Geosynthetics Engineering: In Theory and Practice

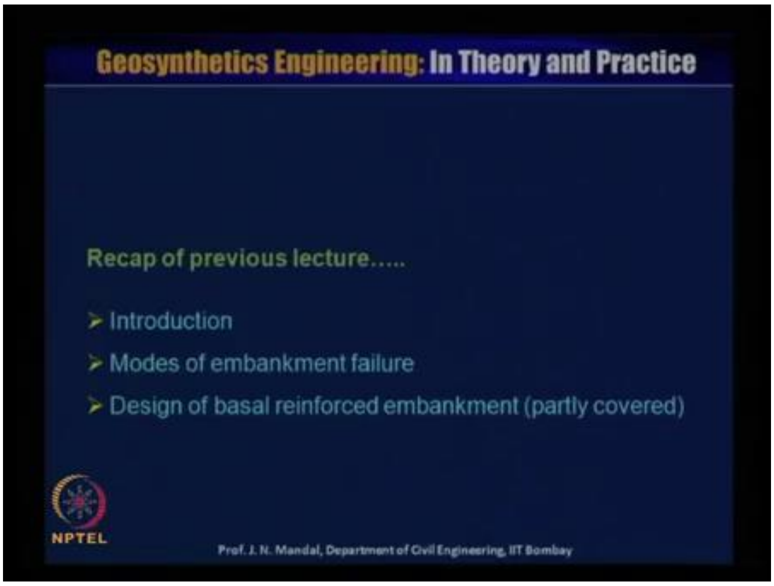
Prof. J. N. Mandal
Department of Civil Engineering
Indian Institute of Technology, Bombay

Lecture - 41

Geosynthetics for embankments on soft foundations

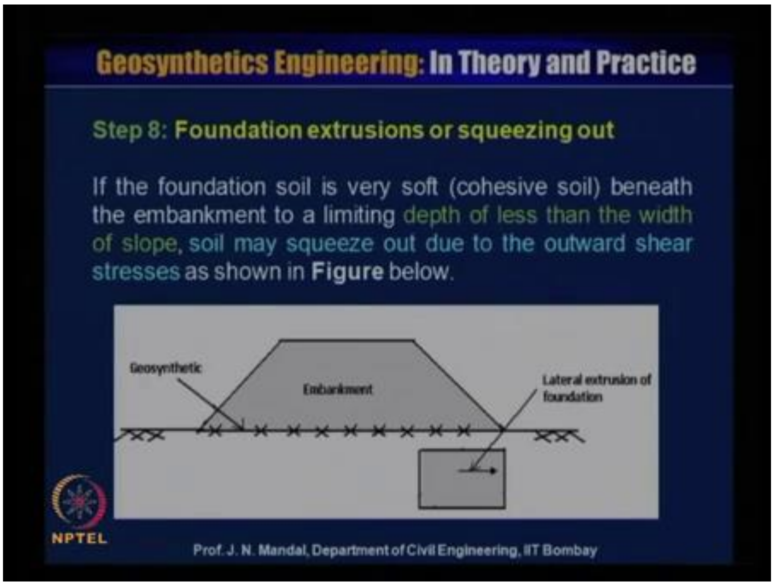
Dear student warm welcome to NPTEL phase two video course on geosynthetics engineering in theory and practice. My name is Professor J. N. Mandal department of civil engineering, Indian institute of technology Bombay, Mumbai India. This lecture number forty one module eight geosynthetics for embankment on soft foundation.

(Refer Slide Time: 00:59)



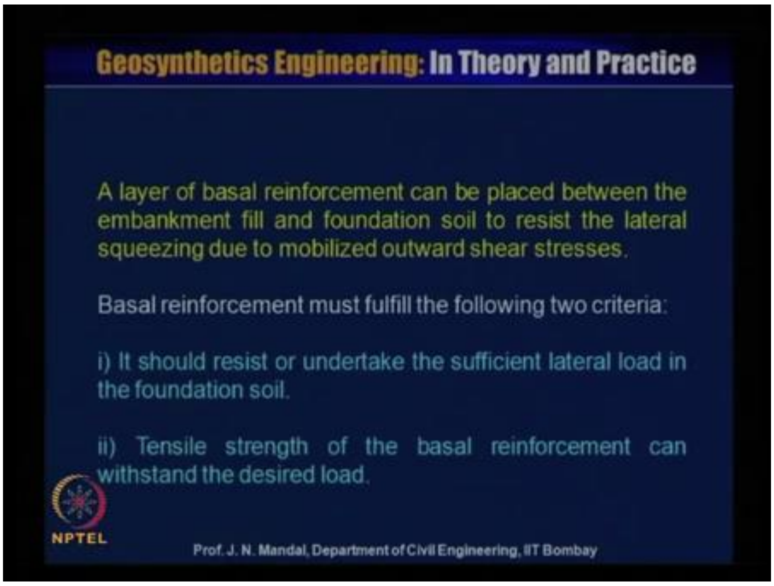
I will address recap of the previous lecture which I covered the introduction mode of embankment failure design of basal reinforced embankment that is partly covered.

(Refer Slide Time: 01:11)



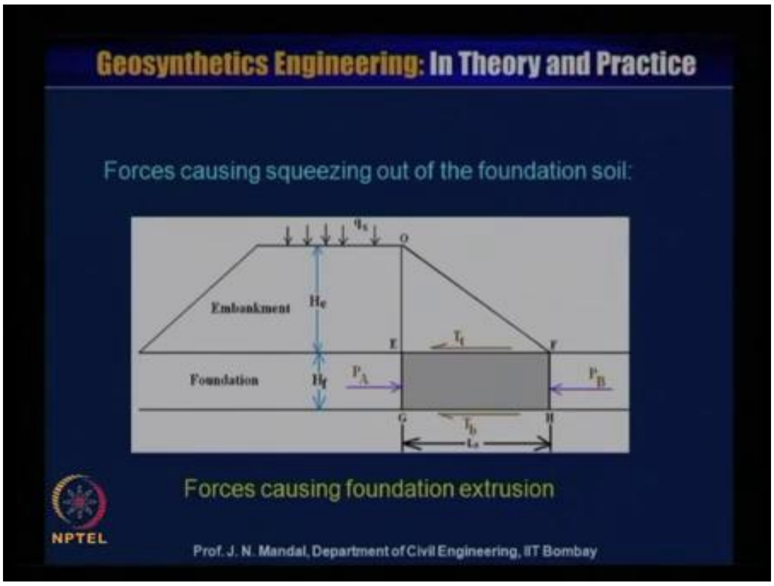
Now, step eight foundation extrusion or squeezing out, if the foundation soil is very soft that is cohesive soil, and beneath the embankment to a limiting depth of less than width of the slope the soil may squeeze out due to the outward shear stresses, here as it is shown. So, this is the lateral extrusion of the foundation and this is geosynthetics material, which is placed between the embankment and the foundation soil. So, you have to check what will be the factor of safety against this squeezing out of the sample.

(Refer Slide Time: 02:23)



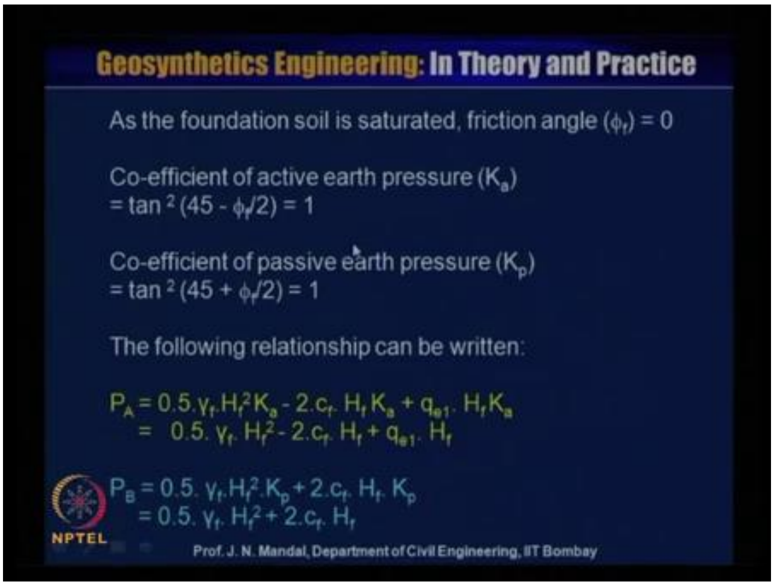
So, a layer of basal reinforcement can be placed between the embankment fill and foundation soil to resist the lateral squeezing due to mobilized outward shear stresses basal reinforcement must fulfill the following two criteria. Number one it should resist or undertake the sufficient lateral load in the foundation soil. Number two the tensile strength of the basal reinforcement can withstand the desired load.

(Refer Slide Time: 03:08)



Now, here it has been shown that what are the forces that causing the squeezing out of the foundation soil. So, this is the foundation right is H f and this is the embankment whose height is H e there is a surcharge load q s and these are the forces which is causing the foundation extrusion. So, this is the E f and this is the g h this is P A this is P B and this length is equal to l of S s this is t top T t the shear stresses which is acting and this is the T b for shear stresses acting at the bottom.

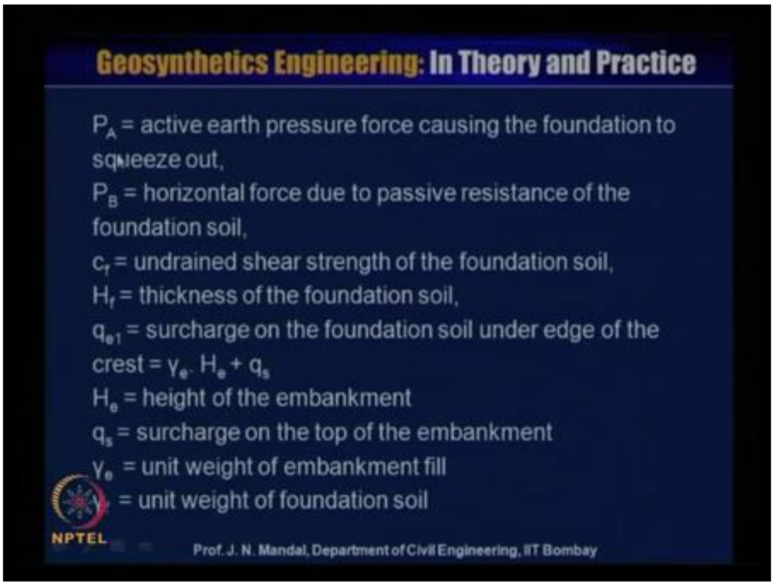
(Refer Slide Time: 04:20)



Now, as the foundation soil is saturated that mean friction angle phi of f is 0 ,so this is the foundation soil this is saturated, so that is why it is only cohesion no friction value. So, phi of f at the foundation soil is 0, so that is why phi f is 0. So, coefficient of active earth pressure K a is equal to tan square 45 degree minus phi f by 2 as phi f is 0, so K a value is equal to 1, coefficient of passive earth pressure K p is equal to tan square 45 degree plus phi f by 2, so this also is equal to 1.

