Geosynthetics and Reinforced Soil Structures
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Lecture - 24
Soil Embankments Supported on Geocell Mattresses

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Very good morning students. In today's lecture let us look at the soil embankments that are supported on geocell mattresses.

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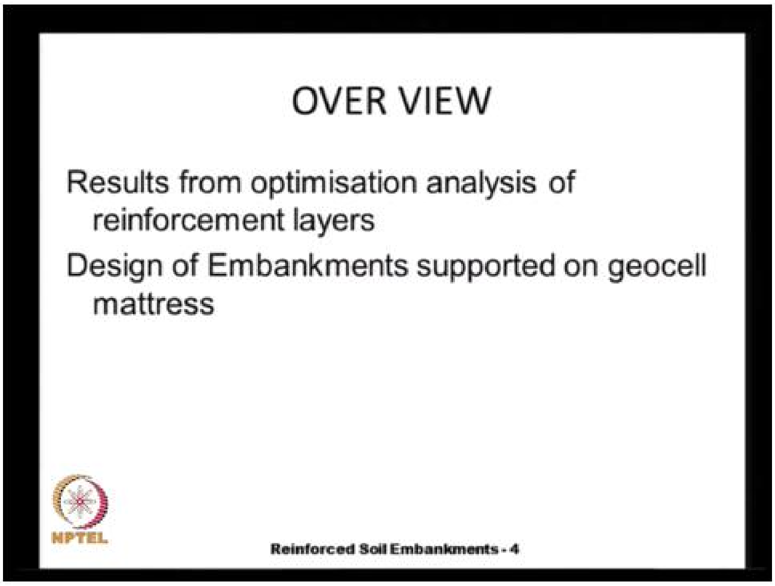

The brief overview of today's lecture is in the previous lecture we have discussed about the optimization of the reinforcement layers. So, that we can economize on the on the reinforcement that is provided, and then we will look at the design of embankments that are supported on geocell mattresses.

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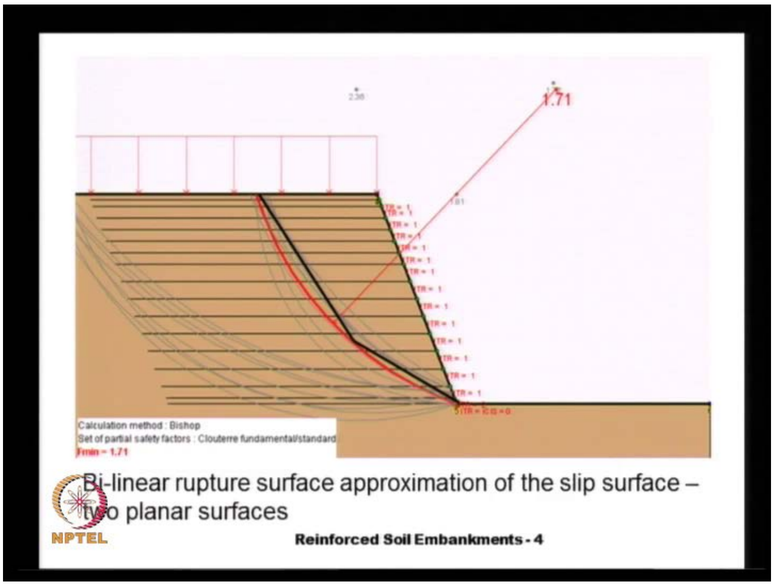

In the previous lectures we have seen the design of a steep slope that is resting on hard foundation soil using planar wedge , and we have seen that we require a sixteen layers of reinforcement layers. And which were provided at spacing of half meter vertical spacing and the slip circle analysis gives as a factor of safety of 1.71, and we have also seen that this slip circle can be represented more appropriately using bilinear wedge or two-part wedge analysis. And which is which we have seen that which is more appropriate because all the the embankments are built using granular soils for which the planar rupture surfaces are more appropriate than curved rupture surfaces.

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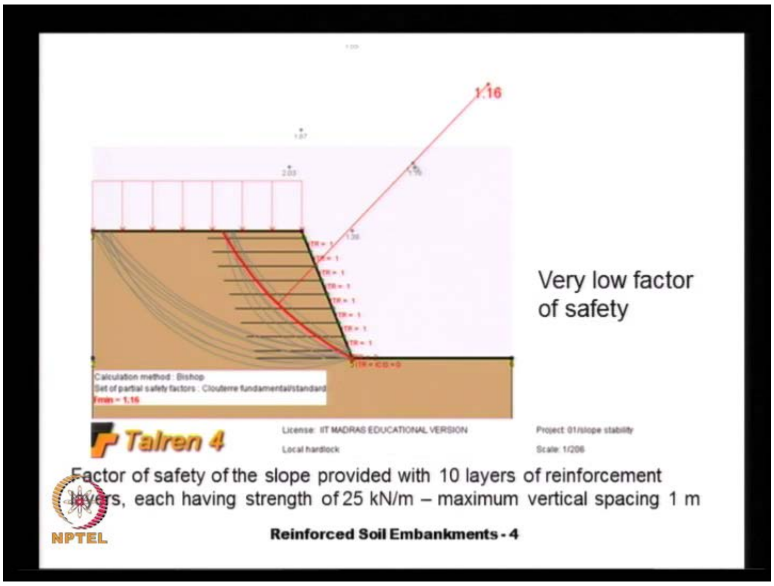

And we have seen that we can redesign that slope using the two-part wedge analysis, and we have the design quantity of reinforcement was ten layers of reinforcement layers each having the strength of 25 kilo newtons per meter. And they were provided at very large spacing 1 meter spacing and we have adjusted the ten layers within the nine meter high embankment and the slip circle analysis gives us a very low factor of safety 1.16 which is unacceptable. Normally we require at least 1.4 to 1.5 for slopes that are carrying permanent highways and railway embankments. So, we need to redesign this.

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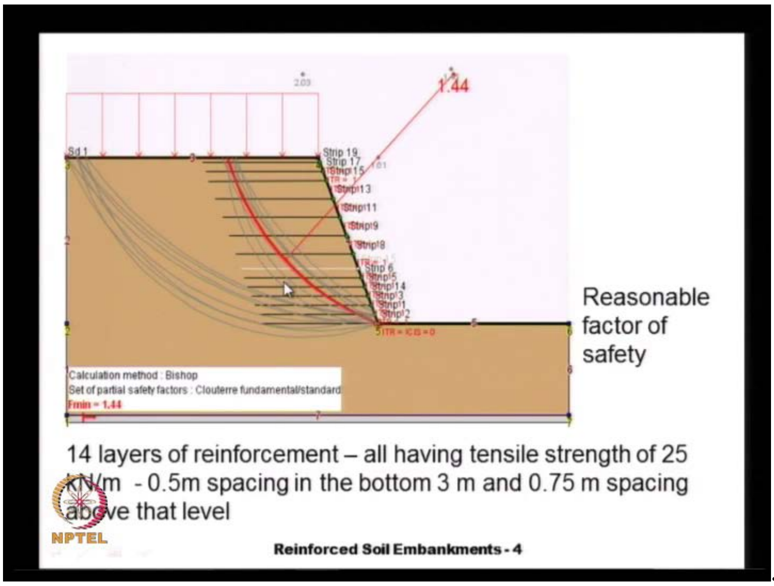

And so we can is actually by decreasing the vertical spacing we can provide a 14 layers, and we see that when we provide a 14 layers of reinforcement all having tensile strengths of 25 kilo newton per meter the factor of safety increases to 1.44. And the reinforcement were reinforcement layers were provided at half meters spacing in the bottom bottom 3 meters and 0.75 meter spacing, and above that level from 3 to 9 meter height and the factor of safety is 1.44, and let us see whether we can do some optimization.

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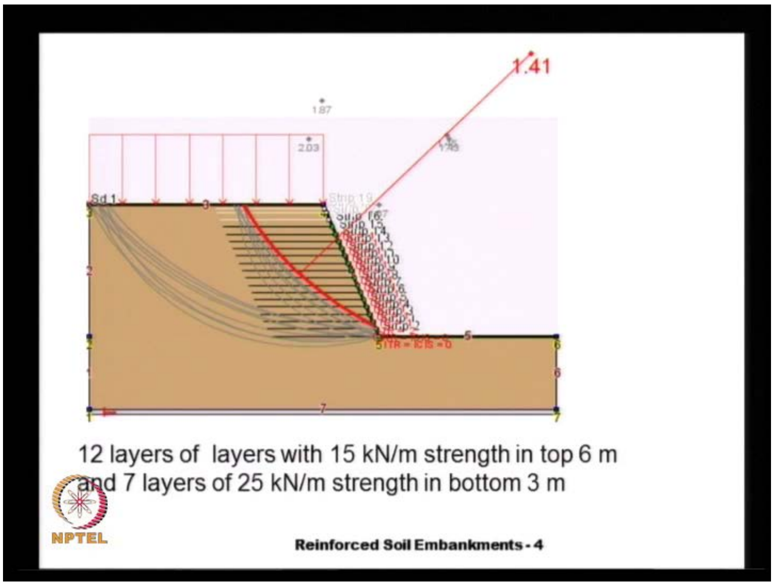

And is actually it is an iterative process we can use a computer program and come out with more efficient alternatives, but here I have considered only two types of reinforcements one having a strength of 25 kilo newton per meter. And the other having strength of 15 kilo newtons per meter and in the in the top 6 meters twelve layers were provided having strength of 15 kilo newton per meter. And in the bottom three three meters stronger geogrid layers having a strength of 25 kilo newton per meter are provided and the factor of safety is 1.41 which is very nearly equal to the previous case where we had provided fourteen layers all having a 25 kilo newton per meter strength.

