Geosynthetics Engineering: In Theory and Practices
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Lecture - 50
Geosynthetics for Improvement in Bearing Capacity

Dear students warm welcome to NPTEL phase two 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 50 module 10, lecture 50 geosynthetics for improvement in bearing capacity.

So, geosynthetics play an important role to improve the ground. Most of the cases as you know that when the infrastructure like reinforced soil wall foundation, and the slope even then in the pear where you have a very poor bearing capacity. So, it is necessary to improve the bearing capacity by the introduction of geosynthetics material. Now, we will focus here what will be the type of the failure, and how the geosynthetics can improve the bearing capacity of the soil.

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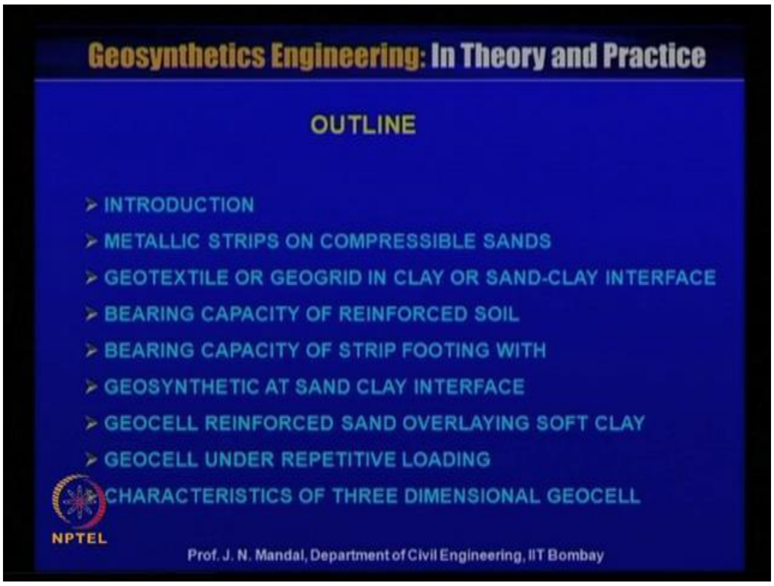

The outline of this course is introduction metallic strip on compressible sand, geotextile or geogrid in clay or sand clay interface bearing capacity of reinforced soil, bearing capacity of strip footing with geosynthetics at sand and clay interface. geocell reinforced sand overlaying soft clay, geocell under repetitive loading and characteristics of three dimensional geocell.

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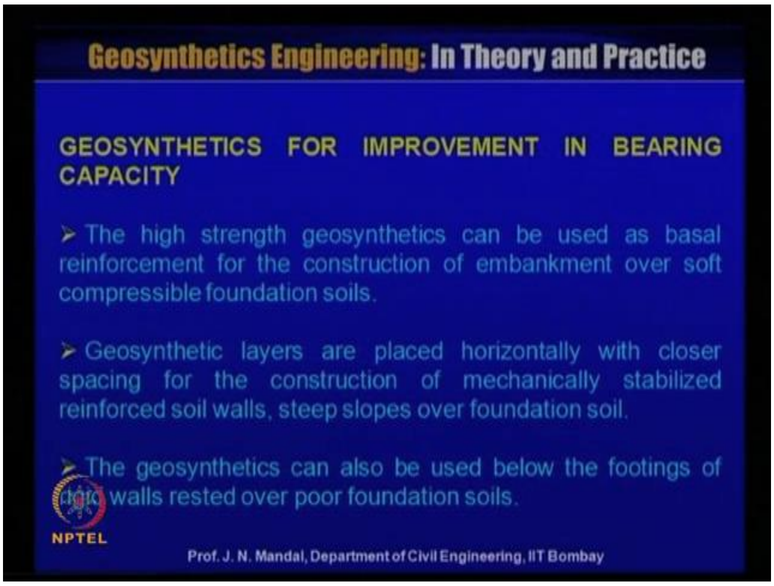

Now, geosynthetics for improvement in bearing capacity require the high strength of geosynthetics can be used as a basal reinforcement for the construction of embankment over soft compressible foundation soil. Geosynthetics layer are placed horizontally closer to the spacing for the construction of mechanically stabilized reinforced soil, wall steep slope over foundation soil. The geosynthetics can also be used below the footing of rigid wall rested over poor foundation soil.

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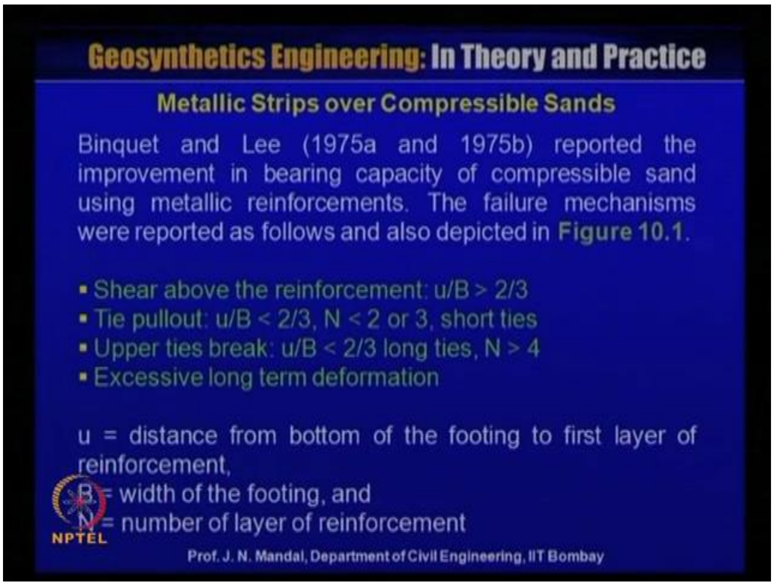

So, initially Binquet and Lee 1975a and 1975b have performed the number of the test with sand as a compressible soil. And this metallic strip as reinforcement and they reported the improvement in the bearing capacity of compressible sand, using metallic reinforcement. The failure mechanism was reported as follow and also depicted in figure I will show you. Now, shear above the reinforcement that means when u by B greater than two third, u means that the distance below the footing to the first layer of the reinforcement at the foundation and B is the width of the footing.

So, shear above the reinforcement occur when u by b greater than 2 by 3. Now, there is a pullout if pullout then u by B less than 2 by 3, when N less than 2 or 3 short ties. N is the number of the layer of the reinforcement. And upper ties break when u by b less than 2 by 3 that is long ties, when the number of the layer of the reinforcement greater than 4. So, multi layer reinforcement can be introduced at the foundation at different spacing and excessive long term deformation.

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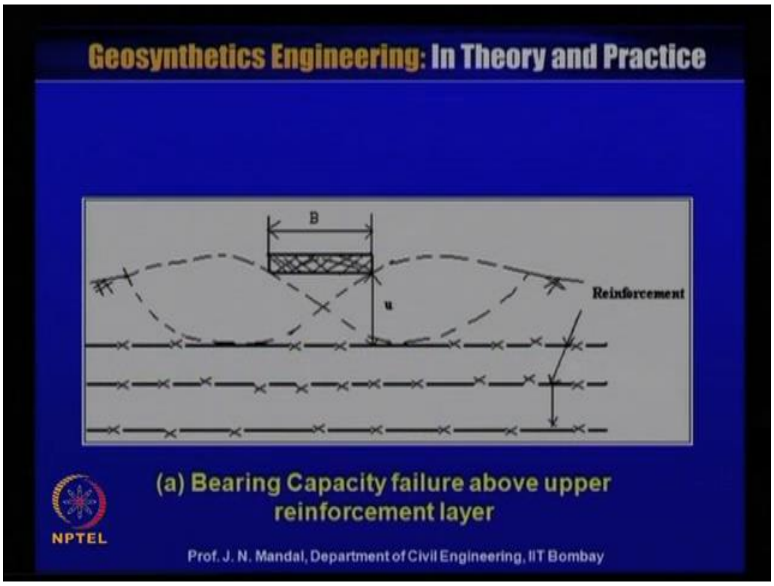

So, this is all the Binquet and Lee, though you have performed number of the test where they used as a sand as a compressible material, metallic reinforcement as a number of the layer. And here b is the footing width and u is the distance from the base of the footing to the first layer of the reinforcement. So, there is a possibility for bearing capacity failure above the upper layer of the reinforcement. However, if we can keep this upper layer of the reinforcement within 300 millimeter then this failure can be avoided.

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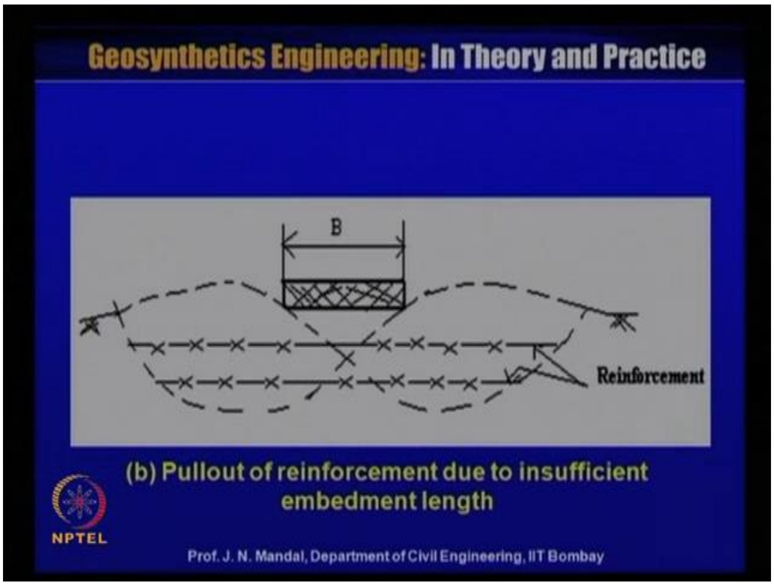

Now, second type the failure pullout of the reinforcement. This is the number of the layer of the reinforcement, this is the footing whose width is b. And there is a possibility for the pullout of the reinforcement due to insufficient embedment length. So, that means beyond the failure plane you require, the sufficient length in order that this failure can be avoided. So, one has to take care for the proper embedment length.

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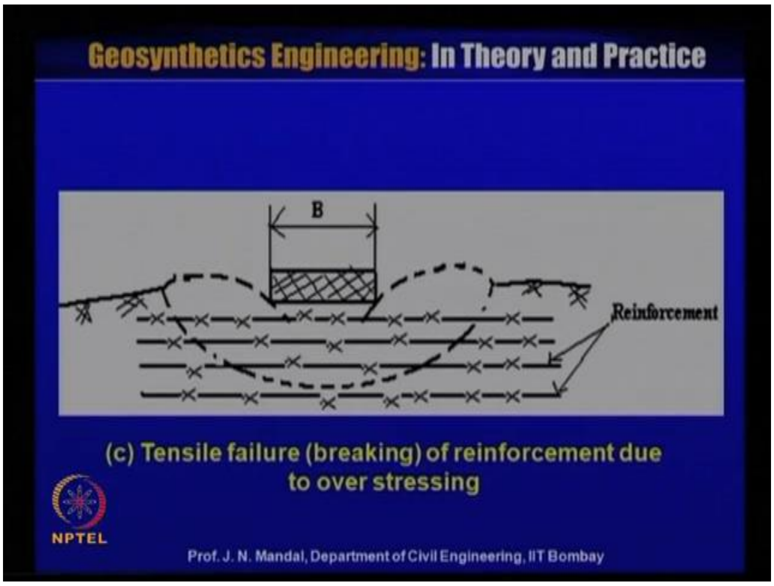

Thirdly c tension failure breaking of the reinforcement due to the over stressing. You can see this is the width and due to the load there is a possibility for the breaking of the reinforcement because for the over stressing. So, this is another kind of the failure have been observed.