Now, the following relationship can be written as P A is equal to half gamma of f into H f into K a minus twice c of f H f into K a plus q of e 1 into H f into K a this is equal to half gamma f into H f square because K a is 1 minus 2 into c f into H f K a is equal to 1 plus q e 1 into H f because K a is equal to 1. Similarly, P B can be written half into gamma f into H f square into K p plus twice into c f into H f into K p as K p is equal to 1. So, can write 0.5 into gamma f plus H f square plus 2 c f into H f, so this I am showing you the explanation for this.

(Refer Slide Time: 06:33)

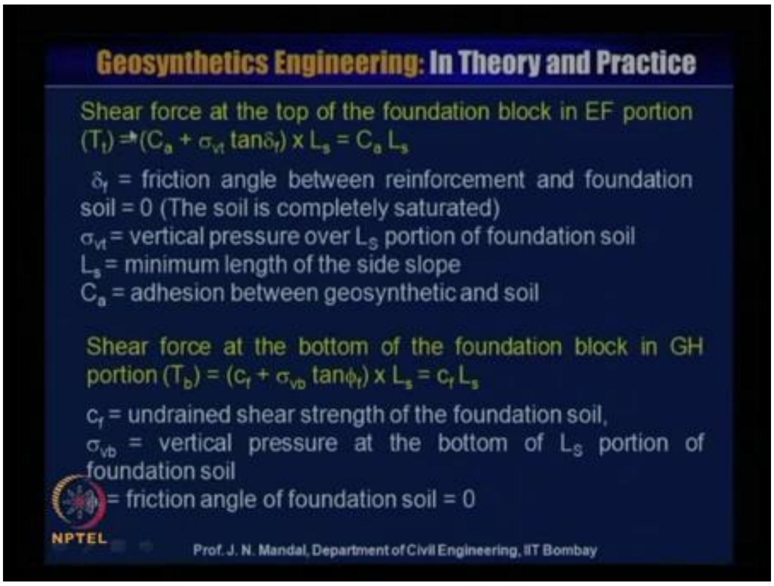


Here, P A is the active earth force causing the foundation to squeeze out here P A active earth force here. Now, P B is the horizontal force due to the passive resistance of the foundation soil this is P B horizontal passive force is acting here. Now, c f is the undrained shear strength of the foundation soil and H f, I showed you thickness of the foundation soil q e 1 surcharge on the foundation soil under the edge of the crest that will give gamma e into H e plus q s. So, here if it is a H e and unit weight of the embankment gamma e, so this will be gamma e into H e and plus this surcharge q s, so gamma e into H e plus q of s.

So, that is why q e 1 is the surcharge on the foundation soil under the edge of the crest, so H e I mentioned the height of the embankment q s surcharge on the top of the embankment gamma s unit weight of the embankment fill and gamma f unit weight of the foundation soil. So, now you can see here this P A force which is acting here this is half into gamma f into H f square here half into gamma f into H f square into k of a, so these are the force acting in this direction.

Now, this minus here is a t that is minus 2 into c f here minus 2 into c f that foundation soil into H f into K a plus due to the that surcharge that is q e 1 H f into K a. Similarly, for the P B on here this will be equal to half into gamma f into H f square into K p here plus 2 into c r, because this direction it is 2 into c of f into H f into K p, so that way you can obtain the equation for P A and P B from this diagram.

(Refer Slide Time: 09:17)



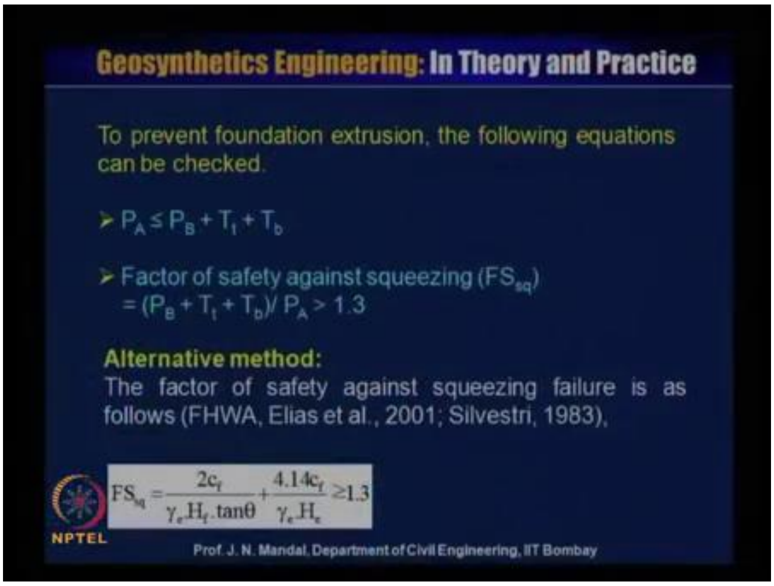
Now, what are the shear force at the top of the foundation block in E F portion so E F portion means this portion E F portion and this is g h portion. So, this is the top portion E F, so shear force at the top of the foundation block in E F portion that is T t, so this will be equal to C a into sigma v t into tan of delta f into L s. Now, where this sigma of v t is the vertical pressure over the L s portion of the foundation soil that is here this is the L s portion. So, whatever the vertical forces acting on the L s portion of the soil, so sigma of v t into tan of delta f. So, this delta f is the friction angle between the reinforcement and foundation soil because we know that this soil is completely saturated, so delta f value will be the 0.

So, that is why this value will be the 0 into it is acting towards the entire length that is l of s l of s. So, we can write that T t is equal to C a into sigma v tan delta f into L s because this friction angle between the reinforcement and foundation is 0, you can write C a into l of s. So, this is T t shear force which is acting at the top of the foundation block E F portion and L s you know that minimum length of the side slope and C a is equal to adhesion between the geosynthetics and soil. Similarly, you have to find out what will be the shear force at the bottom of the foundation block in g h portion of the T b so this is the g h portion this the T b this is g h and this embedded length is this length is L s.

So, this is T b, so T b will be equal to T b will be equal to c of f into sigma v b into tan of phi f into L s, so this sigma v b that means vertical force at the bottom of the L s portion of the foundation soil earlier it was top. Now, it is the bottom of the L s portion of the soil and phi f is the friction angle of the foundation soil you know it is 0. Therefore, the T b will be equal to c f into L s, so c f is the undrained shear strength of the foundation soil.

So, here we are obtaining the shear force at the top of the foundation block e f that is T t is equal to C a into L s where c s is the adhesion between soil and the geosynthetics material and L s you know minimum length of the side slope and here shear force at the bottom of the embankment that is T b t b is equal to c f into L s. So, c f is the undrained shear strength of the foundation soil and L s is the minimum length of the side slope. So, we are having t a T t shear force at the top C a into L s and shear force at the bottom T b is equal to c f into L s, so you know that what about the shear force are acting into that block.

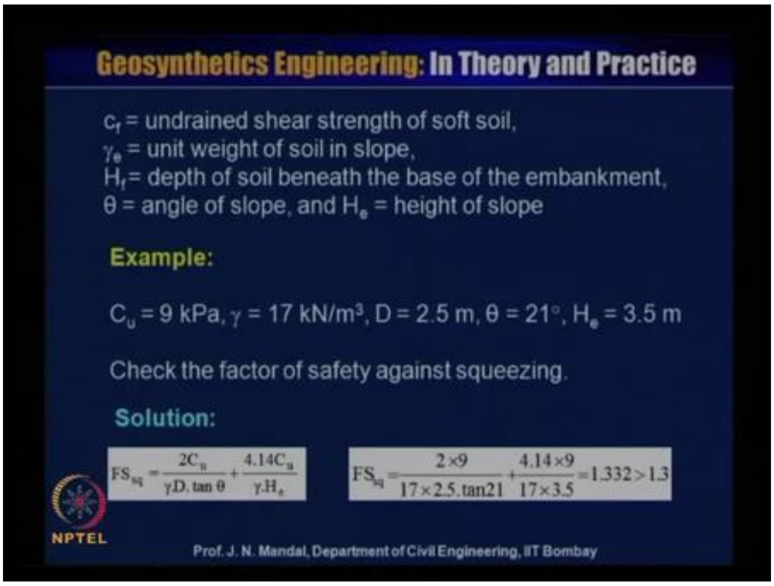
(Refer Slide Time: 13:41)



Now, to prevent the foundation extrusion the following equation can be checked that is P A should be less than equal to P B plus T t plus T b. So, that means this P A should be less than P B plus T t plus T b because this P A is acting in this direction P B is acting this passive is acting this direction. Here is the shear force t top is acting this direction and at the bottom the shear force are acting in this direction. So, P A should be less than equal to P B plus T t plus T b, so which it has been given here that P A should be less than P B plus T t plus T b.

So, factor of safety against the squeezing F S square will be equal to P B plus T t plus T b divided by P of A it should be greater than 1.3, so it should satisfy this criteria, so if it satisfies the criteria then it can be prevented from the squeezing. Now, there are also alternative method the factor of safety against squeezing failure is as follows F H W A Elias et al 2001 and Silvestri 1983. So, they have given the equation the factor of safety against squeezing is equal to 2 into c f divided by gamma e H f into tan theta plus 4.14 c f divided by gamma e into H e should be greater than equal to 1.3.

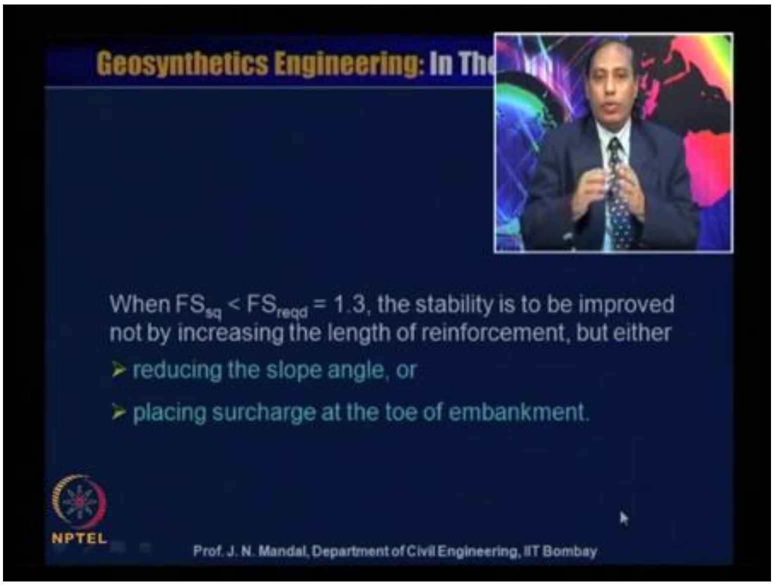
(Refer Slide Time: 15:31)



So, this is the equation given by them where c f is the undrained shear strength of soft soil gamma e unit weight of the soil in the slope, and H f is the depth of soil beneath the base of the embankment and theta angle of slope and H e is equal to height of the slope. Here we have given one example if the undrained shear strength of soil C u is 9 kilo Pascal and gamma e is 17 kilo Newton per meter cube. And this D is 2.5 meter theta is equal to 21 degree, H e the height of the embankment is 3.5 meter.