So, it is is actually the factor of safety of 1.4 is a reasonable value that can give adequate safety for the for the embankment for the long term performance of the embankment. So, at this point we should realize, that it is possible to redistribute given quantity of reinforcement uniformly over the height of the embankment and come out with more efficient solutions. This this 1.41 is obtained with twelve layers of reinforcement layers having a strength of 15 kilo newton per meter, and seven layers of 25 kilo newton per meter strength and we could actually do some more trials. And see whether we can get similar factor of safety, but with will having more combinations of the reinforcement layers that we can try later on through some computer programs.

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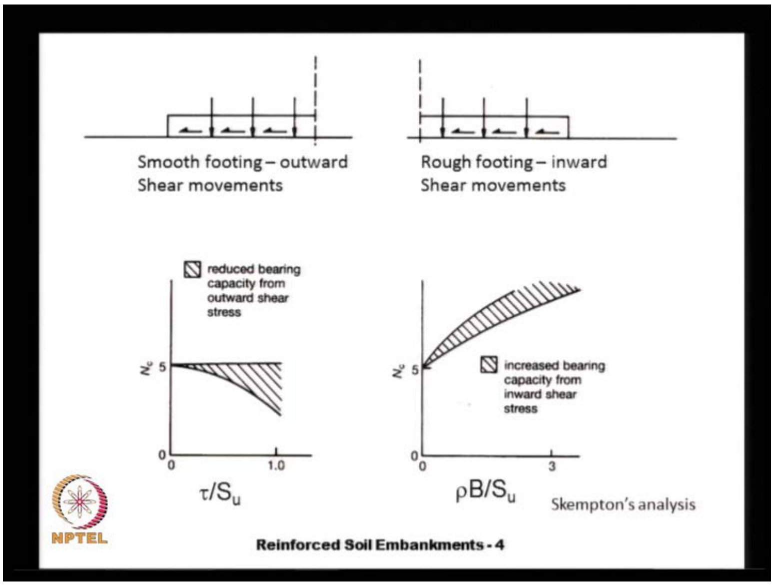

And now let us go to the topic of today's lecture that is the construction of the embankments on geocell mattresses. And the concept for the design of geocell mattress, it goes way back to this skempton's analysis who showed that for smooth footings the shear deformations are outward deformations like for example, here if this is the central line of our footing. And if we apply some loading on a smooth footing where there is no friction between the footing and the soil the the deformations are outward, and he showed that the the bearing capacity. Because of this it can reduce the N c factor of 5.14 is for a rigid rough rigid footing, but if you have a smooth footing it is possible in some cases we can have a strength the N c factor less than 5. That means, that as we make the the footings smoother our bearing capacity reduces on the other hand, if we have a rough footing where in the deformations are inwards that is towards the centre.

He showed that the in this case our bearing capacity factor N c is proportional to the footing width. That means, that as your footing width is increasing your bearing capacity increases and this what he shown here for different cases of the B, that is the footing width. And S u is the undrained shear strength of the soil the bearing capacity shouts up as your footing width increases this rho B by S u is a is a non-dimensional number. And we see that there is a drastic increase in the in the in the bearing capacity of the soil when we have a rough rigid footing.

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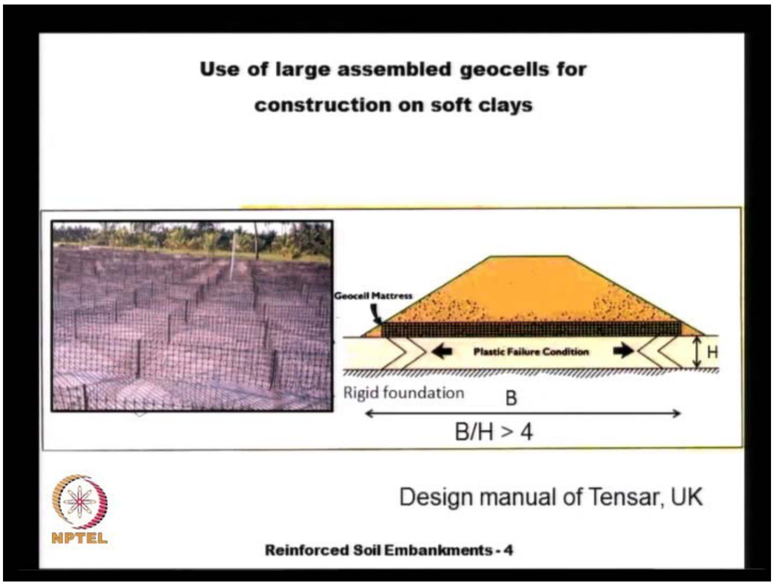

And this concept can be explained like this say that we have an embankment that is resting on geocell mattress like this, and we have a thin soft clay layer. And we have a rigid foundation at the bottom of the the clay layer, and the plastic failure conditions is more similar to squeezing of the clay between two rough rigid platens. And here is on the left hand side we see the geocell mattress being fabricated, and this particular photograph is from the design manual of tensar company from U K.

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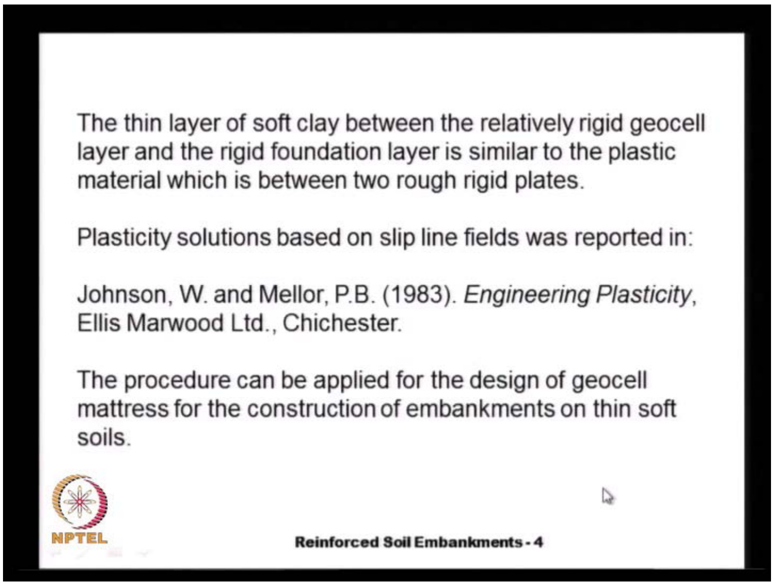

The thin layer of soft clay between the relatively rigid geocell layer, and the rigid foundation layer is similar to the plastic material, which is between two rough rigid platens. And for this case the plasticity solution was was proposed by johnson and mellor in 1983 in their book on engineering plasticity, and who derived the slip line fields for for deriving the for deriving the the bearing capacity or the bearing pressure maximum pressure. That we can apply on the platens, and this procedure can applied for the design of geocell mattress for the construction of embankments on thin soft soil layers.

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And this particular procedure that we are going to discuss is only applicable for the case, where the embankment base width is greater than four times the thickness of the soft clay layer is actually, this is our embankment base width is is B like this. And the height H of the of the thin soft clay layer and the B by H should be at least more than 4 for us to apply the the theory derived by Johnson and Mellor based on the slip line fields. And there were two excellent papers that summarize the the extension of this procedure for the design of the geocell mattresses one was published by 9 1988 by Jenner bush. And Bassett the title is the use of slip line fields to assess the improvement in bearing capacity of soft ground given by a cellular foundation mattress installed at the base of an embankment this was presented at the symposium theory. And practice of earth reinforcement and this subsequent paper in 1990 by bush Jenner and Bassett and the design and construction of geocell foundation mattress supporting embankments over soft grounds is actually the first paper is more on theoretical aspects on how to adopt the slip line field method for calculating the bearing capacity improvement below geocell reinforced embankment.

And the second paper is more on how to apply the theory for the design, and then they have also shown the application of this method for construction of of a large size embankment. And they also provided the lot of field data in this paper and they claim that this method of design is quite successful in many situations where they have achieved uniform settlements, and they bearing capacity was found to be much higher than what what it would be otherwise without our geocell mattress.

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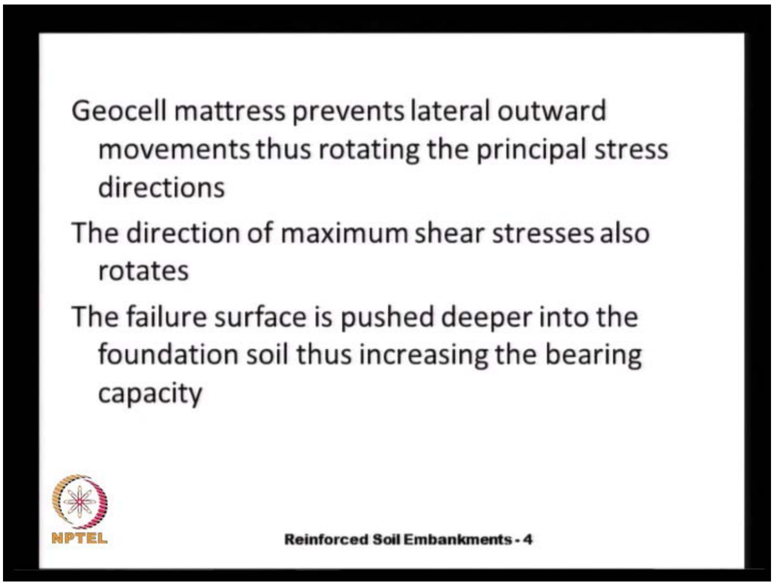

Well, basically the geocell mattress it acts like a very rough and rigid platen, and it prevents lateral outward moment and thus it rotates the principle stress directions. So, without this without geocell mattress, if there is only embankment the principle stresses. We can say that the may the principle stress is vertical and the miner principle stress is horizontal and that may remain. So, because our embankment is relatively flexible in the absence of any geocell mattress, and we can assume that there will be lateral outward of the of the soil. And then we form the normal slip circle, but in this case because of the roughness of the geocell mattress the outward movement is prevented and the direction of the principle stresses is rotated, and the even the direction of maximum shear stresses also rotates. And the result of all these is that our failure surface is pushed deeper into the foundation soil this increasing the bearing capacity and that is the main principle of this of this procedure.