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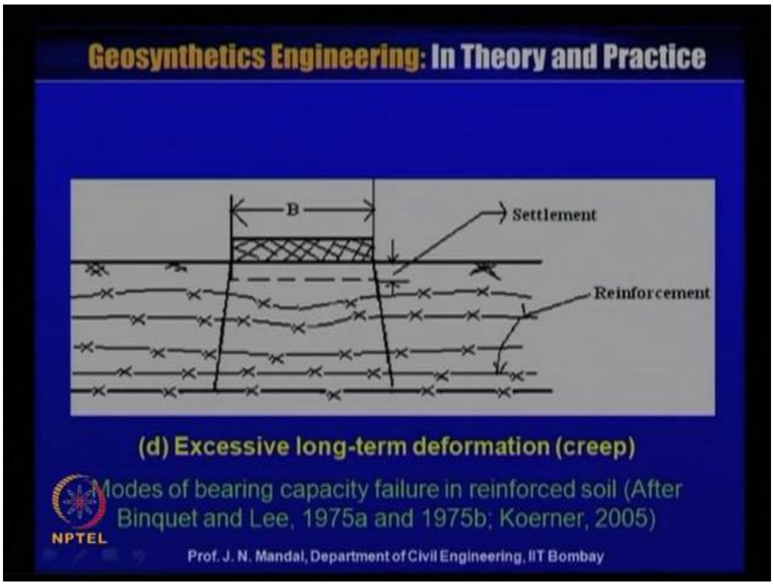

And d is the excessive long-term deformation or what you call the creep. This is width this is the settlement this is number of the layer of the reinforcement. So, these are the four different types of the mode of bearing capacity failure in reinforced soil. As I say after Binquet and Lee 1975 a and b and Koerner also 2005. Now, this possibility for this creep that is sustain the surface load, and subsequent that geosynthetics reinforcement metallic reinforcement stress relaxation can be avoided, if the low allowable stress of this reinforcement you have used. So, this way that excessive long term deformation can be avoided.

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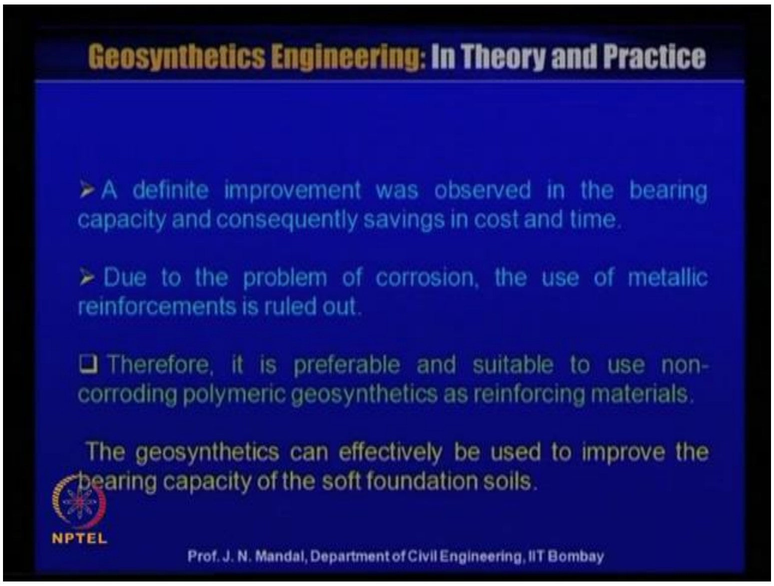

So, we find that what will be the different types of the failure mechanism of the bearing capacity of the soil, where you have provided the number of the layer of the reinforcement. And we observe the different types of the failure that is the creep, also there is a possibility for the anchorage or the pullout failure. And also that what should be the length or depth of the reinforcement is to be placed below the foundation to avoid the failure of the reinforcement or reinforcement itself can fail due to the tension.

So, a definite improvement was observed in the bearing capacity. And consequently saving in cost and time due to the problem of corrosion the use of metallic reinforcement is ruled out. Therefore, it is preferable and suitable to use non corroding polymeric geosynthetics as reinforcing material. The geosynthetics can effectively be used to improve the bearing capacity of the soft foundation soil.

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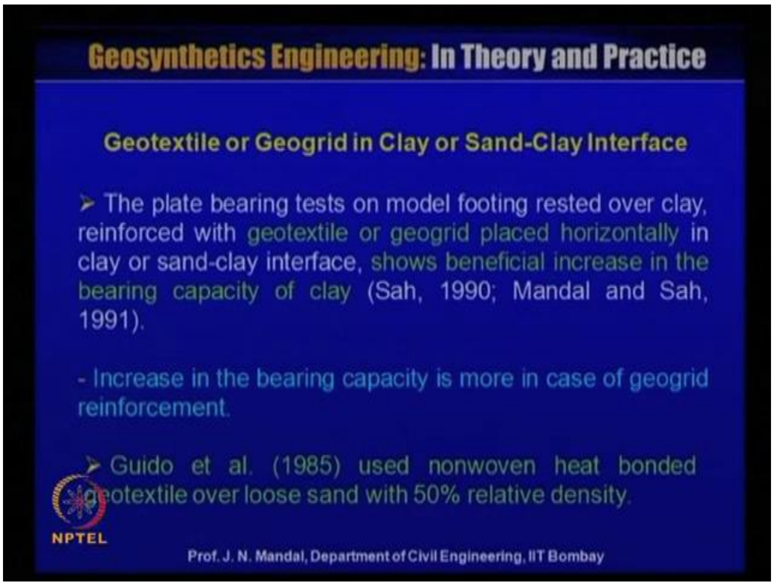

Now, you can use the geotextile or the geogrid in clay or sand clay interface. So, number of research work have been carried out in this institute using the different types of the geosynthetics material, and also the interface between sand and clay. Now, the plate bearing test on model footing rested over clay, reinforced with geotextile or geogrid placed horizontally in clay or sand-clay interface, show beneficial increase in the bearing capacity of clay. That is Sah 1990 Mandal and Sah 1991. So, what it has been observed increase in the bearing capacity is more in case of geogrid reinforcement. Guido et al

1985 used the nonwoven heat bonded geotextile over loose sand with 50 percent relative density.

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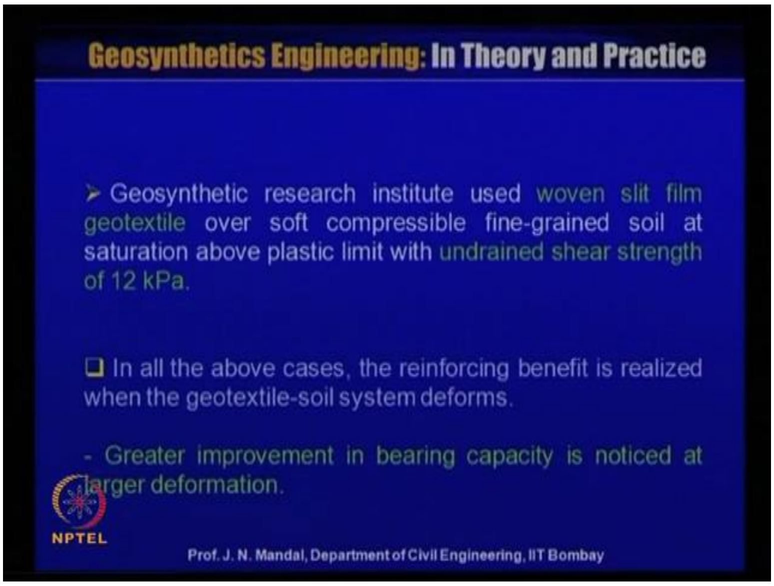

So, you can change the relative density and can observe that improvement of the bearing capacity. Also, sometimes it is not required that multilayer the 1 layer 2 layer 3 layer 4 layer 5 6 7 layer not necessarily. Most of the cases it can be observed that if you can provide with the 3 layer of this reinforcement that will provide you the sufficient improvement in bearing capacity. So, you do not require so many number of the layer to improve the bearing capacity of the soil.

So, geosynthetics research institute used the woven slit film geotextile over soft compressible fine-grained soil at saturation above plastic limit with undrained shear strength of 12 kilopascal. In all the above cases the reinforcing benefit is realized when the geotextile-soil system deforms. Greater improvement in bearing capacity is noticed at larger deformation.

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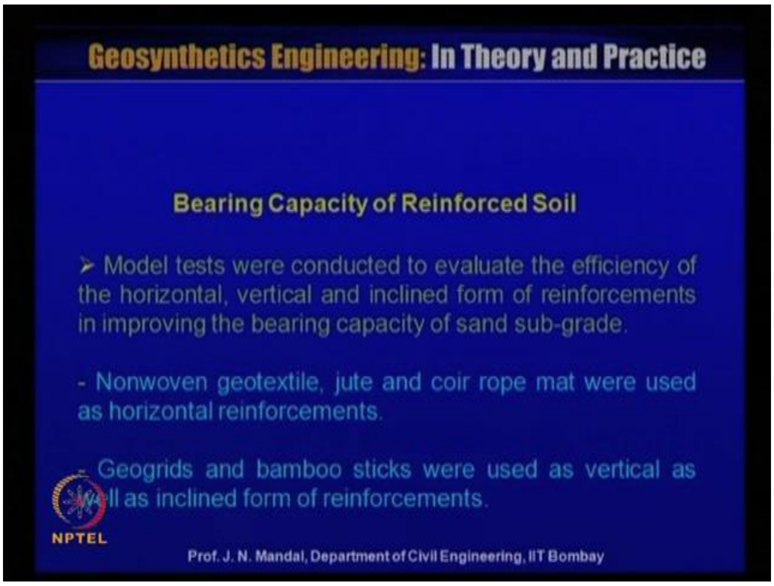

Now, bearing capacity of reinforced soil, model test were conducted to evaluate the efficiency of the horizontal, vertical and inclined form of reinforcements in improving the bearing capacity of sand sub-grade. So, non-woven geotextile, jute and coir rope mat were used as a horizontal reinforcement. Geogrid and the bamboo stick were used as a vertical as well as inclined form of reinforcement.

So, you want to see that behavior observe of the foundation, when you are introducing the reinforcement either in the horizontal layer or you can provide the vertical. So, what will happen, what will be the active pressure, what will be the passive resistance and how it is working, whether there is any improvement or not, or you are providing that any inclined either inward and the outward. And observe there is any development of bearing capacity or not.

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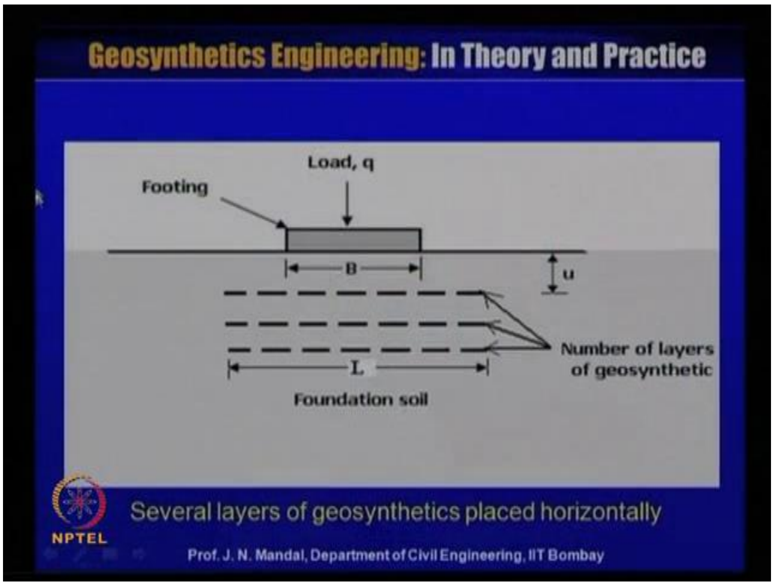

So, here we are showing that footing and this is the number of the layer of the reinforcement. And length of the reinforcement is l and this is the u that is the distance at the bottom of the footing to the first layer of the reinforcement and this is the load q. So, we have to check that what will be the ratio u by b. At what depth it will give the maximum improvement in bearing capacity. And what should be the length of the reinforcement material that is also important. So, length also with respect to the width of the footing, so number of study have been carried out.

