time that is very high strength geogrid material have not been manufactured. But now a day's manufacturer has come up where it is required very high strength of the geogrid material. For example, where it is a related with offshore onshore kind of the project, where you require very high strength geogrid material. So, if it is required manufacturer can also manufacture the very high strength geogrid material.

Now, here that two types of the geogrid has been used. One geogrid name is geogrid U3000 another geogrid U2100, that is type 1 and 2 and ultimate tensile strength of the geogrid is 3000 kilo Newton per meter and 2100 kilo Newton per meter. So, these are the reinforcement strength then interaction parameter. So, as I say that geogrid name, geogrid 3000 and geogrid 2100 and interaction parameter is from the direct sliding and the pullout. So, direct sliding what should be the C d s by for geogrid U3000 is 0.8 and geogrid 2100 is 0.8 and for the direct sliding C ds c cohesion that is 0 and 0.

But for pullout C i for geogrid 3000 0.8, alpha value also 0.8, geogrid 2100 for C i is 0.8 and alpha is 0.8. You know what is the alpha, which I have already discussed earlier about the pullout test and how the alpha value can be used in case of the geogrid. So, alpha value for geogrid, you considering 0.8. So, this is the reinforcement strength and the interaction parameter for direct sliding and the pullout. Now, what should be the input model in ReSSA software?

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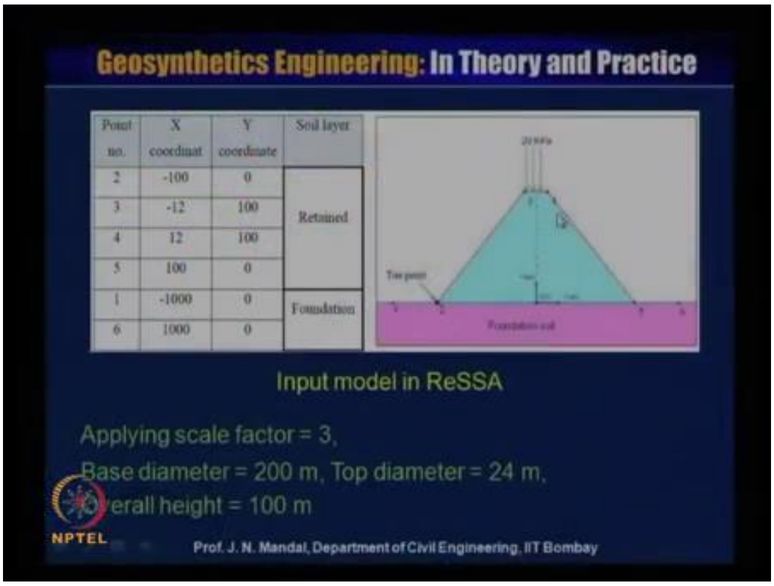


So, this is the model you can see this is the point number 2. This is point number 2. This is the X coordinate, this is Y coordinate and this is soil layer is the retained and this is soil layer in the foundation. That means this point 2, this is point 2 and you are applying the scale factor 3. So, this is coordinate, X coordinate is minus 100 because base diameter is 200. If the self factor is 3 basically it is a 600 by applying the scale factor. This base diameter will be 200 and the top diameter will be 24 meter and overall height will be the 100 because if you take the width adopting the base factor 3 otherwise this will be the 300, this will be the 600 and this will be the 48.

So, this is two point X coordinate is minus 100 and Y is 0 for the point number 3 that means this is point number 3. The X coordinate is minus 12 because this diameter is base, top diameter is 24. So, this will be the 12 so for the point 3 this is 12 and this Y coordinate is 100 and for the 4 this will be the 12 and this will be the 100 for 4 point. For the point 5 that means this for the point 5, this will be the 100 and this 0 and for the foundation you are taking this 1 and this 6. So, 1 is minus 1000 and this is 0 and 6 is plus 1000. So, this is the input model in the ReSSA. So, apply this scale factor 3.

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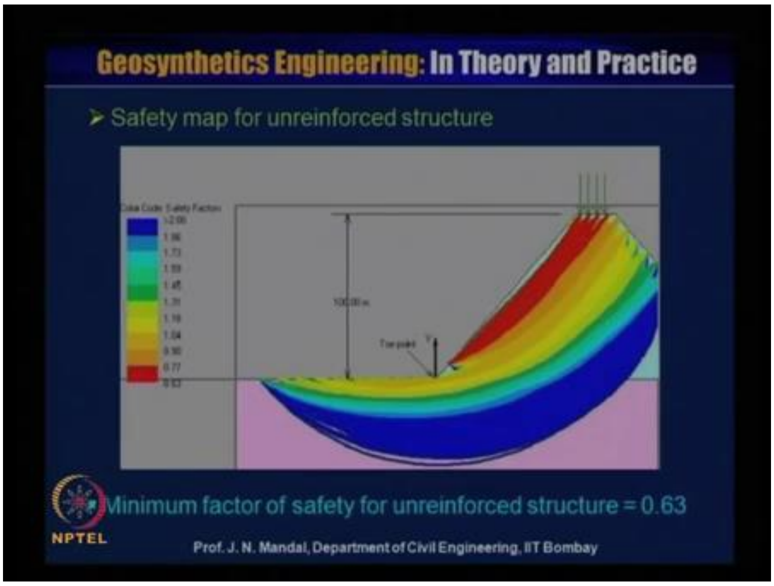


So, now you can see safety map for unreinforced structure. First of all we have performed and find out that what should be the minimum factor of safety for unreinforced structure. So, here you can see that critical surface is the one, and you have to find out the critical surface for sliding a number of trial arc to be made for the different trial circle. And then ultimately you have to find out what should be the minimum factor of safety or what should be the critical slip circle, and then you can calculate that what will be the minimum factor of safety for unreinforced soil. Here you can see for the unreinforced soil the minimum factor of safety is 0.63. So, this is 0.63 because it is unstable thing so it is not a stable structure so you require some reinforcement, now this critical slip circle and the wedge in the reinforced case.