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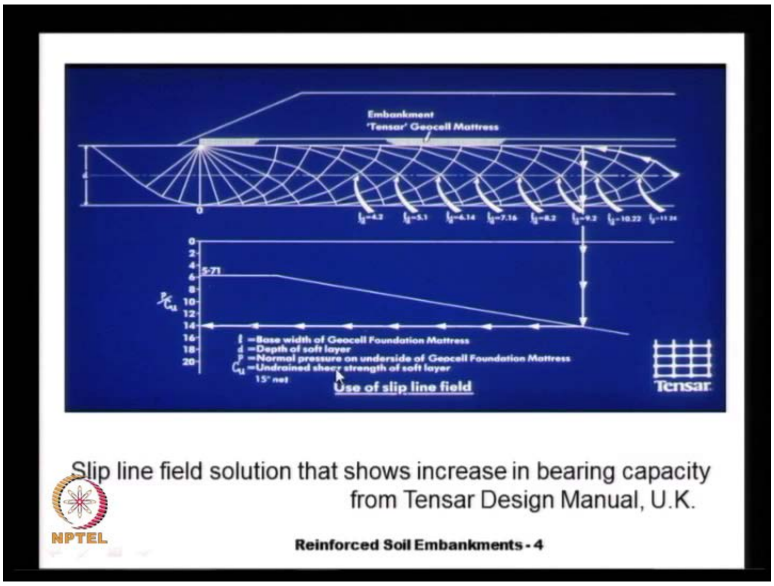

And once again this photograph is from the Tensar design manual, and here we see that we have an embankment resting on a on a thin clay layer. And these are all the slip lines slip line fields that we can draw each of them is drawn at at 15 degree intervals, and Terzaghi bearing capacity theory says that our the N c factor p by C u is 5.71. And because we are preventing the formation of the of the plastic failure surfaces, because of the rotation of these this plastic, the slip line fields our bearing capacity factor goes on increasing for very thin footings or very thin, very narrow embankments up to may be about B by H of about one our bearing capacity factor is nearly equal to 5.7.

But we see that as our footing width is increasing the bearing capacity increases, and it attains maximum value of about 16 to 17. But for this particular case depending on the width of the embankment in this particular case our bearing capacity factor increased to 14, which is quite substantial, because the normal bearing capacities five times e u, whereas here. Now, we have fourteen times C u it is almost increase of three times and more importantly, we can expect uniform settlements, because of the provision of this the relatively stiff geocell mattress.

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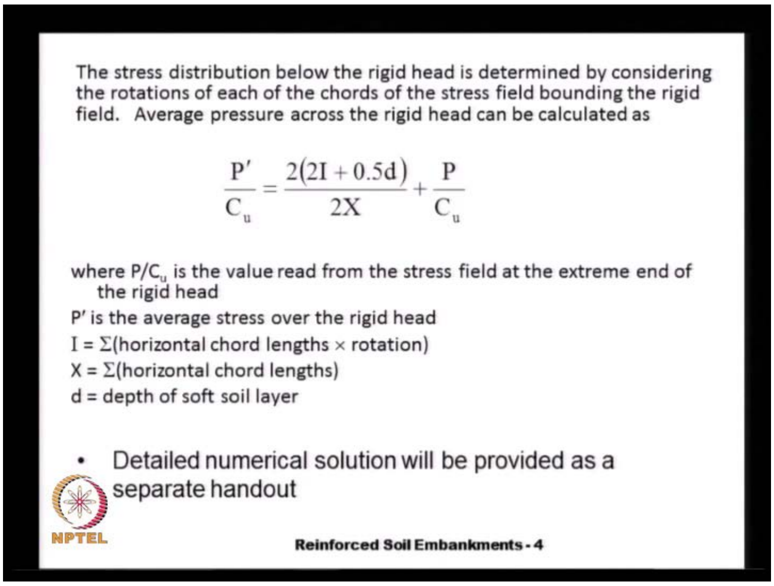

And the equation that explains the stress the redistribution, and the increase in the and the the bearing capacity is given like this here this the P by C u is the value read from the stress field at the extreme end that is our 5.7. And then this internal quantity 2 I by 0.5 d by 2 X the I is the the sum of the horizontal chord lengths times the rotation the rotation of the slip line fields, and the X is the the net sum of the horizontal chord lengths and d is the depth of the soil layers.

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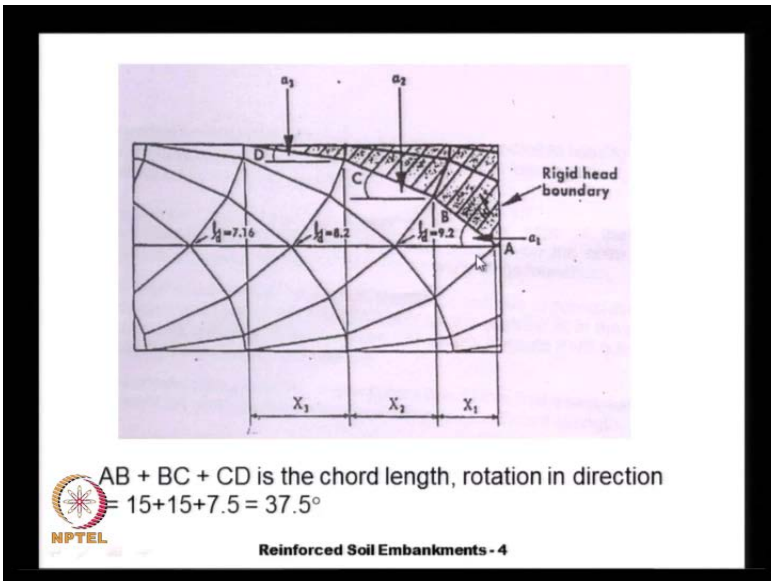

And in principle this is obtained like this is actually, let us consider four flip line fields A B C D and the chord lengths A B A A B plus B C plus C D is the chord length. And the rotation is basically this is this is the rotation 15 degrees 15 degrees and 7.5 degrees that is totally 37.5 is the rotation that is is undergone by the slip line fields and this type of calculations need to be performed for the given case of width of the the embankment. And then the thickness of the of the soft clay layer and then we have to estimate the increase in the in the bearing capacity factor the solution look something like this basically we plot a into graph by drawing the embankment, and the geocell to some scale and then we super impose this slip line fields. And then we can read off the increase in our bearing capacity factor.

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And now let us see some practical aspects on how to construct the the geocell layer and the geocell layer is usually constructed out of the biaxial type geogrids. The biaxial as we know those are the the geogrids that have significant tensile strengths both the principle directions. And here we see that we have typical biaxial geogrids the rib width seems to be the same in both the directions, and the aperture openings also the same and here we have the geogrids that are cut to required height. And the assembled at the site and at the bottom we have a geogrid layer this basically the bottom geogrid layer acts as a separator. And when we infill this these geocell mattress with some granular material the bottom layer prevents the separation or the in the downward flow of this aggregate.

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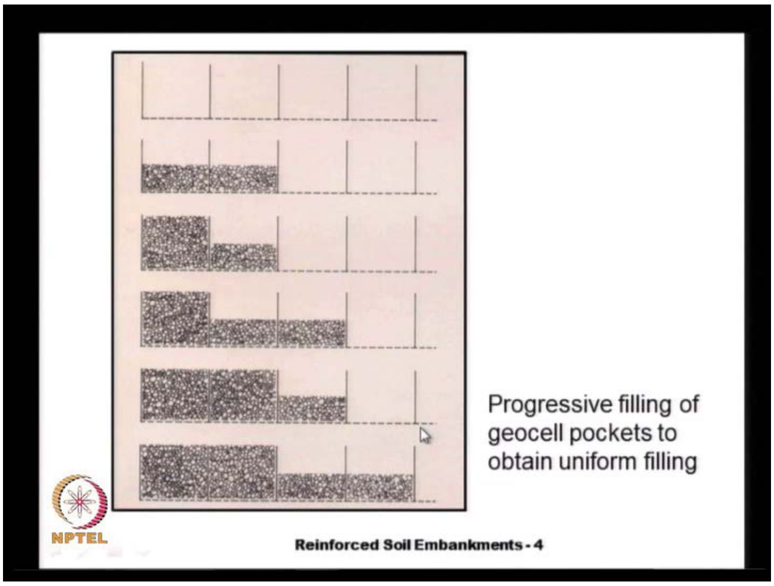

And is actually when we construct these geocells there all empty ,and now we need to fill them with some aggregate or some granular material, and the we need to carefully do that filling. Because the otherwise if we fill it randomly we may not get uniform consistency or we may not get we may damage the geocell layer, and the suggested procedure is like this we fill aggregate only to some small height. And once we fill one pocket we fill the neighboring pockets to the same height, and then we can increase the height of the aggregate and the in the first pocket, and then then we can increase the height in the next pocket and then we can fill the the subsequent neighboring pocket, and so on.

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And after all the the geocell mattresses are filled with aggregate. We can have the normal a vibro rollers to compare the entire layer. So, that we get good compact fill.