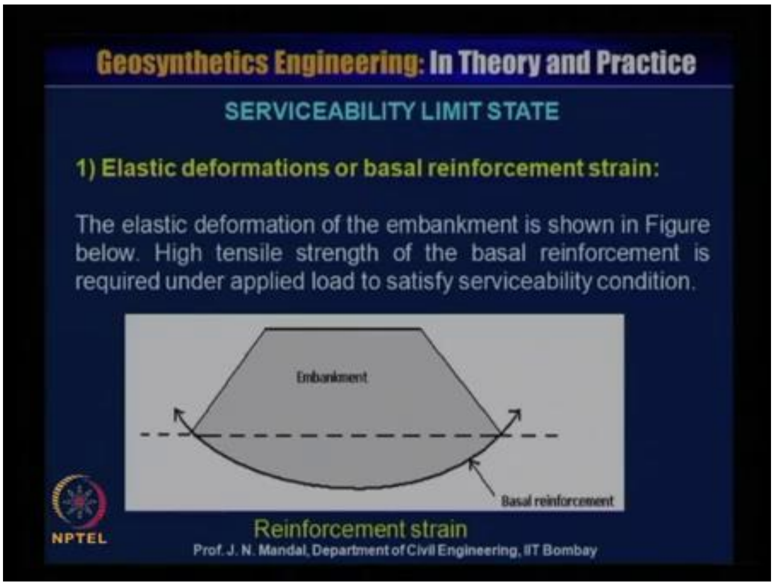
So, you can check the factor of safety against squeezing the solution is this is the equation F S square is equal to 2 C u by gamma D into tan theta plus 4.14 C u by gamma into H e. So, here you are substituting the C u value is 2 into 9 divided by gamma is 17 and D is 2.5 into theta is 21, so tan 21 degree plus 4.14 into c u again the c u is 9 this divided by gamma is 17 into H e is 3.5. So, this you can see give the value of factor of safety against squeezing is 1.332, so it is greater than 1.3, so it is ok.

(Refer Slide Time: 17:16)



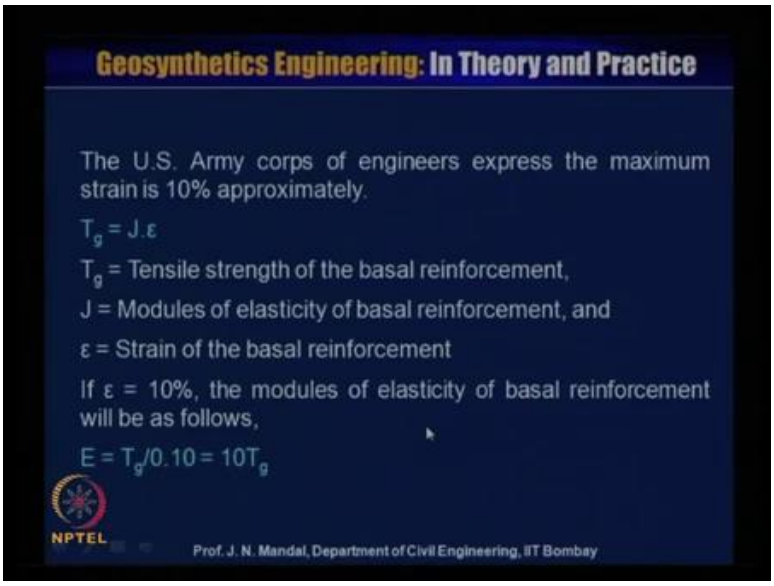
So, you can check that factor of safety against squeezing, so when the factor of safety is squeezing is less than factor of safety is required, this stability is to be improved not by increasing the length of the reinforcement, but either reducing the slope angle or placing the surcharge at the toe of the embankment.

(Refer Slide Time: 17:44)



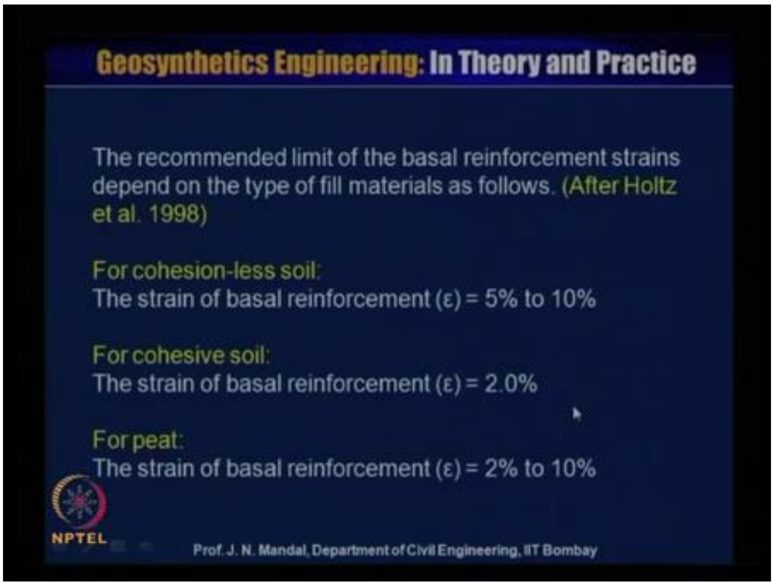
Now, serviceability limit state one elastic deformation or basal reinforcement strain the elastic deformation of the embankment is shown here. High tensile strength of basal reinforcement is required under the applied load to satisfy the serviceability condition. So, this is the reinforcement strain due to the load.

(Refer Slide Time: 18:23)



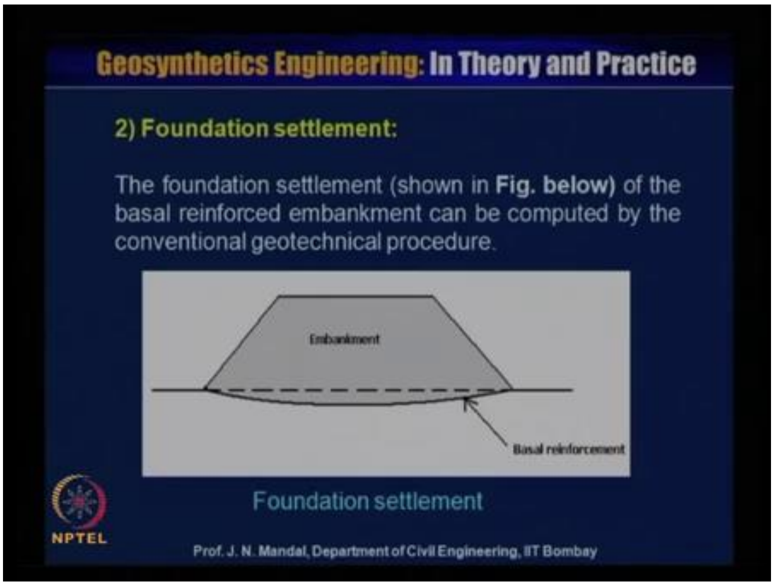
So, US army corps of engineer express the maximum strain value is 10 percent approximately. So, T g is equal to j into epsilon where T g is equal to tensile strength of the basal reinforcement and j is modules of elasticity of basal reinforcement and epsilon is strain of the basal reinforcement. If the epsilon is equal to 10 percent then modulus of elasticity of basal reinforcement will be as follow that e will be equal to T g divided by 10 percent in 0.10, so e will be 10 into T g where T g is tensile strength of basal reinforcement. So, you can calculate that what should be the modulus of the elasticity, so that is ten times the tensile strength of the basal reinforcement.

(Refer Slide Time: 19:22)



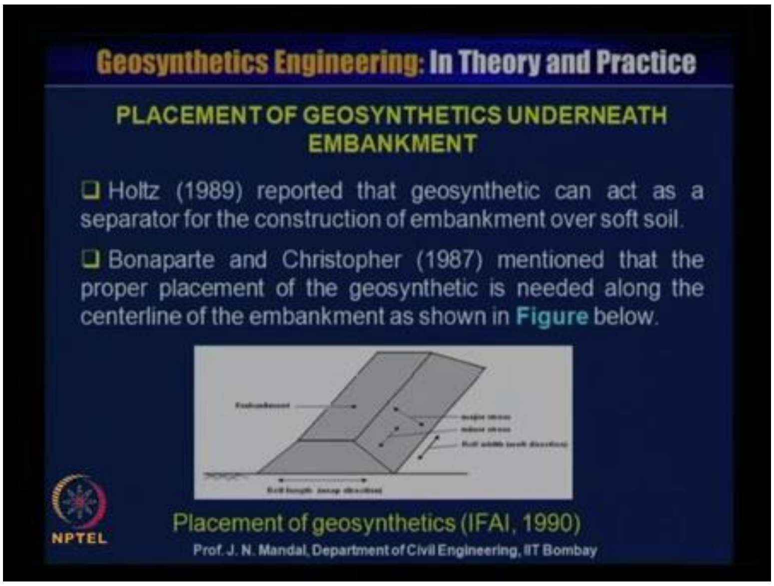
Now, the recommended limit of the basal reinforcement strain depends on the type of fill material as follow after Holtz et al 1998. For cohesion-less soil this strain of the basal reinforcement epsilon is equal to 5 percent to 10 percent, for cohesive soil strain of basal reinforcement epsilon is equal to 2 percentage, for peat the strain of basal reinforcement epsilon is equal to 2 percent to 10 percentage. So, you see that in case of the peat and in case of the cohesion-less soil this strain value is on the higher side, where in case of the cohesive soil this strain value is on the lower side because that in cohesive soil there may be some kind of the problem. So, it is always preferable to keep the strain of the basal reinforcement is on the lower side.

(Refer Slide Time: 20:35)



The foundation settlement, so you can see here this is the embankment how the basal reinforcement has been settled due to application of the load and this settlement can be computed by the conventional geotechnical procedure. So, you can handle any basic soil mechanics book, and then you can calculate what will be the settlement for the embankment.