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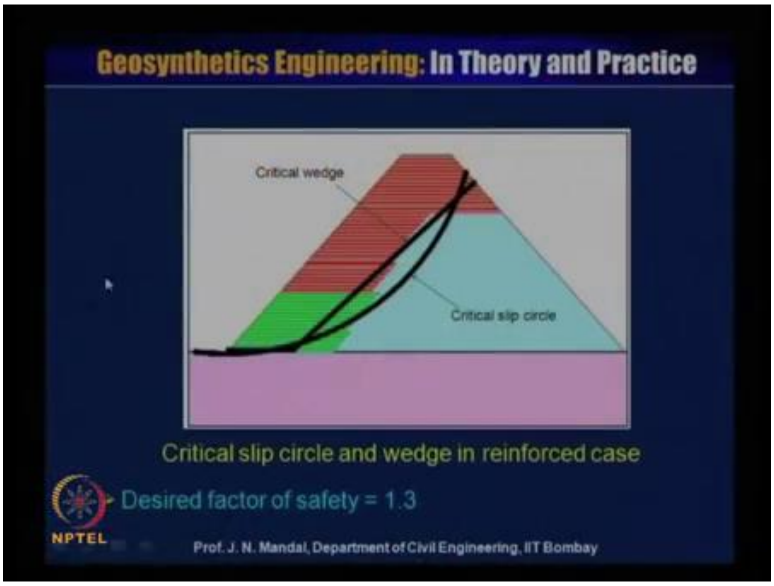


So, these are the reinforcement different layer and with the placing with the different strength have been used and you have analyzed with the critical wedge as well as the critical slip circle. So, this is the critical slip circle and the wedge in reinforced case and then you have to check what should be the factor of safety for this case. So, we are adopting the desired factor of safety, let us say 1.3. So, that is the desired factor of safety.

Now, here it is shown safety map of reinforced structure. Now, we apply the reinforcement. This is by rotational analysis top you can see that number of the slip circle and here you have used the reinforcement and then we find out that what should be the factor of safety. So, this is the check code for safety factor. You can see that here where is this failure may occur or safe what it should be this zone. So, this is the rotational analysis top. So, here the minimum factor of safety 1.30. So, it is the safe for rotational analysis.

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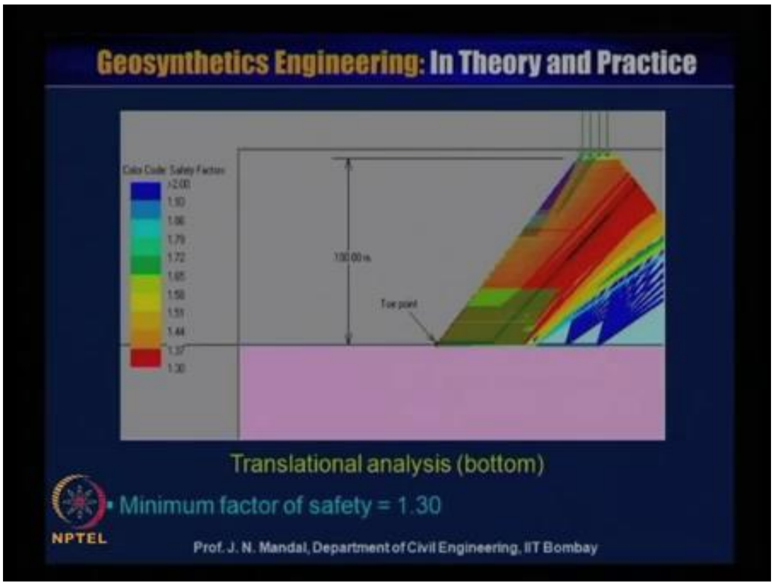


Now, what will be the translational analysis, this structure may collapse due to the translational. So, here the translational analysis bottom has been done and you can see that what will be the failure. Here you can see. So, here the minimum factor of safety is 1.30. So, this is minimum factor of safety 1.30. So, it satisfies both the criteria.