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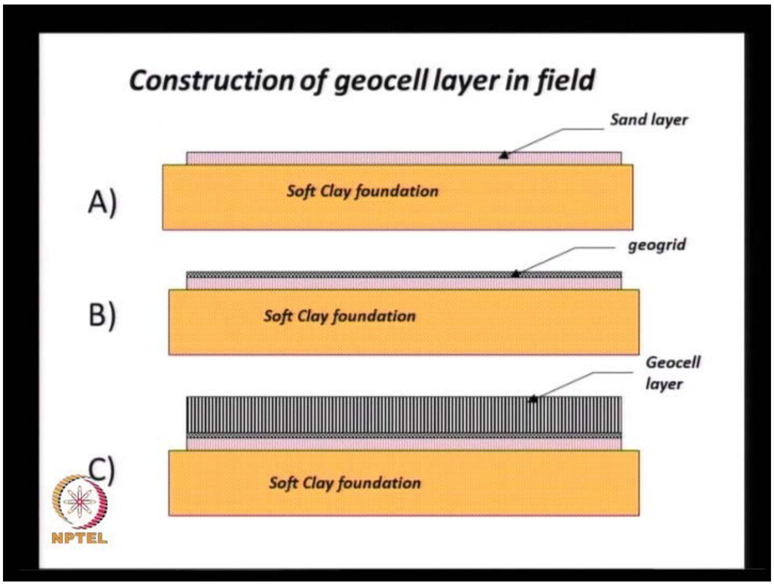

And the procedure for constructing the geocells in field is something like this, see if you have a soft clay foundation usually we need a working mat. So, that we can bring in our construction equipments, and that working mat will be in the form of a sand layer or some aggregate layer, then we will provide a horizontal layer of a geogrid that acts as a as a separator. So, that the infill material that we fill in the geocell mattresses does not escape into the soft foundation soil. And then we we construct these geocell hm these layers vertical geogrid layers.

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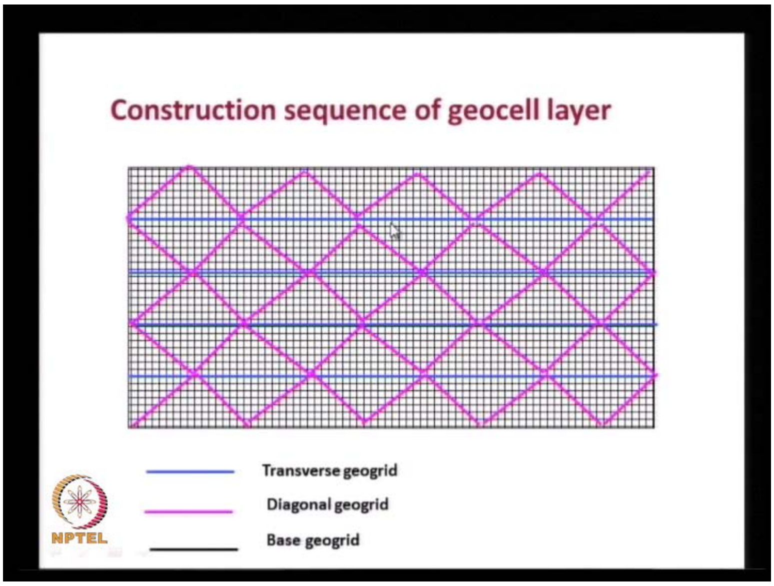

The procedure is something like this, this is a plan view we lay the the the geogrid separator on the ground, and then we have these transverse geogrid layers that are constructed. And for this purpose we need to provide some some supports along the length like like this, what we see here these are all called as the bodkin joints and they also provide some vertical support for the formation of this geocell. So, after we construct these these longitudinal geogrid layers we can now connect the transverse members the transverse members. And then once the whole thing is the entire mattresses assembled it is ready for filling with aggregate, and this is what we have the this is soft clay foundation and the geocell layer a filled with aggregate.

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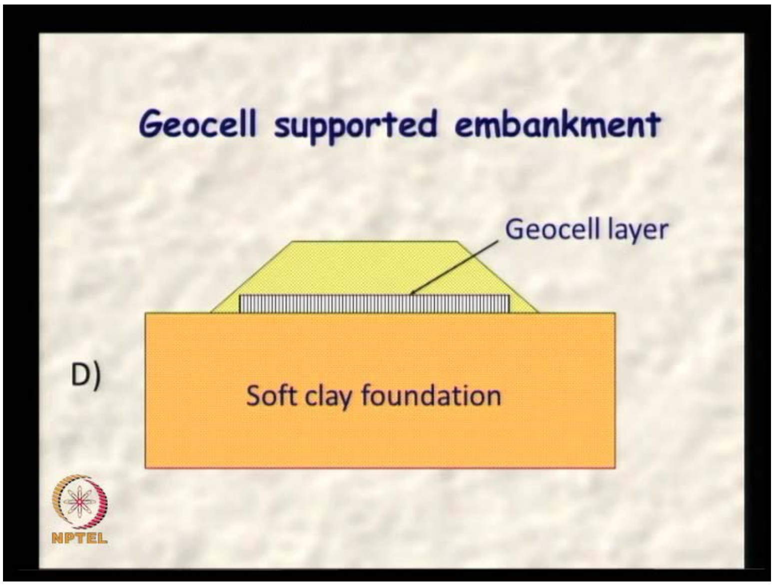

And then our our embankment.

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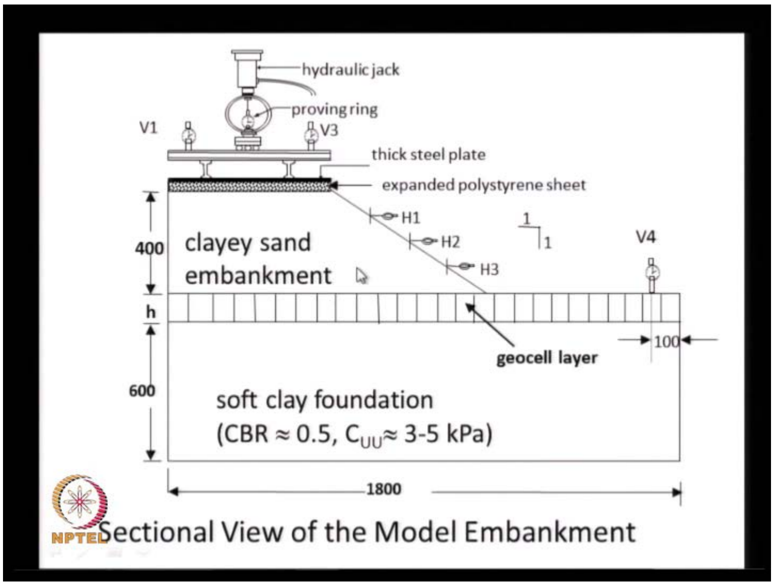

Well in this lecture I want to briefly present a some experimental results that we have obtained at IIT, Madras based on some laboratory tests here, we have taken soft clay soil of 600 m m depth the length of this tank is 1.8 meters. And it is filled with soft clay soil almost at liquid limit consistency, and which has a C B R of 0.5. And the untrained cohesive strength that we get from the vein shear test is about 3 to 5 kilo pascals very low strength, and the consistency is such that the person stands on this clay they just simply sink up to the knees. Then this the on the soft clay layer one layer of geocell was spread of height H that itself is a variable that we will see, and on top of this clayey sand embankment of height 400 m m and to stimulate height embankments the uniform pressure load was applied. And this uniform pressure load was distributed evenly by providing a some e p s layers, and then there was a thick steel plate. And then the load was applied a through a proving ring and hydraulic jack measured three vertical deformations there is one here, there is one dial gauge just behind this proving ring and there is one more dial gauge here. And then the horizontal deformations within the height of the of the embankment, and then the heaving of the foundation soil was measured at the at the far end of the of the tank through this dial gauge.

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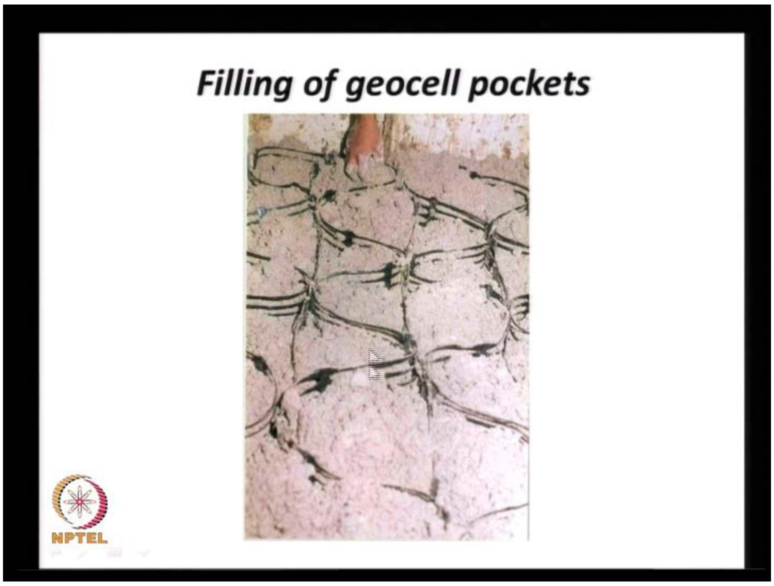

And here we see the the formation of the geocell mattress, and then filling with filling with soil, and two types of infill materials were considered one is the granular soil material and the other is soft clay material itself.