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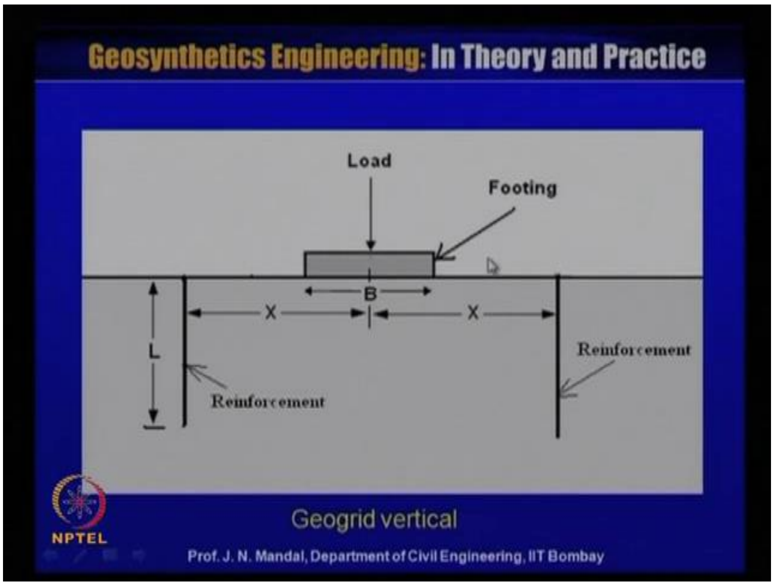

You can see here that this is the width of the footing. And this is the reinforcement the length of the reinforcement l which is placed the vertical at a distance x. So, you can varying this width and also you can varying the length of the reinforcement. So, spacing also can vary and can check. So, here the geogrid as a vertical reinforcement has been used.

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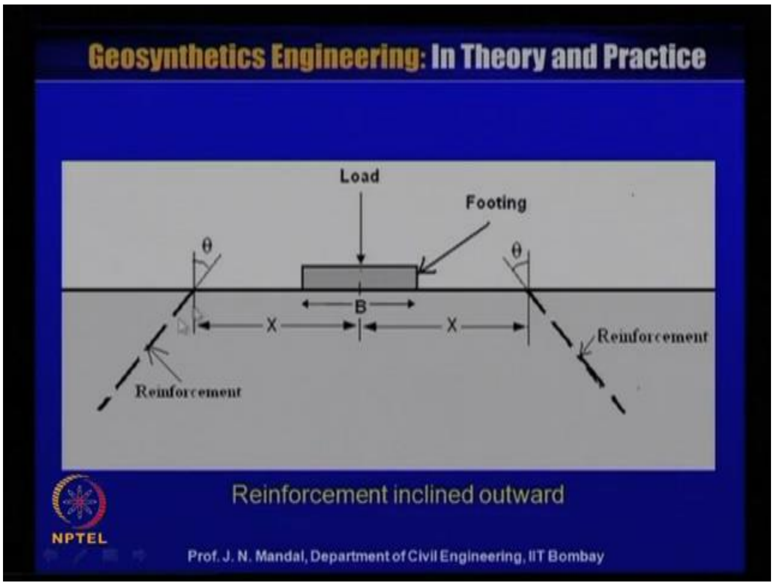

So, you can make inclined. This is the reinforcement, this is inclined, this is making at an angle theta. So, this reinforcement inclined outward both side you are placing outward then you are applying the load. Similarly, you can place the reinforcement inclined inward, this is making at an angle theta another load. And this is the width and footing we have placed. And see that what will be the behavior of the reinforcement.

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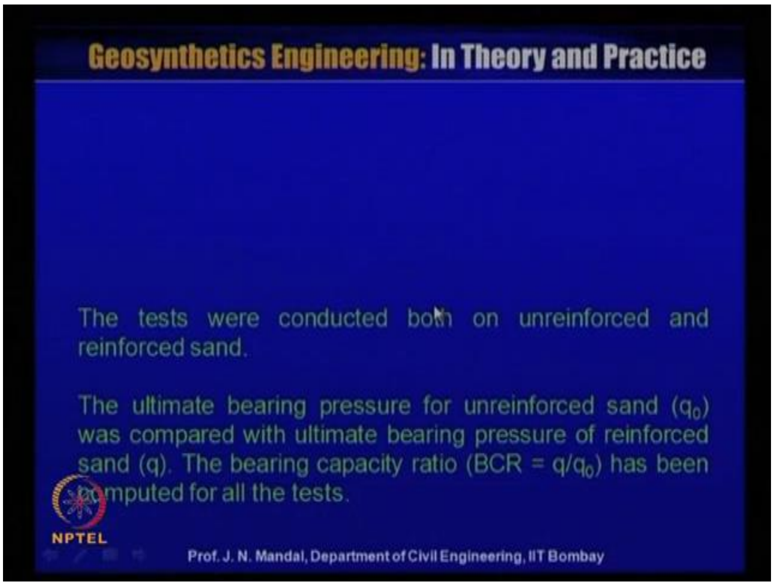

Now, test was conducted both on unreinforced and reinforced sand. So, ultimate bearing pressure for unreinforced sand q 0 was compared with the ultimate bearing pressure of reinforced sand that is q. So, the bearing capacity ratio BCR is equal to q by q 0 has been computed for all the test.

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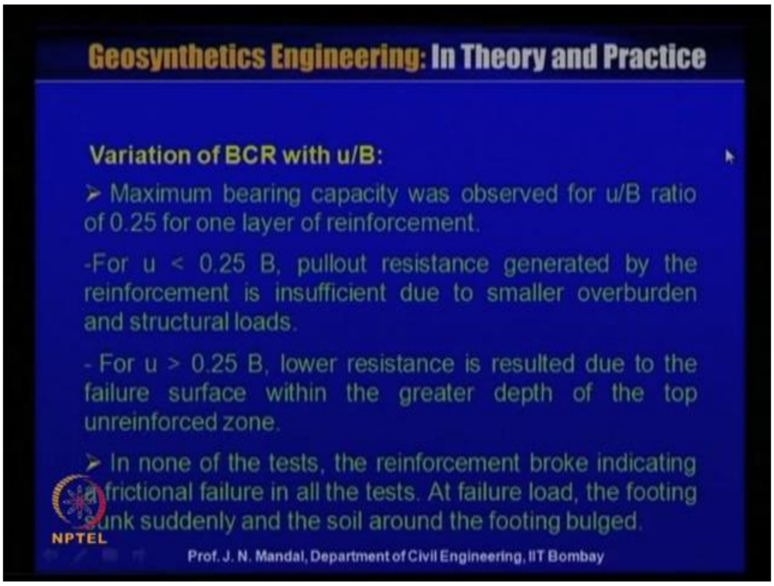

So, here we are showing the variation of BCR bearing capacity ratio with u by b. So, maximum bearing capacity was observed for u by b ratio of 0.25 for one layer of the reinforcement. For u less than 0.25 B pullout resistance generated by the reinforcement is insufficient due to the smaller over burden and structural load. For u greater than 0.25 B lower resistance is resulted due to the failure surface within the greater depth of the top unreinforced zone. In none of the tests, the reinforcement broke indicating a frictional failure in all the test. At failure load the footing sunk suddenly and the soil around the footing bulged.

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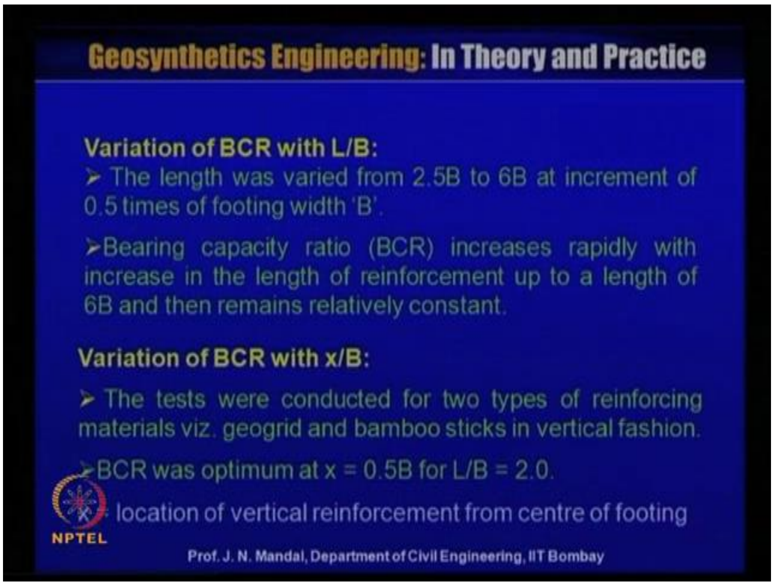

Also variation of BCR with l by b that is length of the reinforcement versus by width of the footing, so length was varied from 2.5 B to 6 B, B is the width of the footing at increment of 0.5 times of the footing width B. So, bearing capacity ratio BCR increases rapidly with the increase in the length of the reinforcement up to a length of 6 B and then remain relatively constant. So, we can say there you do not need more than 6 time the width of the footing in terms of length, variation of BCR with x by B.

So, test was conducted for two types of the reinforcing material that is geogrid and the bamboo stick in the vertical fashion. And x is the distance from the footing, where the vertical reinforcement is located. So, bearing capacity ratio optimum at x is equal to 0.5 B for l by B is equal to 2.0, where x is the location of vertical reinforcement from the centre of the footing.

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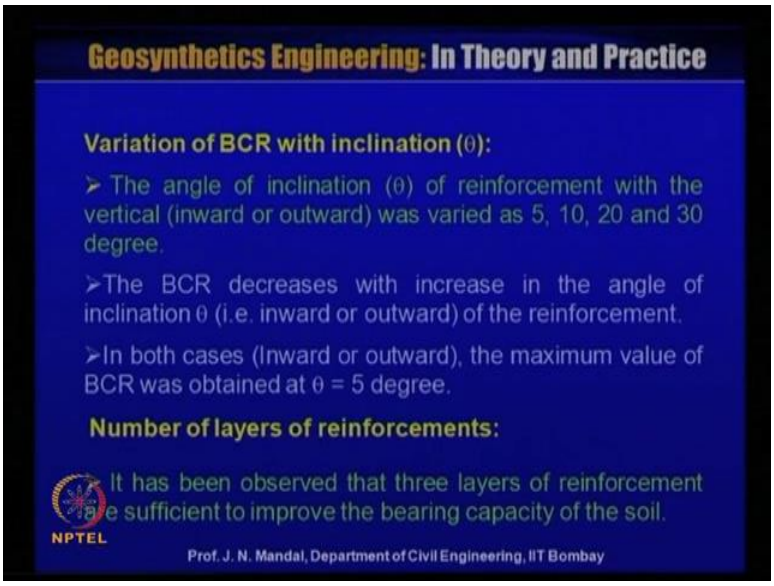

Now, variation of BCR with inclined theta. The angle of inclination theta of reinforcement with the vertical inward or outward was varied as 5 degree, 10 degree, 20 degree and 30 degree. So, BCR decreases with increasing in the angle of inclination theta, that is either inward or out ward of the reinforcement. In both cases inward or outward the maximum value of BCR was observed at theta is equal to 5 degree.

