Foundation Engineering
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Module – 01
Lecture - 02
Shallow Foundation

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So, friends, in the last lecture I discussed about basic principles of shallow foundation, what are different types of shallow foundations? And how the failure of the soil mass take place? Whether it is the general shear failure case or may be the local shear failure case or punching shear failure case. I have also discussed about the Terzaghis bearing capacity theory. Now, which is based on strip footing, which is resting on this soil mass of infinite extent and, that is taken as the case of a plane strain problem.

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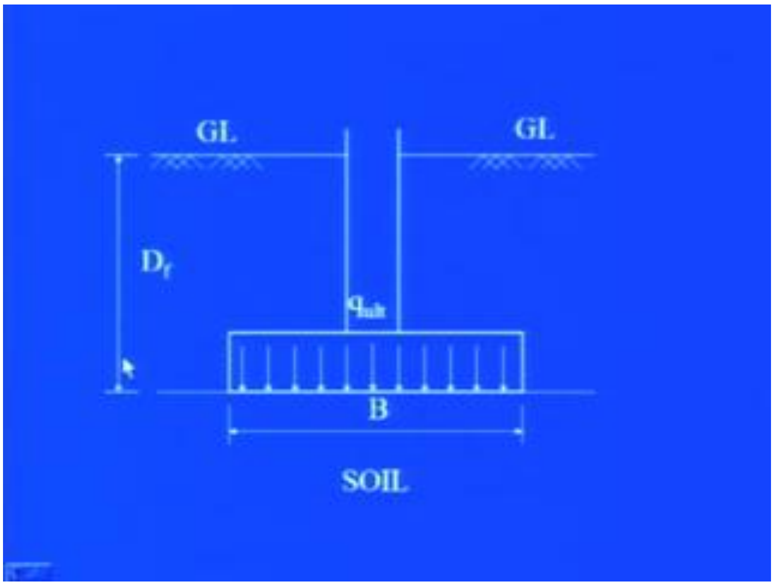

Now, if you see this figure, now in this figure, you can see that there is a column and foundation. This foundation transmits load on the soil underneath it. This foundation is placed at a depth D f below the ground surface and the width of the foundation is B.

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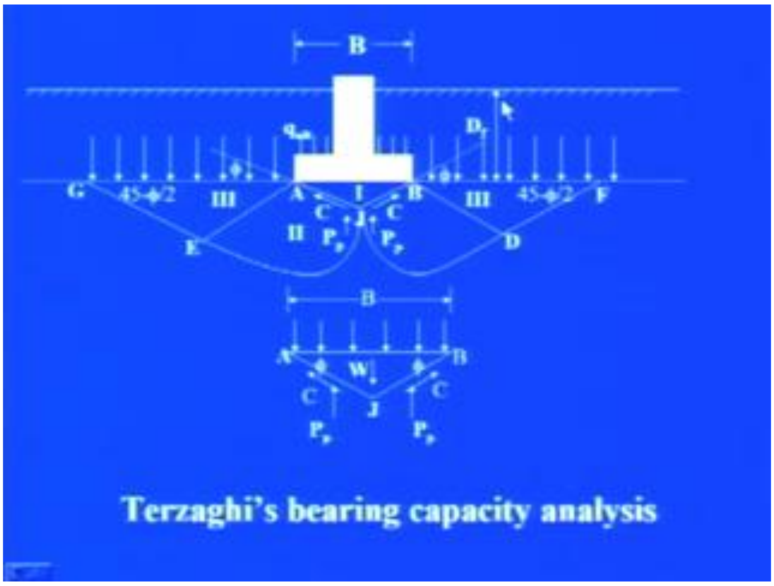

Now, when the loads are transmitted through this foundation, on to the soil and as the base of this foundation is rough, there is an active wedge, which is formed below the foundation. And the angle which it makes with the horizontal is 5, in the Terzaghi's theory. And they when this foundation is the becomes the part of this particular foundation. And this when this wedge posses the soil mass you will find that the shearing stress are developed in the soil. And the movement of this is resisted by the soil mass underneath it. Now you can see here there are 2 zones numbered as 2 and 3 this is the zone of radial shear. And this is the third zone which is giving the passive resistance.

Now, the free body diagram of this particular wedge is shown in the next figure, like ABJ. In which B is the width and the load which is applied that is actually the net ultimate bearing capacity of the foundation. The forces to which it is subjected on the AJ and BJ sides these are the resistance which are offered due to the cohesion, and the these sides at as the rough retaining walls, and the forces which are acting as it is pushing. So, the forces are the passive resistance offered by this. You can also very well see that these this shearing surfaces, do not go behind the horizontal surface at the base of the level. And it means it is the shearing resistance is not consider of the soil which is in this depth a D f. And its effect is only taken into account. I considering ((refer time: 3:35)) which is equivalent to gamma D f.

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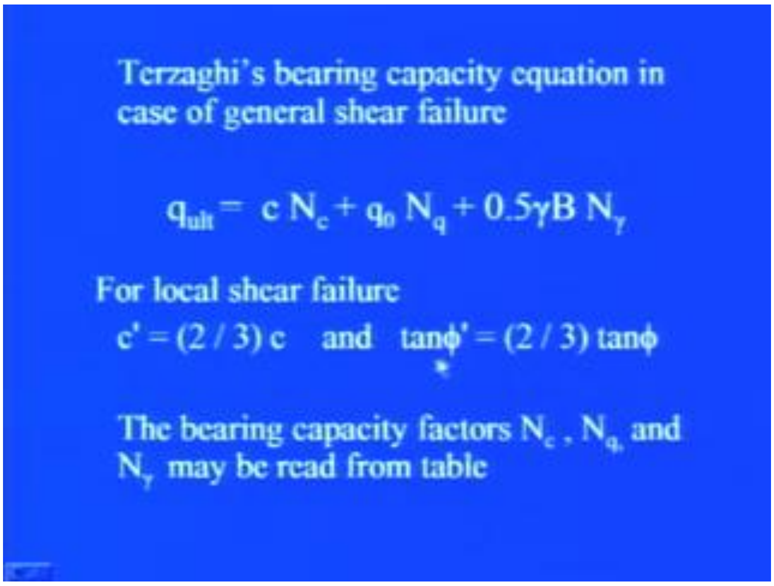

So, this is the Terzaghi's bearing analysis and on the basis of this, while considering the static equilibrium of the wedge. We I have found that the bearing capacity equation in the general shear failure case, will be given by q ultimate equal to c N c plus q 0 N q plus 0.5 gamma BN gamma here c is the cohesion. And q 0 q 0 is the over burden on at the foundation level that is determined as gamma into D f where gamma is the unit weight of the soil gamma B is the width of the foundation. And factors N c N q and N gamma are known as bearing capacity factors. The and the expression for these we have seen in the last lecture.

Now, in the case of local shear case, the when the failure is in local shear then there are some modifications made like c is replaced by two- third of c. And in order to determine bearing capacity factors N c and N q N gamma which are based on the angle of shearing resistance of the soil. Then that angle of shearing resistance is determined by phi dash. When this phi dash may be determined as tan phi dash equal to two- third of tan phi. It means that phi dash is the shearing resistance for the local shear failure case. And all these bearing capacity factors can be read from the table correlations are also available but for read use we can use these tables.

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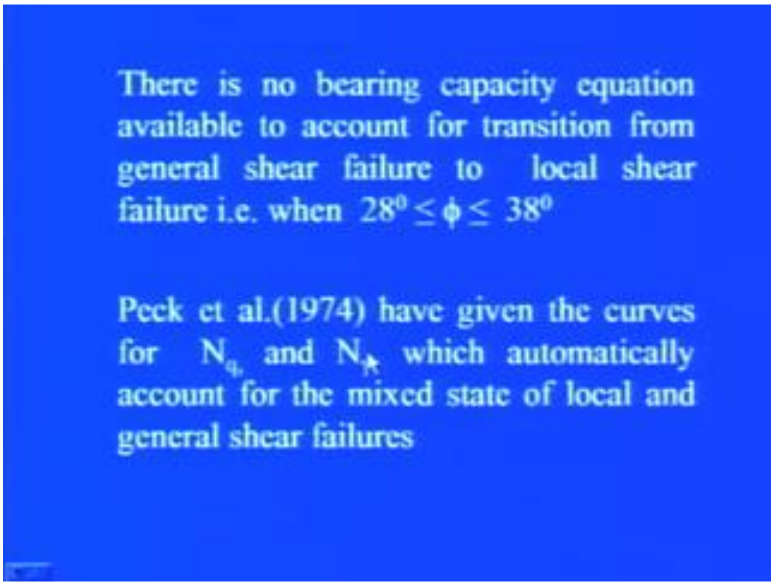

Now, you will find that there is no bearing capacity equation available to account for the transition from the general case and from the local shear failure case. We know that the general shear failure case will take place when the phi value is greater than 38 degrees. Whereas for the local shear failure case, that phi is less than 28 degrees, but between 28 and 38 degrees there is no bearing capacity equation. So, in order to take into account this transition Peek et al in 1974, have given the curves for N q N gamma N gamma which automatically account for the mixed state of local and general shear failure.

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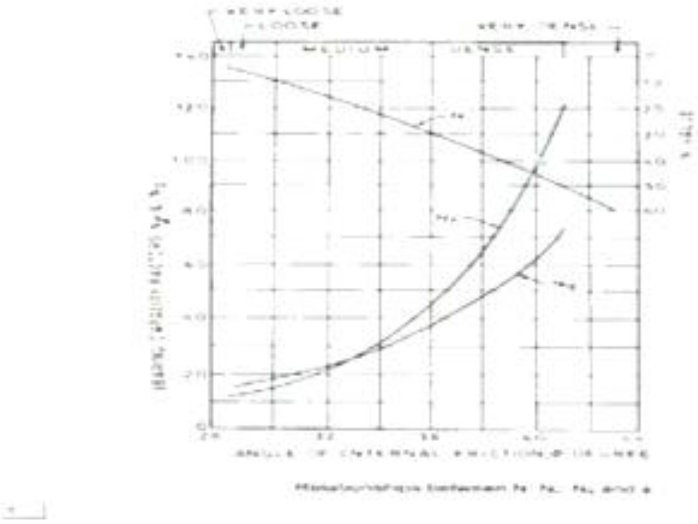

And they have given chart like this, in which these factors N gamma and N q are dependent on angle of internal friction. These are the bearing capacity factors. You will find here that if the soil is loose to very loose there may be possibility of the local shear failure case.

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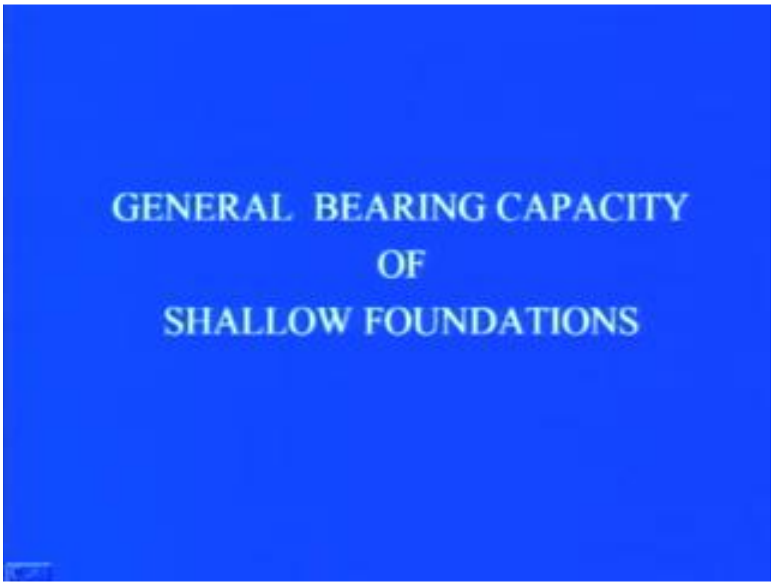

So, this particular chart accounts for all the cases general shear failure, local shear failure, and then the transition. So, this is what we are discuss in the last lecture, now I am going to a extend it for the general bearing capacity of shallow foundation.

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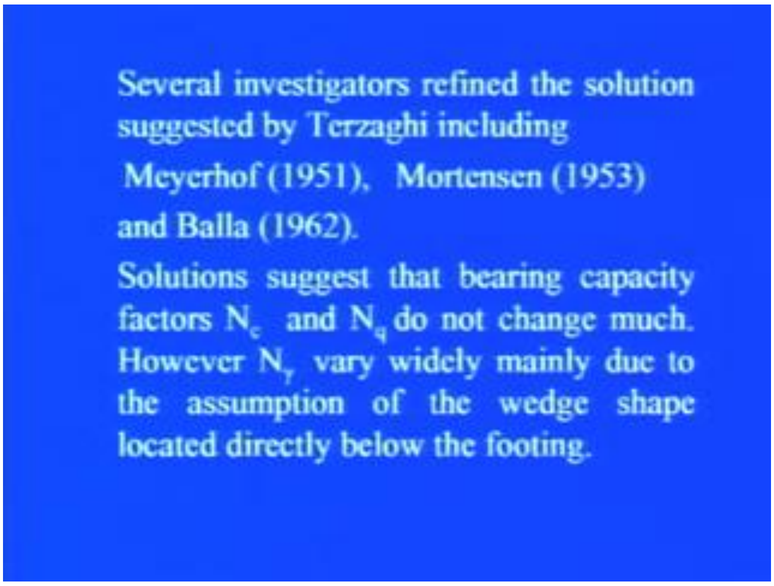

Now, several investigators refined the solution suggested by Terzaghi including Meyerhof in 1951, Mortensen in 1953 and Balla in 1962. Now, all the solutions suggest that the bearing capacity factors N c and N q do not change much. However, N gamma vary widely mainly due to the assumption of the wedge shape located directly below the footing. It means that is the elastic wedge which is formed below the foundation. Now, model test had been have shown that the sides of the wedge ABJ which makes angle of 45 plus 5 by 2 instead of 5 as suggested by Terzaghi. Now, this type of failure mechanism is shown in the next figure.

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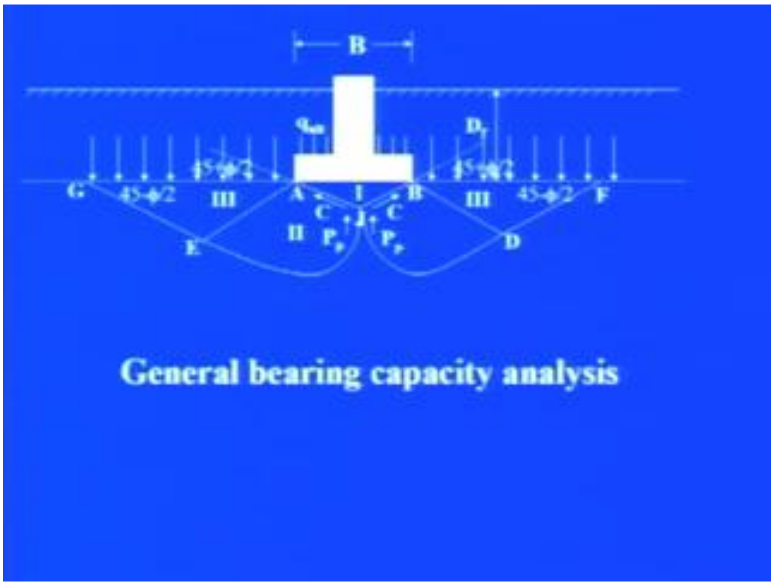

Now, here you can see again, as for as the failure zones are concerned or the wedges are concerned. They are similar to what we have seen in the case of Terzaghi 1 2 3 only difference is that the inclination. which this particular sides of the elastic wedge. We are making that was 5 in the case of Terzaghi and now it is 45 plus 5 by 2 in the case of other theories proposed. Now, these are this particular observation has been obtained on the basis of model studies carried out by those researchers. The equation is in the same general form as that given by Terzaghi. However, the bearing capacity factors are not the same, because the because of this inclination of the wedge. However, Terzaghi bearing capacity equation yield good results for all practical purposes that is why you will find that the Terzaghi bearing capacity factors is preferred.