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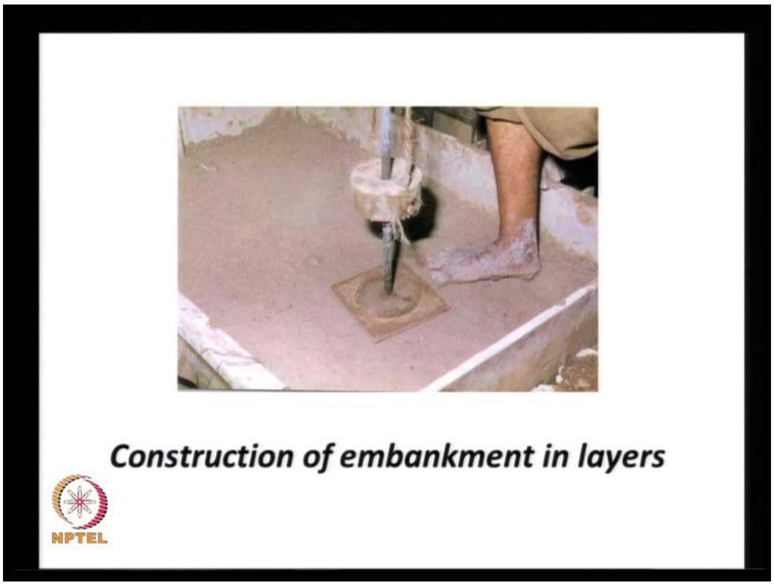

And here we see the formation of the embankment that was done with by compaction.

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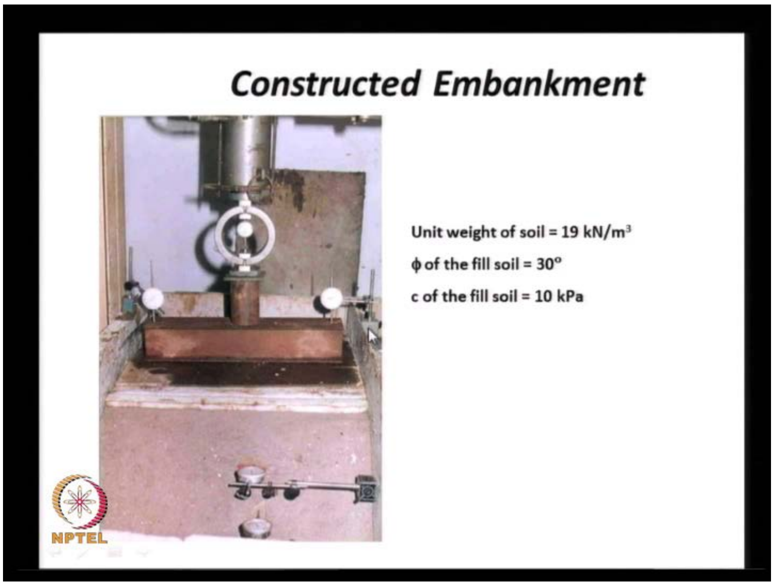

And here we see the constructed embankment this is the embankment slope, and this is the top surface, and the embankment was constructed using a soil the it is a it is a clay sand. So, it has got some cohesion of 10 k P a, and the friction angle of the fill soil was 30 degrees and the unit weight was approximately 19 kilo newtons per meter.

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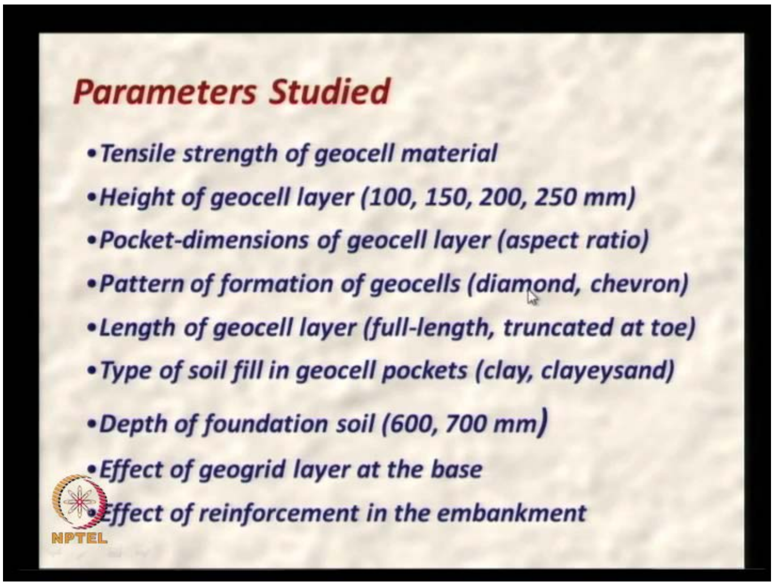

And the very large number of laboratory test was performed by varying different parameters the the ten the first parameter that was varied was the tensile strength of the the geogrid that was used for fabricate in the geocells. And the height of the geocell layers four different heights were considered 100 m m 150 m m 200 and 250 m m and then the pocket opening size of these geocell layers, that we call as aspect ratio and then the pattern of formation of the geocells. And there are two patterns one is a diamond pattern and the the other is chevron pattern that we will see through a slide later.

And then the length of the geocell layer the full length means the the geocell was provided over the full length of the tank, and then the truncated length means the geocell is provided only after the two of the embankment that is normally, what is done in the field? Then the type of a soil in fill in the in the geocell pockets the clay soil. And the clayesand and then two depths of foundation soil were were considered 600 m m and 700 m m and the and then the separator layer and the effect of geogrid layer at the base and the reinforcement within the embankment soil.

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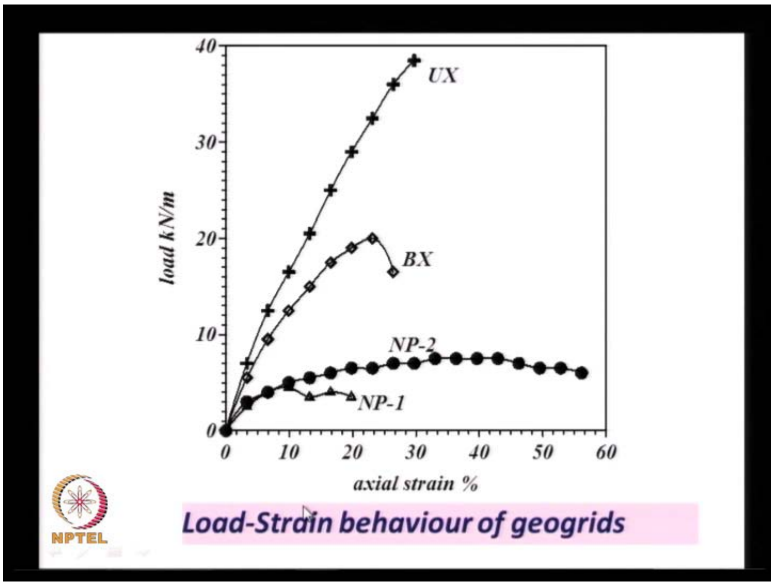

And the typical load strain behavior of the geogrid layers is like, this is actually four types of geogrids over used for fabricating the the geocell two of them are very soft mesh’s which are called N P 1 and N P 2. They have a tensile strength of hardly about 6 to 7 kilo newtons per meter and their peak strengths is developed at very large strain anywhere from about 15 percent to to 30 percent, then there was a biaxial geogrid with a peak strength of about 20 kilo newtons at a strain level of about 20 percent. And then uniaxial geogrid that has a peak strength above 40 kilo newton per meter and that develops at about 25 percent axial strain.

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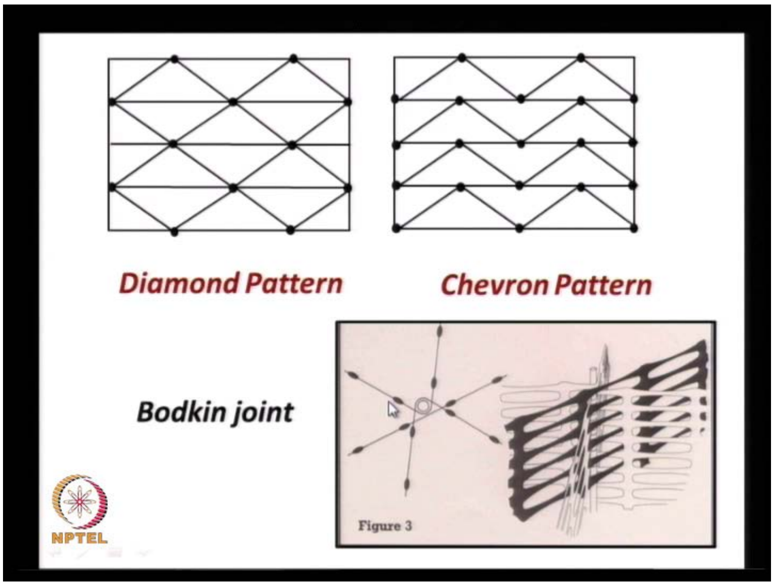

And two patterns were considered for formation of the geocell one is the diamond pattern, that is what we have seen earlier in the in the animation the each of these is like a diamond. Then chevron pattern this is like a half diamond shape and the we use a bodkin joint to support to form the these vertical joints like this. We have a plastic rod and we have the geogrids going in different directions in the length direction and then the transverse direction. And we attach them by passing the geogrid through each other thrugh these aperture openings, and then we inset this plastic rod in between to form the joint and these are all the joints these dots there all the joints.

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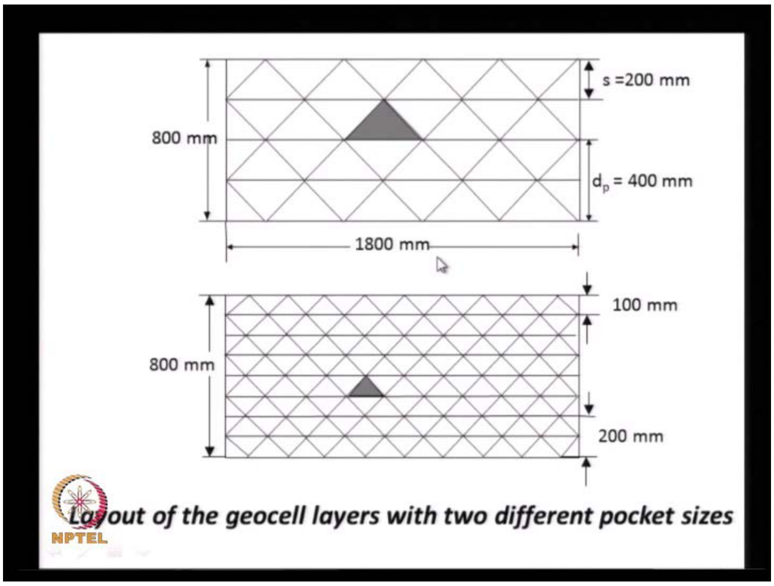

And in plain view this is the this is the view and two types of pocket openings over considered the tank width was 800 m m, and the length of the tank is 1800 m m and the spacing of 200 m m like this dimension. And then 100 m m and the the triangular opening space that we get that was converted into an equivalent circle just for the purpose of calculating the aspect ratio, and other things and equivalent diameter corresponding to this triangle was used in all over calculations.