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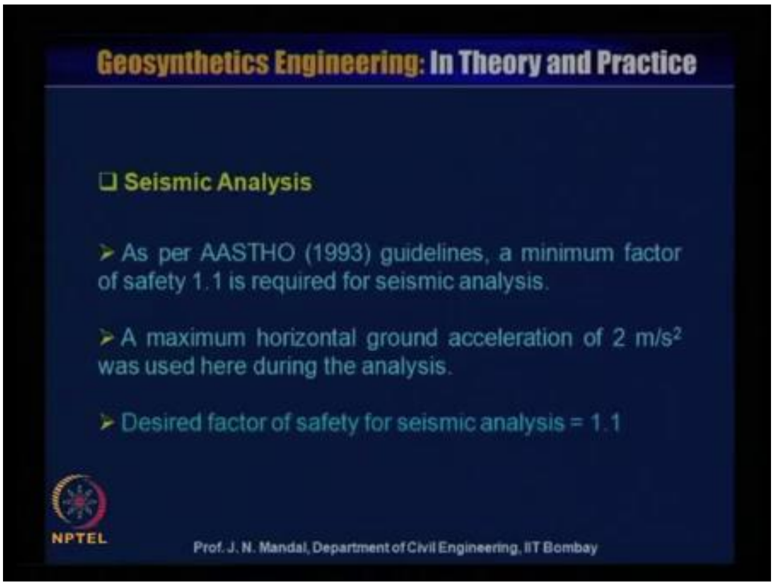


Apart from this it is also essential for the seismic analysis. As per AASTHO 1993 guidelines, a minimum factor of safety 1.1 is required for seismic analysis. A maximum horizontal ground acceleration of 2 meter per second square was used here during the analysis. We have the different zone and from the different zone you will be knowing what will be the maximum horizontal ground acceleration of that zone and it has also given in the different specification. So, here we have considered the maximum horizontal ground acceleration of 2 meter per second square for this analysis has been used and we require desired factor of safety for seismic analysis is equal to 1.1.

Now, we see that what is happening for the rotational analysis top and here is the safety map for the reinforced structure due to seismic, you can see due to the seismic what is happening and you check the code safety factor. This minimum factor of safety is 1.10. So, this is for the rotational analysis and next for the translational analysis. So, you can see for the translational analysis with seismic effect and you can see that what kind of the translational slip surface and this is the color code for the safety factor and this is minimum factor of safety is 1.08. So, we have checked the slip. Also we have check with the translational analysis for both for the static case and as well as also seismic case and we find that it satisfy that what will be the desired factor of safety. So, this way this design have been made.

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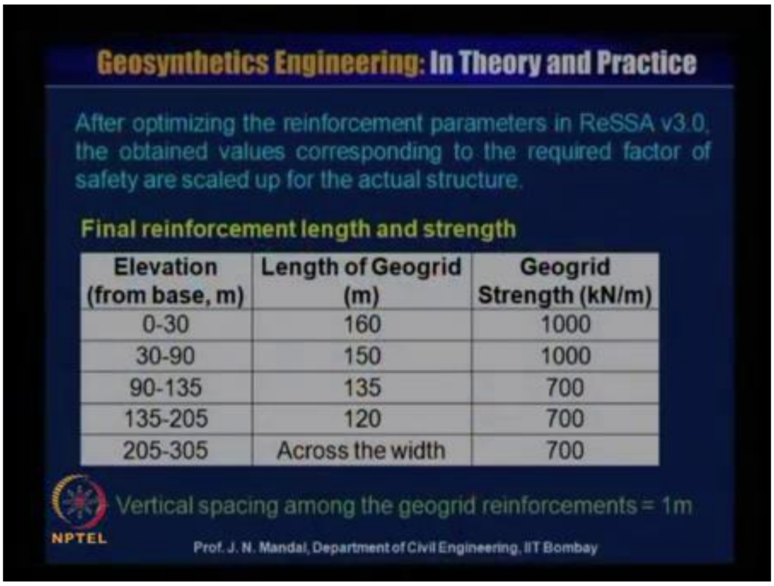


| Elevation (from base, m) | Length of Geogrid (m) | Geogrid Strength (kN/m) |
|---|---|---|
| 0-30 | 160 | 1000 |
| 30-90 | 150 | 1000 |
| 90-135 | 135 | 700 |
| 135-205 | 120 | 700 |
| 205-305 | Across the width | 700 |



After optimizing the reinforcement parameter in ReSSA v3.0 the obtained value corresponding to the required factor of safety are scaled up for the actual structure. So, this is the final reinforcement length and the strength. So, elevation from the base in meter 0 to 30 meter, the length of the geogrid is 160 meter and the geogrid strength is

1000 kilo Newton per meter and we are considering the vertical spacing among the geogrid reinforcement means 1 meter.

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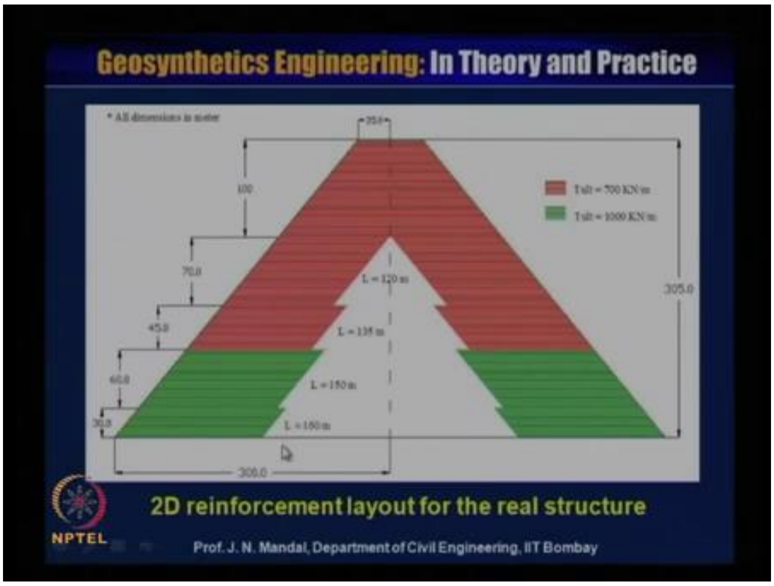