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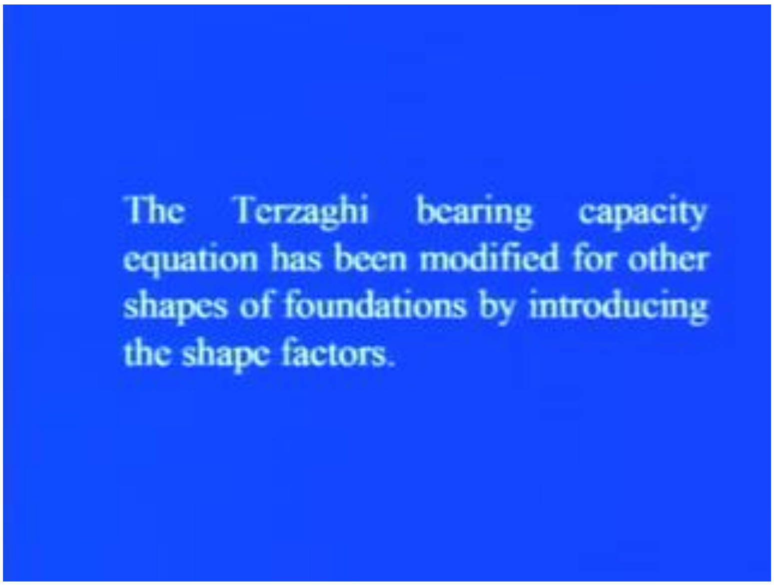

The Terzaghi bearing capacity equation has been developed for a strip footing of size B which is resting at a depth gamma D f. Now, this, these particular correlations or the equation can be extended in the case of square foundations.

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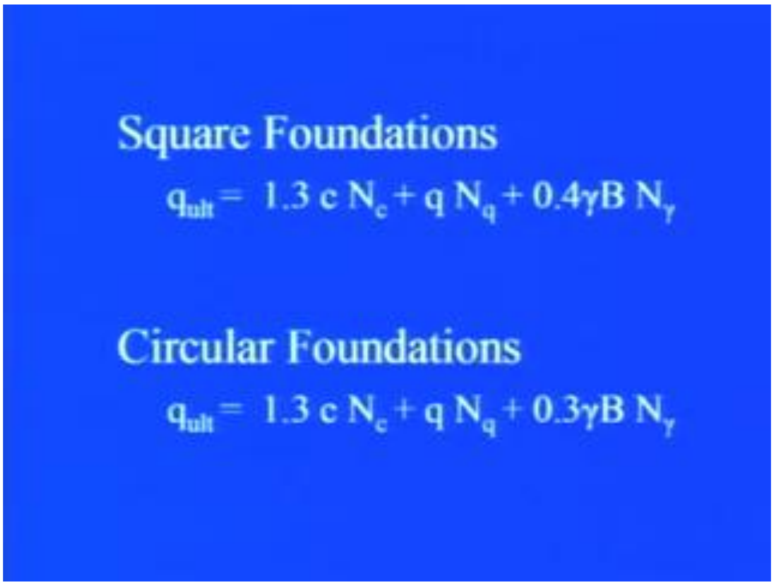

In the case of circular foundations, in the form like in the case of square foundations this q ultimate is 1.3 c N c plus q N q plus 0.4 gamma BN gamma. You can see form here that that c is replaced by 1.3 c and 0.5 is replaced by 0.4. Similarly, the case for circular foundations in which this is 1.3 c N c plus q N q plus 0.3 gamma BN gamma.

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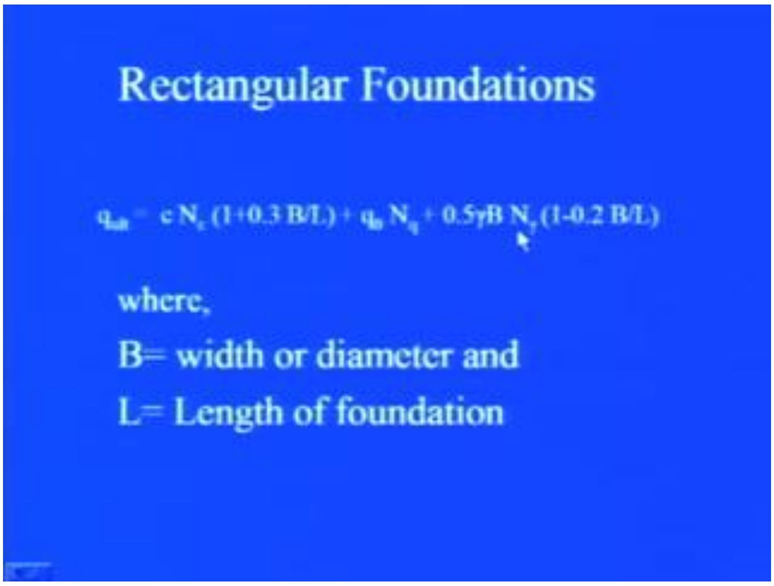

Now, in the case of rectangular foundations, the safe factors can be determined by these this particular equation in. And the safe factors are included here like this, q ultimate bearing capacity is given by c N c plus 1.3 B by L where B is the width of the foundation or the diameter of the foundation. L is the length of the foundation and other factors remaining as it is. So, for the rectangular foundations this ultimate bearing capacity will be given by c N c 1 plus 0.3 B upon L plus q 0 N q plus 0.5 gamma BN gamma 1 minus 0.2 B upon L.

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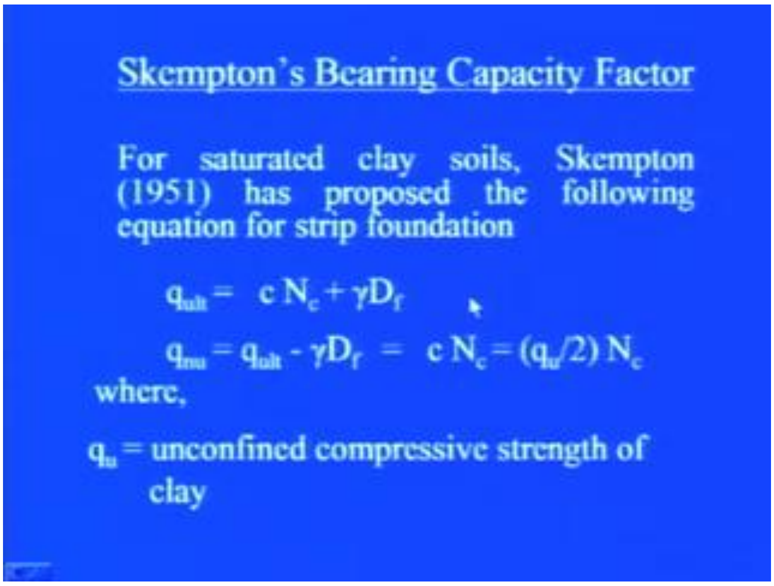

Now, the specially for the case of saturated clay, Skempton has given bearing capacity factors in 1951. And he has proposed that the following equation holds good for the bearing capacity of a strip foundation resting on saturated clays. Now, in the case of clays as phi is 0. So, other parameters, when is and we are left with equation q ultimate equal to c N c plus gamma D N f gamma D f. And by definition net ultimate bearing capacity is equal to ultimate bearing capacity minus over burden gamma D f. So, net ultimate bearing capacity will become equal to c into N c. Now, this cohesion is actually the undrained cohesion. This undrained cohesion can be determine by conducting unconsolidated undrained test in laboratory in ((refer time: 11.23)).Or may be conducted may be obtained directly by the unconfined compression test which is conducted on the clay sample obtained from the field. And cohesion is equal to this unconfined compressive strength divided by 2 where, if we assume that the factor of safety is equal to 3.

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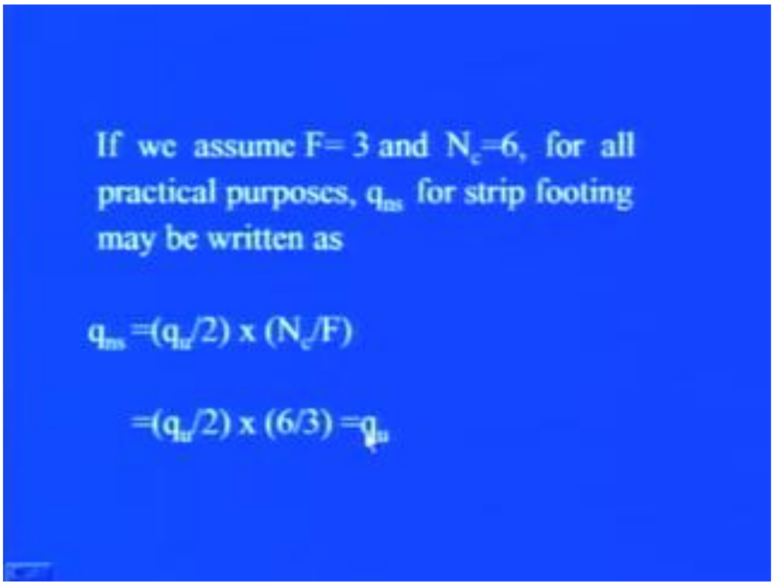

Because most of the time we considers factor of safety from 2.5 to 3, and suppose we consider factor of safety equal to 3 and N c is equal to 6. Because you will find that in most of the tables that factor of safety is around 65.14 to 5.7 different researchers have given different value. So, if factor of safety equal to 3 and N c equal to 6 for all practical purposes the net safe bearing capacity for strip footing may be written as q n s equal to q u by 2 into N c upon F. Now, here this q by 2 into 6 by F if this substitute these values here, then we will get this net safe bearing capacity almost equal to the unconfined compressive strength of the clay. So, if clay the foundations resting on clay will have at least the unconfined compressive strength as the bearing capacity net safe bearing capacity of the foundation strip foundation.

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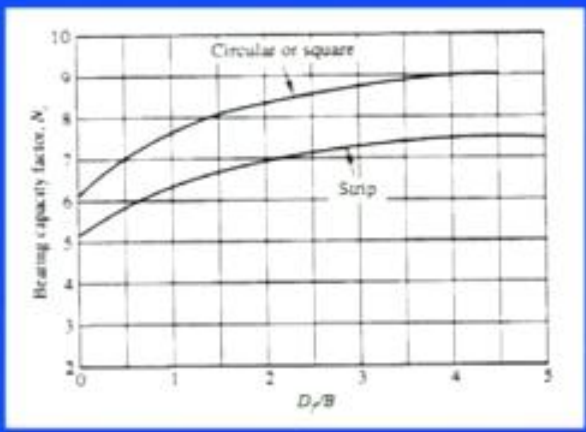

Skempton's bearing capacity factor N_c for clay soils

Now, this factor N c has been found to vary with the shape of the foundation as well as the depth at which it is place. So, here there is a chart which is shown by shown by ((refer time: 13.16)) this Skempton's bearing capacity factors are for clay soils.

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The lower and upper limiting values of N_c for strip and square foundations may be may be written as follows:

Type of Foundation	Ratio of D_f/B	Value of N_c
Strip	0	5.14
	≥ 4	7.5
Square	0	6.2
	≥ 4	9.0

Now, in the case of you can see from these this plot that the lower and upper limiting values of the N c for strip. And square foundations may be written as follows, like for the different type of foundation and for different ratio of D f by B. For the strip footing it can be 0 for 0 it will be 5.14, if it is greater than or equal to 4 it is 7.5. For square footing it is 0 if D f by B is 0 then it is 6.2 and if it is greater than or equal to four it can be taken as 9.

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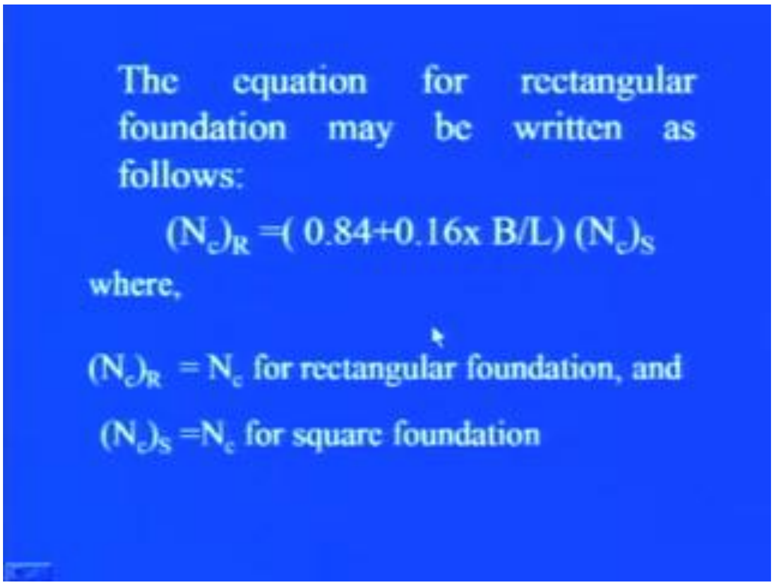

The equation for rectangular foundation for obtaining the value of N c may be written as this N c R, R is representing the safe of the foundation. That is equal to 0.84 plus 0.16 B upon L, where B is the width of the foundation, L is the length of the foundation. And N c S is the N c value for the strip footing. Now, this N c value of the strip footing may be obtained by the previous graph or the table. So, here this N c R is N c for the rectangular foundation and N c S is N c for the, I am sorry this is for the square foundation.

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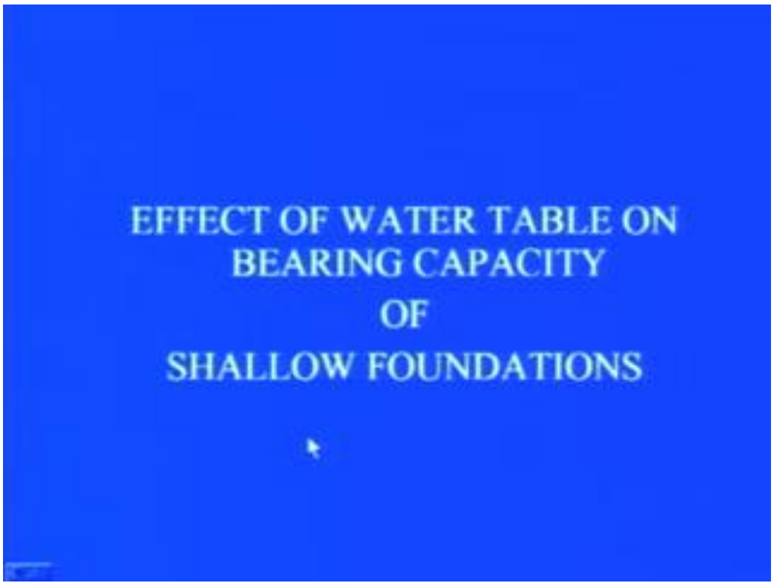

Now, all these correlations are valid when the soil is dry. Now, we know that there are lot of fluctuations in the water table and various seasons. So, the effect of water table on bearing capacity of foundations will have to be taken into account. The theoretical equations developed for computing bearing capacity of soil are based on the assumption that the water table lies at a depth of foundation equal to or greater than the width of the footing. Now, suppose the water table lies at any intermediate depth which is less than D f plus B the bearing capacity gets affected due to the presence of water table. We know that due to the presence of water table, or fluctuations in the water table. There is decrease or increase in stresses the effective stresses are increases increased or decreased and then and hence the bearing capacity also increases or decreases.