(Refer Slide Time: 21:06)

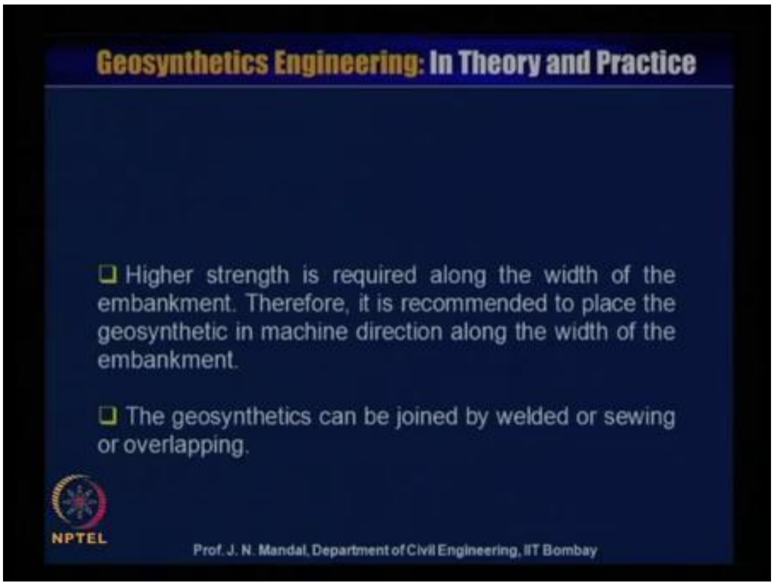


Now, this is the placement of the geosynthetics underneath the embankment Holtz 1989 reported that geosynthetics can act as a separator for the construction of embankment over soft soil. Bonaparte and the Christopher 1987 mentioned that the proper placement of the geosynthetics is needed along the centerline of the embankment. You can see as it is given here the placement of geosynthetics by I F A I 1990 I am showing you. So, this is the this is the embankment and this is the roll length in the wrap direction and this is the major stresses and this is the minor stresses.

This is the roll width will be in the wave direction because the geotextile have a wave direction and the wrap direction, and placement of the geosynthetics also very important factor for example, that there are two kind of the fill one is that linear fill. For example that you wanted to place the geosynthetics material for the construction of the road embankment, and the dike that means the length of the side is larger than the width. So, there is a major principle stress direction, and also seam in the minor principle stress direction.

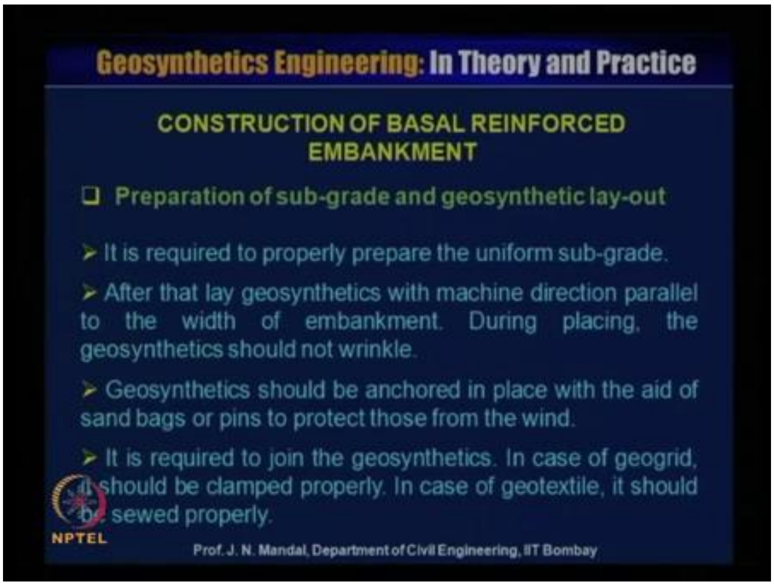
So, you have to be place the geosynthetics in the proper direction, so when it is a linear fill linear fill means the length of the site is longer than the width. But sometimes the length and the width of the site is almost equal in such case no clear define the principle stress direction for example, that you want to construct a building or a industrial site where the site is square that means length and width is the same. So, in such case the strength of the geotextile are same in all the direction and no clear define of the principle stress. Also you have to be take care for the seam in the both the direction because it is required some stitching, so that also you have taken care for the placement.

(Refer Slide Time: 24:40)



So, higher strength is required along the width of the embankment. Therefore, it is recommended to place the geosynthetics in the machine direction along the width of the embankment the geosynthetics can be joined by welded or sewing or overlapping.

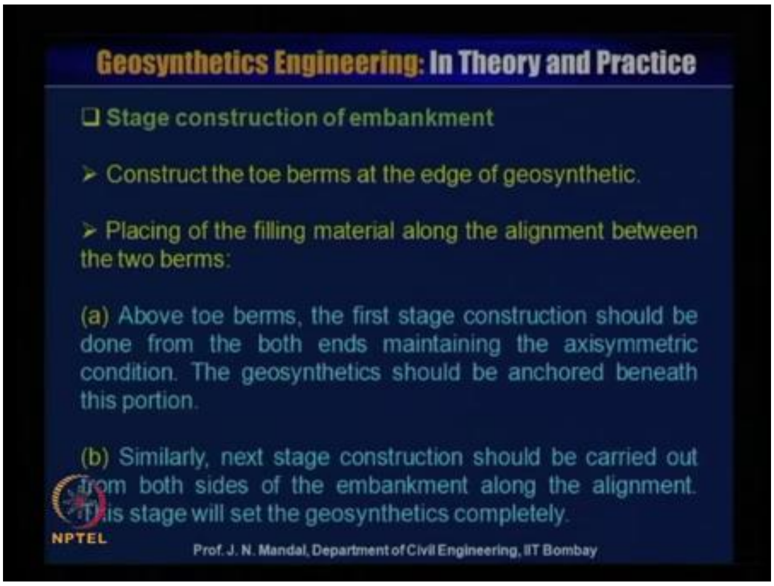
(Refer Slide Time: 25:06)



Now, construction of basal reinforcement embankment, so preparation of the sub grade and the geosynthetics layout, it is required to properly prepare the uniform sub grade. After that lay the geosynthetics with machine direction parallel to the width of the embankment during placing the geosynthetics should not wrinkle, so you should remember it should not be wrinkle.

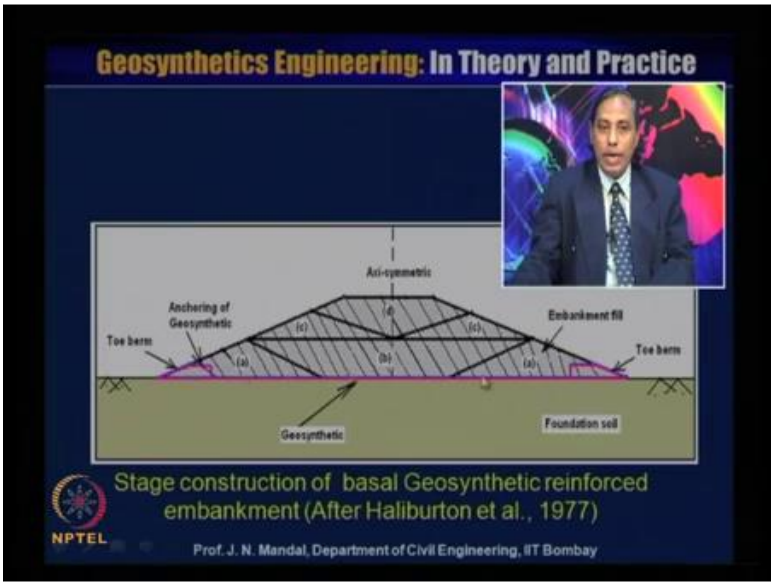
Therefore, geosynthetics should be anchor in place with the aid of sand bag or pin to protect those from the wind at a certain interval you can place the sand bag or the pin. So, there should not be formation of any wrinkle it is required to join the geosynthetics in case of geogrid, it should be clamped properly in case of geotextile it should be sewed properly.

(Refer Slide Time: 26:19)



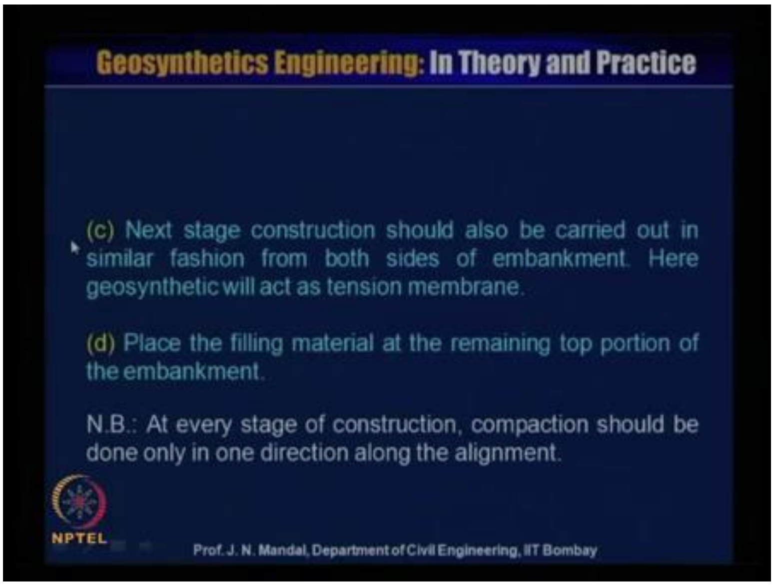
Stage construction of embankment construction, construct the toe berm at the edge of geosynthetics, placing of the filling material along the alignment between the two berm. So, it is very important that how you will construct the embankment when you are using this geosynthetics material I just show you that you can see a that means above toe berm. The first stage construction should be done from the both side maintaining the axisymmetric condition these geosynthetics should be anchored beneath the portion, so it is like this.

(Refer Slide Time: 27:16)



So, this is the geosynthetic material, this is the foundation and this a here anchoring the geosynthetic material this is a toe berm, this is also toe berm and you are anchoring the geosynthetic material here. So, when you will stage construction of basal reinforcement embankment then this is given after Haliburton et al 1977 this is a and a that means that you are above the toe berm. The first stage construction should be done from the both end maintaining the axisymmetric condition these geosynthetics should be anchored beneath the portion. Now, b similarly, next stage construction should be carried out from both side of the embankment along the alignment and this stage will set the geosynthetics completely. So, this is the case that b this place you have to placed.

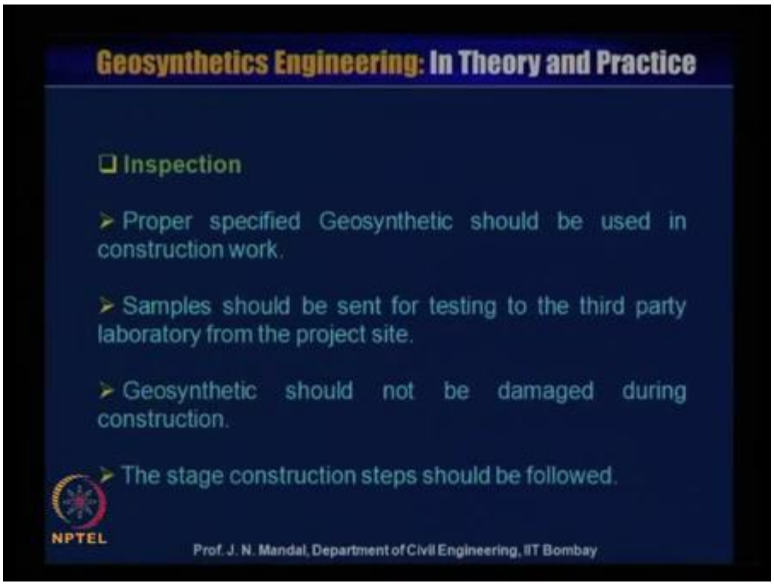
(Refer Slide Time: 28:24)



Then after the c next stage construction should also be carried out in similar fashion from both side of the embankment here geosynthetics will act as tension membrane here c. This is c from this state that the geosynthetics material will act as a tension and after that d the place the filling material at the remaining top portion of the embankment. So, here the d the remaining top portion of the embankment, so you have to mention also the axisymmetric.