I am showing you this. This is the 2 dimensional reinforcement layout for the real structure. So, here from the bottom that what I say that 0 to 30 elevation meter. So, this is 0 to 30 and length of the geogrid is 160 meter and strength is 1000 kilo Newton per meter. So, that is why from 0 to 30 the length of the geogrid 160 meter and geogrid strength 1000 kilo Newton per meter. Now, 30 to 90 so you can see from 30 to 90 here. So, here the length of the geogrid is 150 meter and strength of geogrid is 1000 kilo Newton per meter. That is why 30 to 90, 150 length of the geogrid and geogrid strength 1000 kilo Newton per meter.

Now, again from 90 to 135 that means from 90 to 135 this zone for length of the geogrid is 135 meter but ultimate tensile strength of the geogrid is 700 kilo Newton per meter. So, here 135 length of the geogrid and geogrid strength 700 kilo Newton per meter. Now, next 135 to 205 and length of the geogrid 120 and geogrid strength 700, you can see here the length of the geogrid is 120 meter and the ultimate strength is 700 kilo Newton per meter and next that is 205 to 305. This is across the width and length of the geogrid is 700 kilo Newton per meter.

So, here from here to here across the grid this is 700 kilo Newton per meter and spacing is keeping constant. The spacing is 1 meter. So, you can see very high strength of the geogrid at the base and the lower strength of the geogrid at the top and this is about 300 to 300 means about 600 meter width and this height of this structure about 305 meter and this width is about 75 meter. So, this space has been kept that open and sometimes there may be any copy or this slopes and then people can go on the top of this embankment and can see a site seeing from this place. So, this is all the dimensions are in meter.

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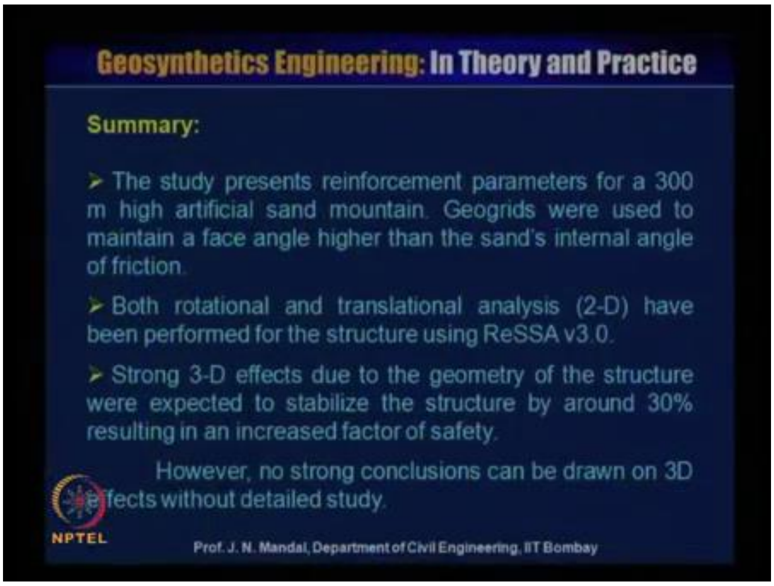


So, what is the summary in the conclusion? The study present the reinforcement parameter for a 300 meter high artificial sand mountain and geogrids were used to maintain a face angle higher than the sand's internal angle of friction. Both rotational and translational analysis 2D have been performed for the structure using ReSSA v3.0. Strong three dimension effect due to the geometry of the structure were expected to stabilize the structure by about 30 percent resulting in an increased factor of safety. However, no strong conclusion can be drawn on 3D effect without detailed study.

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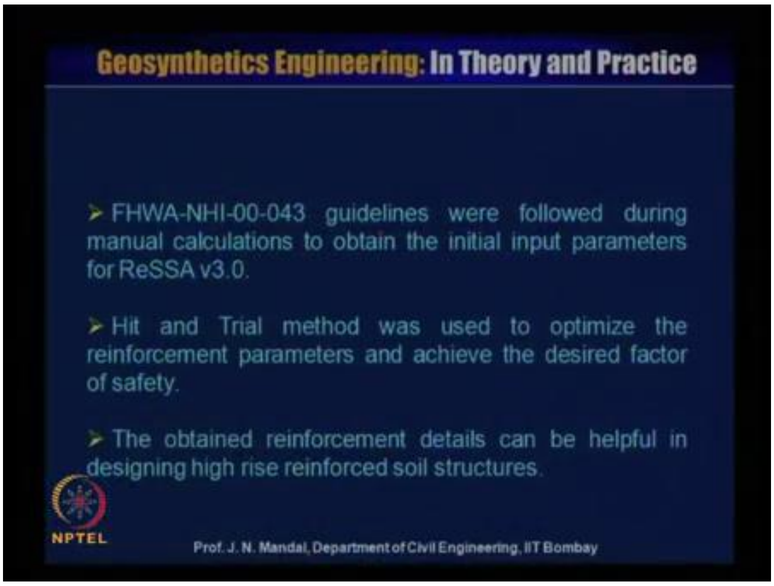


FHWA NH1 00 043 guideline were followed during the manual calculation to obtain the initial input parameter for ReSSA v3.0, and hit and trial method was used to optimize the reinforcement parameter and achieve the desired factor of safety. The obtained reinforcement detail can be helpful in designing high rise reinforced soil structure. So, these are the idea that how you can also design a very high reinforced soil slope.