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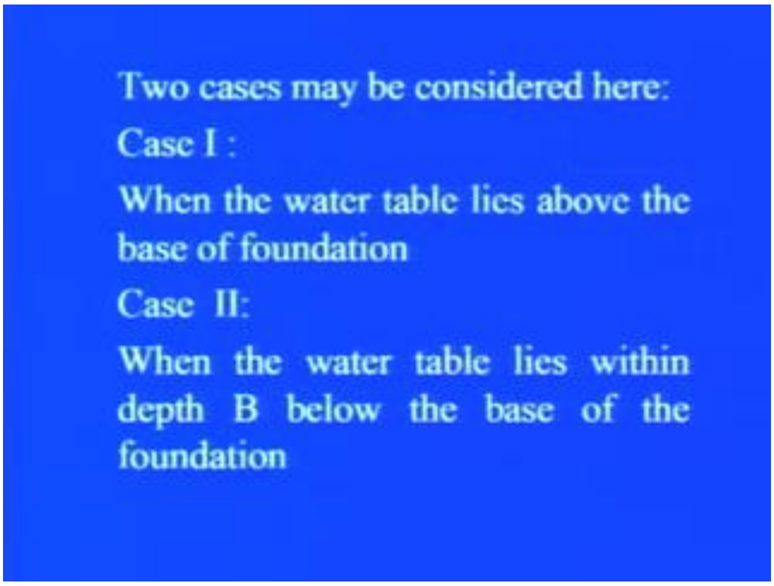

Now, here we can consider 2 cases. In case 1 when the water table lies above the base of the foundation, means it is between 0 from the ground surface 0 to depth of the foundation. And in the case 2 when the water table lies within the depth B below the base of the foundation now, these 2 cases can be considered and solved by using 2 different methods.

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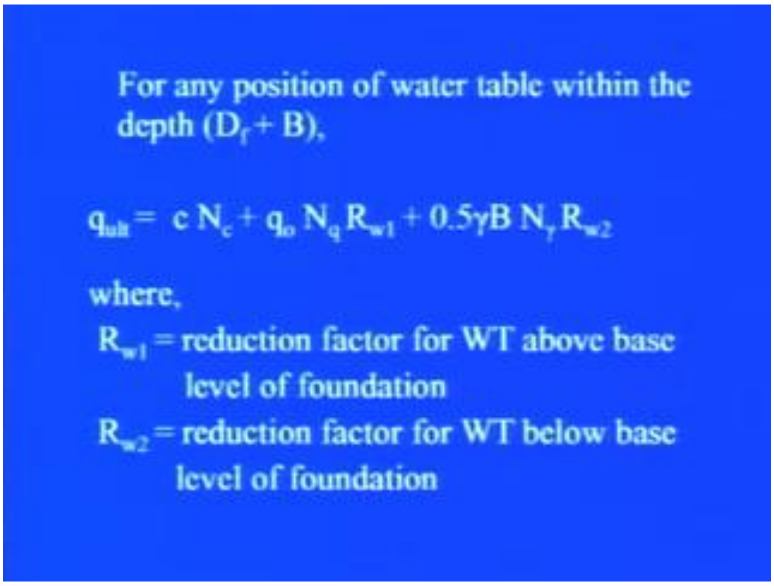

In the first method for any position of the water table within the depth D f plus B, this q ultimate will be given by c N c plus q 0 N q R w 1 plus 0.5 gamma BN gamma R w 2. Now, the factors R w 1 and R w 2 are known as the reduction factors for water table 1 is the reduction of factor for water table above base level of foundation. R w 2 is the reduction factor of for water table below base level of the foundation.

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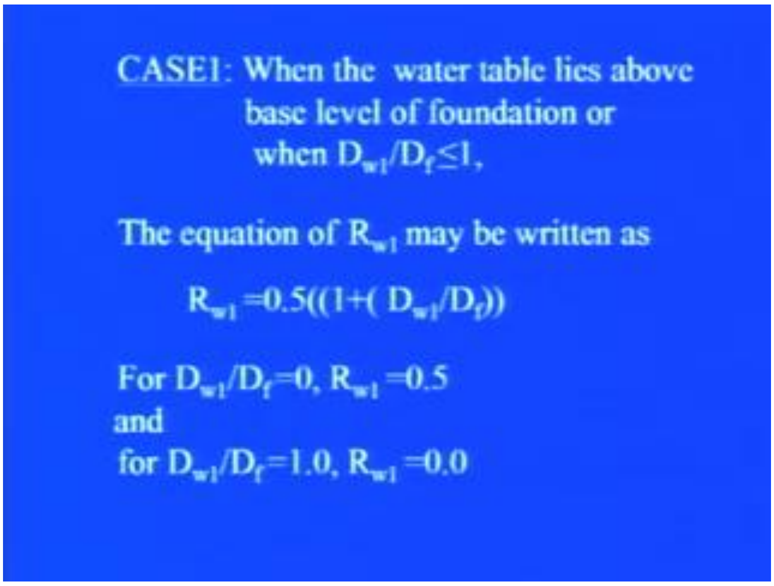

Now, in the case 1, when the water table lies above base level of foundation, or when the depth of the water table divided by depth of foundation is less than or equal to 1.The equation for R w 1 may be written as R w 1 equal to 0.5 in bracket 1 plus D w 1 upon D f. And from this equation we can find out that if this ratio is 0, D w 1 upon D f then R w 1 equal to 0.5. But if the ratio is equal to 1, means the depth of the water table which is above the foundation level is at the level of the foundation itself then it becomes equal to 1. If this ratio become 1 and hence R w 1 becomes equal to 0 now, this can be made clear by this particular figure.

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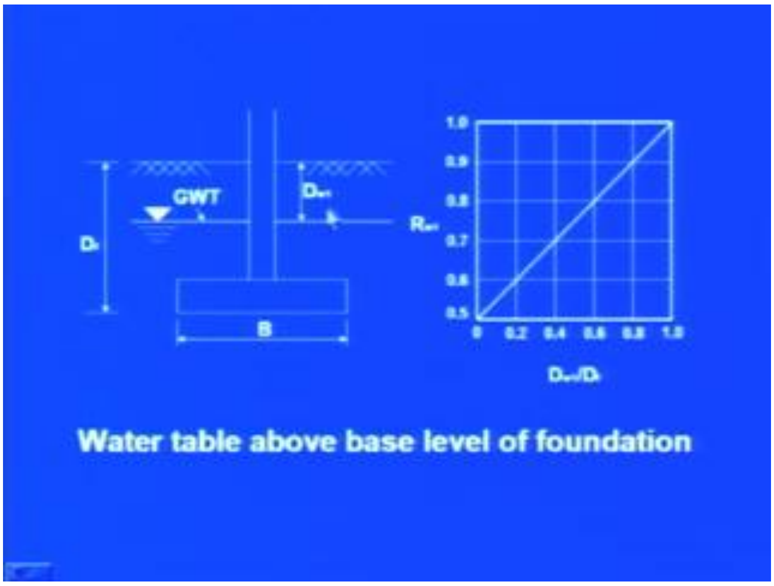

Now, here we are considering the case when the ground water table is above the base of the foundation. And D w 1 is the depth of the water table below the ground surface. D f is the depth of the foundation. Now, based on those 2 equations we can develop our relationship between R w 1 and D f, D w 1 upon D f.

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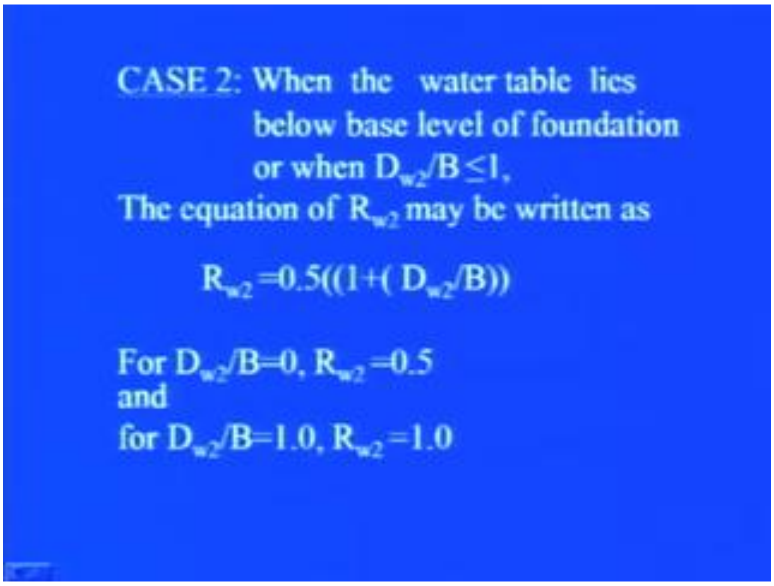

And similarly, for the other case, when the water table is below the level of the foundation or when D w 2 by B is less than or equal to 1. Now, similar to the previous equation this equation for R w 2 may be written as 0.5 1 plus D w 2 by B where, D w 2 by B is 0. Then R w 2 will be equal to 0.5 and for the case when D w 2 by B is equal to 1, R w 2 will be equal to 1.

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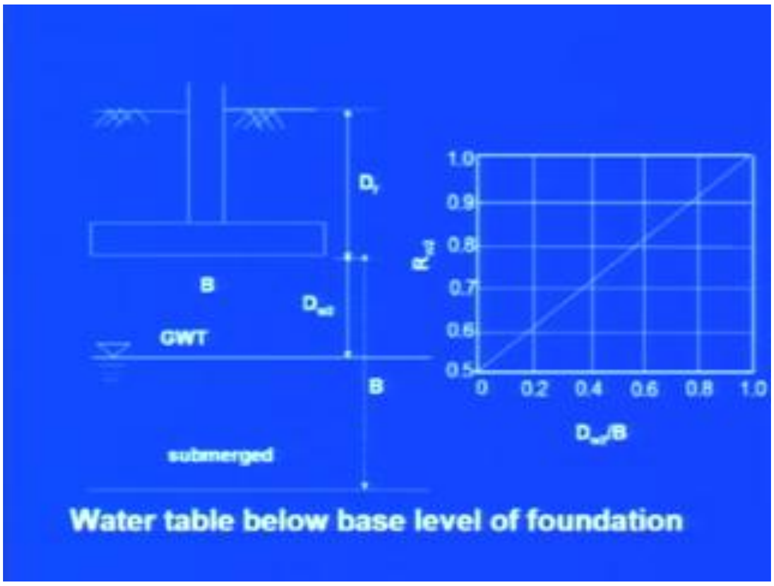

Now, again this can be made clear by this particular figure, you can see that this ground water table is below the base of the foundation. But it is lying between these 2 depth where this is the B and the depth of the foundation additional depth of the foundation which is considered as B. Now, from the previous equation or relationship between R w 2 and D w 2 by B can be developed and that that relationship is nothing, but a straight line. So, this particular graph can also be use to find out the R w 2 for intermediate values of D w 2 by B.

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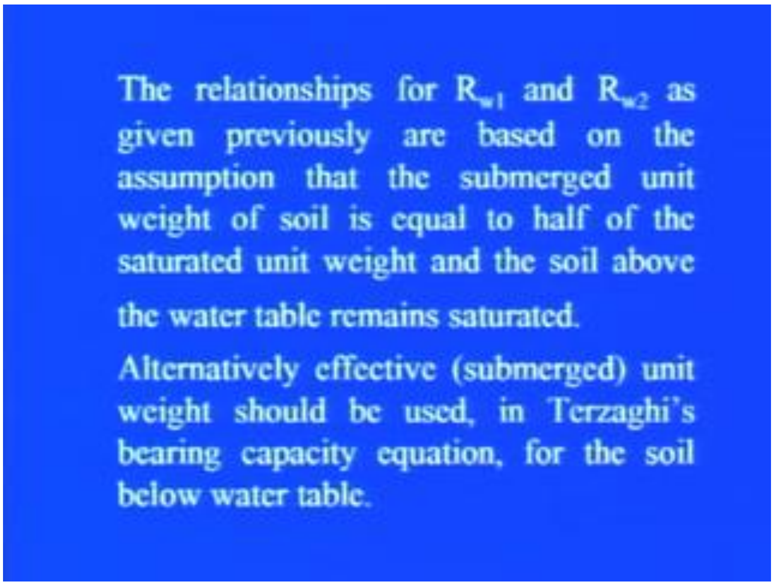

The relationships for R w 1 and R w 2 as given previously, are based on the assumption. That the submerged unit weight of the soil is equal to half of the saturated unit weight and the soil above the water table remains saturated. Alternatively effective that is submerged unit weight should be used in the Terzaghi's bearing capacity equation for the soil below water table. Now, I will explain method 2, now this method is takes into account the equivalent effective unit weight.

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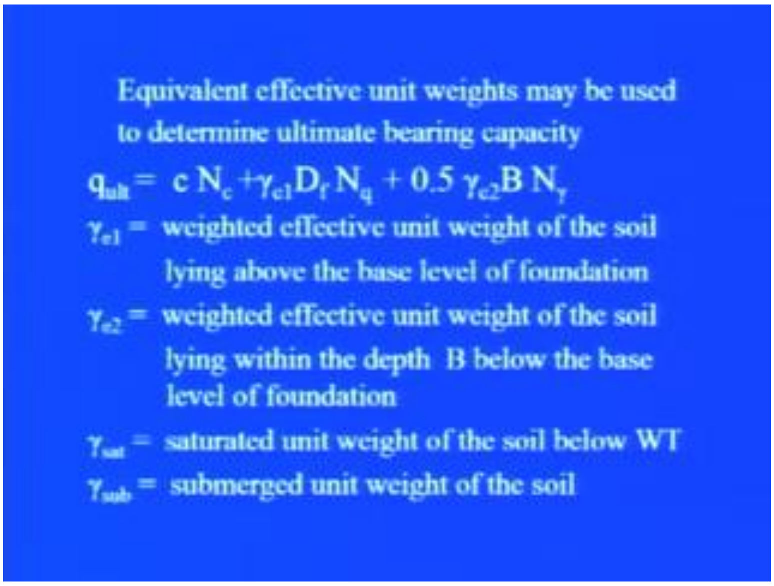

And these may be use to determine ultimate bearing capacity like what we will do we will replace unit weight of soil which is above the foundation level. And the unit weight of the soil up to depth B below the foundation level by gamma e 1 and gamma e 2 where, gamma e 1 is the weighted effective unit weight of soil lying above the base level of foundation. And gamma e 2 is the weighted effective weight of the soil lying within the depth B below the base level of the foundation. Gamma saturated is the saturated unit by depth the soil below the water table and gamma submerged is the submerged unit weight of the soil.

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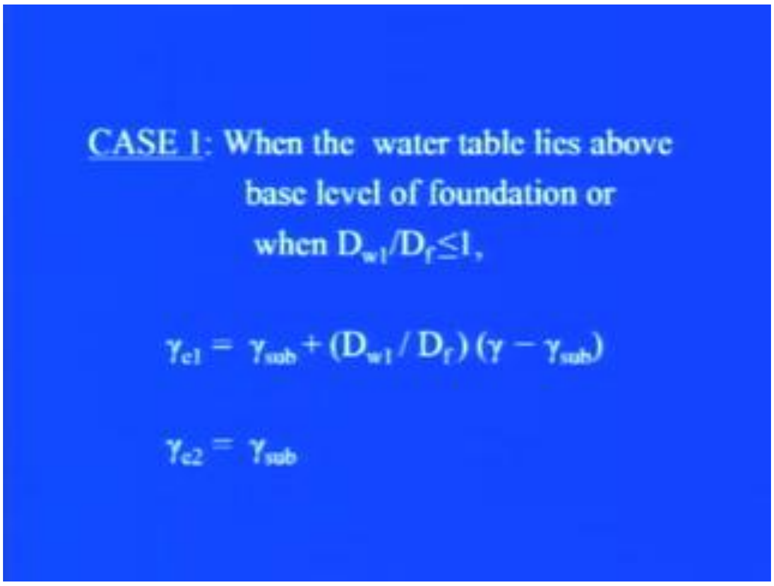

Now, case 1; when the water table lies above the base level of foundation or when D w 1 upon D f is smaller than or equal to 1 then this gamma e 1 can be written as gamma submerged plus D w 1 upon D f in bracket gamma minus gamma submerged. Whereas, gamma e 2 will remain gamma submerged. Now, in the case 2 when the water table lies below base level of the foundation.