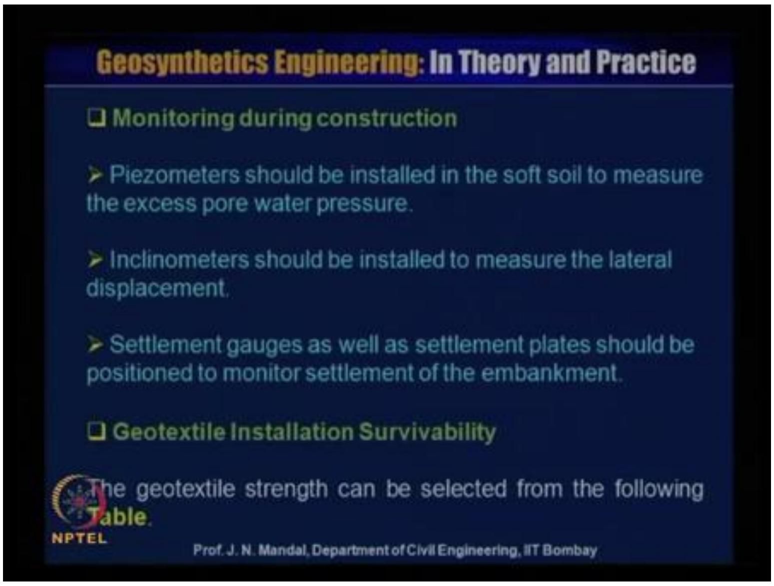
So, this is very important that how you will go for stress construction of the basal reinforced embankment. So, here it is noted that at every stage of construction compaction should be done only in the one direction along the alignment. So, you have some idea about that how you can go for the stress construction of the basal geosynthetics reinforced embankment.

(Refer Slide Time: 29:45)



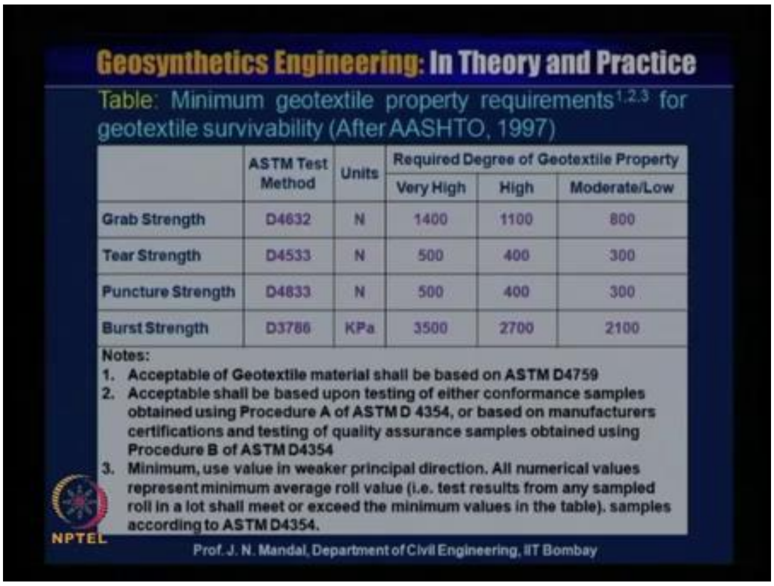
Inspection proper specified geosynthetics should be used in the construction work, sample should be sent for testing to the third party laboratory from the project site. It should not be from the manufacture side this material should reach to the testing place from the project site, where it has been delivered the geosynthetics should not be damaged during the construction. This stage construction step should be followed.

(Refer Slide Time: 30:23)



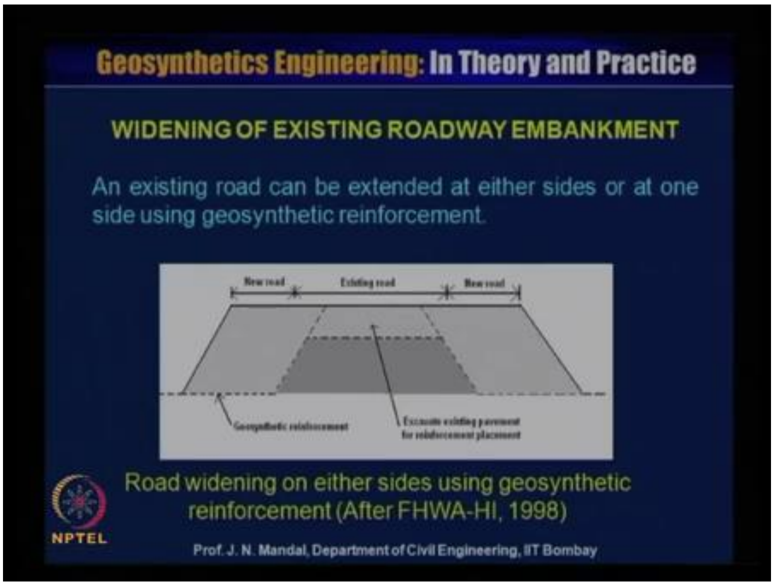
Now, monitoring during the construction piezometers should be installed in the soft soil to measure the excess pore water pressure, inclinometer should be installed to measure the lateral displacement. Settlement gauge as well as settlement plates should be positioned to monitor the settlement of the embankment. So, this is very important for any major project you must that monitor, and check that what is happening and what kind of the improvement how you can say that there is the embankment is in stable. So, we should measure that what will be the excess pore water pressure you also you could measure, whether the embankment is also laterally there is displacement occur or there is a settlement that also you should maintain and you could check and using this instrument. Geotextile installation serviceability, so geotextile strength can be selected from this stable

(Refer Slide Time: 31:47)



This is the minimum geotextile property requirement for geotextile serviceability after A A S H T O 1977. So, this is the grab strength A S T M this is D 4632 and it is required degree of geotextile property whether very high than 1400 then if it is a high then 1100 if it is moderate or low then 800. Similarly, tear strength as per D 4533 and this is very high 500 Newton high is 400 Newton and moderate or low is 300 Newton puncture strength as per D 4833 this 500 for very high. 400 for high and 300 for moderate and low, and burst strength as per A S T M D 3786 this is 3500 kilo Pascal for very high 2700 kilo Pascal for high and 2100 moderate and this low. So, you can follow this geotextile property what is required for the serviceability as per A S T M.

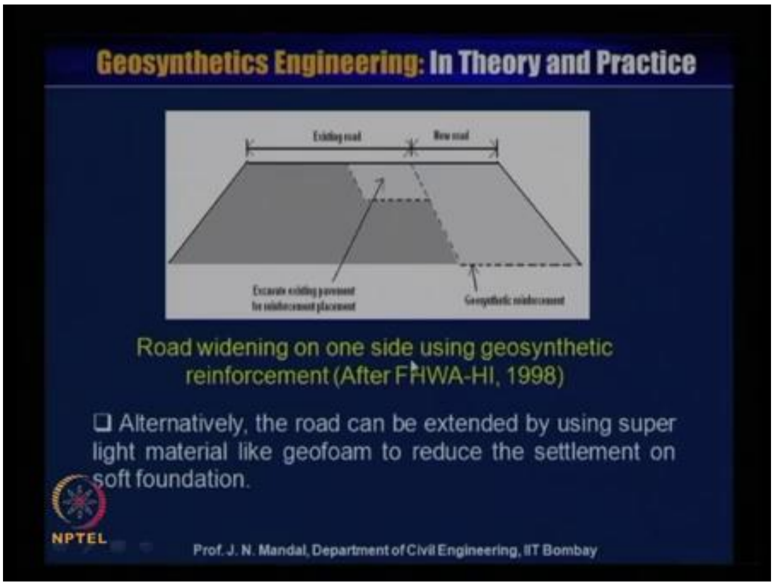
(Refer Slide Time: 33:06)



Now, many stresses you can observe that it is required to widen the existing roadway embankment, so here 1 roadway widening on either side using geosynthetic reinforcement is given as per F H W A-H 1 1998. This is the existing road and this can be extended either side or at one side using this geosynthetic reinforcement. So, what you can do that you can excavate the existing pavement for the reinforcement placement then you can place the reinforcement like this. And then like this and then you can fill up with the soil and you can construct a new road.

Similarly, on the right hand side also you can lay down this geosynthetics material after this excavation, and then you have filled up with the filling material and you can construct a new road. So, you can see the how the this is the existing road and how it can be extended or widening from the existing road embankment for both side of the road, so this kind of the system also can be applied.

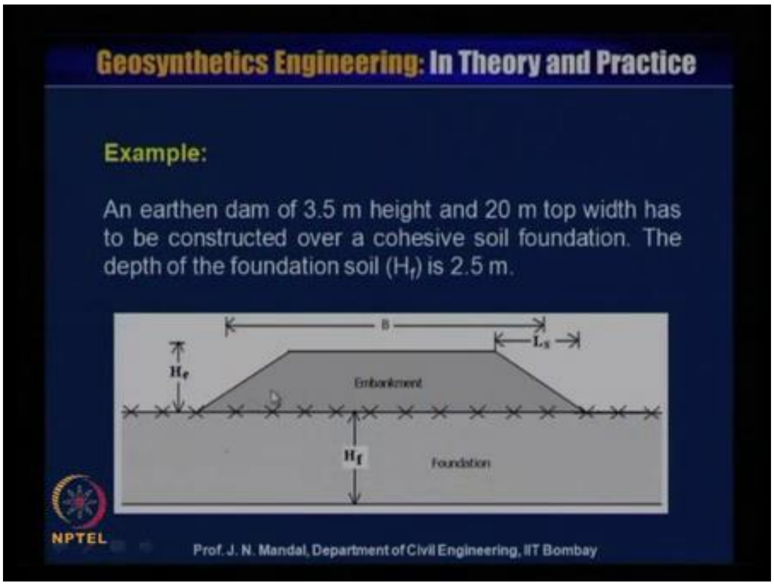
(Refer Slide Time: 34:38)



Similarly, this is road widening on the one side using geosynthetic material after FHWA-H1 1998. So, here this portion of this is the existing road here and then you require for the excavate, the existing pavement for the reinforcement placement here dot dot is the reinforcement placement. It is like this you can place the reinforcement and then you can fill up with the filling material and this is the new road.