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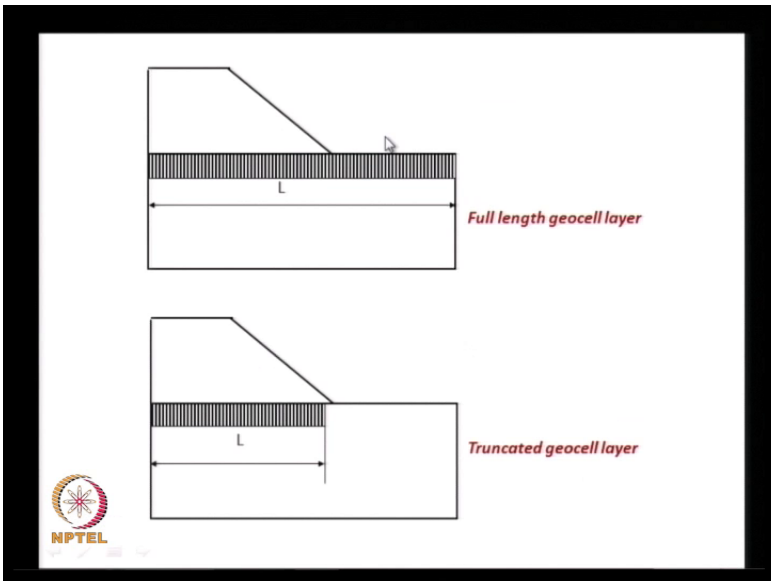

And the two cases of embankment lengths considered this is the full length case where in the entire length of the tank was covered with a geocell, and the other is the truncated geocell where in the geocell was provided up to the two of the embankment like this.

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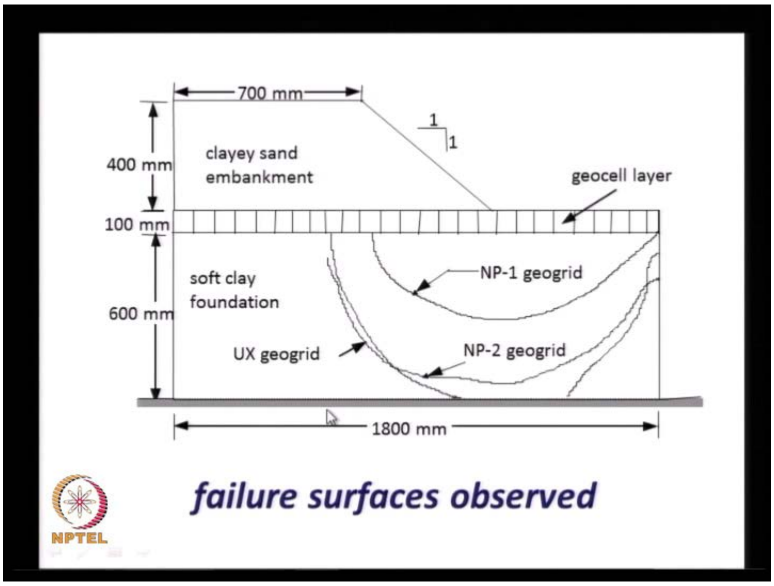

And all the test were performed by having a prospects sheet on one side of the tank which is transparent, and we can observe the internal deformations, and with N P 1 type of geogrid reinforcement the slip circle was something like this. And N P 2 interestingly it has the same the similar tensile strength, but then the its opening sizes the aperture opening sizes are much smaller, and the performance with N P 2 geogrid was almost equal to that of the U X the unaxial geogrid. And the effect of using a stiffer geogrid layer for forming the performing the the geocell is that the slip surface is pushed down and when we used a very stiff geogrid U X geogrid is actually the slip surface was intersecting the the tank foundation. And so the result of this at the different slip circles is reflected in the amount of pressure that we can apply.

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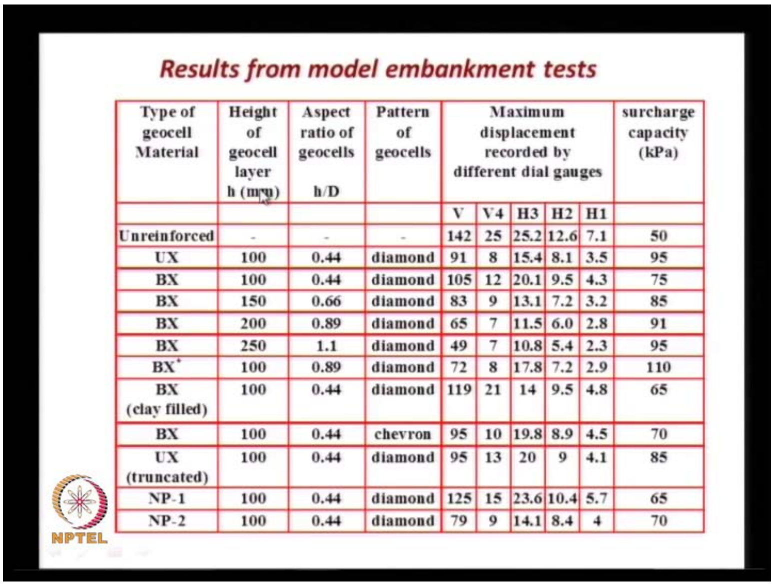

Results from model embankment tests

Type of geocell Material	Height of geocell layer h (mm)	Aspect ratio of geocells h/D	Pattern of geocells	Maximum displacement recorded by different dial gauges					surcharge capacity (kPa)
				V	V4	H3	H2	H1	
Unreinforced	-	-	-	142	25	25.2	12.6	7.1	50
UX	100	0.44	diamond	91	8	15.4	8.1	3.5	95
BX	100	0.44	diamond	105	12	20.1	9.5	4.3	75
BX	150	0.66	diamond	83	9	13.1	7.2	3.2	85
BX	200	0.89	diamond	65	7	11.5	6.0	2.8	91
BX	250	1.1	diamond	49	7	10.8	5.4	2.3	95
BX*	100	0.89	diamond	72	8	17.8	7.2	2.9	110
BX (clay filled)	100	0.44	diamond	119	21	14	9.5	4.8	65
BX	100	0.44	chevron	95	10	19.8	8.9	4.5	70
UX (truncated)	100	0.44	diamond	95	13	20	9	4.1	85
NP-1	100	0.44	diamond	125	15	23.6	10.4	5.7	65
NP-2	100	0.44	diamond	79	9	14.1	8.4	4	70

And these are all the different results that were obtained from large number of test, and the first call we have the geocell material the unreinforced one where in there was no geocell mattress, and the maximum pressure. That we could apply on top of the the crest of the embankment was about 50 k P a is actually. If you recall the pressure code was applied applied like this and constant the the pressure was applied in small increments and the usually about about 3 to 4 k P a pressure was applied, and then we wait until the deformations sees until under that particular pressure increment.

And then then only we go on to the next pressure increment it was done a fairly slow pace and the unreinforced embankment fail that pressure of about 50 k P a, and when the geocell was made of uniaxial geogrids of height 100 m m that has a aspect ratio of height to diameter of 0.. And the pattern of geocell was diamond pattern and the surcharge pressure capacity as increase to 95 k P a, and then if there is no subscript for the type of geocell material. That means, that geocell pockets were filled with with clays and and there were some tests performed with clay infill for example, the B X that is the biaxial with 100 m m height is actually this is the second one the biaxial.

When the geocell was made of biaxial geogrid that has a lower strength and the same height of 100 m m, and the same aspect ratio of 0.44 the maximum surcharge capacity was only 75 k P a. And when the same configuration was used, but the infill material was clay soil instead of clayesand the the maximum surcharge pressure that could be applied was only 65 k P a. And then the as the height of the the geocell mattresses were increased the surcharge capacity has increased, and more importantly it is we found that it is not just simply the height, but the aspect ratio that is the the ratio between the height of the geocells.

And then and then the the equivalent diameter, because the hits by D ratio more or less defines the the the stiffness that the the geocell system. We can provide because for very small values like for example, the small value means very large pocket surfaces in which case the vertical geogrid layers will not have adequate straining effect, and they behave like a like much softer materials. So, our for B X of about this 1.1 the surcharge capacity was 95, and for one case where the the aspect ratio was about 0.9 the surcharge capacity increased to 100 and 10 the height in both the cases say this case number 3, and this one with star. The height is the same 100 m m, but the pocket opening sizes is different in this case the aspect ratio was 0.44, and in this case the aspect ratio was 0.89 the result is substantial increase in the in the surcharge capacity. And so these are all the results from different analysis, and we see that the surcharge capacity not only depends on the type of geogrid that was used, but also on the aperture opening sizes and then the size of the the the geocell mattress openings.