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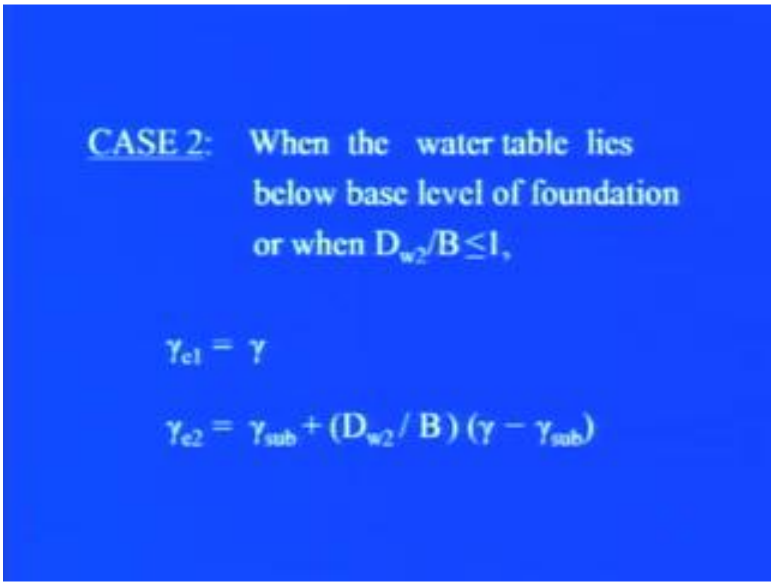

Or when D w 2 by B is less than or equal to 1, then gamma e 1 will be equal to gamma and gamma e 2 will be equal to gamma submerged plus D w 2 by B gamma minus gamma submerged.

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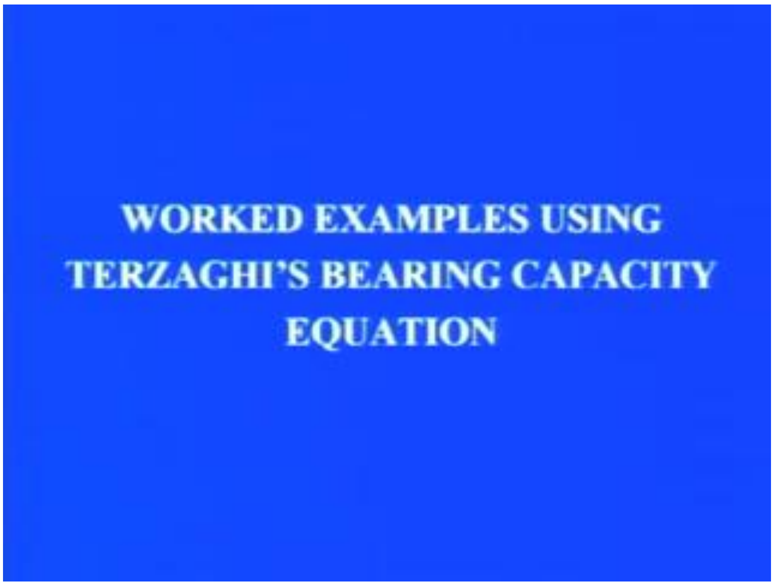

Now, we have discussed so, far the Terzaghi bearing capacity equation. And now I will explain or we will be more conversant with the use of this Terzaghi bearing capacity equation and by solving 2 few work examples.

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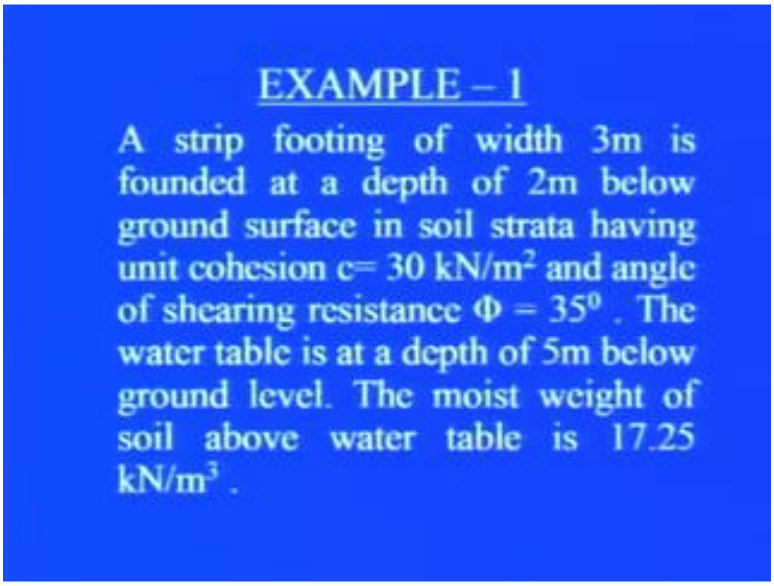

Let us say the first example is a strip footing of width 3 meters is founded at a depth of 2 meter below the ground surface in soil strata having unit cohesion as 30 kilonewton per meter square. And angle of sharing resistance 5 equal to 35 degrees. The water table is at a depth of 5 meter below the ground level the moist weight of the soil above the water table is 17.25 kilonewton per meter cube.

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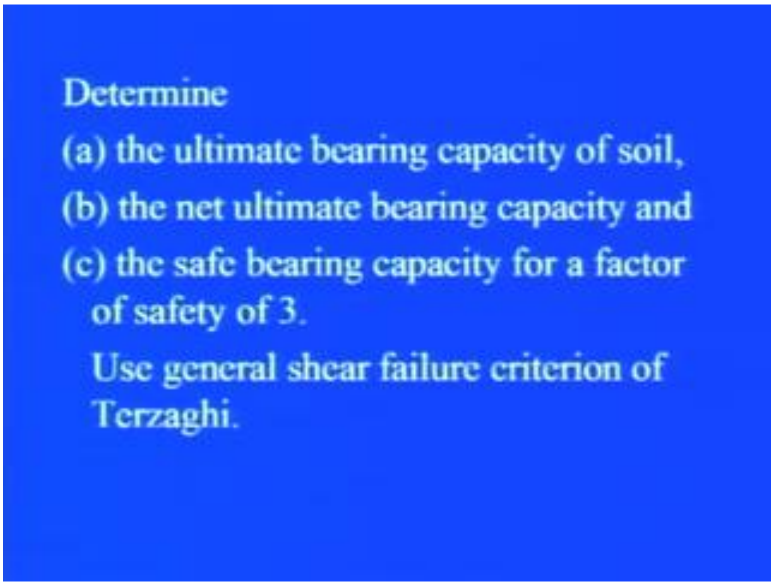

Now, we will be using Terzaghi bearing capacity equation to determine the ultimate bearing capacity of soil, the net ultimate bearing capacity of soil and the safe bearing capacity of soil for a factor of safety equal to 3. Now, in this case general shear failure criterion of Terzaghi has been considered. Now, depending upon the description this is the sketch which shows, the depth of the foundation as 2 meter width of the foundation and this is water table is 5 meter below the ground surface. Here, 5 equal to 35 degrees gamma equal to 170.25 kilonewton per meter cube and c equal to 30 kilonewton per meter square.

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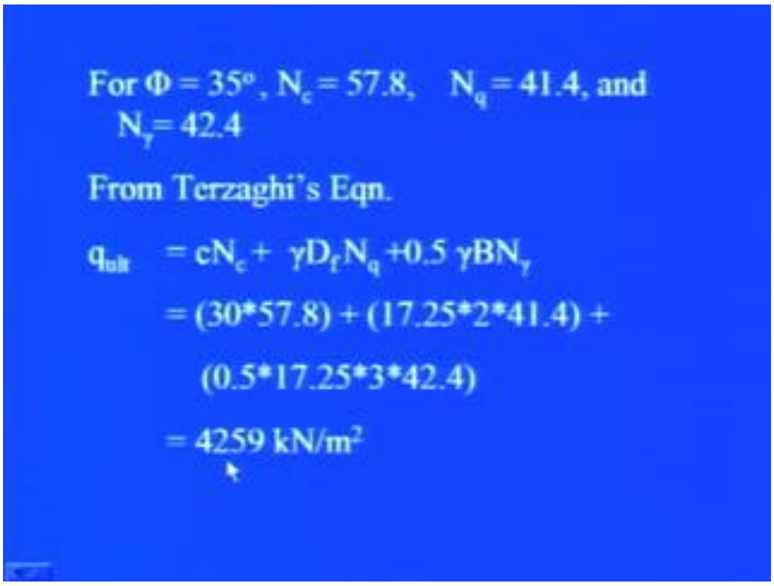

Now, for 5 equal to 35 degrees the bearing capacity factors can be obtained by the plots available or the tables. Now, if you use tables then you can find that 5 equal to 35 degrees N c is equal to 57.8, N q equal to 41.4 and N gamma equal to 42.4. Now, from Terzaghi equation, if you substitute this in the equation q ultimate equal to c N c plus gamma D f N q plus 0.5 gamma BN gamma. If you substitute respective values here, and solve it. You will get ultimate bearing capacity as the 4 to 59 kilonewton per meter square.

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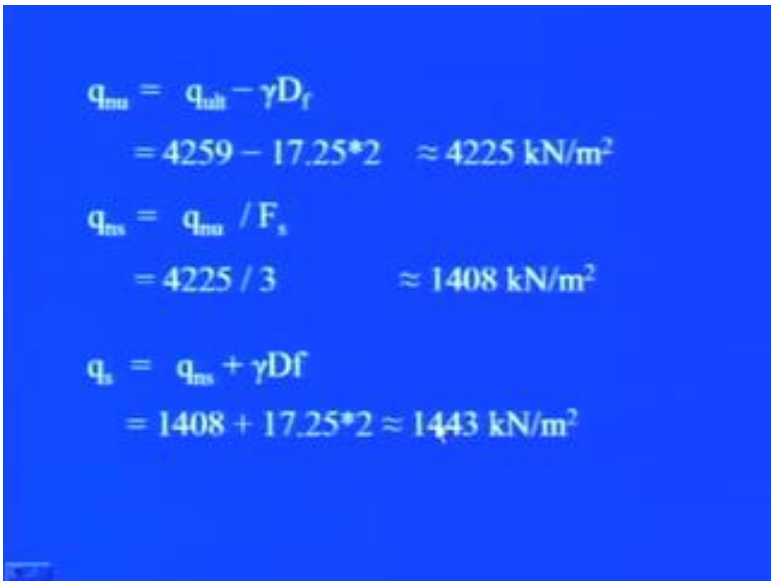

We know that net ultimate bearing capacity is equal to ultimate bearing capacity minus gamma D f. So, this will become equal to 4225 kilonewton per meter square. Now, we can find out net safe bearing capacity, if we know net ultimate bearing capacity by dividing it by a factor of safety. Now, here this factor of safety equal to 3. So, 4225 divided by three that will become equal to 1408 kilonewton per meter square. Now, in order to determine the safe bearing capacity we will have to add gamma D f to the net safe bearing capacity and it comes out to be 1443. It means, if all the quantities are known we can find out the bearing capacity, ultimate bearing capacity, net safe bearing capacity and ultimate safe bearing capacity of the foundation.

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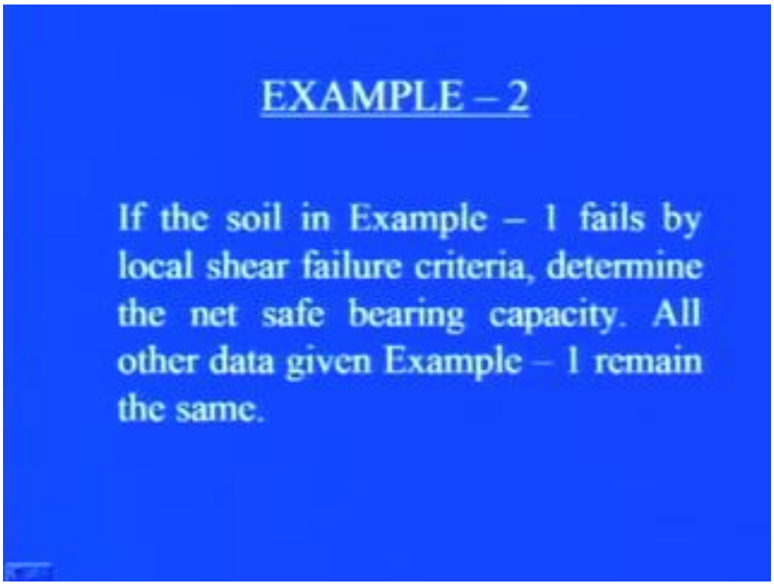

Now, in the example 2 it has been extended with all other data remaining the same. Only thing is, that was for the general shear failure case now we are using it for the local shear failure case.

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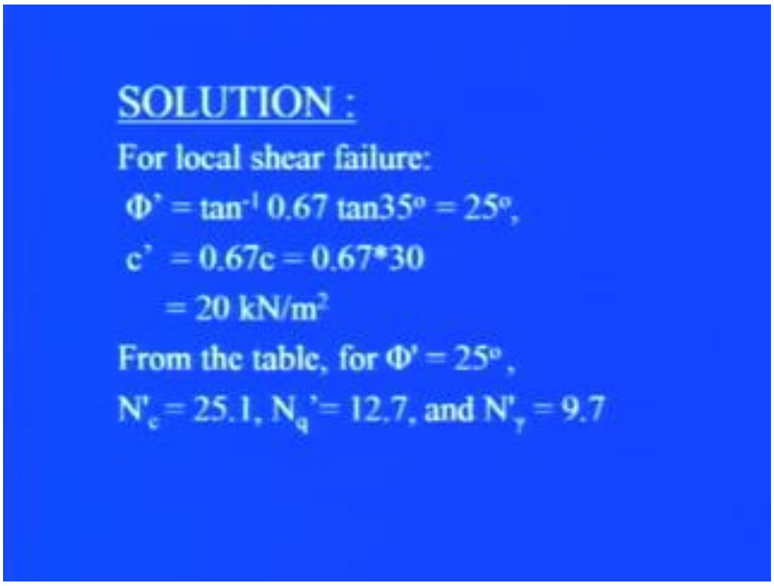

Now, for local shear failure case we have seen that tan phi dash becomes equal to two-third of tan phi and c dash becomes equal to two- third of c and using those values here. We obtain this phi dash is 25 degrees and c dash as 20 kilonewton per meter square. Now, from the table for phi dash equal to 25 degrees, we can find out bearing capacity factors for the local shear failure case given as N c dash N q dash and N gamma dash. So, this is 25.1, 12.7 and 9.7.

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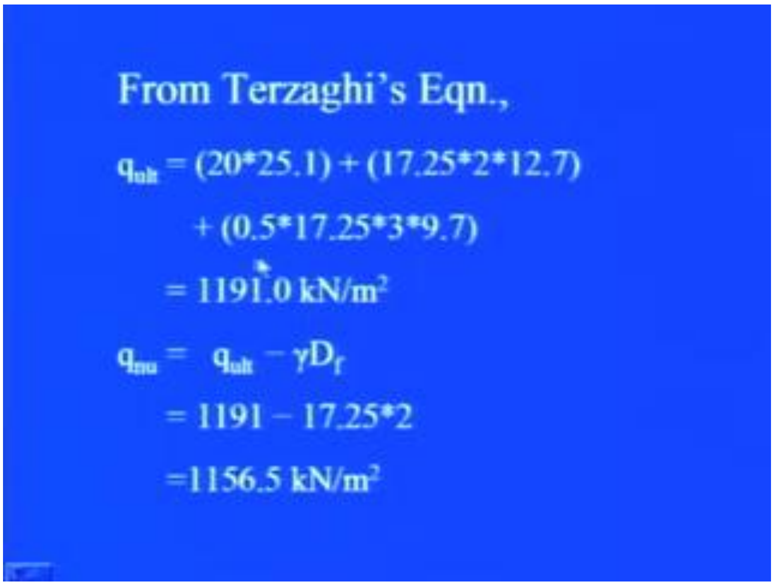

Now, again in the Terzaghi bearing capacity equation, if you substitute these values we will get this ultimate bearing capacity as 119.0 1 kilonewton per meter square.