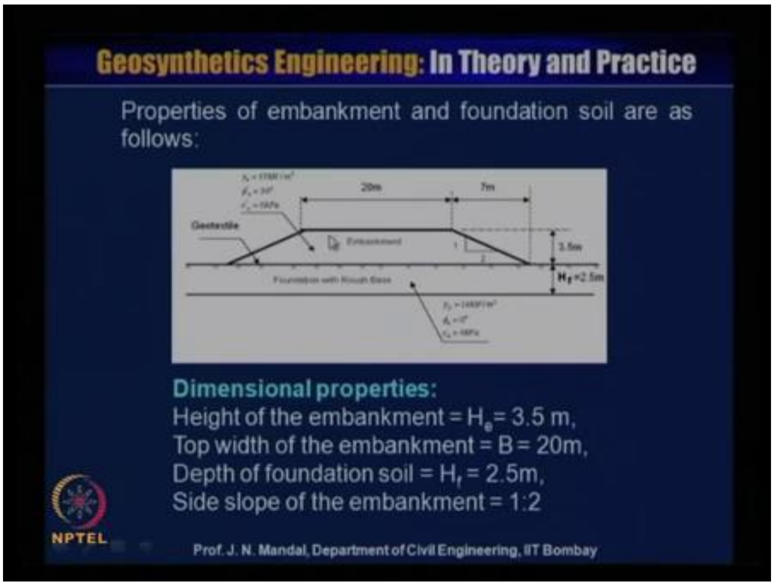
So, road widening on one side using geosynthetics reinforcement, so alternatively this road can be extended by using the super light material like geofoam to reduce the settlement on soft foundation. So, you can also use the geocell material or geofoam or cellular reinforcement for extending the road. So, there are various systems are available for the widening of the road and then you can check their economy, and stability and what material will be the suitable for that project site.

(Refer Slide Time: 36:01)



Now, I will give one example let us it is an earth dam of 3.5 meter height and 20 meter top width has to be constructed over a cohesive soil as a foundation and depth of the foundation soil is H f is equal to 2.5 meter. So, here this H e is equal to height of the dam or embankment and this is the L s this is the length slope, this is the length and this is the B the middle of this slope two the middle of the other slope is the B.

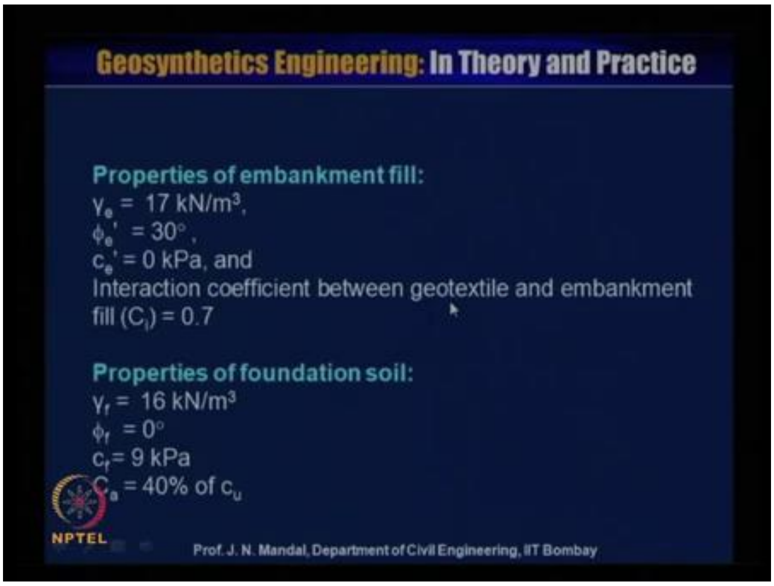
(Refer Slide Time: 36:50)



So, this is the properties of the embankment and foundation soil is given, so this you can see this is to there is 20 meter this is the here is 7 meter and slope is one vertical to horizontal. This height of the embankment is 3.5 meter and the depth of the foundation H f is equal to 2.5 meter and this is the geotextile material is placed between the embankment and the foundation soil and properties of the embankment.

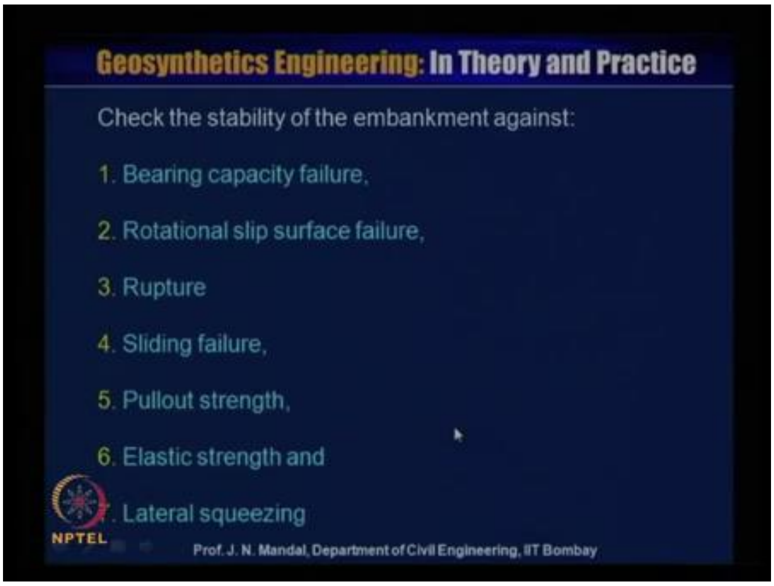
That is gamma of e is 17 kilo Newton per meter cube, phi of e is 30 degree and this is C a is 0 kilo Pascal and for the properties of this foundation with the wrap based you remember this is a wrap based. You have considered wrap base here that gamma f unit weight of the foundation is 16 kilo Newton per meter cube and phi of f is equal to 0 and C of u is equal to 9 kilo Pascal. So, this is the dimensional of the properties is given, so I say the height of the embankment is 3.5 and this B is width of the embankment top width of the embankment is 20 meter and slope also 1 is to 2, so these are the property given.

(Refer Slide Time: 38:34)



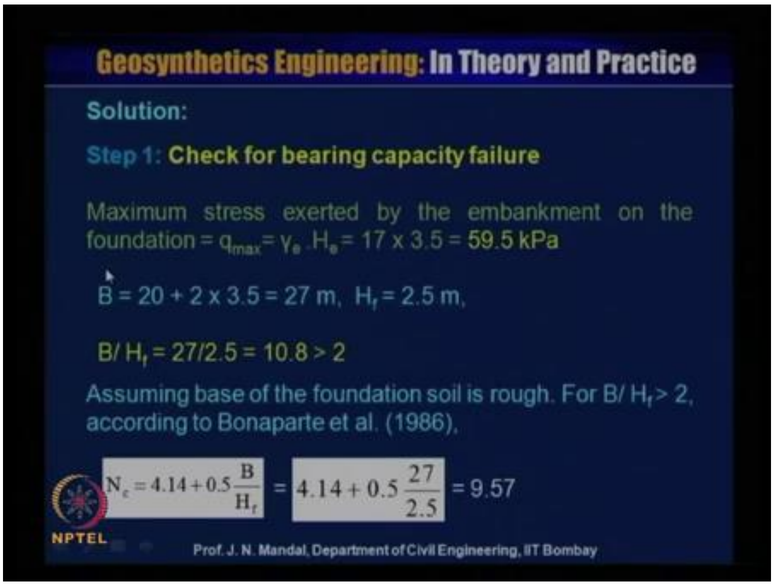
So, this is the properties of the embankment fill, I just told you only here that interaction coefficient between geotextile and a embankment fill C i is equal to 0.7. In case of the properties of the foundation soil that C a should be 40 percentage of C of u. So, whatever value given in the foundation, so C a is to be considered for 40 percent of C u, if it is a 9 of c f then C a will be 40 percent of 9, so we will consider this value.

(Refer Slide Time: 39:15)



Now, for this example will check the stability of the embankment one bearing capacity failure. You have to check all the factor of safety against the bearing capacity failure, two there is a rotational slip surface failure, three rapture, four there is a sliding failure, five pullout strength and six elastic strength and seven is lateral squeezing. So, you have to check all these point for the stability of embankment.

(Refer Slide Time: 39:59)



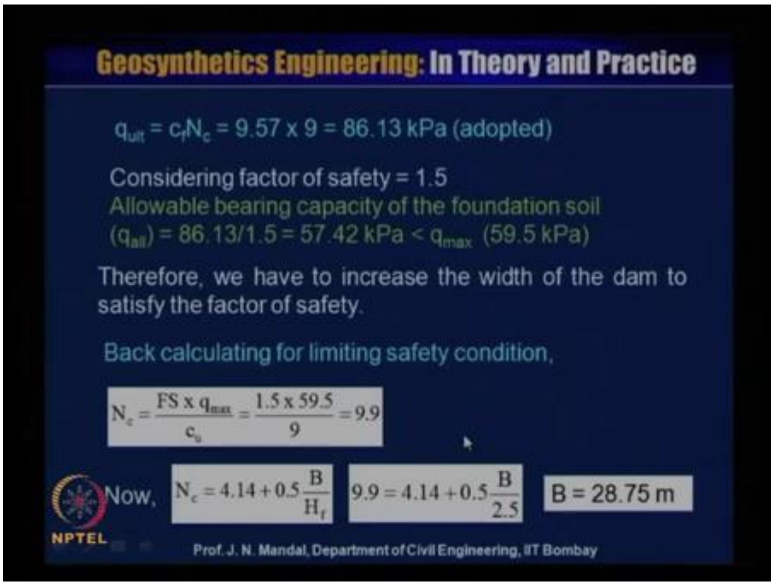
Now, solution step one check the bearing capacity failure. So, you know that maximum stress exerted by the embankment on the foundation that is q maximum will be equal to gamma e into H e gamma e is the unit weight of the embankment. H e is equal to height of the embankment and height of the embankment is given 3.5 and gamma h is 17. So, 17 into 3.5 it will given the maximum stress exerted by the embankment on foundation is 59.5 kilo Pascal.

Now, what is the B, B will be equal to 20 because top width of the embankment is 20 it is like this, this is the top width of the embankment is equal to 20. This slope one vertical to horizontal and this height is 3.5 meter, so this distance will be 2 into 3.5 that means this will be above 7 meter. So, this will be 20 plus 2 into 3.5 is 7 meter, so this B will be equal to 27 meter then B you have to consider at the middle of this slope to this slope. So, this will be the B, so that is why this B will be 20 plus 3.5 and 3.5 that is total 27 meter and this is the height of the foundation depth of the foundation is 2.5 meter.

Now, from this you can calculate what is B by H f, so you know B is equal to 27 meter and H f is equal to 2.5 meter, so this will give 10.8, so this is greater than 2 B by H f greater than 2. Now, assuming the base of the foundation soil is rough, I say that in the problem it is given the base of the foundation soil is rough and earlier we have shown according to Bonaparte et al 1986 that in a table. It is given that for the B by H f, if it is a greater than 2 then you can calculate the N c value using this equation that is N c will be equal to 4.14 plus 0.5 into B by H f.