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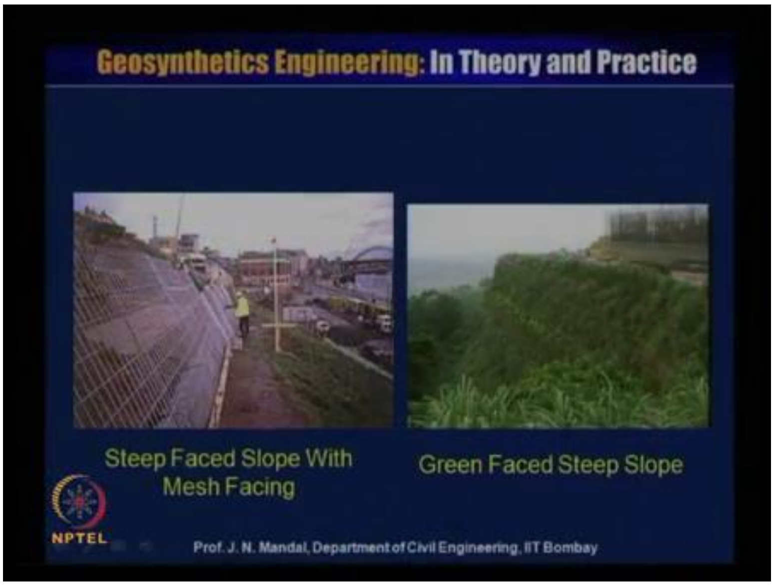

This are some of the steep faced slope with this mesh facing and this we can see some also the green faced steep slope has been also constructed, also it is coming about the slope about 100 meter in India.

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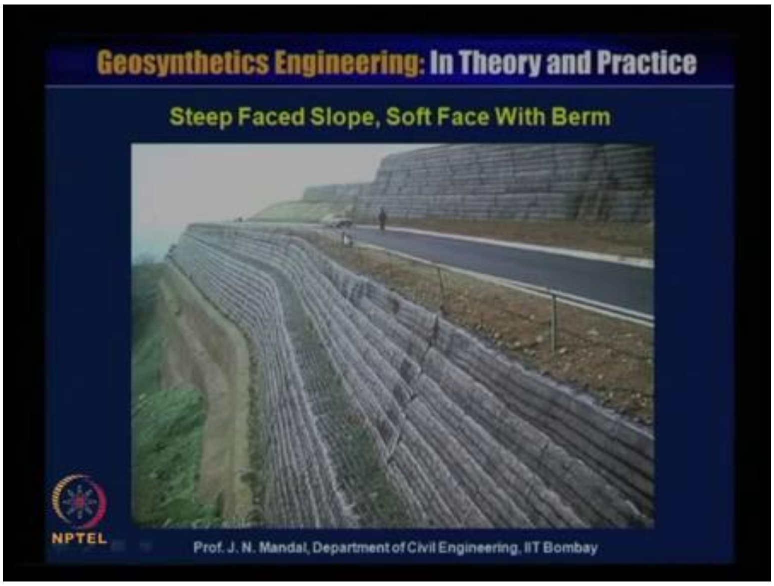


And this is steep slope and soft face with the berm. This is for the geogrid reinforcement has been used and this is the berm.

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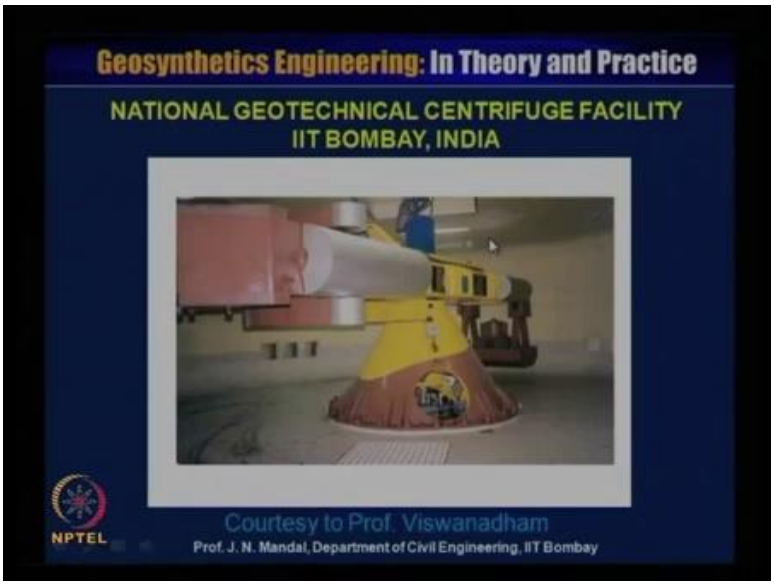

Next slide will that present our national geotechnical centrifuge facility in IIT Bombay and is courtesy to my colleague professor Viswanadham, and this is the national geotechnical centrifuge and this is only the first of its kind in India.