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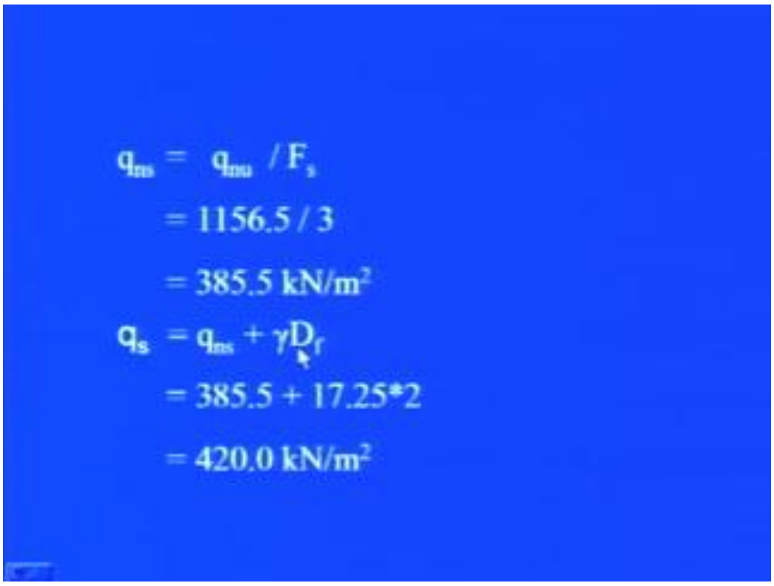

Following the same approach we can find out net ultimate bearing capacity as ultimate minus gamma D f. Then net safe by net ultimate by factor of safety and then finally, safe as net safe plus gamma D f. In this manner we can find out bearing capacity for the local shear failure case also.

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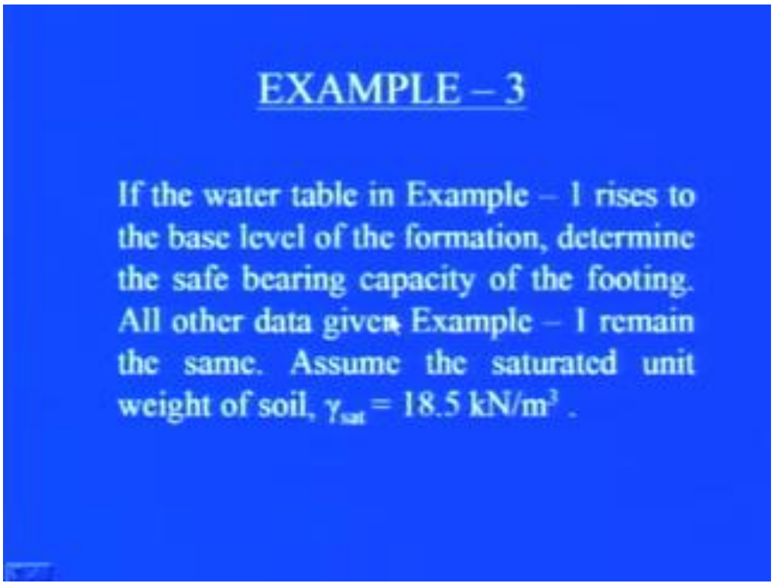

Now, there is another example in which the effect of water table has been taken into account. The data is similar to what is given in example 1, only thing is the there is change in the location of water table. Such that the water table rises to the base level of the foundation. Determine the safe bearing capacity of the footing, all other data remaining the same only thing only change is in the saturated unit weight of the soil that is considered as 180.5 kilonewton per meter cube.

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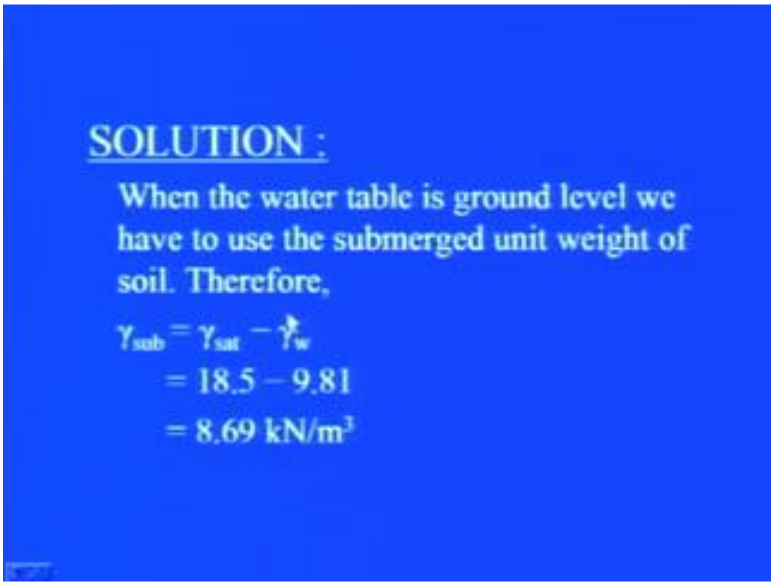

Now, when the water table is at the ground level, we have to use the submerged unit weight of the soil. Therefore, gamma submerged will be equal to gamma saturated minus gamma w 180.5 minus gamma w is the unit weight of water. So, this is 180.5 minus 9.81 it comes out to be 8.69 kilonewton per meter cube.

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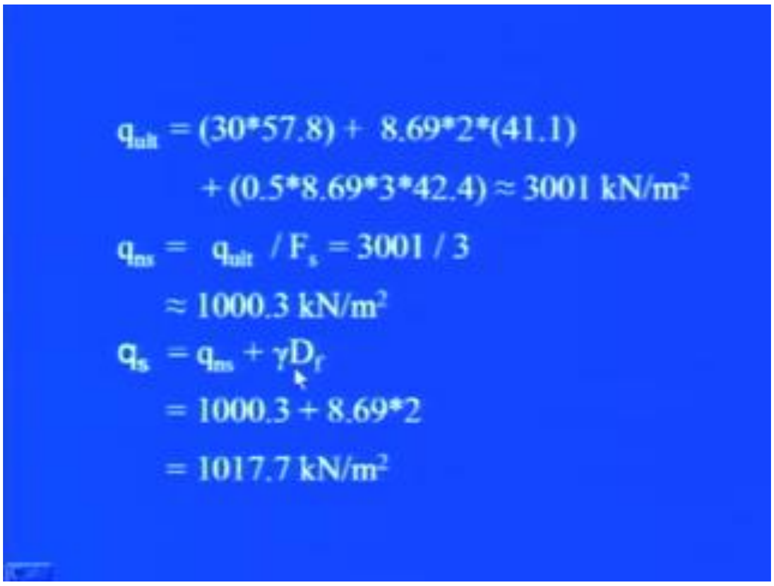

Now, again substituting all these values, we will find that the q ultimate comes out to be 3001 kilonewton per meter square. Again we find out q net safe as q ultimate by factor of safety and q safe by q net safe plus gamma D f.

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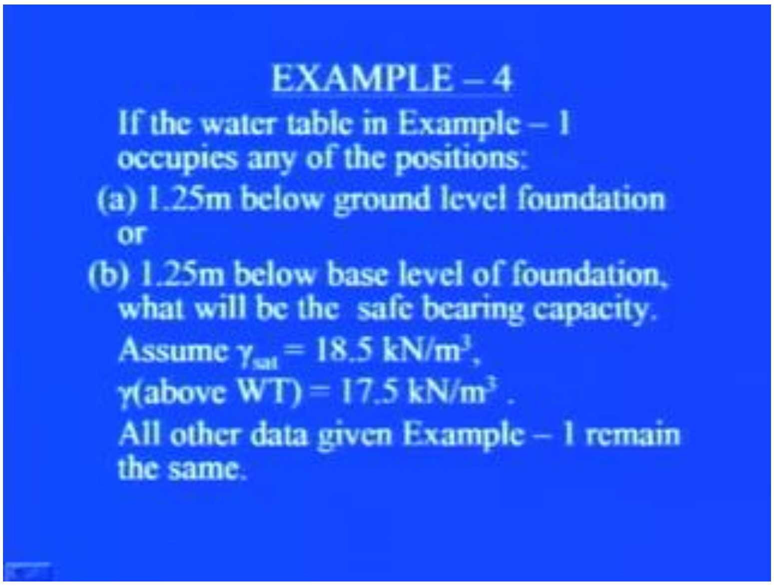

So, in this manner we can take into account the effect of water table. Now in another example, suppose the water table occupies some other positions like for case a water table is 1.25 meter below ground level, it is 1.25 meter below base level of the foundation, what will be the safe bearing capacity. Now, assuming again gamma saturated as 180.5 kilonewton per meter cube gamma above the water table as 170.5 kilonewton per meter cube other data remaining the same.

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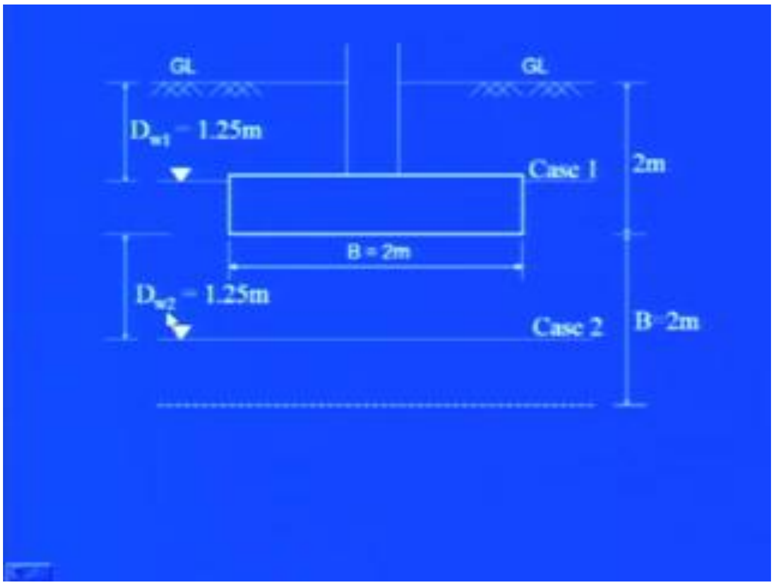

Now, this is the sketch for the description here now here there are 2 cases when the water table is above the foundation D w 1 is 1.25 meter. Another case water table is below the foundation D w 2 is 1.25 meter below the base level of the foundation. So, this is case 1 this is case 2. Now, in order to obtain the solution we can use either method 1 or method 2.

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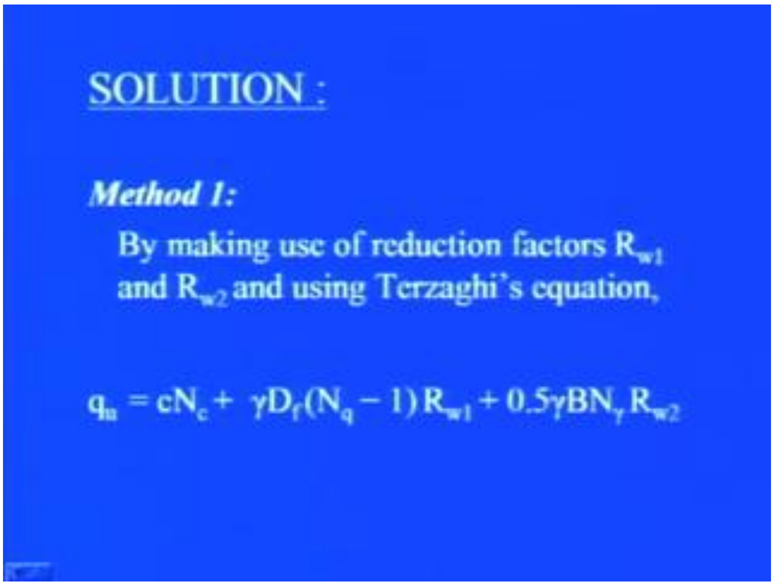

In the method 1 we have seen that the water table connection factors R w 1 and R w 2 are determined whereas, in the method 2 we go for the equivalent effective unit weight. Now, in the case of method 1 by making use of the reduction factors R w 1 and R w 2 and using Terzaghi equation. This Terzaghi bearing capacity equation is written as q ultimate equal to c N c plus gamma D and q minus 1 R w 1 plus 0.5 and B gamma N gamma R w 2. In order to determine R w 1 and R w 2 either we can use equation directly or we can go for the charts which I have shown earlier.

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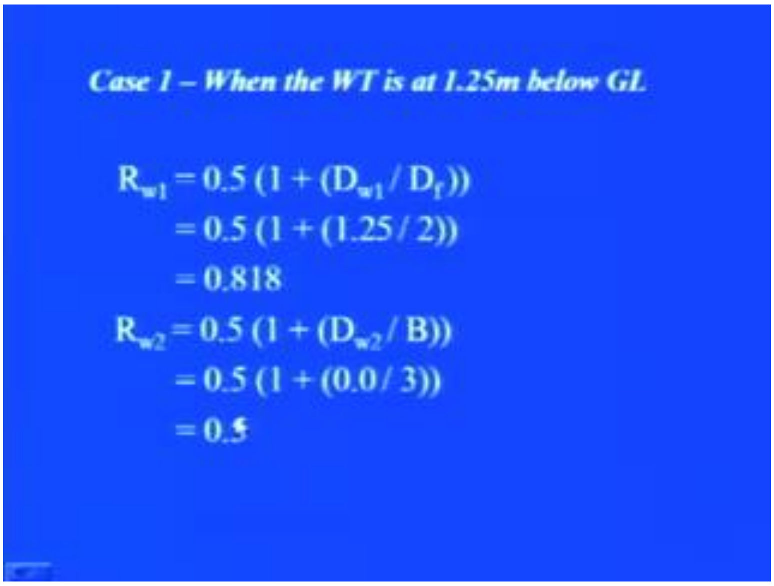

Now, if you substitute respective values of D particular 1 D f D w 2 and B we can obtain R w 1 and R w 2 in this particular case these are found out as 0.818 R w 1 and R w 2 equal to 0.5. Now, by substituting known values in the equation the net ultimate bearing capacity can be determine as 3547 kilonewton per meter square.

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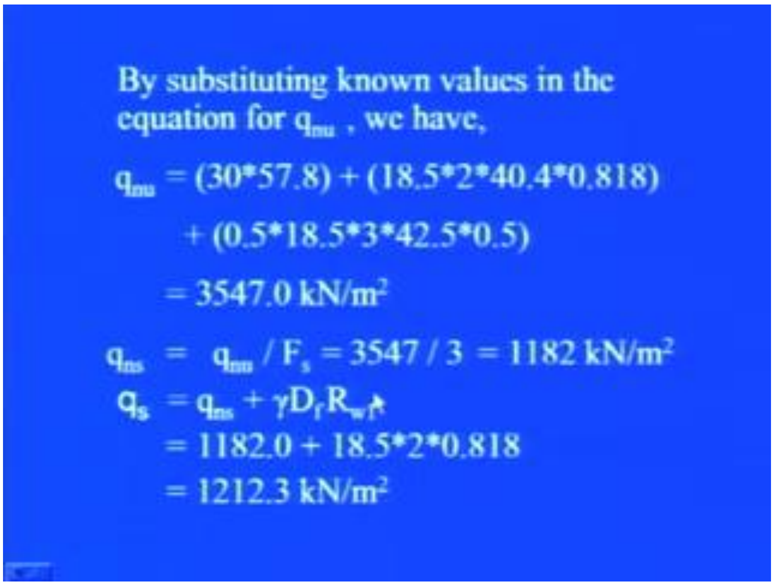

And by the usual method we can find out q net safe if q net ultimate is known factor of safety is known. So, we simply divide it by factor of safety and we obtain net safe bearing capacity and that is equal to 1182 kilonewton per meter square. And the q safe is equal to q net safe plus gamma D f into R w 1 and that comes out to be equal to 1212.3 kilonewton per meter square. So, in this manner we can find out the effect of the water table. Now, when case 2 when the water table is at 1.25 meter below.