Now, number of the layer of the reinforcement. It has been observed that 3 layer of the reinforcement are sufficient to improve the bearing capacity of the soil. So, you do not need that more number of the layer of the reinforcement. And also you observe that if we make a some inclination of the reinforcement there is not so substantial improvement in the bearing capacity, but maximum with the 5 degree will give quite reasonable improvement in bearing capacity.

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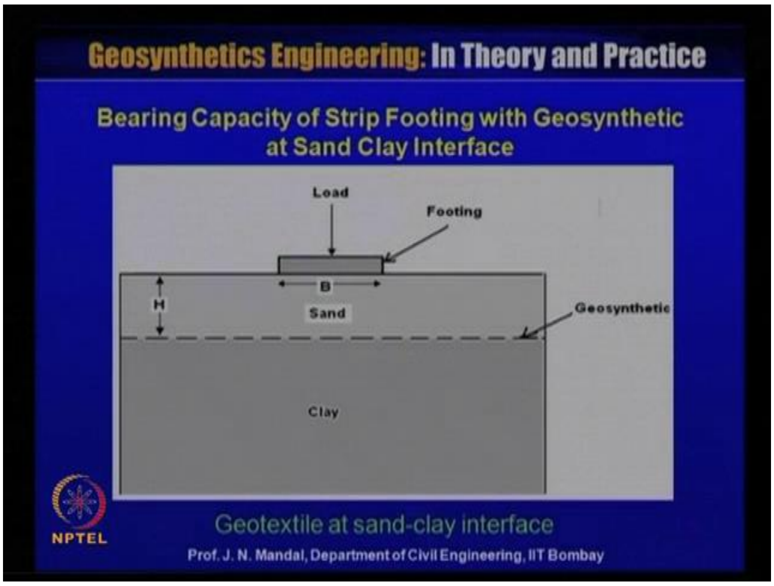

Now, we have performed bearing capacity of strip footing with geosynthetics at sand clay interface. So, here this is the clay and this is the sand. And in between the sand and the clay, we have deployed of one layer of the geosynthetic material. And this is the footing width b, and this is the h, the distance between the base of the footing to the geosynthetics material where it lies between the sand and the clay layer. So, geotextile at the sand clay interface.

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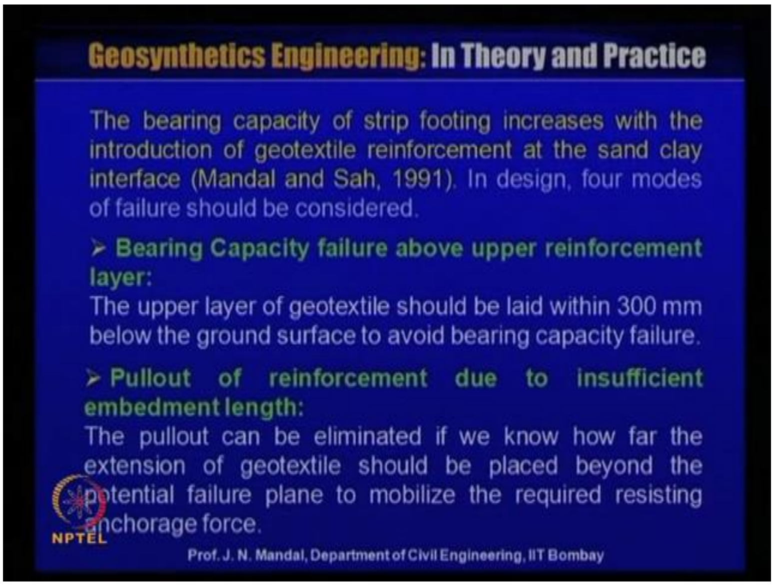

So, number of test have been performed. And we have seen that what will be the behavior. The bearing capacity strip footing increases with the introduction of geotextile reinforcement at the sand clay interface Mandal and Sah 1991. In designing four modes of failure should be considered. Bearing capacity failure above upper reinforcement layer that means upper layer of the geotextile should be laid within 300 millimeter, below the ground surface to avoid bearing capacity failure.

So, it is preferable to you could provide the 300 millimeter spacing between the footing and the first layer of reinforcement. Now, pullout of the reinforcement due to insufficient embedment length. The pullout can be eliminated if we know how far the extension of geotextile should be placed beyond the potential failure plane to mobilize the required resisting anchorage force.

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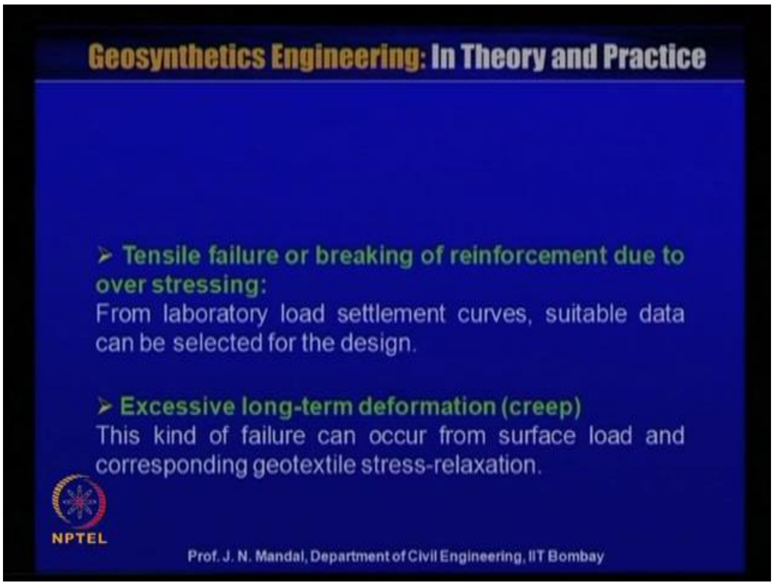

Tensile failure or breaking of the reinforcement due to over stressing, from laboratory load settlement curve the suitable data can be selected for the design. And excessive long term deformation that is creep this kind of failure can occur from surface load and corresponding geotextile stress relaxation.

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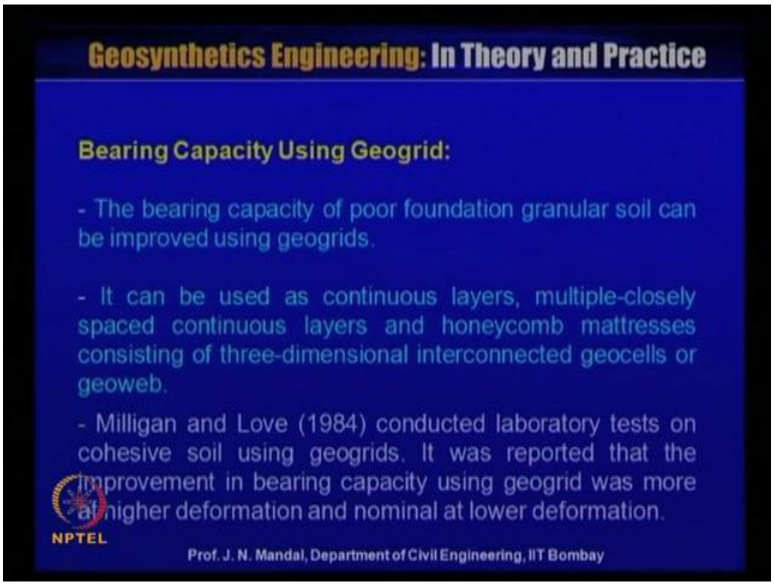

Now, bearing capacity using geogrid. The bearing capacity of the poor foundation granular soil can be improved using geogrid. It can be used as continuous layer of multiply closely spaced continuous layer of honeycomb mattresses consisting of 3 dimensional interconnected geocell or geoweb or cellular reinforcement. Milligan and Love 1984 conducted laboratory test on cohesive soil using geogrid. It was reported that the improvement in bearing capacity using geogrid was more at higher deformation and nominal at lower deformation.

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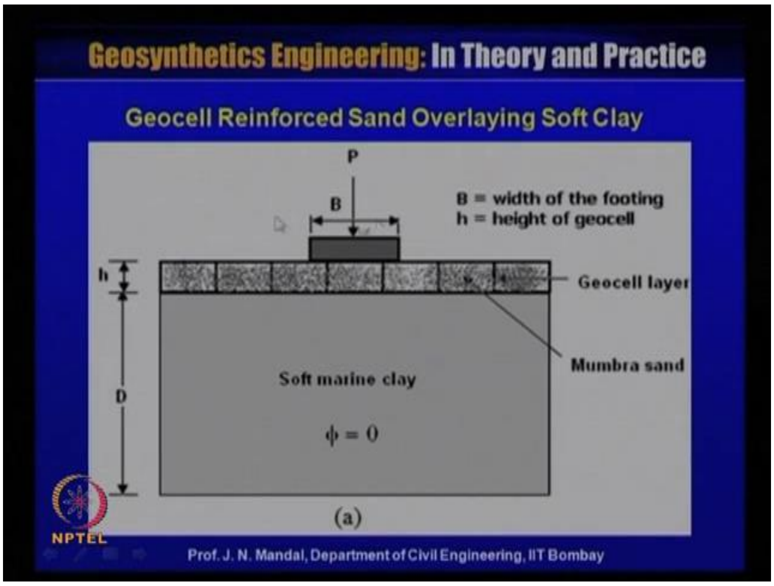

So, here we have also studied at some geocell reinforced sand overlaying soft clay. So, this is the soft marine clay where phi is equal to 0. And this is the depth D, and these are the geocell it is a honeycomb structured geocell, and the height of the geocell is h, and the B is the width of the footing. And you are applying the load P and this geocell is filled up with the granular material and number of test have also been performed.

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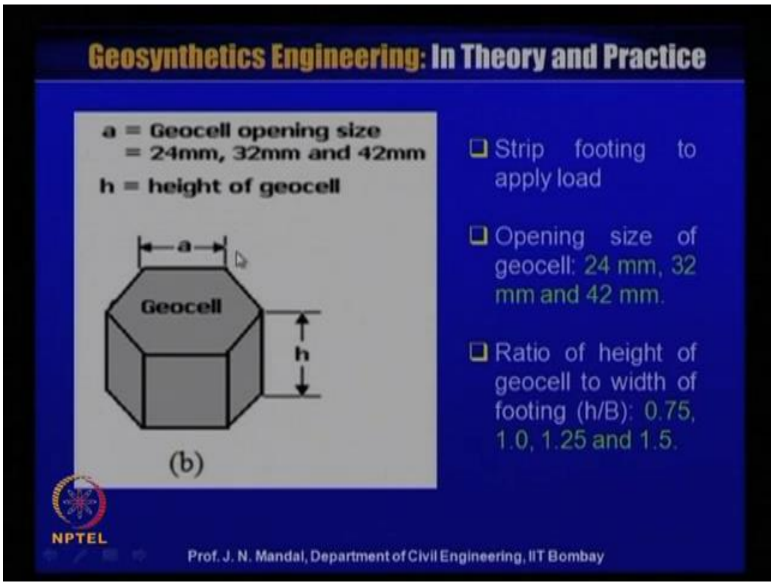

Here this geocell is made of the geotextile and this a is the geocell opening size and that we have kept 24 millimeter 32 millimeter and 42 millimeter and h is equal to height of the geocell. So, this is the one geocell is configuration have been shown. So, we have to perform the test with the different configuration of the geocell and optimize that what should be the height, what should be the width of the geocell, which will provide you the maximum bearing capacity. So, we have performed number of the test both static and the cyclic loading test using this geocell material.