So, this is 4.14 plus 0.5 into B is 27 this is B is 27, this is 27 divided by H f h f is 2.5. So, this will give N c value 9.57, so if the foundation soil is rough then you can if it is smooth then equation is different as per given in the Bonaparte which we have explained in the earlier. Now, you know what is N c value, that is 9.57.

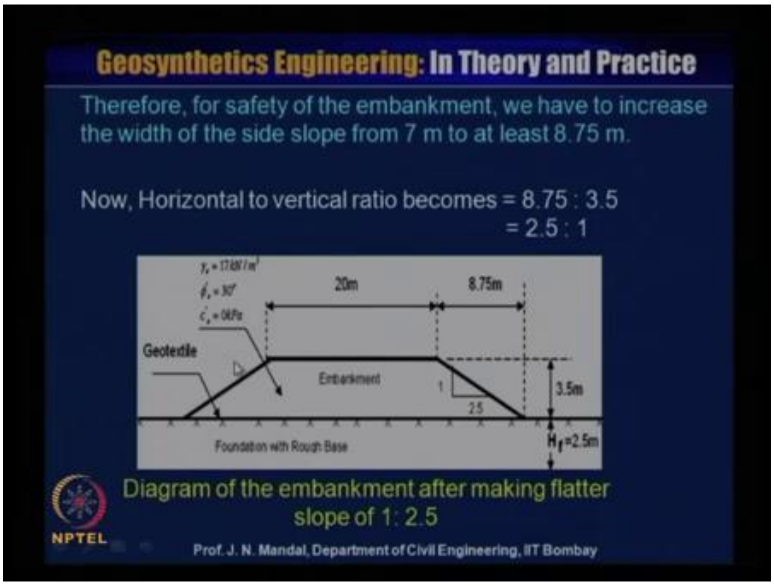
(Refer Slide Time: 43:14)



Now, what will be the q ultimate c f into N c, now you know N c 9.57 into c f you know that is 9 kilo Pascal. So, 9 into 9.57 will give the q ultimate value 86.13 kilo Pascal which is adopted. Now, I am considering the factor of safety is equal to 1.5 allowable bearing capacity of the foundation soil that is q allowable will be equal to 86.13 divided by 1.5 will give 57.42 kilo Pascal which is less than the q of maximum because we have calculated earlier that is q maximum is 59.5, so it is less than q of maximum. Therefore, we have to increase the width of the embankment to satisfy the factor of safety. So, it is required to increase because it is unstable because in case of allowable bearing capacity foundation soil is less than the ultimate value that q of maximum value.

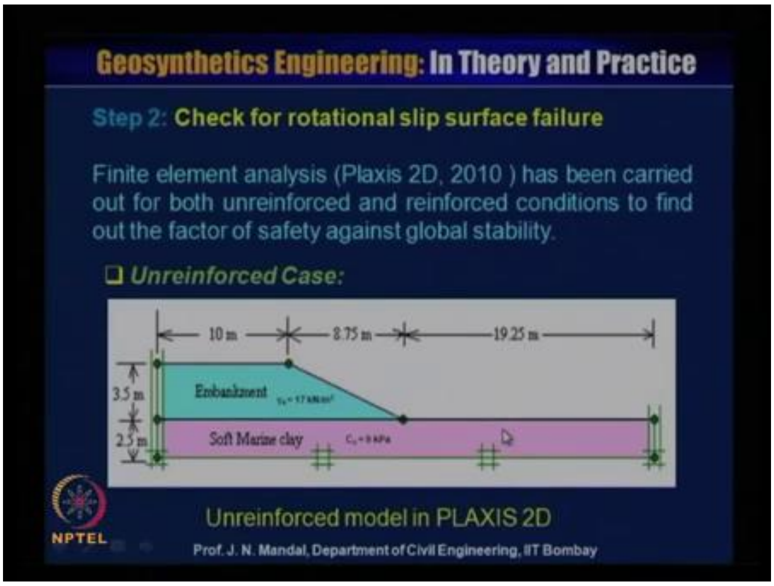
So, we can go for back calculating for limiting safety condition, so you write the equation N c is equal to F S into q maximum by C u and F S is 1.5, q maximum is 59.5 divided by 9 that means your N c value is considered 9.9 what we earlier considered. So, this value has increased 9.9, now N c will be equal to 9.9 is equal to 4.14 plus 0.5 B divided by H f. So, H f is the height of the foundation or depth of the foundation is 2.5 meter, so from this you can calculate the B. So, B will be 28.75, so what you earlier considered that B, now you have to widening the width of the embankment that means you have to increase the width of the embankment to satisfy this factor of safety, so B will be now 28.75.

(Refer Slide Time: 45:52)



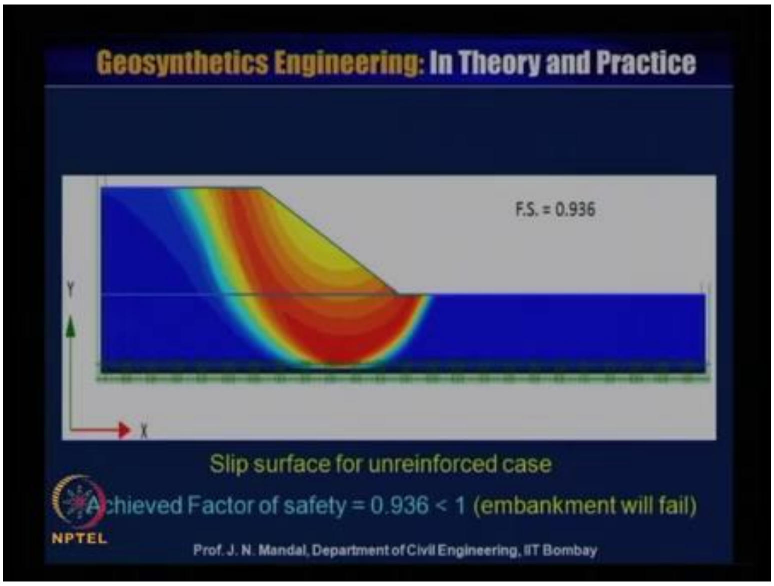
Now, you can see here diagram embankment after making flatter slope you can make a flatter slope this is top width of the embankment is 20 meter, if you make a slope one vertical to 2.5, so this will give you 8.75. So, this B will be ultimately 20 plus 8.75 that means this will be 28.75. Therefore, for safety of the embankment we have to increase the width of the side slope from 7 meter to 8.75 meter, now horizontal to vertical ratio become 8.75 to 3.5 that is 2.5 into 1. So, you have to draw a new diagram of the embankment after making flatter at the slope by 1 horizontal to 2.5 vertical.

(Refer Slide Time: 47:01)



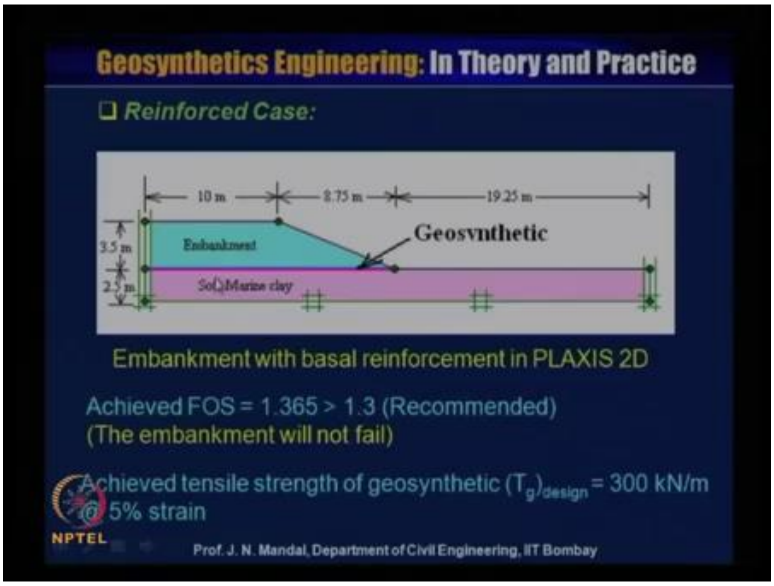
Now, you have to check also then it can satisfy these criteria, now step two check for rational slip surface failure. Now, here the finite element analysis PLAXIS 2 D 2010 has been carried out for both unreinforced and reinforced condition to find out the factor of safety against global stability. So, here is the unreinforced model in PLAXIS 2 D this is soft marine clay and this is the depth of the foundation is 2.5 meter and this is the embankment and whose height is about 3.5 meter. This unit weight of the embankment soil 17 kilo Newton per meter cube and here the undrained shear strength of the soil C u is equal to 9 kilo Pascal and this is axisymmetric. So, this earlier it was 20 then we are making 10 meter and this is 8.75 meter and this we have considering this boundary at a 19.25 meter.

(Refer Slide Time: 48:23)



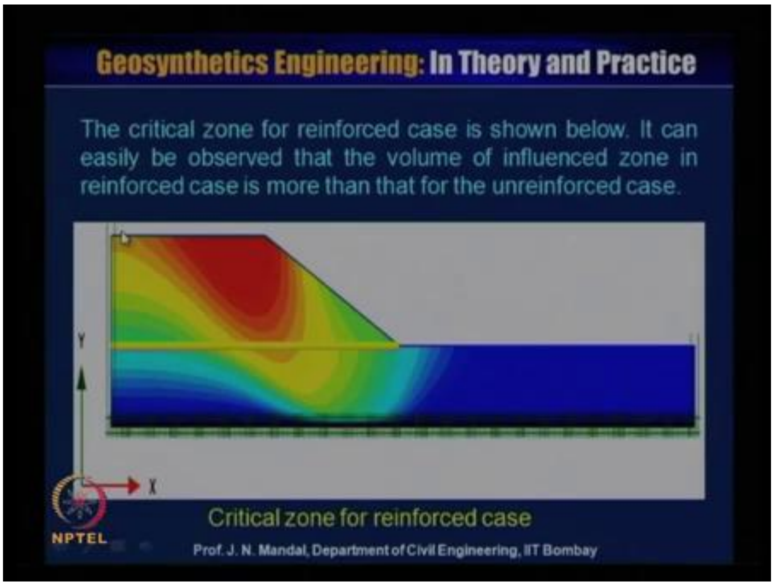
So, this is unreinforced case and then you have solve that what will be the factor of safety. So, this is the slip surface for unreinforced case, so number of the trial and error slip circle has been drawn and then it has been found that achieved factor of safety is 0.936 which is less than 1, so embankment will fail. Therefore, it is required to provide the high modulus of the geotextile or the geogrid material to make the slope stable. Now, here this embankment with the basal reinforcement here you are providing this reinforcement.