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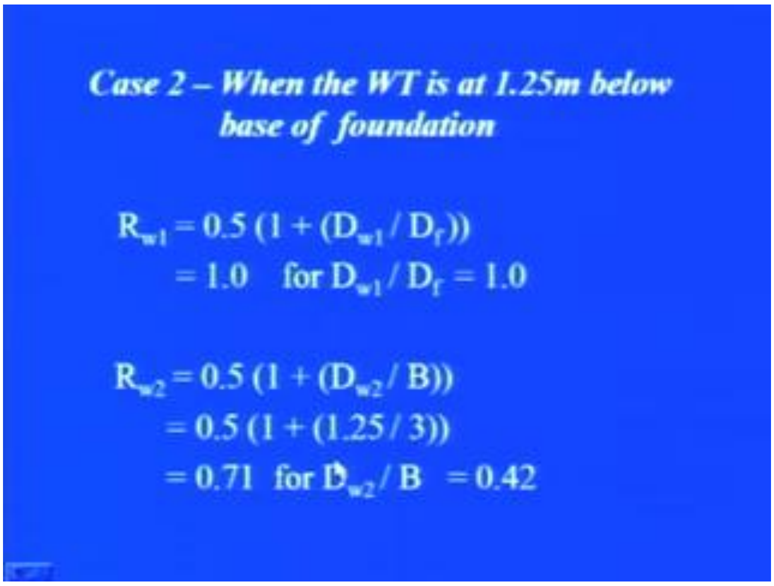

The base of the foundation then again using the formula as described earlier we can find out R w 1 by this particular equation. And it comes out to be one. R w 2 by this particular equation which comes out to be 0.42 only thing we will have to substitute 1.25 for D w 2.

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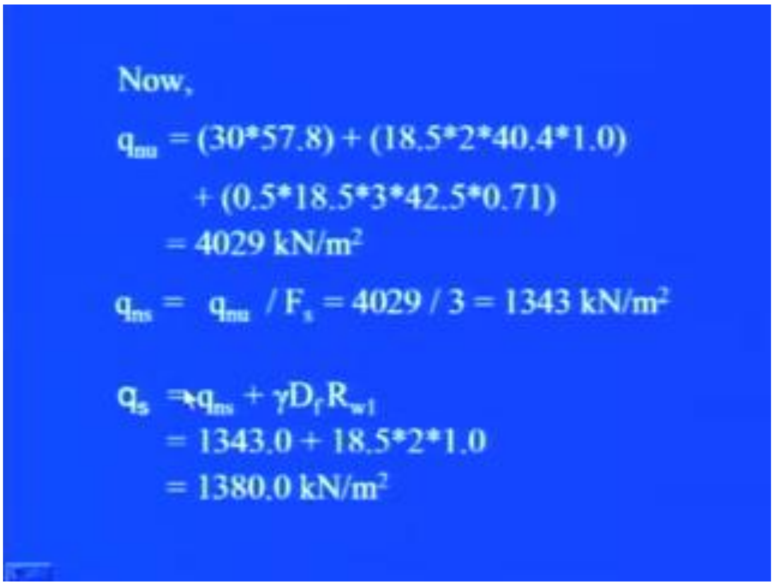

Now, again using the equation for net ultimate bearing capacity we can substituting different parameters and solving it. We will get this net ultimate bearing capacity as 4029 kilonewton per meter square. By the usual procedure we can find out net safe bearing capacity and then finally, the safe bearing capacity of the foundation.

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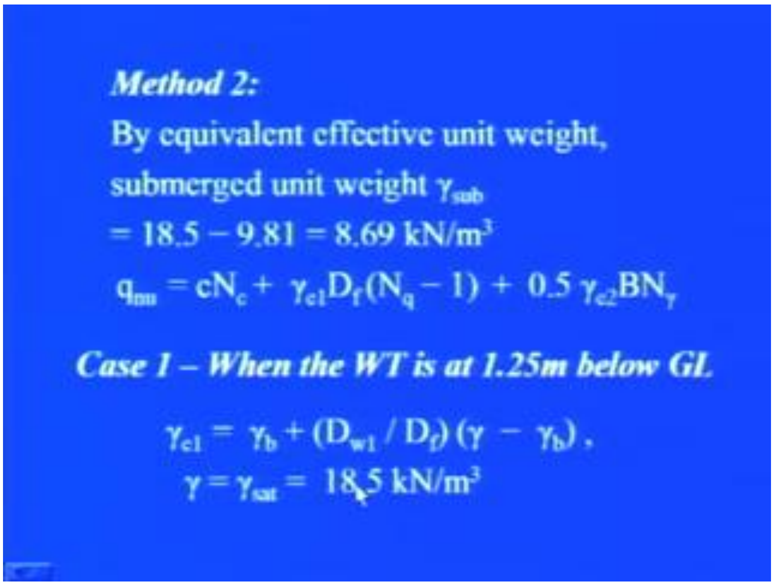

Now, alternately we can we can go for method 2 which we had discussed by equivalent effective unit weight, submerged unit weight comes out to be gamma saturated minus gamma w that is equal to 8.6 kilonewton per meter cube. And net ultimate bearing capacity is given by c N c plus gamma e 1 D f N q minus 1 plus 0.5 gamma e 2 BN gamma. Now, case 1 when the water table is at 1.25 millimeter below the ground level then gamma e 1 can be determine by this particular equation. That is equal to point unit weight plus D w 1 upon D f plus gamma minus gamma b here gamma b is the gamma submerged gamma equal gamma saturated. This gamma equal to gamma saturated that comes out to be that is given as 18.52 kilonewton per meter cube

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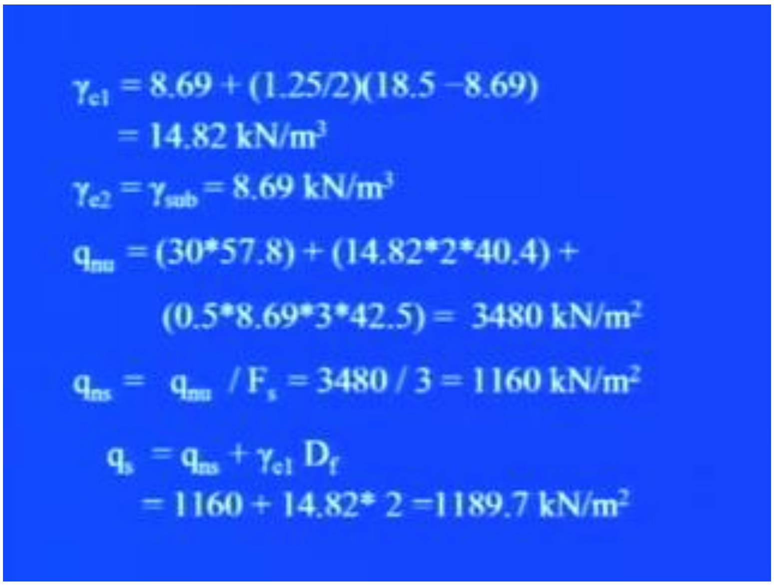

So, gamma e 1 is determined as 8.69 plus 1.25 by 2180.5 minus 8.69 using the formula. So, we get this gamma e 1 as 14.82 kilonewton per meter cube gamma e 2 is nothing but gamma submerged in this case it comes out to be 8.69 kilonewton per meter cube. So, when we substitute all these values along with the bearing capacity factors we find out q net ultimate that comes out to be 3480 kilonewton per meter square. And q net safe as q net ultimate divided by factor of safety as 1160 kilonewton per meter square and hence q safe as 1189.7 kilonewton per meter square.

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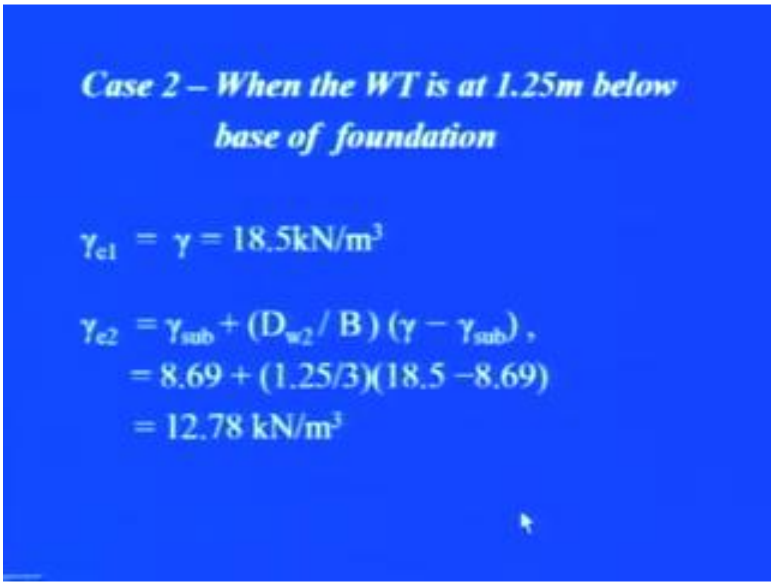

Now, case 2 when the water table is at 1 2 5 meter below the base of the foundation this gamma e 1 is taken as gamma 18.5 kilonewton per meter square cube. And this gamma e 2 is taken as gamma submerged plus Dw 2 by B gamma minus gamma submerged. If you substitute different values of gamma submerged gamma gamma saturated etcetera you will find that it come out to be equal to 12 78kilonewton per meter cube. So, in place of the gamma we used now gamma e 1 and gamma e 2 appropriately and if get this net ultimate as 4044 kilonewton per meter square.

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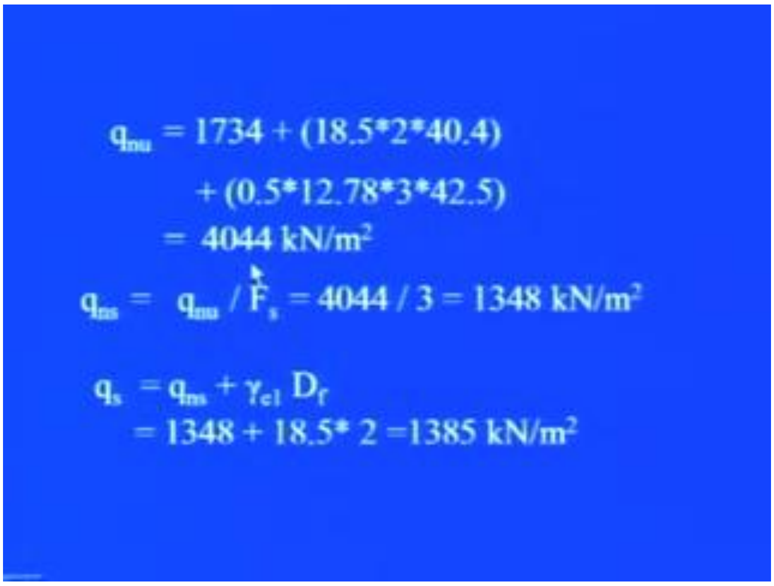

Then q net safe again by this formula we will get 1348 kilonewton per meter square and q safe as 1345 kilonewton per meter square. Now, another example if we take into account the shape of the footing now. Here we have considered the case for the earlier we considered the case for the strip footing now here it is square footing which fails by general shear failure in cohesion less soil means c equal to 0.

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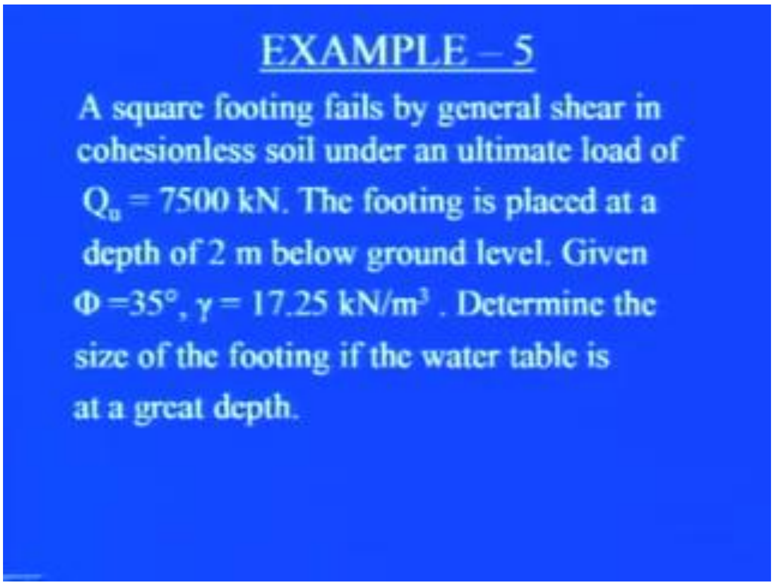

Under N ultimate load of 7500 kilonewton; the footing is placed at a depth of 2 meters below the ground level given phi equal to 35 degrees gamma equal to 17.25 kilonewton per meter square. We will have to determine the size of the footing if the water table is at great depth.

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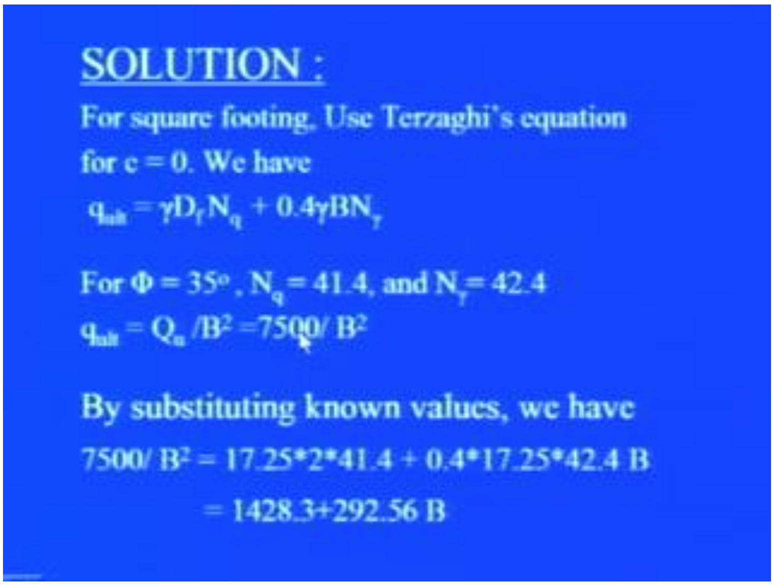

So, this can be solved by using Terzaghi's equation for a square footing here we have c equal to 0. So, c hence it term will vanish and we will be left with Q ultimate equal to gamma D f and Q plus 0.4 gamma BN gamma. Because this footing is a square footing for 5 equal to 35 degrees N q equal to 41.4 and N gamma equal to 42.4 these can be obtained either form the table or by the charts. So, when you substitute these values of N q N gamma gamma D f B in this ultimate varying capacity equation. We will be left with the varying capacity as 1428.3plus 292.56 B where B is the unknown. Now, we also know that the q ultimate will be equal to the load divided by the area of the foundation. So, it becomes Q u upon B square that is equal to 7500 kilonewton divided by B square. Now, if you simplify this equation and transpose we will get.