So, in this model also the strip footing is applied the load. And then opening size as I say geocell is keeping 24 millimeter, 32 millimeter, and 42 millimeter. And the ratio of height to geocell to width of the footing that mean h by B is 0.75 1.0 1.25 and 1.5. So, number of test have performed by Mhaiskar. And we see that what should be the behavior or improvement in bearing capacity using this kind of geocell material.

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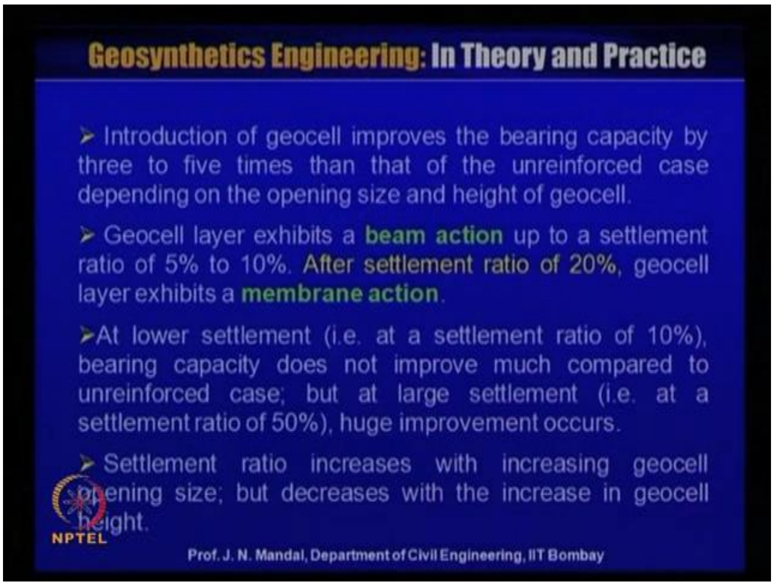

So, introduction of the geocell improve the bearing capacity by 3 to 5 times than that of unreinforced case depending on the opening size and the height of geocell. That is very important that, what will be the opening size and the height of that that has been variation has been performed and optimized. So, geocell layer exhibit a beam action up to a settlement ratio of 5 percent to 10 percent. After settlement ratio of 20 percentage, geocell layer exhibit a membrane action. So, this is the mechanism, what is happening in the geocell during the experiment. At lower settlement that is, at a settlement ratio of 10 percent, bearing capacity does not improve much compared to unreinforced case, but at large settlement that is at a settlement ratio of 50 percent, huge improvement occurs. Settlement ratio increases with increasing the geocell opening size, but decreases with the increase in the geocell height.

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So, that Mhaiskar and Mandal 1992 and 1994 have performed the number of test on geocell under repetitive loading. So, this is not only the static loading repetitive loading also have been performed. And experimental as well as the finite element investigation on geocell structure rested over a soft clay subg-grade. Loose and dense sand as a backfill material, monotonic and repetitive undrained on highway loading condition.

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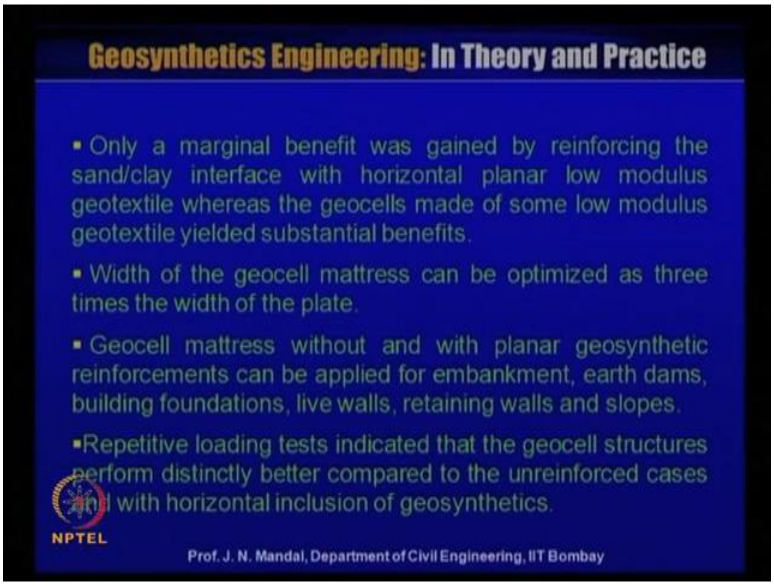

Only a marginal benefit was gained by reinforcing the sand clay interface with horizontal planar low modulus geotextile. Whereas, the geocell made of same low modulus geotextile yielded substantial benefits, width of the geocell mattresses can be optimized at 3 times the width of the plate. Geocell mattresses without and with planar geosynthetic reinforcement can be applied for embankment, earth dam, building foundation, live wall, retaining wall and slope.

Repetitive loading test indicated that the geocell structures perform distinctly better compared to the unreinforced case and with horizontal inclusion of geosynthetics. So, number of the test have been performed even with the horizontal layer of the reinforcement, same material horizontal layer of the reinforcement. But it has been observed that if we form the geocell with the same material, it gives better performance than the horizontal layer of the reinforcement.

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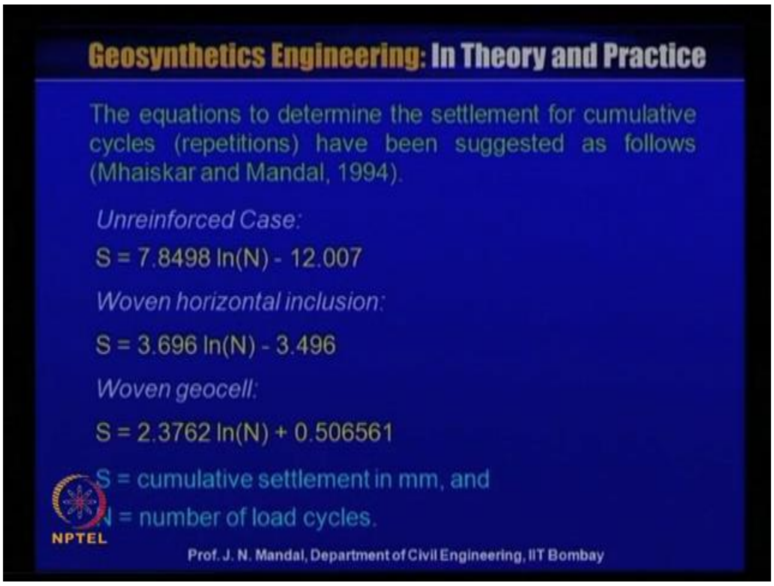

Now, based on the repetitive loading the equation to determine the settlement and cumulative cycle repetition have been suggested as follow Mhaiskar and Mandal 1994. Unreinforced case that S is equal to 7.8498 ln N minus 12.007. Woven horizontal inclusion S is equal to 3.696 log n N minus 3.496. Woven geocell S is equal to 2.3762 log N plus 0.506561. Where S is the cumulative settlement in millimeter and N is the number of load cycles.

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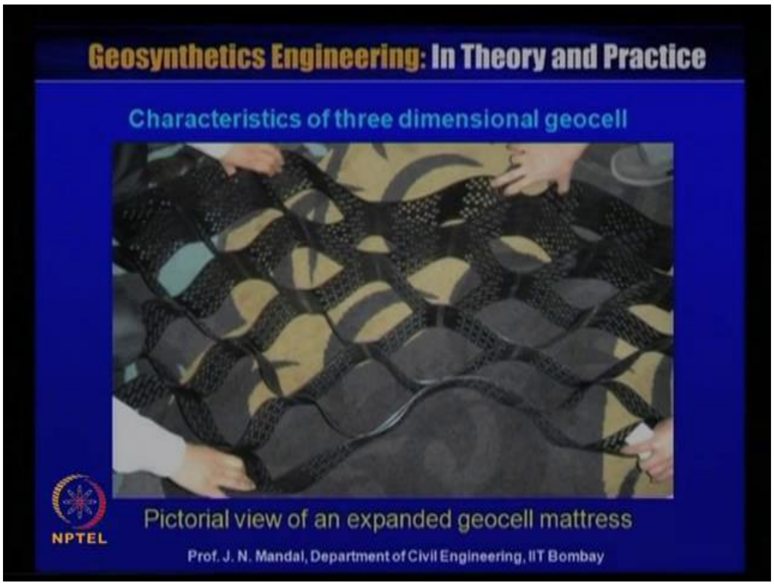

So, this is the characteristics of the 3 dimensional geocell. This is some pictorial view of an expanded geocell mattresses. And geocell you can bring it in the collapsed form and can be expanded. And then you fill up with the granular material and can be compacted and can be used.

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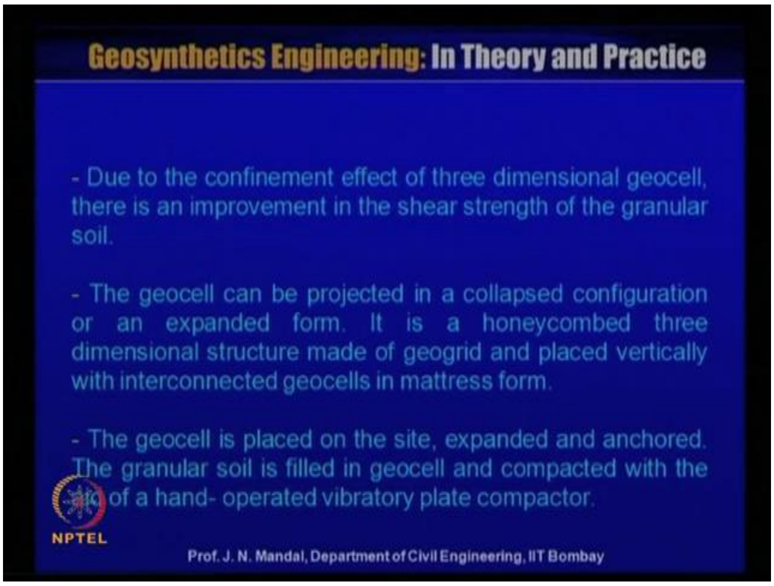

Now, due to the confinement effect of three dimensional geocell there is an improvement in the shear strength of the granular soil. The geocell can be projected in a collapsible configuration or an expanded form. It is a honeycombed three dimensional structure made of geogrid and placed vertically with interconnected geocell in mattresses form. The geocell is placed on the site, expanded anchored. The granular soil is filled in the geocell and compacted with the aid of hand-operated vibratory plate compactor.

So, it is easy to carry and easy to place on the subsoil surface. And also it is easy to filled up and can be compacted. So, generally it is the 100 meter with width at a interval of 300 millimeter then it is been connected. And it is thickness also is very less 1.2 millimeter or like that it may be made of high density polyethylene, or may be woven or non-woven geotextile material. Now, we will see that what type of the failure may occurs.