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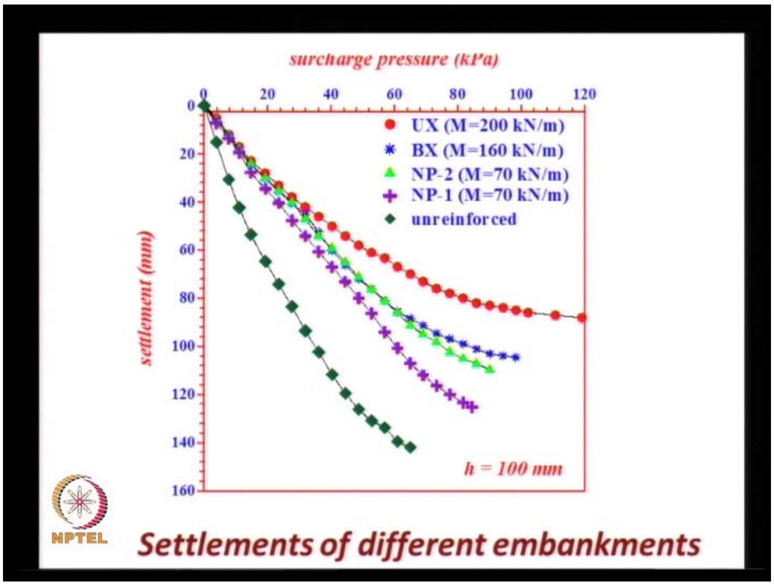

And these are all the the results that we have the U X is the uniaxial a geogrid that has a slope of m is the modulus is about 200 kilo newton per meter. And obviously, this has given the the stiffest response, that is for a given surcharge pressure the settlement of the embankment supported on U X type of material is the least. And this is the the bottom most one is the unreinforced one and the it has the highest settlement, and the all these results were obtain with with a height of geocell of 100. And we see that both N P 1 and N P 2 they have the same modulus of 70 kilo newton per meter like this, but then a one of them the N P 2 has has smaller aperture openings. And because of that the the strength is slightly higher, and is actually here we see that in all the test done with N P 2 geogrid the the slip surface is a pushed deep into the foundation soil.

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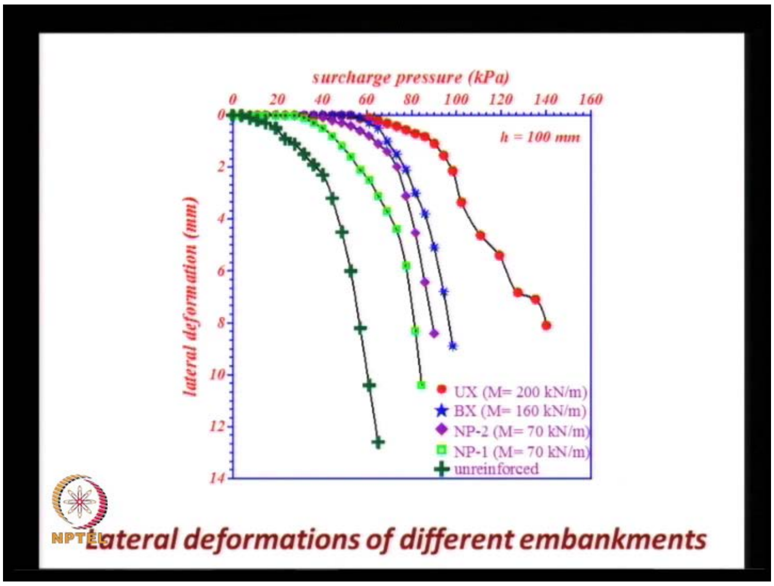

And these results they show the lateral deformations the surcharge pressure. And then lateral deformation on the y axis, and all the results a pertent to the case of 100 m m height of the geocell the when we have the uniarc geocells made of uniaxial geogrids the and the pressure is higher. And then and then at the the deformations are smaller and here on the extreme side, we have the unreinforced embankment which has undergone largest deformations and in between we have the this biaxial geogrid and then N P 1 and N P 2.

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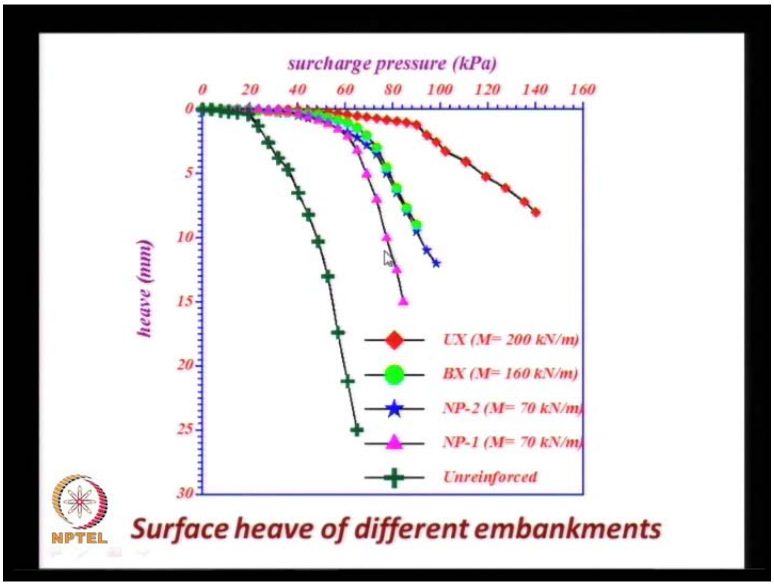

And these these results they show for the results for 100 m m height of the geocell, and the these results they show the the the heave that is measured at the far end of the far, end of the tank. And Obviously with unreinforced embankment the heave was the maximum almost 25 millimeters, but when the geocell made of u uniaxial geogrids were provided the heave was reduced about 7 or 8 millimeters even at a much higher pressure of 140 k P a, and for the other geogrids it is a somewhere in between.

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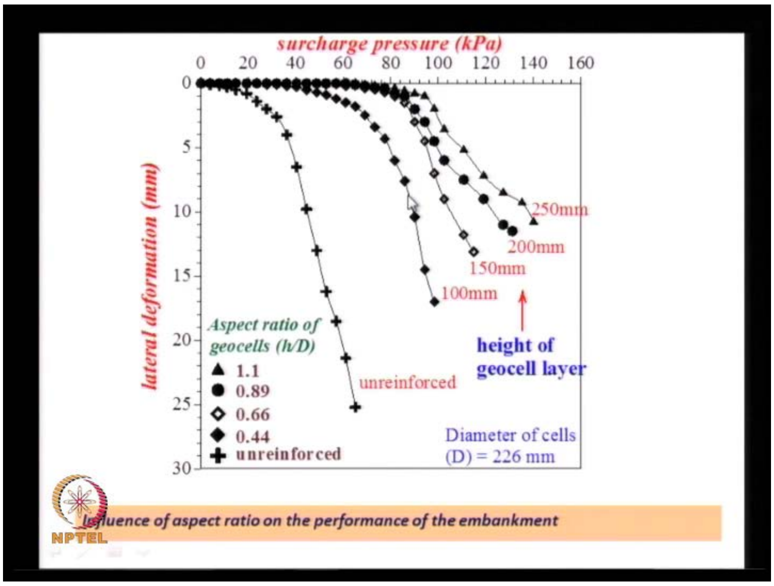

And the results with a different height of geocell layers, and the each height of the geocell layer will result in a different aperture opening size, because of all the the equivalent diameter of the the geocell pockets was 226 millimeters. And this height divided by 226 is listed here when the the height is 250 m m the the aspect ratio is about 1.1 it has probably the best performance in terms of the lateral deformations. Then as the aspect ratio decreases the the lateral deformations were found to increase then of course, the unreinforced embankment has a the highest lateral deformations.

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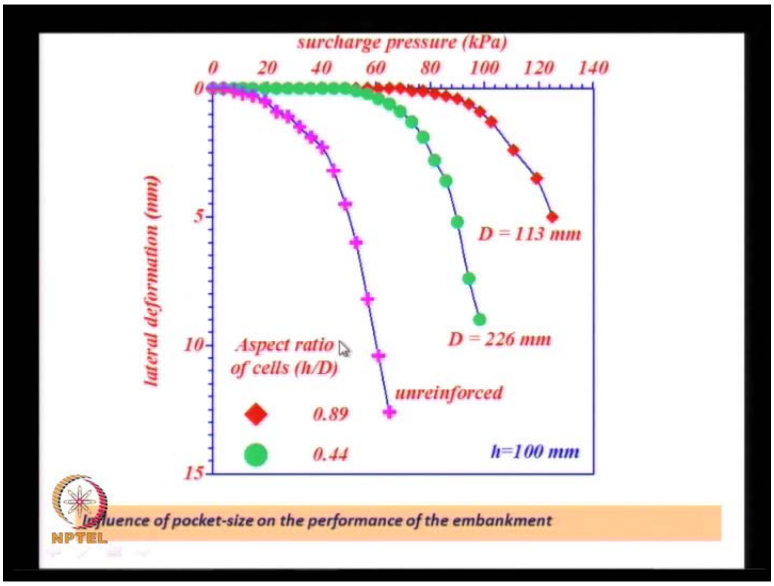

And these are the results that are obtained with the same height of the geocell, but with two different aspect ratios 0.89 and 0.44. And this is the result with a stiffer geocell mattress as the aspect ratio increases the we have the pocket size decreasing; that means, the stiffness of the geo the geocell mattress increases that results in higher load capacity under smaller deformations.