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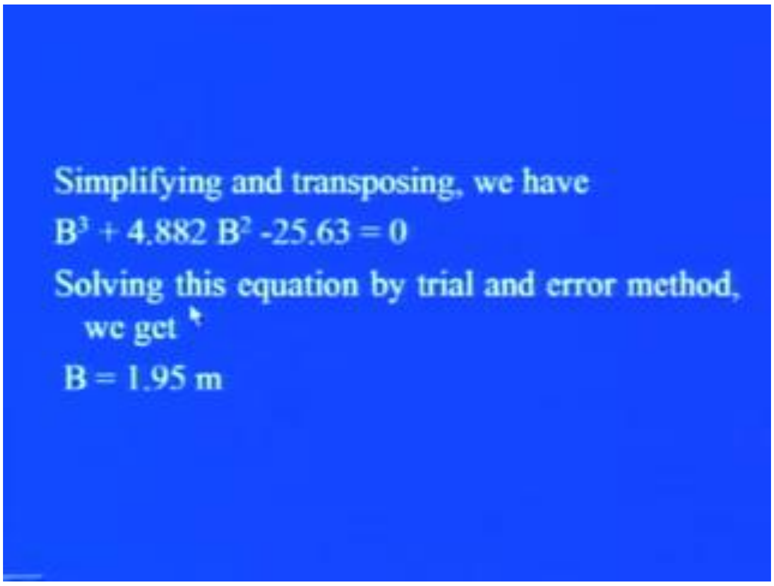

This cubic form of the equation as B cube plus 4.882 B square minus 25.63 equal to 0. Now, when we solve this equation by trial and error we will get that the width of the foundation is 1.95 meter. It means I square foundation of 1.95 by 1.95 meter will be used now in another example the that is the case of a rectangular footing.

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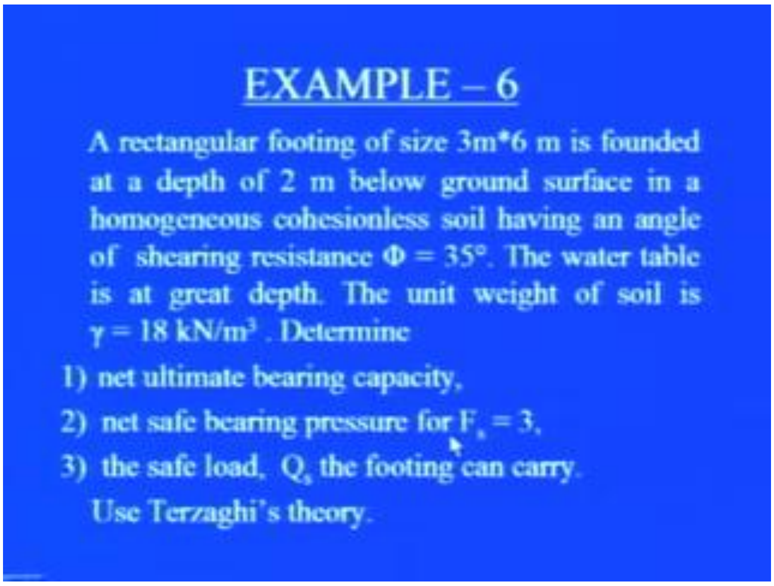

A rectangular footing of size 3 meter by 6 meter is founded at a depth of 2 meter below ground surface in a homogeneous cohesionless soil. It means again c equal to 0 having an angle of shearing resistance 5 equal to 35 degrees the water table is at great depth. The unit weight of soil is 18 kilonewton per meter cube, you have to determine net ultimate bearing capacity net safe bearing pressure for factor of safety equal to 3. The safe load Q s for the the footing can carry now again use Terzaghi's theory.

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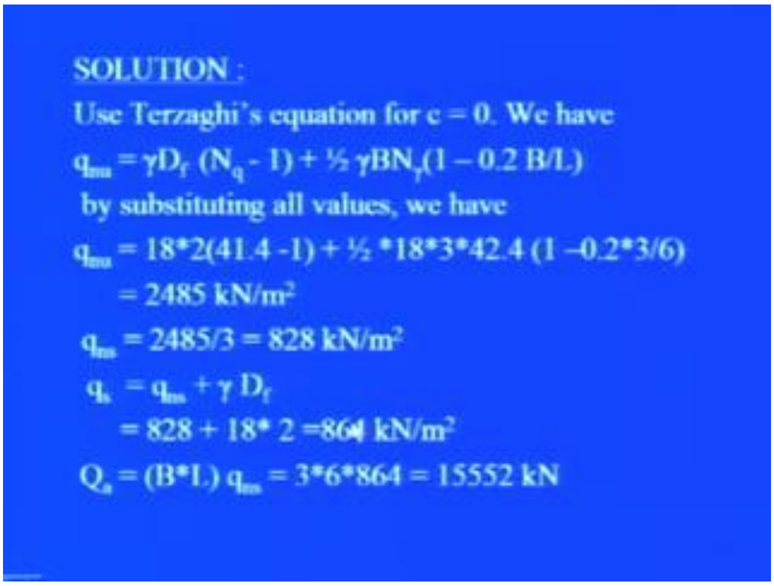

Now, using Terzaghi equation for c equal to 0, we will get this as the equation for rectangular footing gamma D f equal into N q minus 1 plus 0.5 gamma BN gamma 1 minus 0.2 B upon L. Now, by substituting different values we will get net ultimate as 24585 kilonewton per meter square. Now, from this net ultimate we can find out net safe if we know factor of safety. So, 2485 divided by factor of safety that is 3 equal to 828 kilonewton per meter square. Now, once this q net safe is known we can find out q safe that is the ultimate safe bearing capacity equal to q n s equal plus gamma D f it comes out to be 864 kilo Newton per meter square. And hence the allowable load will be equal to the area of the footing into q net safe and that comes out to be equal to 15552 kilonewton.

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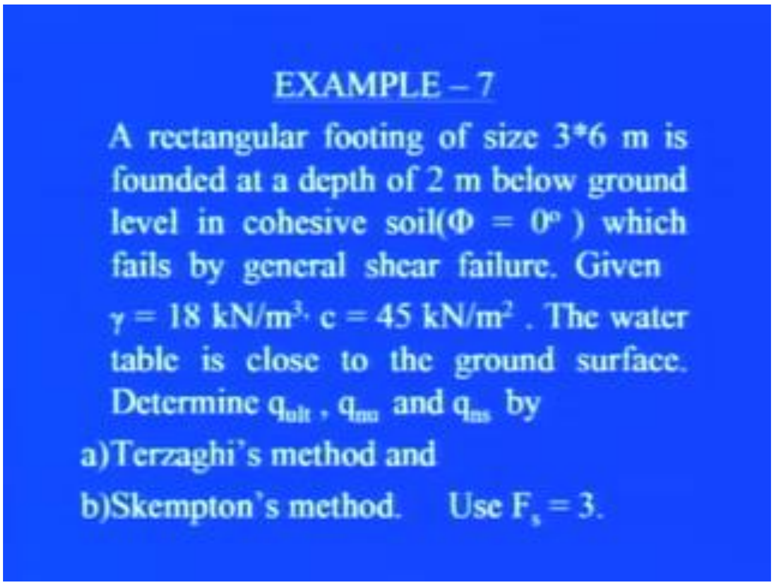

Here we consider another example of a rectangular footing of size 3 meter by 6 meter which is founded at a depth of 2 meter below ground level in cohesive soil in the means phi equal to 0 which fails by general shear failure given that gamma is 18 kilonewton per meter cube c equal to 45 kilonewton per meter square. The water table is close to the ground surface we will have to determine ultimate bearing capacity net ultimate bearing capacity. And net safe bearing capacity by Terzaghi's method and by Skempton's method here we use factor safety equal to 3 now, first of all by Terzaghi's method as phi equal to 0.

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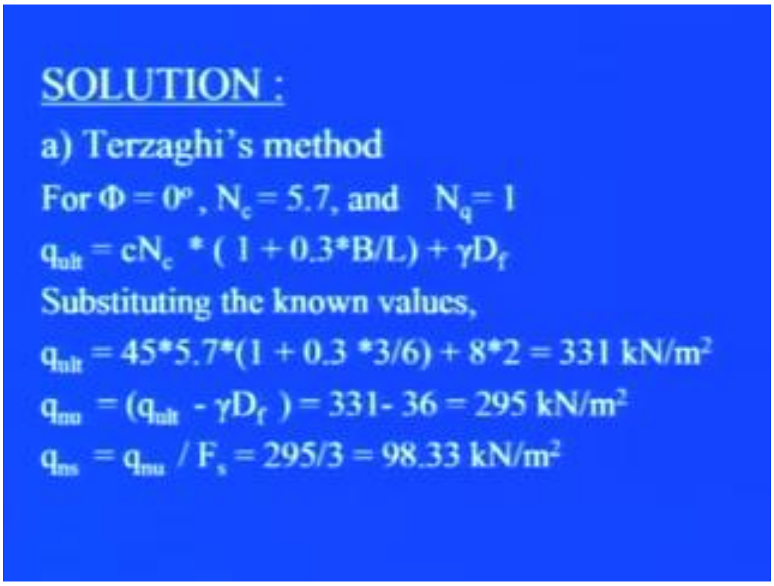

Other parameters containing at five term will vanish and we will be left with only N c. And N c will come out to be equal to 5.7 and N q becomes equal to 1 for this case. So, this ultimate varying capacity will be written as c N c plus 1 plus 0.3 B upon L. Because it is a rectangular footing plus gamma D f now substituting the known values of other parameters like c N c and N q and gamma and Df. We will get this ultimate bearing capacity as 3301 kilonewton per meter square net ultimate bearing capacity. That will be equal to q ultimate minus gamma D f comes out to be 295 kilonewton per meter square. Net safe; if we know net ultimate divided by factor of safety you will get it as 98.33 kilonewton per meter square.

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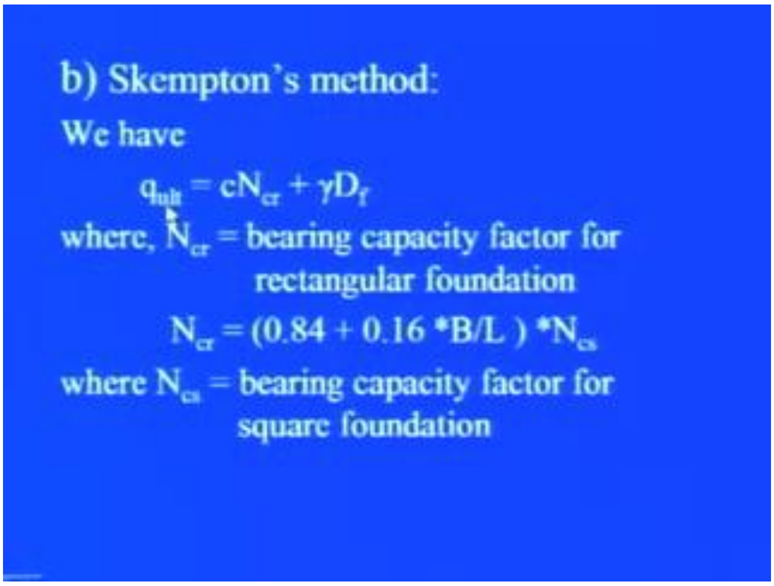

Now, if we use a Skempton method now using a Skempton method we have q ultimate equal to N c r plus gamma D f where this N c r is the bearing capacity factor for rectangular foundation. And as discussed earlier this N c r is equal to 0.84 plus 0.16 B by L into N c s where this c s is for the this square foundation. Now, either we can use this graph also.

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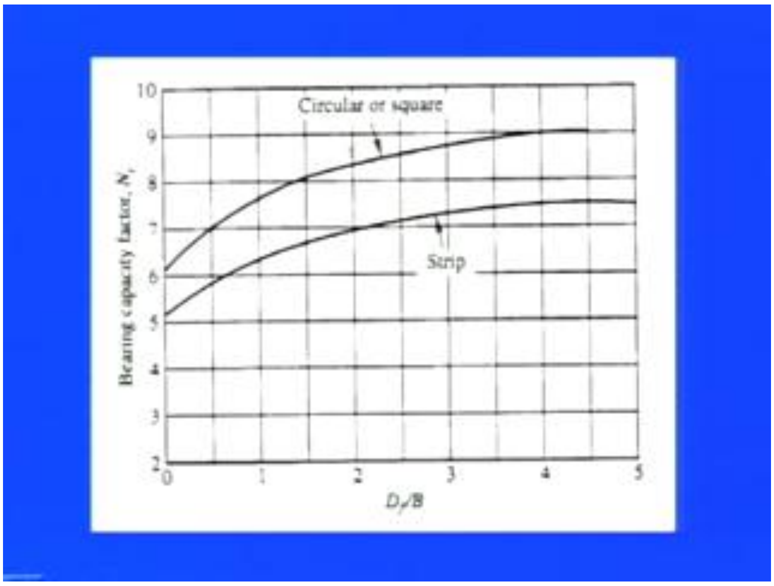

By which we can find out what is the value of for the circular or square foundation the value of N c depending upon the ratio D f by B.

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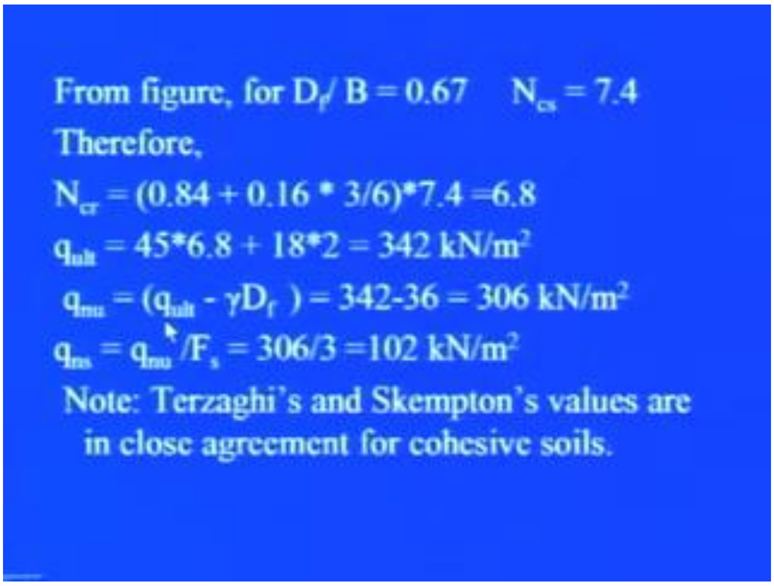

So, using this particular plot we can obtain from this figure for D f by B equal to 0.67 N c s comes out to be 7.4 it can be seen again from this figure we can find out it comes out to be 0.64. And from this when we substitute for the bearing capacity factor Nc for the rectangular foundation when we substitute it here and the value of D f by B we will get this as 6.8. And once N c for rectangular for rectangular foundation is know is substitute in the ultimate bearing capacity equation.

We find out ultimate bearing capacity as 342 kilonewton per meter square and net ultimate bearing capacity as 306 kilonewton per meter square. If we know factor of safety again qnu upon factor of safety will give you q net safe that comes out to be 100 1 0 2 kilonewton per meter square. Now, one thing can we noted here that Terzaghi's and Skempton's values are in closed agreement for cohesive soils.

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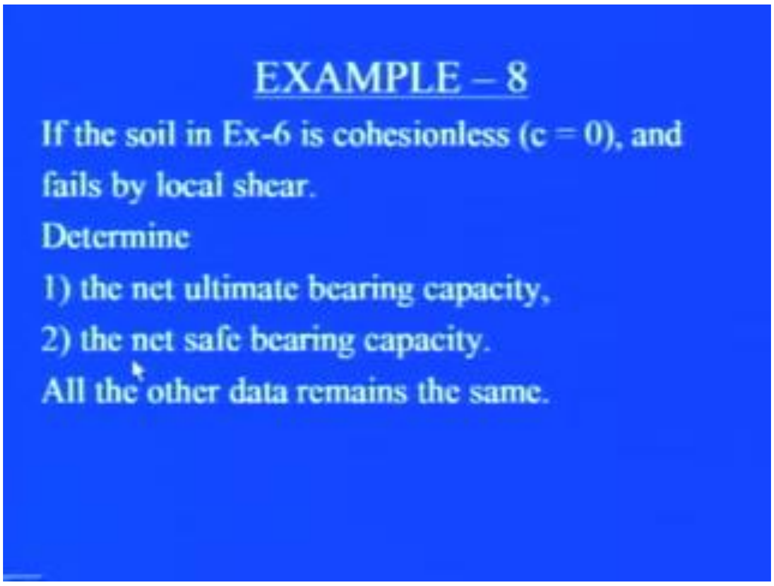

Now, in the example 6 which we have considered previously if the soil in example 6 cohesionless c is equal to 0 and if it fails by local shear then, how to get this value of net ultimate bearing capacity and net safe bearing capacity with other data remaining the same this is explained in this particular example.