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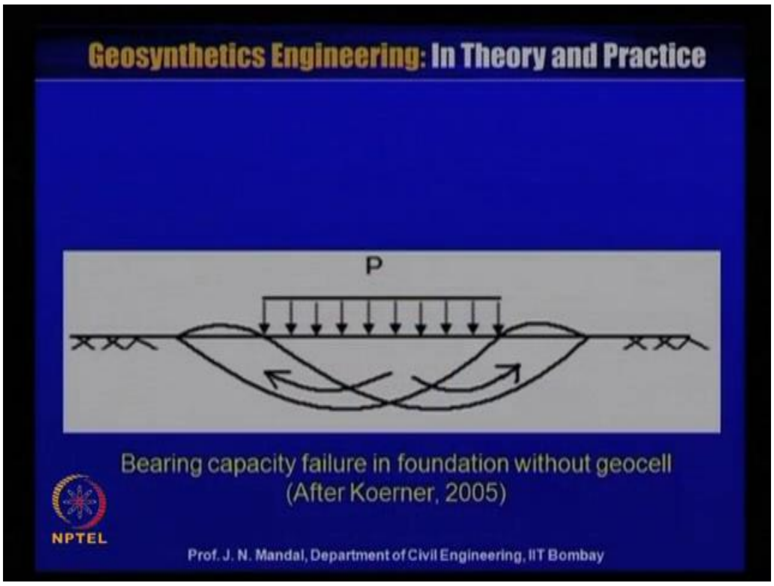

So, here bearing capacity failure of foundation without geocell. When there is no geocell material this is given after Koerner 2005. You can see that kind of the failure and it is when there is no geocell material.

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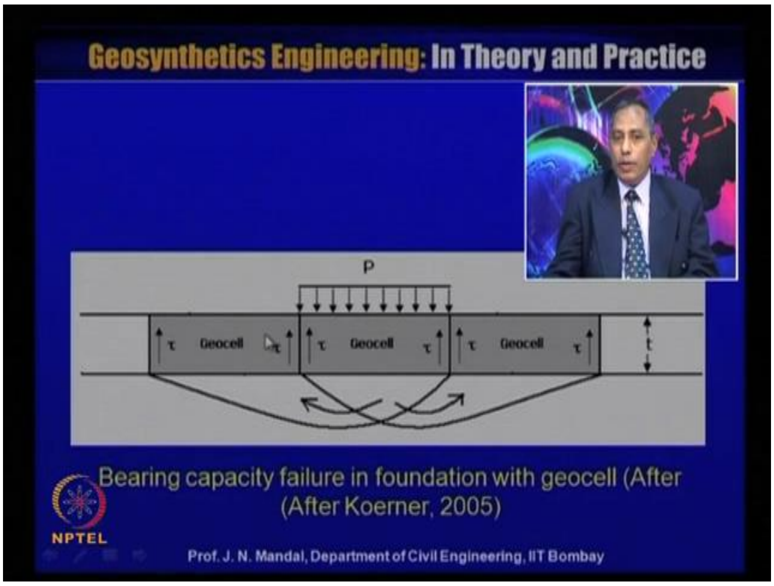

Now, if you place this geocell material, this is the geocell and you are applying the load. And the bearing capacity failure in foundation soil here in geocell also given by Koerner 2005. And this is the tau, the shear stresses which is acting between the granular field material and the shield wall. So, this is the load so this width is shear stresses there is a improvement of the bearing capacity of the soil. There also development of the hoop stress, there also development of the resistance from here.

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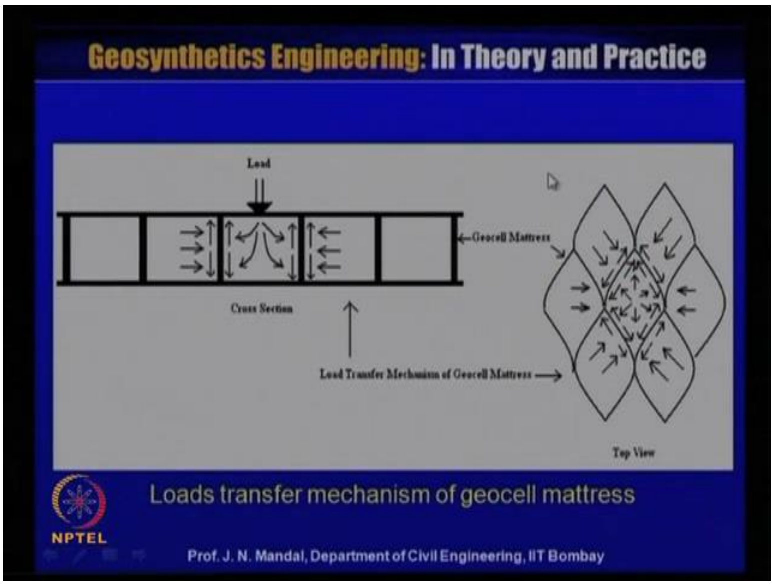

So, with this concept I can show you here that, this is the cross section this is the top view of the geocell material. So, here you can see that this is the load is applying. And load transfer mechanism through the geocell mattresses. So, here you can see this is the horizontal stresses in the cell. This horizontal stresses in the cell due to the load here. And also you can find here the hoop stresses in the shield wall, hoop stress is acting on the shield wall.

Apart from that this are the arc resistance in adjacent cell. So, this is the reinforcement mechanism of the geocell for horizontal stress, which is acting in the cell and hoop stresses is also acting in the cell wall. Apart from that there is a earth resistance in adjacent cell. So, this is the what you say that basic mechanism of the geocell. With this concept you can see that how the load transferred into the geocell mattress.

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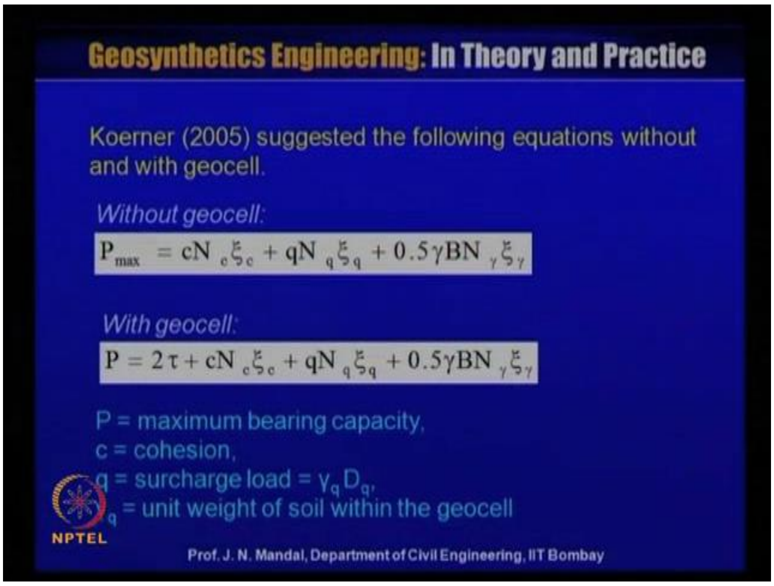

Now, Koerner 2005 also they suggested the following equation without and with geocell. So, without geocell P maximum is equal to c into N c epsilon c plus q into N q epsilon q plus 0.5 gamma B N gamma epsilon gamma. With geocell P is equal to 2 into tau plus c into N c epsilon c plus q into N q epsilon q plus 0.5 gamma B N gamma and epsilon gamma. Here you can see that due to the geocell this is improvement, this is 2 tau that means that this is 2 tau, which is acting in between geocell wall and the granular material.

So, this 2 tau is improvement the bearing capacity of the soil other remain almost same. So, here that P is the maximum bearing capacity, c is the cohesion and q is the surcharge load that is gamma q into D q, where gamma q is the unit weight of the soil within the geocell.

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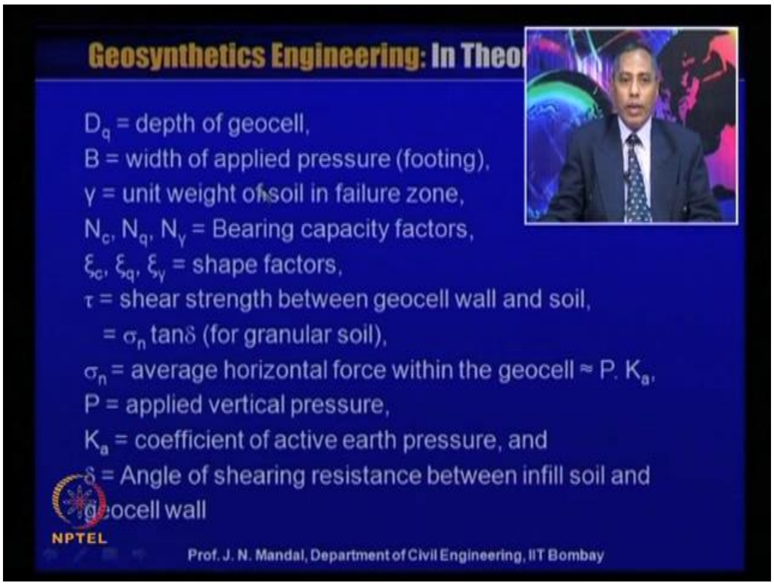

And D q is the depth of the geocell, B is the width of the applied pressure that is footing and gamma is unit weight of the soil in failure zone, N c N q N gamma bearing capacity factor. And epsilon c epsilon q epsilon gamma is equal to shape factor, and tau that is the shear strength between the geocell wall and soil. And that shear strength tau will be sigma n into tan delta for granular soil.

So, there is no c so c terms will not be there. And sigma n what is the average horizontal force within the geocell so that will be P into K a because you know the P is the load and K is equal to coefficient of active earth pressure. And P is the applied vertical pressure, and delta is angle of shearing resistance between the infill soil and the geocell wall.

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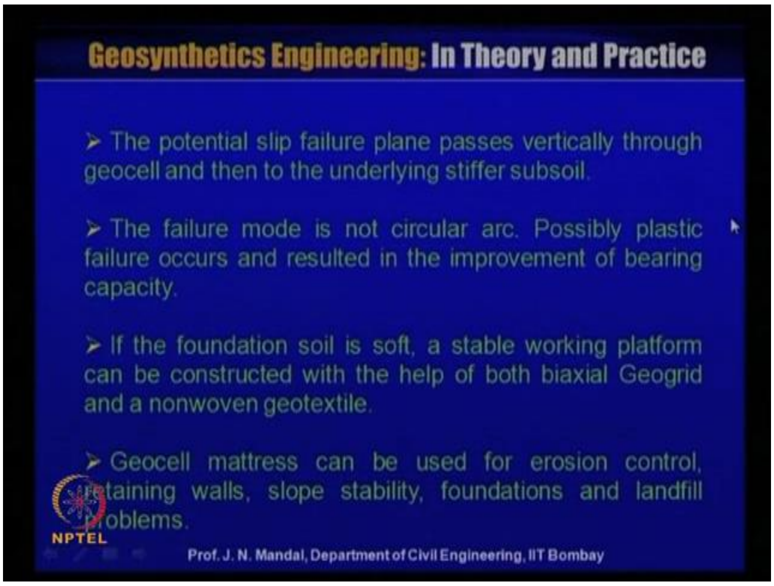

So, potential slip failure plane passes vertically through the geocell and then to the underlying stiffer subsoil. The failure mode is not circular arc, possibly plastic failure occur and resulted in the improvement of bearing capacity. If the foundation soil is soft, a stable working platform can be constructed with the help of both biaxial geogrid and a non woven geotextile material. Geocell mattress can be used for erosion control, retaining wall, slope stability, foundation and landfill problem.