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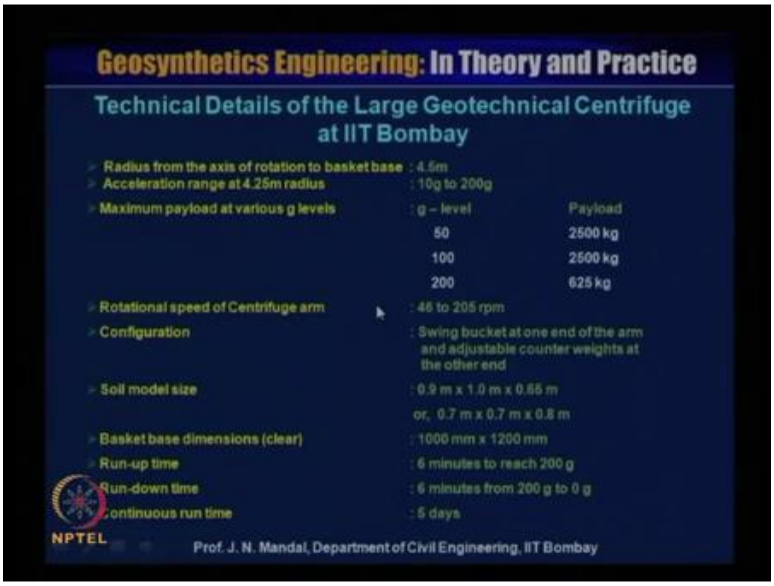


The technical detail of the large geotechnical centrifuge at IIT Bombay. The radius from the axis of the rotation to basket base is about 4.5 meter, acceleration range at 4.26 meter, radius it is from 10 g to 200 g maximum payload at various g level. So, if the g level is 50, pay load is 2500 kg, if g level is 100, the pay load is 2500 kg and if g level is 200, this pay load is 625 kg and rotational speed of the centrifuge arm is 46 to 205 rpm and configuration this is the swing bucket at one end of the arm and adjustable counter weights at the other end like this. This is counterweight and this is the bucket is here. So, it can be adjusted.

So, this is the swing bucket at one end of the arm and adjustable counterweight at the other end and soil model size. So, here you can make this model. I can place here and counterweight is here. So, this model size is 0.9 meter into 1 meter into 0.65 meter or you can make 0.7 meter into 0.7 meter into 0.8 meter. So, basket base dimension that clear about 1000 millimeter into 1200 millimeter and the run up time is 6 minute to reach 200 g and run down time is 6 minute from 200 g to 0 g and it will continuous run time for the five days. I must appreciate for acknowledge my first colleague professor B S Chandrashekaran, who has taken this initiative and developed and the fabricated in-situ in India, first of its kind in centrifuge modeling. I was associated initially as a member of this group.

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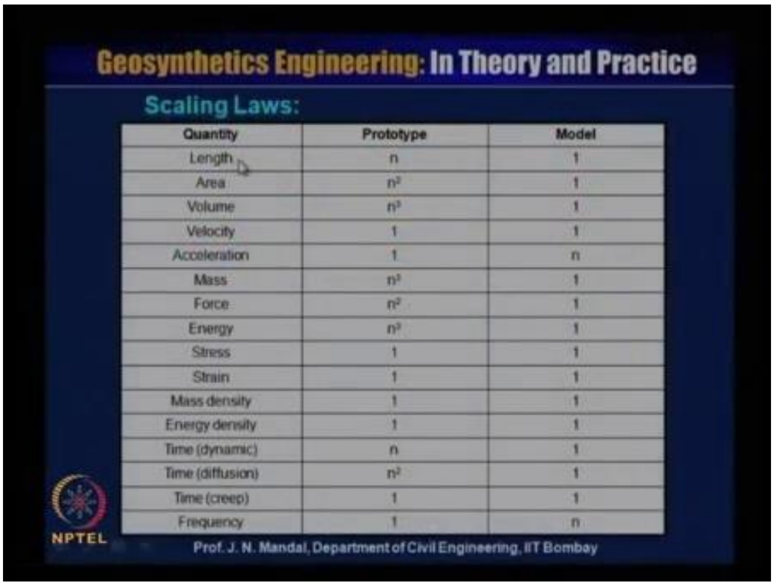


| Quantity | Prototype | Model |
|---|---|---|
| Length | n | 1 |
| Area | $n^2$ | 1 |
| Volume | $n^3$ | 1 |
| Velocity | 1 | 1 |
| Acceleration | 1 | n |
| Mass | $n^3$ | 1 |
| Force | $n^2$ | 1 |
| Energy | $n^3$ | 1 |
| Stress | 1 | 1 |
| Strain | 1 | 1 |
| Mass density | 1 | 1 |
| Energy density | 1 | 1 |
| Time (dynamic) | n | 1 |
| Time (diffusion) | $n^2$ | 1 |
| Time (creep) | 1 | 1 |
| Frequency | 1 | n |

So, scaling law this is quantity and prototype and model because this centrifuge modeling is required where it is not possible to know that what would be the behavior of the soil you know that when we are installing the pile at a very deep depth. So, it is very difficult but using this centrifuge modeling we can scale down for example that if the length of the pile is 29 meter. So, you cannot perform the test with the 20 meter length of the pire but in a centrifuge you can model down by scaling, let us say it is 8 centimeter. So, you can scale down and can perform that test and you can obtain the accurate result and that is why it is required, the scaling law.