(Refer Slide Time: 49:12)



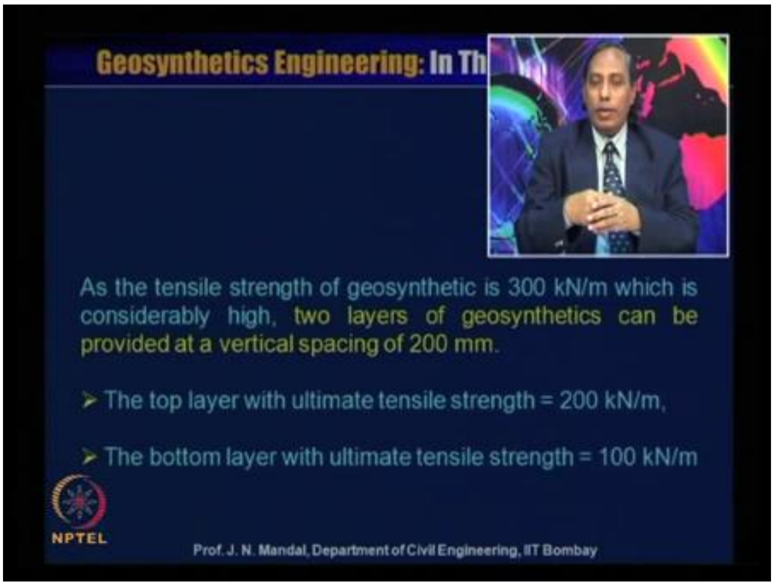
So, this is the reinforced case and only we have deployed a layer of the basal reinforcement in between the embankment and the foundation soil which is soft marine clay. Now, you can check and using the PLAXIS 2 D and then you have achieved the factor of safety is 1.365 which is greater than 1.3 that is recommended, so embankment will not fail. Now, you have to achieve that, what will be the tensile strength of the geosynthetic that is T g design, let us say that is 300 kilo Newton per meter at 5 percent strain. So, you are selecting a geosynthetics material whose tensile strength value is 300 kilo Newton per meter at 5 percent strain.

(Refer Slide Time: 50:35)



Now, this is the critical zone for the reinforced case the critical zone for reinforced case is shown here, it can easily be observed that the volume of the influenced zone in the reinforced case is more than that for the unreinforced case. So, that is the reason that it can sustain the load, so it can accept the load more load than the unreinforced case.

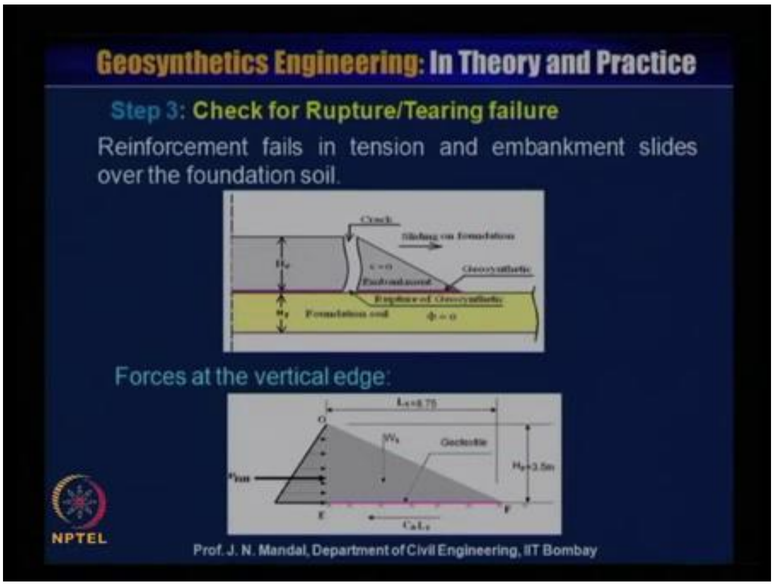
(Refer Slide Time: 51:19)



As the tensile strength of the geosynthetics material is 300 kilo Newton per meter which is considerably high in some cases. If we find that one layer of the geosynthetic material very high strength value, sometimes these value comes also 400 kilo Newton per meter 500 kilo Newton per meter 700, 900 kilo Newton per meter. In such case it is advisable that you can provide two layers of the geosynthetics can be provided at a vertical spacing of 200 millimeter here. It has been provided two layers and top layer with the ultimate tensile strength is 200 kilo Newton per meter and bottom layer with the ultimate tensile strength of 100 kilo Newton per meter.

But here it has been observed that you see we are providing the very high strength geosynthetics material at the top, and the lower and the minimum strength of the geosynthetics material. At the bottom this is very typical situation when you apply the load and you can see the most of the time, you have a feeling that the tensile strength will be taken care by the lower one first then the top. But it has been observed that if you can provide the high strength of the geosynthetics on the top layer, and the low strength of the geosynthetics material at the bottom layer is preferable.

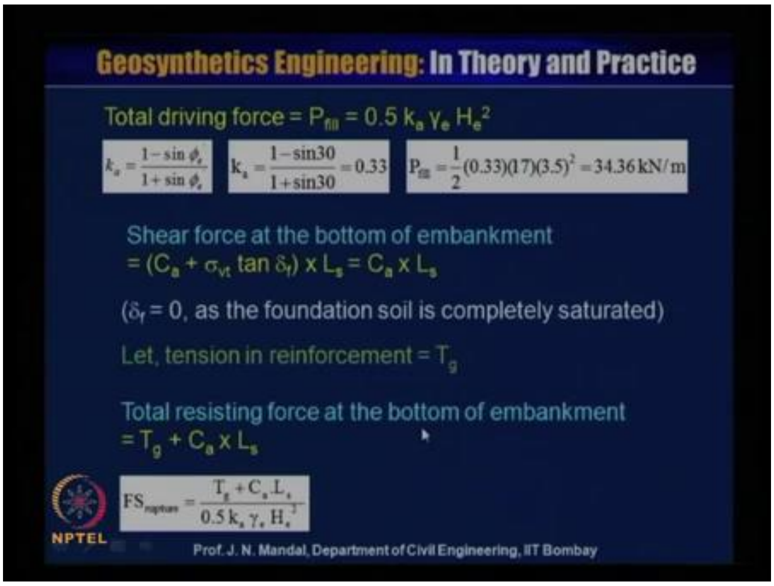
(Refer Slide Time: 53:03)



Step three check for rupture or the tearing failure. So, there two cases we have also discussed, one is that embankment slide over the foundation soil that means there is a rupture of the reinforcement. The other case that embankment slide over the reinforcement after the formation of the crack in the embankment, so you have to check both the cases. So, here one of the case that check for the rupture and the tearing failure, so reinforcement fail in tension and embankment slide over this foundation soil reinforcement fail here is the reinforcement. This reinforcement fail, you can see here is a permission of the crack when the embankment sliding on the foundation, so reinforcement failed in tension and embankment slide over this foundation.

So, there is a rupture of the geosynthetics material and here you can see that what are the forces at this vertical edge. So, from here you can see here is the P fill which is acting this is the o e and this is the f and this is the w of s this is the geosynthetics material this is the height of the embankment 3.5 meter. Due to these forces there will be the resisting force here which is acting C a into l of s this is the adhesion and L s is this part this length this is slope length L s is equal to 8.75. So, we have to check up for the rupture or the tearing failure of the geosynthetics material.

(Refer Slide Time: 56:01)

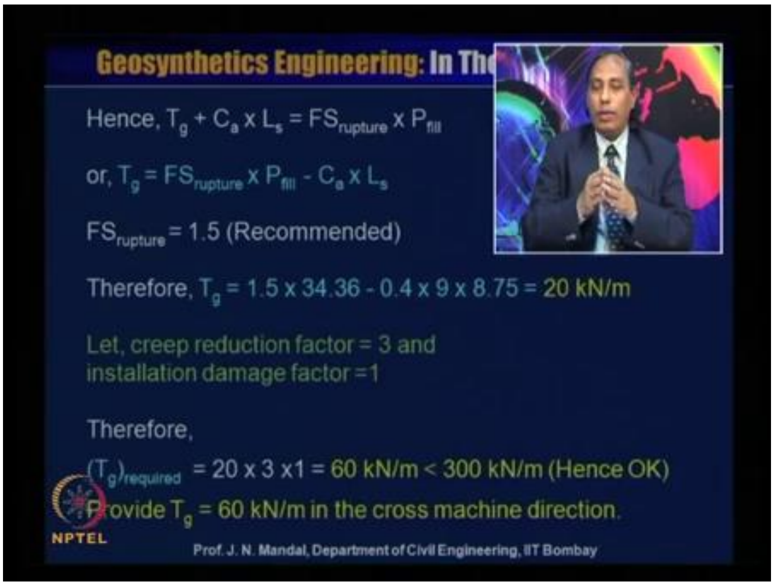


Now, you have to calculate what will be the total driving force that means this is the P fill here, so that will be half into K a into gamma e into H e square you know K a is equal to 1 plus sin phi e divided by 1 plus sin phi e, so phi e is equal to 30 degree. So, K a is equal to 1 minus 30 by 1 plus sin 30 is 0.33, so P fill will be half into K a is 0.33 into gamma e you know 17 unit weight of the embankment height of the embankment 3.53, 0.5 square so P fill is equal to 34.36 kilo Newton per meter.

Now, shear force at the bottom of the embankment here the shear force at the bottom of the embankment that is C a plus sigma v t tan delta f into L s, basically this is sigma v into tan delta f here because the tan delta f because that foundation soil is completely saturated here. The foundation soil is completely saturated, if it is completely saturated there is no phi, phi is equal to 0, so delta f will be equal to the 0, so this part will be the 0. So, only the C a into L s because this is the C a is acting and this is the length L s, so C a into L s, so shearing force at the bottom of the embankment is C a into L s.

Now, let the tension in the reinforcement is T g here is the tension in the reinforcement this is the reinforcement tension is T g. So, total resisting force at the bottom of embankment will be equal to T g plus C a into L s then you have to check the what will be the factor of safety against rupture that is T g plus C a into L s this divided by this that means point 5 K a gamma e into H e square.

(Refer Slide Time: 58:22)



Hence, you can write T g plus C a into L s is equal to factor of safety against rupture into P fill. So, T g will be equal to F S rupture into P fill minus C a into L s, so we considered that F S rupture is 1.5 is recommended. Therefore, T g will be equal to 1.5 into P fill is 34.36 minus C a is 40 percent of the C a we should consider that is 0.4 into 9 that is the C a is 9 into L s is 8.75, so this will give 20 kilo Newton per meter.

Now, let creep reduction factor is equal to 3 installation damage factor is equal to 1. Therefore, T g required will be 20 into 3 into 1 that is 60 kilo Newton per meter which is less than 300 kilo Newton per meter. Hence, it is so provide T g is 60 kilo Newton per meter in the cross machine direction, so you require the tensile strength of the basal reinforcement of 60 kilo Newton per meter in the cross machine direction.

So, you know that partly that how you can design this embankment and how you can design then if it is a reinforcement fail and how you can determine the factor of safety. Also you should know that what should be the tensile strength of the basal reinforcement and what strain you should consider depending upon the type of the soil, whether it is a cohesive soil whether it is a cohesion less soil or whether it is a peat. So, with this I finish my lecture today, let us hear from you any questions.

Thanks for listening.