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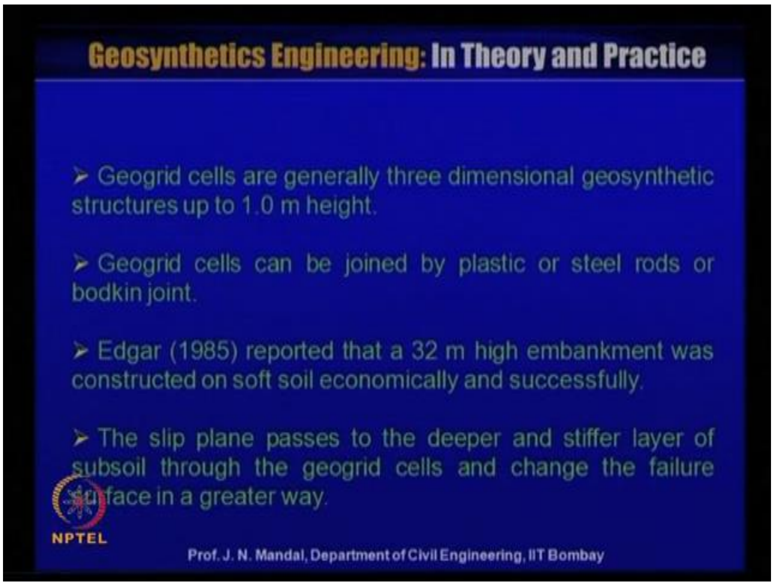

Geogrid cell are generally the three dimensional geosynthetic structure up to 1.0 meter height. You can also vary the height with using the geogrid material. Based on the type of the project geogrid cell can be joined by the plastic steel rod or the bodkin joint. Edgar 1985 reported that a 32 meter high embankment was constructed on soft soil economically and successfully. The slip plane passes to the deeper and stiffer layer of subsoil through the geogrid cell and change the failure surface in a greater way.

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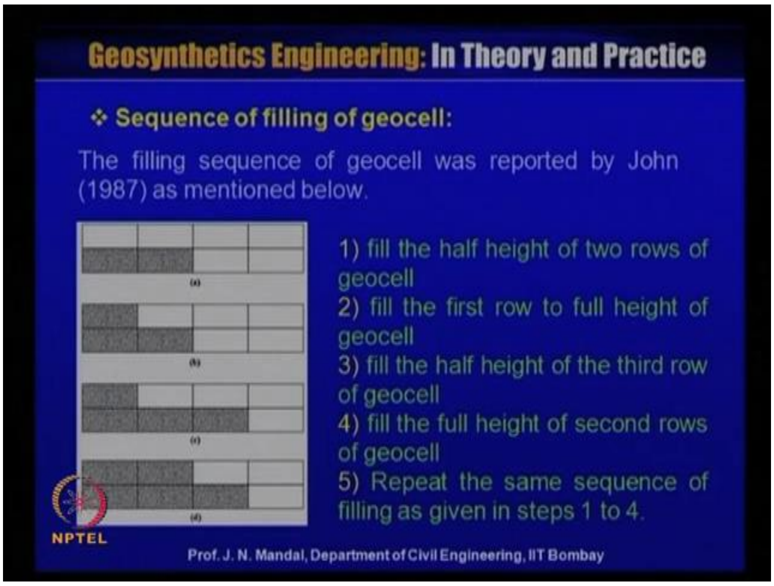

Now, you should know that how to fill the geocell. So, sequence of filling the geocell. The filling sequence of geocell was reported by the John 1987 as given here. One first of all that fill the half height of the two row of geocell. And second fill the first row to full length of the geocell. And then third fill the half height of the third row of geocell. And fourth fill the full height of second row of geocell. And finally, the repeat the same sequence of filling as given in the step 1 to 4.

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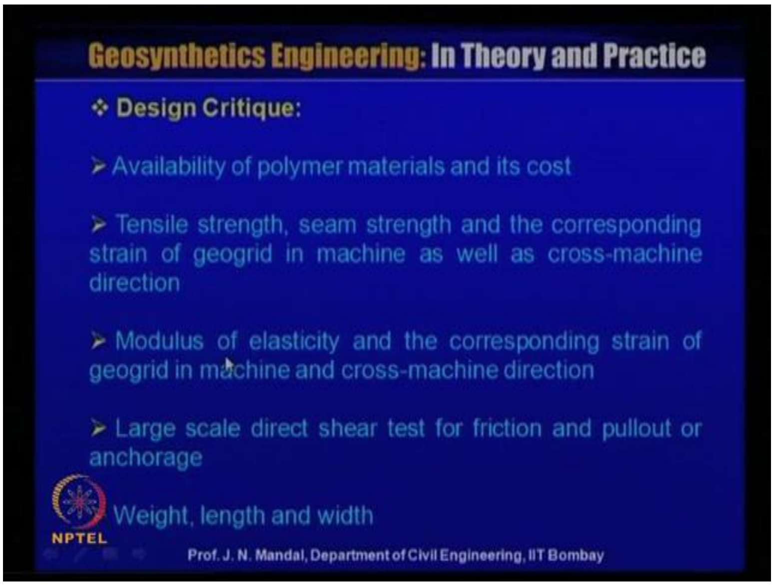

So, there is a requirement that how you should fill the geocell material with the granular material. So, we should fill the 2, then the first one, then the third one, then the second one like that sequence you should adopt. So, design critique availability of polymer material and it is cost. Tensile strength, seam strength and the corresponding strain of geogrid in machine as well as cross machine direction. Modulus of elasticity and the corresponding strain of geogrid in machine, and cross machine direction, large scale direct shear test for friction and the pullout or anchorage. And weight, length and the width.

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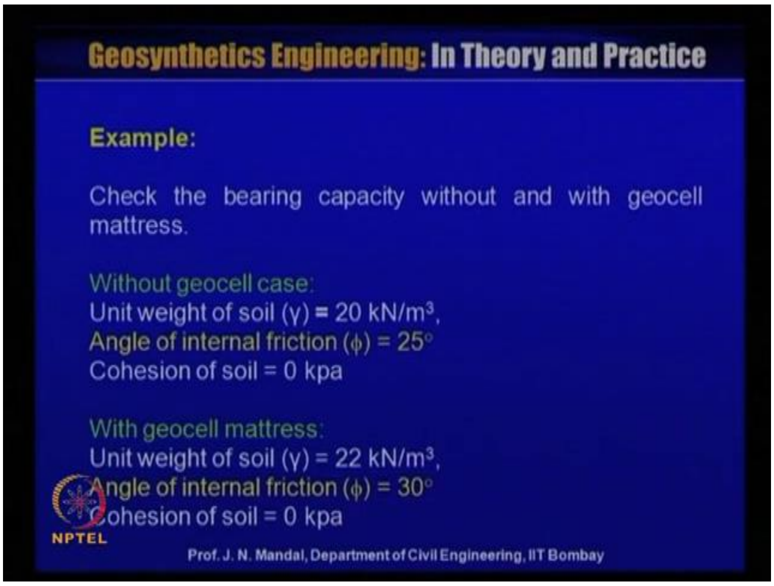

Here one example check the bearing capacity without and with geocell mattresses. So, without geocell mattresses, let us say unit weight of the soil gamma is equal to 20 kilonewton per meter cube, angle of internal friction phi is equal to 25 degree, cohesion of the soil 0 kilopascal. With geocell mattresses unit weight of the soil gamma 22 kilonewton per meter cube, angle of internal friction phi is equal to 30 degree and cohesion of soil is 0 kilopascal.

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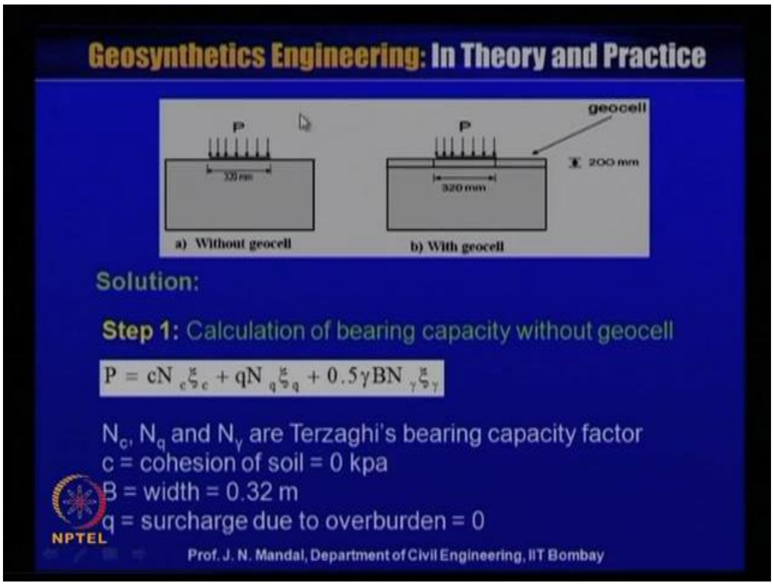

Now, you can see here this is the without geocell and this is 320 millimeter and this is the load P. And this is with geocell this foundation 320 millimeter and this is the load P and this is the geocell so this is 200 millimeter. Now, the solution step one calculation of bearing capacity without geocell. So, you know this equation that P is equal to c N c epsilon c plus q N q epsilon q plus 0.5 gamma B N gamma epsilon gamma. Here N c, N q, n gamma are Terzaghi's bearing capacity factor, c cohesion of soil is equal to 0 kilopascal, B width is equal to 0.32 meter because this is the B so 0.32 meter, 320 or 0.32 meter. And q is the surcharge due to over burden, that is 0.

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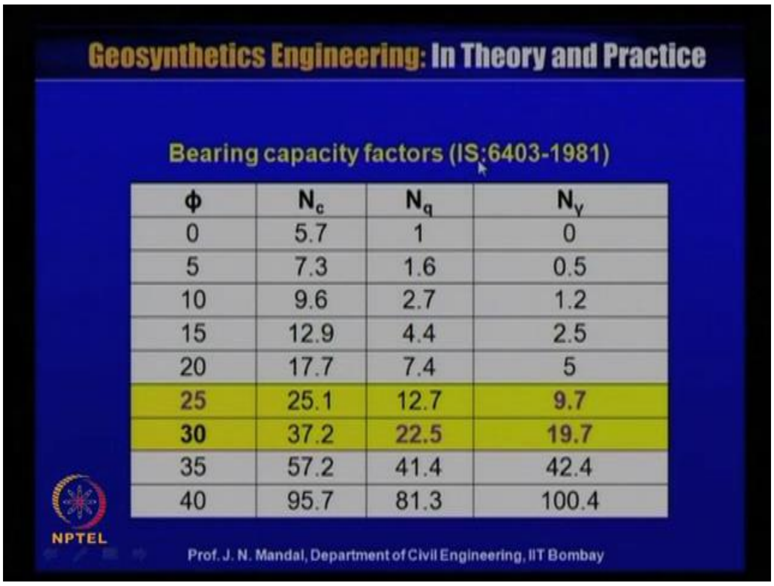

So, these are the bearing capacity factor. For this different angle, you know that is 25 degree without geocell and with geocell is 30 degree. So, we are taking this bearing capacity factor N c, N q, N gamma as per IS 6403-1981 for 25 degree. So, N gamma value is 9.7 when without geocell. When phi value is equal to 30 and N gamma value is equal to 19.7 when using geocell material.