So, you can see from the scaling law what is prototype and what is model. So, length prototype n model 1 area prototype, n square model 1 volume prototype, n cube and model 1 velocity prototype, 1 model 1 acceleration prototype, 1 model n mass prototype, n square model 1 force prototype, n square model 1 energy prototype, n to the power cube model 1 stress prototype, 1 model 1 strain that is prototype. 1 model 1 mass density prototype, 1 model 1 energy density prototype, 1 model 1 time dynamic prototype n and model 1 time diffusion, that is prototype n square model 1 and time creep prototype, 1 model 1 frequency prototype 1 and model n.

So, these are the scaling law. So, if we use that for example very high strength of the geogrid material and then accordingly, you could do scale down that very thin geogrid material.

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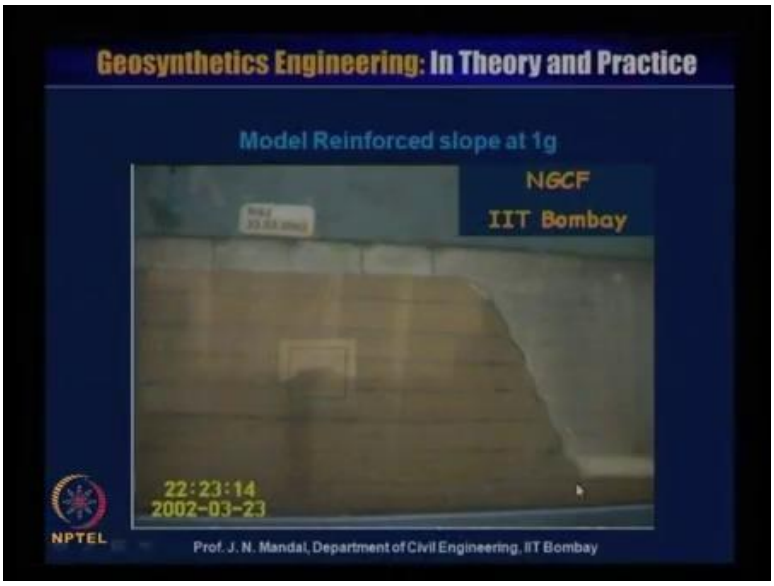


So, here that some of the experiment also have been performed in 2002 where here you can see that the number of the layer of the reinforcement. Here this black color you can see the number of the layer of the reinforcement and the sand has been used as a filling material. So, then you have construct a slope like this. So, this is the model reinforced slope at 1 g, this is the national geotechnical centrifuge facility at IIT Bombay.

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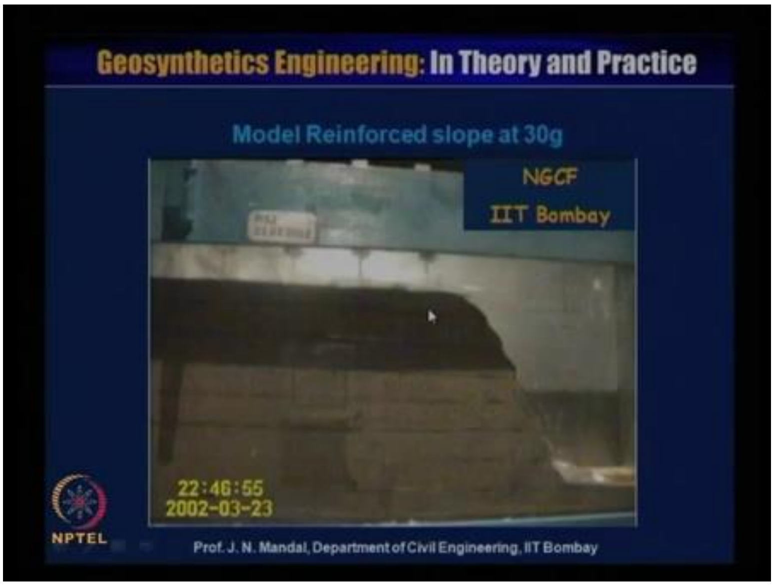


And next the model reinforced slope at 30 g. You can see when it is been 30 g then you can see what is happening in the model. You can see that naturally the kind of the slope failure may occur but here it is not properly visible but you can see later little bit more about this.

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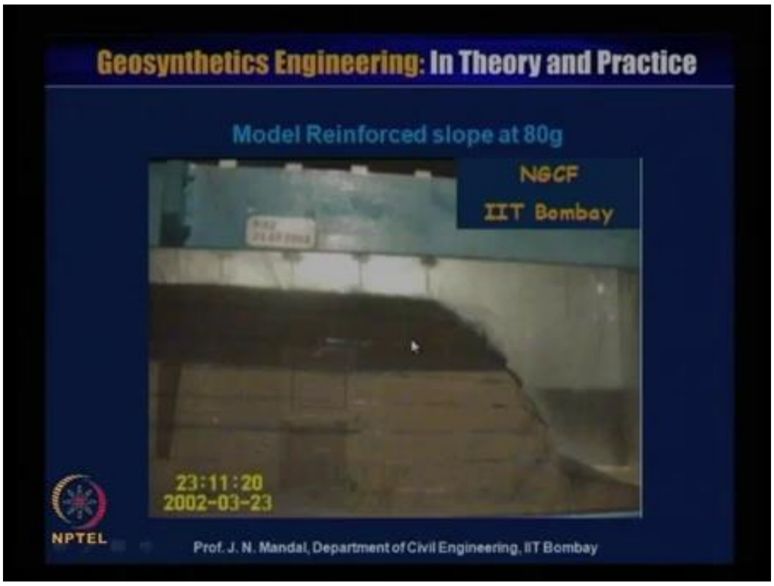


Now, next when the model reinforced slope has 80 g you can see this soil is pushing towards this direction and there is a possibility of the slip failure of the reinforced soil slope like this and this model reinforced slope at 80 g. Also many of my student also have used this centrifuge modeling for I was telling the fiber and the geogrid fly ash slope.