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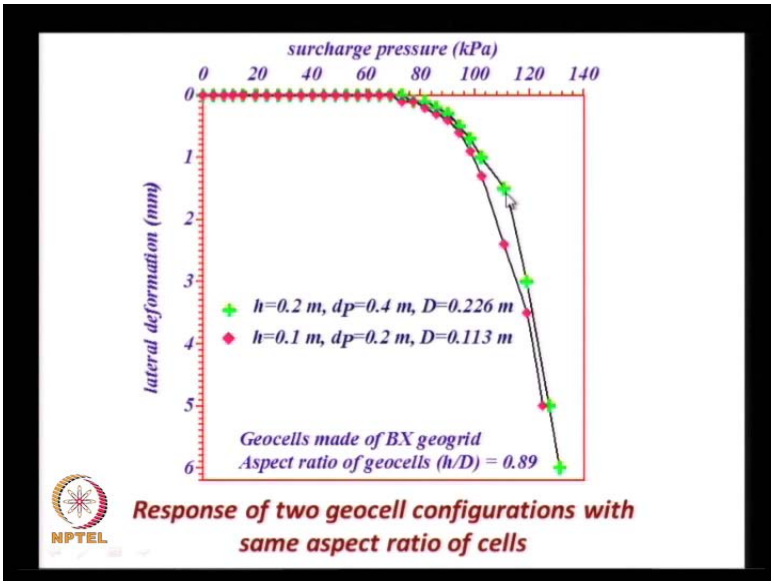

And this graph it shows the two results that were obtained with the same aspect ratio of the geocell, but with a two different depths like here the green color symbols indicate the result for a height of 200 m m and the pocket opening size of 0.4 meters and.

Ah this the equivalent diameter is 226 millimeters and this is height of 100 m m and then the the equivalent diameters was 100, and 10 13 millimeters and both of them they have h by duration of the nearly same 0.89. And we see that the lateral deformations were almost the same; that means, that the aspect ratio of the of the geocell pocket openings is very important, and that should be one of the the the design factors that need to be considered.

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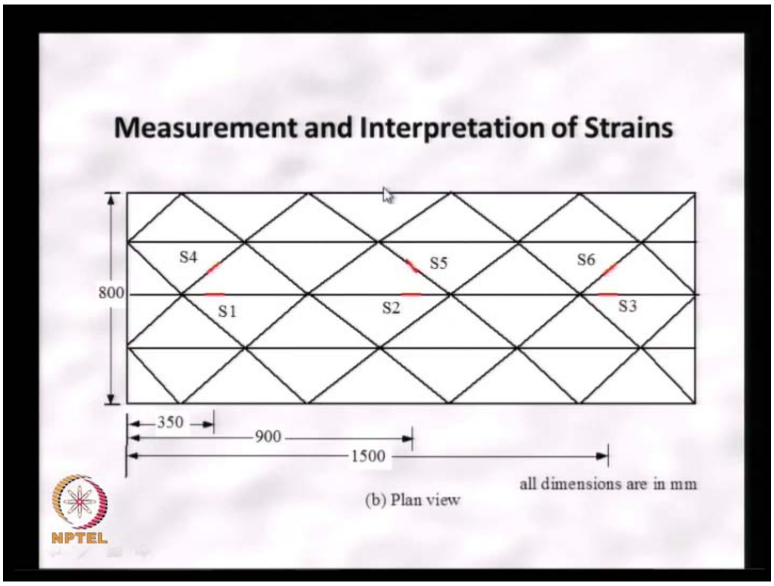

To actually see how the geocell is is responding as the as the pressure is gradually increased we have measured the strains that are developed in the in the geogrid layers at different stages. These were all the locations where the strains were measured S 1, S 2, and S; these are the strains. That are measured in the longitudinal geogrids at different heights S 1 is in the is in the below the load S 2 is near to the toe of the embankment, and S 3 is away from the away from the embankment. And S 4, S 5, and S 6; they are the strain gauges to measure the reinforcement strain, and the transverse strains once again S 4 is below the loaded loaded the area S 5 is near to the toe and S 6 is away from the away from the at the embankment.

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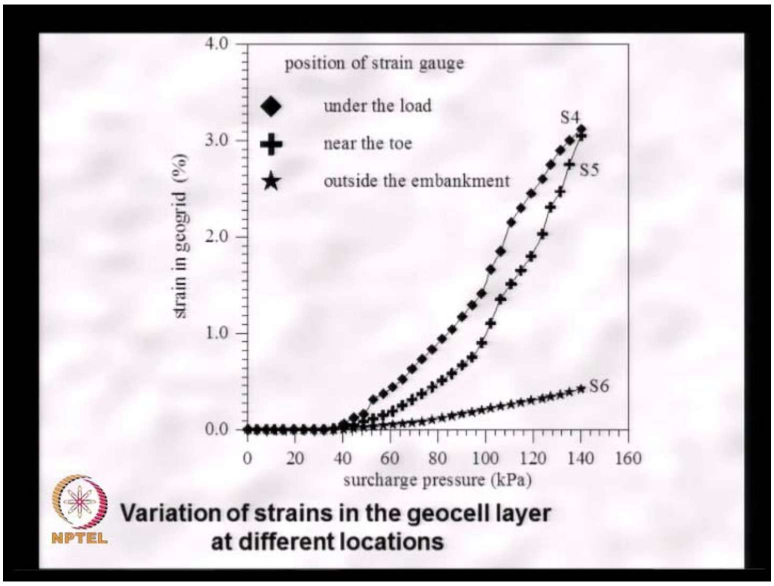

And this is how all the strain gauges have responded as the surcharge pressure was increased initially there were negligible strains; that means, that the geocell has not really started taking the load. Because the soil itself was strong enough to take the pressures and gradually as the soil was failing we could observe the formation of the slip surface, and that is when the effect of the the geocell layer got kicked in. And then we started seeing the increase in the in the reinforcement strains a within the geocell layer, and these diamond shaped one is the strains under the load is actually as much as three percent strain was measured. And the plus sign is near the toe and outside the the embankment is the star, and the the the strains that developed in the geo in the a geocell layer outside the embankment or relatively small whereas, below the load and near to the toe there of comparable magnitude.

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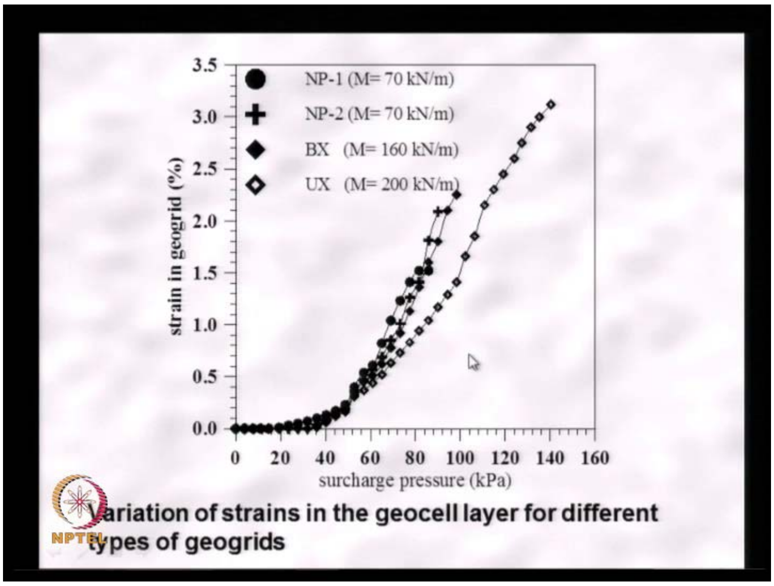

And these are the strains that are developed with different materials the U X is the the uniaxial geogrid that has the lowest stress, because its modulus is the highest is much higher is actually the modulus is 200 kilo newton per meter. Whereas, the biaxial the diamond shape it has a modulus of about 160 kilo newtons then N P 1 and N P 2 they have much lower modulus values of 70. And the the strain, that is measured was found to be related to the into the modulus of these geogrid layers, and the stiffer geogrid layer has developed smaller strains as compared to the softer geogrid layers.

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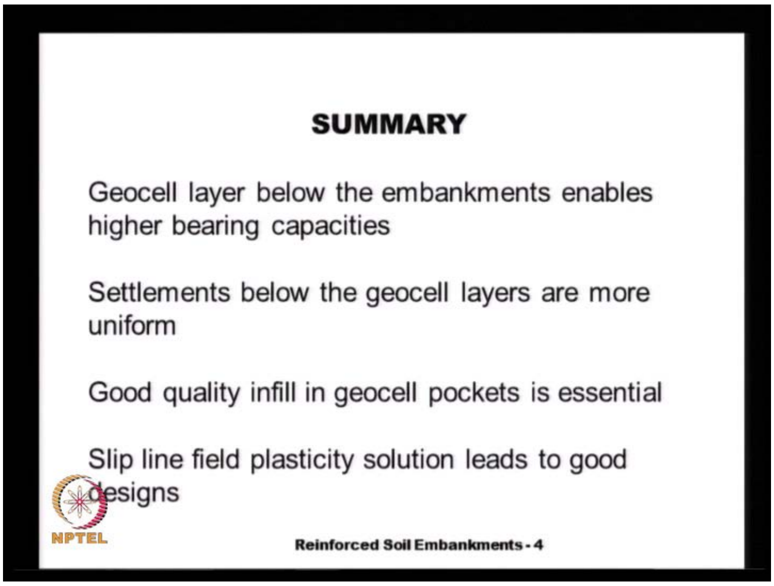

And the summary is we have seen that the use of geocell layers below the embankment enables the mobilization of higher bearing , this is mainly because of the rotation of the of the principles directions, and it prevents the formation of the normal slip circle. And if we form a normal slip circle the bearing capacity factors about five, but in this case because of the provision of very stiff geocell layer. And the action is similar to the squeezing of claim between two stiff and rough rigid platens the the principle stress field itself this rotated and we underpreth a higher bearing capacities.

And the settlements that we have below the the geocell reinforced embankments are found to be more uniform, and we need very good quality infill for the geocell to be affective. And the slip line field plasticity solutions leads to good designs is actually those students who are interested can refer to the to the papers, that are listed and some field data is given those papers very interesting field data that show that the geocell reinforcement is actually increased their performance in terms of uniform settlements and lower settlements.

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So, thank you very much. And if you have any questions you can contact me on the email.

Thank you.