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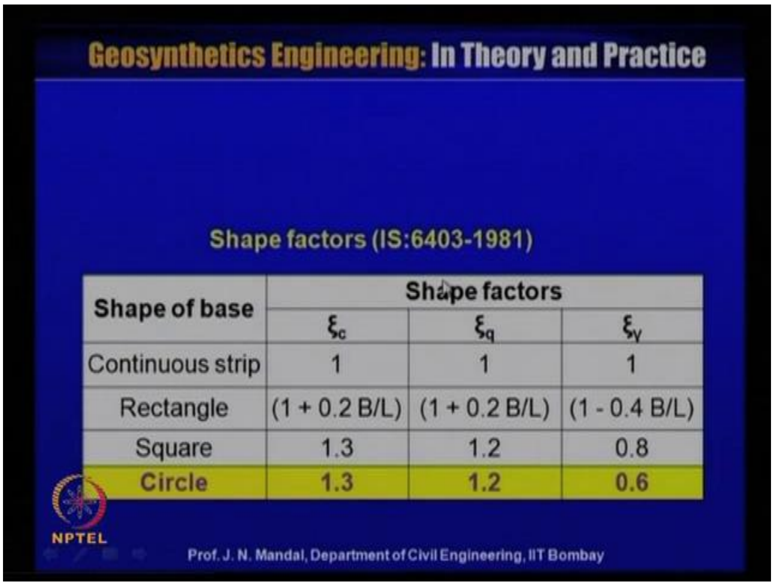

And also shape factor is taken from IS 6403-1981. And this is the shape of the base whether it is a continuous strip then what is the value of epsilon c, epsilon q and epsilon gamma that is 1, 1, 1. If it is a rectangle then epsilon c will be 1 plus 0.2 into B by l and epsilon q 1 plus 0.2 into B by l and epsilon gamma 1 minus 0.4 into B by l. If it is a square then shape factor epsilon c is equal to 1.3, epsilon q is equal to 1.2 and epsilon gamma is equal to 0.8. If it is a circle then shape factor epsilon c is equal to 1.3 and shape factor epsilon q is equal to 1.2 and shape factor epsilon gamma is equal to 0.6. So, these are the shape factor value and this bearing capacity factor value have been chosen from this IS code. And now, we will substitute this value into this equation. And we observe that what kind of the improvement in bearing capacity without and with the geocell material.

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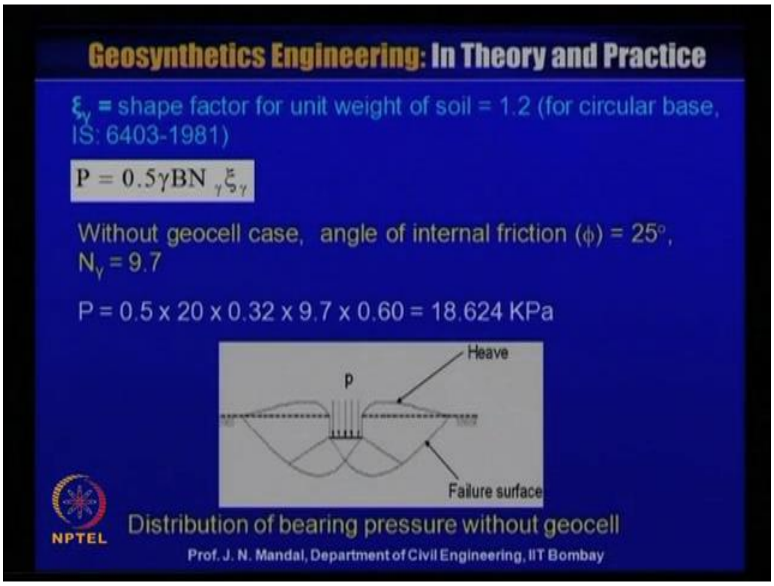

Now, epsilon b is the shape factor for unit weight of the soil is 1.2 for circular base as per IS 6403-1981. So, P will be equal to 0.5 gamma B N gamma into epsilon gamma. So, when there is no geocell that means without geocell case. So, angle of internal friction phi is equal to 25 degree. If phi is equal to 25 degree N gamma value is 9.7. We have seen that here when phi is equal to 20 degree N gamma, this N gamma value is 9.7. So, you are substituting this N gamma value 9.7. So, P will be equal to 0.5 into gamma is equal to 20 and B width of the foundation that is 0.32 and N gamma is equal to 9.7 and epsilon gamma is 0.6. So, epsilon gamma because it is a circular so epsilon gamma value here you have taken from the safe factor from IS 6403-1981.

So, because it is a safe of the base is a circle so epsilon v will be equal to gamma will be equal to 0.6. So, if substitute value 0.6 so this will give P is equal to 18.624 kilopascal. So, in case of without geocell you can see that distribution due to the load. And this is a failure surface and there is a formation of heave, so distribution of bearing pressure without the geocell material.

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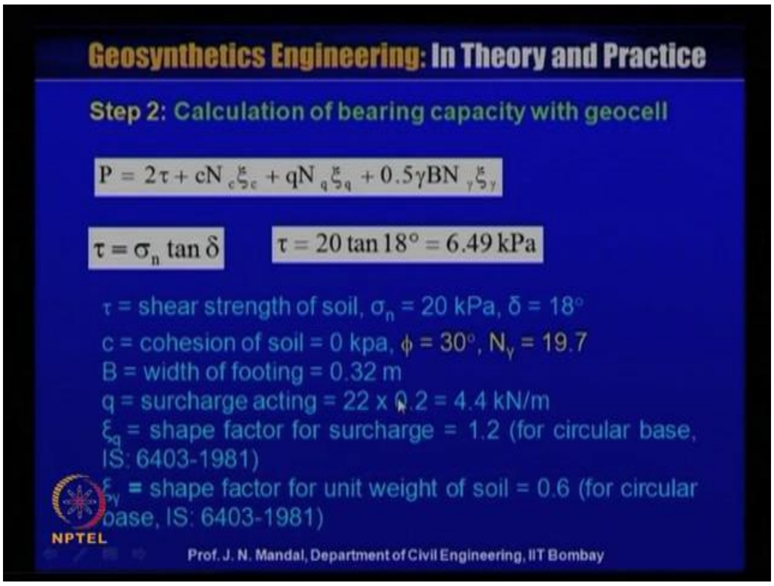

So, step 2 calculation of bearing capacity with geocell. So, equation P is equal to 2 tau plus c N c epsilon c plus q N q epsilon q plus 0.5 gamma B N gamma epsilon gamma. And here tau is equal to sigma n into tan delta, where tau is equal to shear strength of the soil. Sigma n is 20 kilopascal is given and delta is eighteen degree. And c is cohesion of the soil is 0 kilopascal. So, here the phi value is 30 degree so N gamma value is 19.7. So, you can see here phi value is 30 phi value is 30 degree N gamma value is 19.7.

So, here we can see that phi value 30, N gamma value 19.7 and b is the width of the footing is equal to 0.32 meter. And q is the surcharge acting that is 22 into 0.2 is equal to 4.4 kilo Newton per meter because that you have seen that the height of the geocell is 0.2. So, this will act as a surcharge load. So, 22 with the density into 0.2 that means 4.4 kilo Newton per meter, and epsilon q is the shape factor for surcharge is 1.2 for circular base this is as per IS 6403-1981.

So, epsilon q is taken from here, this is a circular shape of the base so shape factor will be 1.2. So, we put this value 1.2 for circular base and epsilon gamma is the shape factor for unit weight of the soil is 0.6 for circular base. So, you can see epsilon gamma also here, this is 0.6. So, we take this shape factor is equal to 0.6.

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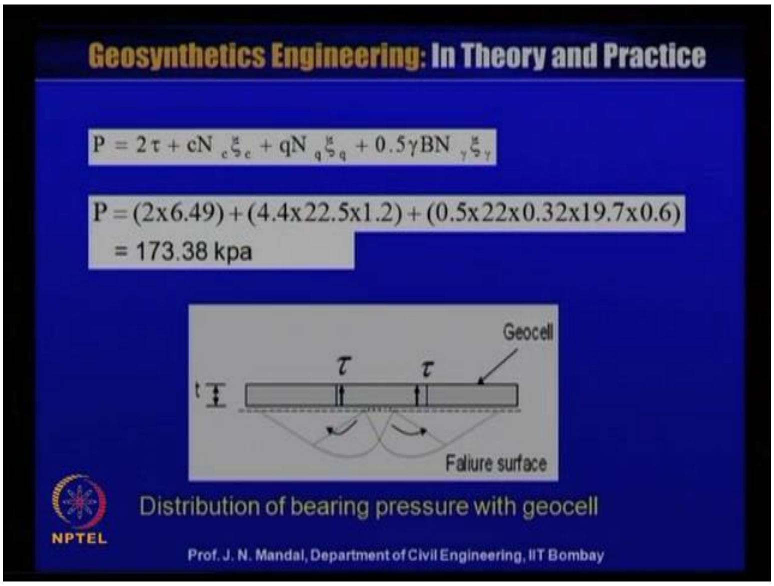

So, now P will be equal to 2 into tau plus c into N c epsilon c plus q into N q epsilon q plus 0.5 gamma BN gamma epsilon gamma. So, P will be equal to 2 into tau. Tau you have calculated from here sigma n into tan of delta sigma n is 20 delta value eighteen degree. So, you can calculate tau, tau value is 20 into tan 18 degree is 6.49. So, this is 6.2 into 6.49 plus c into N c into epsilon c. So, this is 4.4 into 22.5 into 1.2 plus 0.5 into gamma is 22 plus B you know 0.32 and N gamma is 19.7 and epsilon gamma is 0.6. So, you know all these value, so you can calculate and determine the P. So, P will be equal to 173.38 kilopascal. Now, in case of the geocell you can see that failure surface. There is no formation of the heave. So, this is the distribution of bearing pressure with geocell. Here it is tau is acting. Here t is the thickness or this height or thickness of the geocell material. So, failure pattern is absolutely the different from the without reinforcement.

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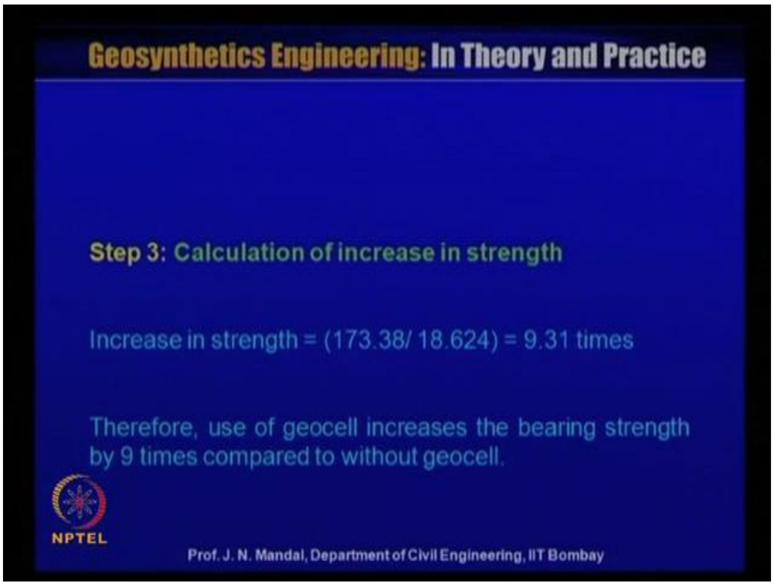

Now, step 3 calculation of increase in the strength. So, you see that increase in the strength here 173.38 this divided by, when it is the without geocell 18.624. So, increase in strength about 9.31 times. Therefore, the use of geocell increase the bearing strength by 9 times compared to without geocell material. So, we observed that if you use this geocell then there is a substantial improvement in the bearing capacity of the soil, and because for geocell it is a very good confinement effect.

And there is a also development of the shear strength and that shear strength developments occur due to the confinement effect. So, one has to use that proper kind of the material proper kind of the geometry of the geocell, which you can optimize and can be used in various projects for the improvement of the bearing capacity of the soil. So, with this I finish my lecture today. Please let us hear from you, any question?

Thanks for listening.