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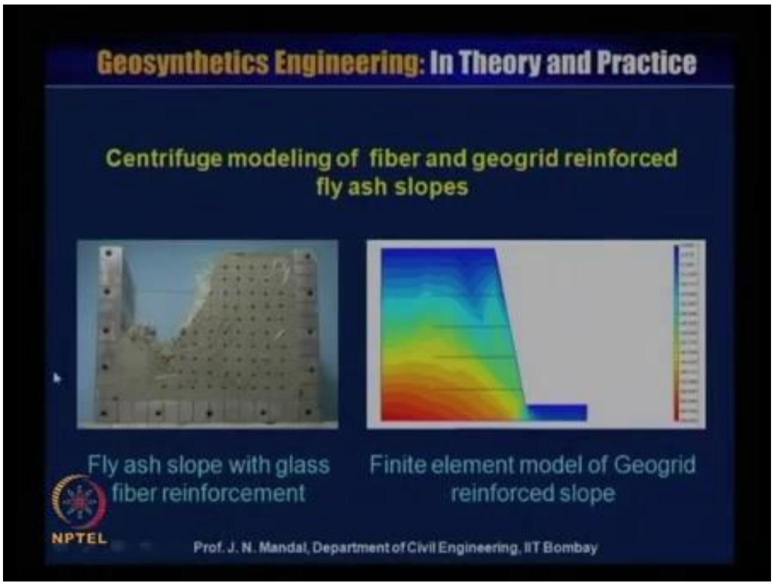


So, this is the basket for fly ash slope and also glass fiber has a reinforcement is used. This white color is the glass fiber and this centrifuge test has been performed. This is a small scale one centrifuge has been used and you can see that typical failure slope failure of the structure where we have used the fly ash. And also the glass fiber as a reinforcement, also that number of the layer of bamboo geogrid also has been used and performed the test is the centrifuge modeling. And here the finite element model using the geogrid reinforced soil slope has been also used.

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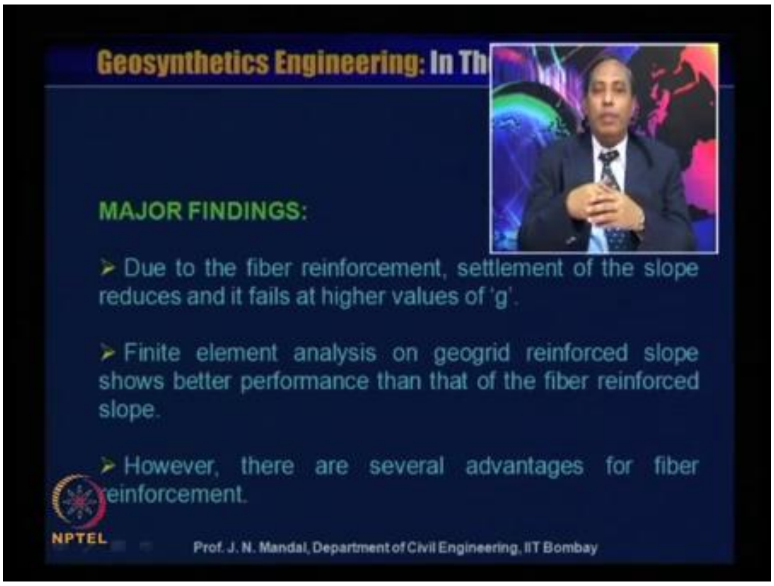


So, what are the major finding due to the fiber reinforcement? The settlement of the slope reduces and it fail at higher value of g, finite element analysis on geogrid reinforced slope shows better performance than that of the fiber reinforced slope. However, there are several advantage of the fiber reinforcement and now I have covered here that how that you have used this, used this model that back wrapping technique where the passive resistance also is developed. How it has been made the design chart for the different pore pressure ratio where R u is equal to 0 or 0.25 or 0.50. From this design chart you can calculate that what will be the tensile strength of the geogrid material and also, you can calculate what will be the length of the geogrid.

And next I have also discussed about the 305 meter height reinforced steep soil slope using the sand and geogrid as a construction material and this sand is easily available and you can see that how we have used the ReSSA models. Software package has been used and how this for this model how the scale has been down and the how the strength of the geogrid material has increased and also unit weight, also has been increased and how the geogrid strength also has been decreased. And ultimately we have calculated what will be the factor of safety for the rotational failure as well as for the translational failure.

It is under both for in the static condition as well as in the seismic condition and you have seen that how these road also have been performed but I am not gone through the details about the road and the foundation problem there, and at the end we talk about our centrifuge modeling and the number of test have also been performed. You have been used that geogrid material, even then geotextile material, even then fiber, different types of the fiber material and we find how it is more effective and stable. That slope can be constructed apart from that also we covered that Texsol method, how the filament or the thread mixed with the soil has been used for the slope stability. With this I just finish my lecture today. Please let us hear from you any question.

Thank you for listening.