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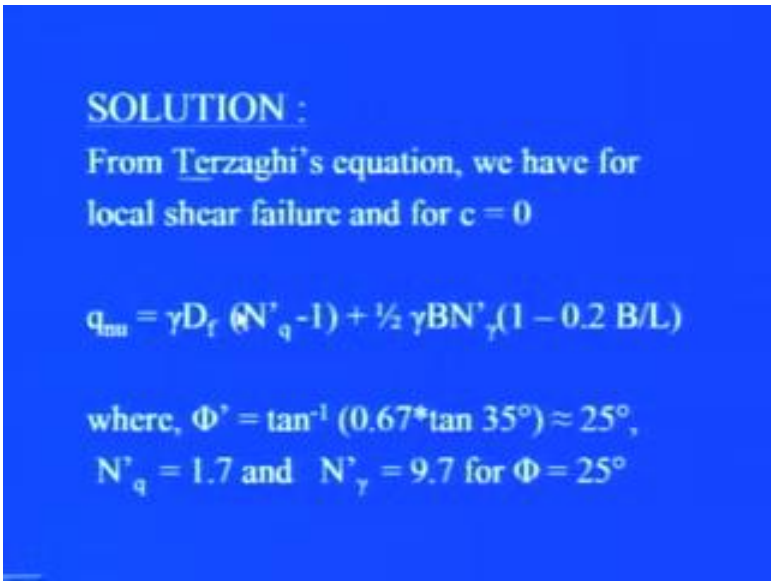

Now, from Terzaghi's equation we have for local shear failure and c equal to 0. This net ultimate bearing capacity given by gamma D f N q dash minus 1 where N q dash N gamma dash are the bearing capacity factors for the local shear failure case these can be obtained. If we obtain value of 5 dash and that 5 dash will be given by 10 inverse two third of 10 35 degrees where 35 degrees is the five value when it is the case of general shear failure. So, when we substitute it here we will get five dash equal to 25 degrees and for this 5 dash equal to 25 degrees using the tables we can find out what is N q what is N gamma. And those will be the local shear failure bearing capacity parameters.

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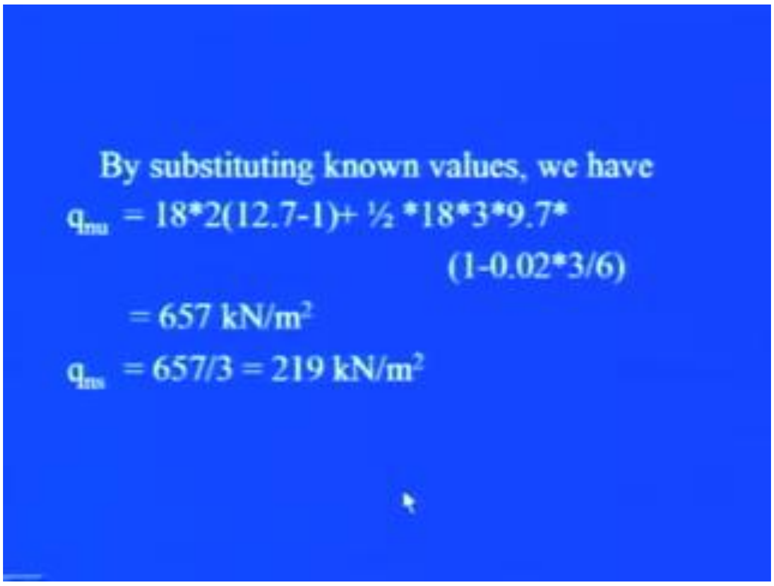

Now, when we substitute these know values we will get net ultimate. And finally, net safe as net ultimate divided by factor of safety. Now, in this particular case is it comes out to be 219 kilonewton per meter square.

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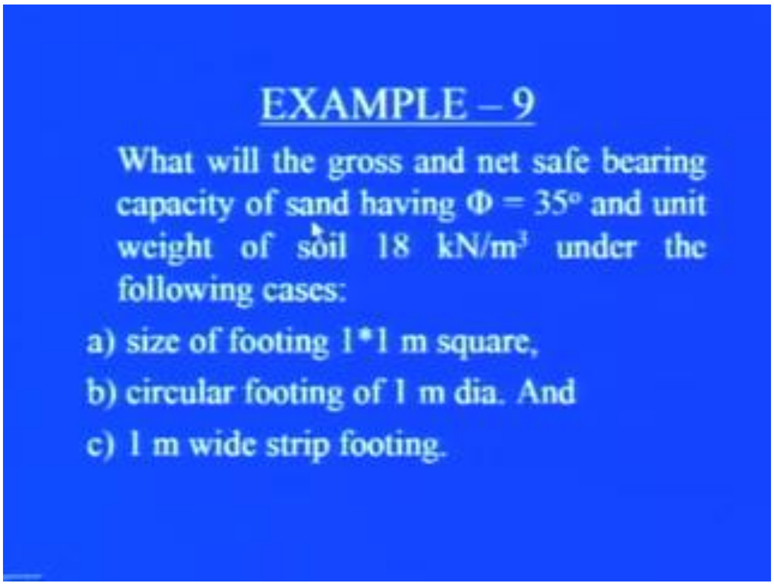

Now, this is another example, what will the gross and net safe bearing capacity of sand having 5 equal to 35 degrees and unit weight of soil 18 kilonewton per meter cube under the following cases. When the size of the footing is 1 meter by 1 meter square or the size of the footing is circular diameter of 1 meter dia and thirdly is 1 meter wide is strip footing. Iit means in this through this example, we can compare the bearing capacity for different type of footings whether it is square footing or is circular footing or a strip footing.

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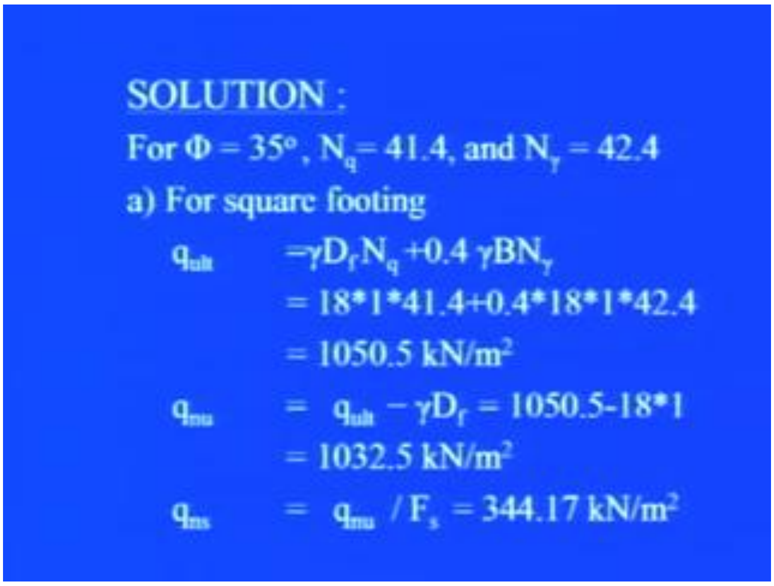

For 5 equal to 35 degrees N q and N gamma factors are can be read out from the table. For square footing this ultimate bearing capacity is equal to gamma D f N q plus 0.4 gamma BN gamma here this factor is 0.4 where as in the case of strip footing it is 0.5. So, when we substitute respective values of gamma D f gamma again and B and N gamma we find we get ultimate bearing capacity. And that comes out to be in this particular case equal to 1050.5 kilonewton per meter square. Once ultimate bearing capacity is known we can find out net ultimate bearing capacity as q ultimate minus gamma D f in this case it is 1032.5 And then net safe bearing capacity as net ultimate bearing capacity divided by factor of safety. So, this comes out to be 344.17 kilonewton per meter square for the case of circular footing, this factor in this equation is 0.3.

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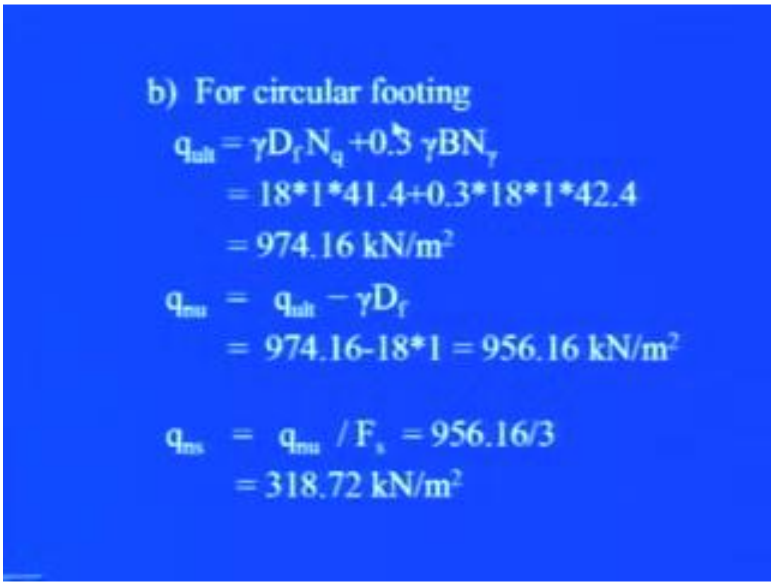

And other factors remaining same is substitute values we get q ultimate then we get q net ultimate and finally, we get q net safe. So, different values of q ultimate net ultimate and q net safe are 974.16 kilonewton per meter square 956.16 kilonewton per meter square and 318.72 kilonewton per meter square respectively. For the case of a strip footing when we substitute respective values in the Terzaghi bearing capacity equation.

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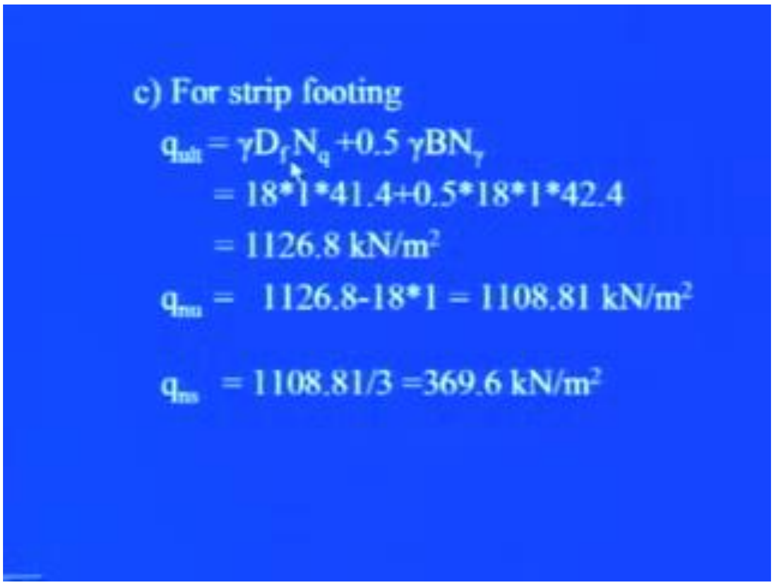

We get q ultimate as 1126.8 kilonewton per meter square q net ultimate as 1108.81 kilonewton per meter square. And q net safe as 369.6 kilonewton per meter square.

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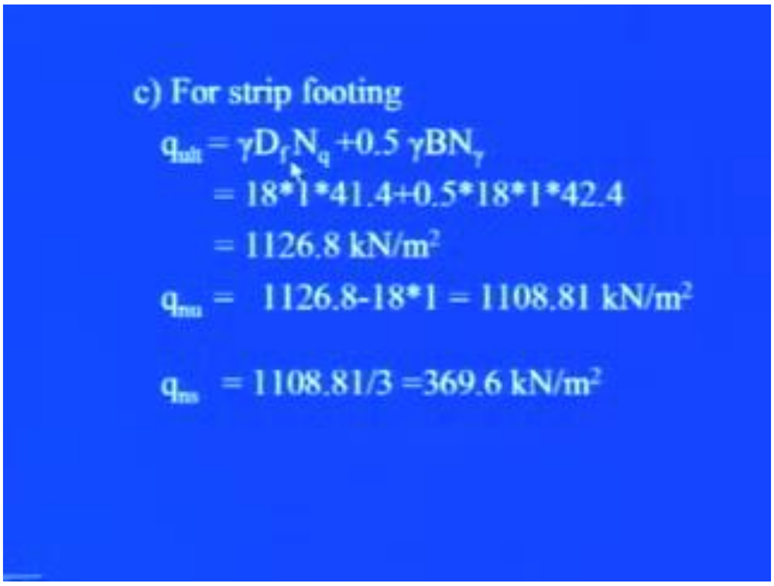

Now, this is another example that is of a strip foundation which is founded at a depth of 1 0.5 meter below the ground surface water table is close to the ground surface and the soil is cohesionless The footing is supported to carry a net safe load intensity of 400 kilonewton per meter square with factor of safety equal to 3. Given that saturated unit weight of the soil as 20.85 kilonewton per meter cube and 5 equal to 35 degrees. Find the width of the footing under general shear failure criterion given by Terzaghi. Now, again in order to solve this problem once we know value of five N q N N gamma parameters are obtained from the table.

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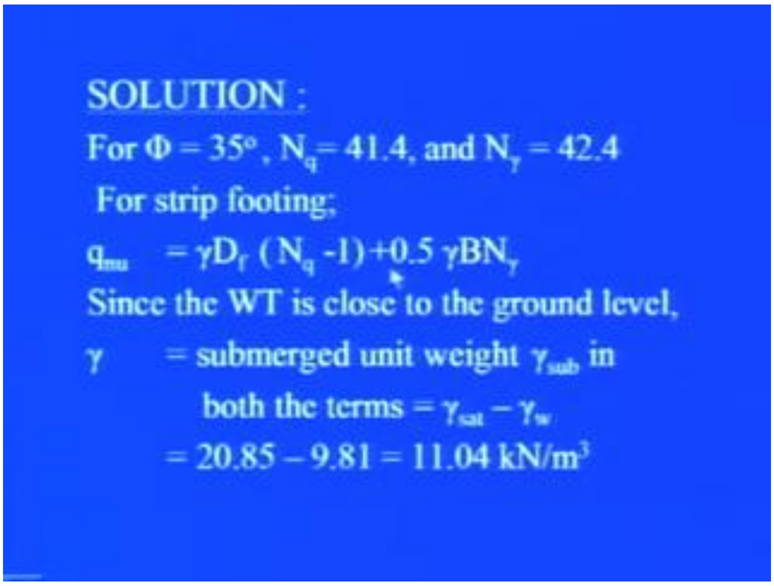

And we substitute these values in the equation of Terzaghi for the strip footing and that is gamma D f N q minus 1 plus 0.5 gamma BN gamma. Now, we know that the water table is very close to the ground surface. So, the gamma will be used as the submerged unit weight where gamma submerged in both the terms a and that is equal to gamma saturated minus gamma W. So, this is the gamma saturated minus unit weight of water will give 11.04 kilonewton per meter cube as the submerged unit weight of the soil mass. And when we substitute these values and it is given that the net safe equal to 400 kilonewton per meter square then for this net safe, if we multiply it by factor of safety we will get net ultimate.

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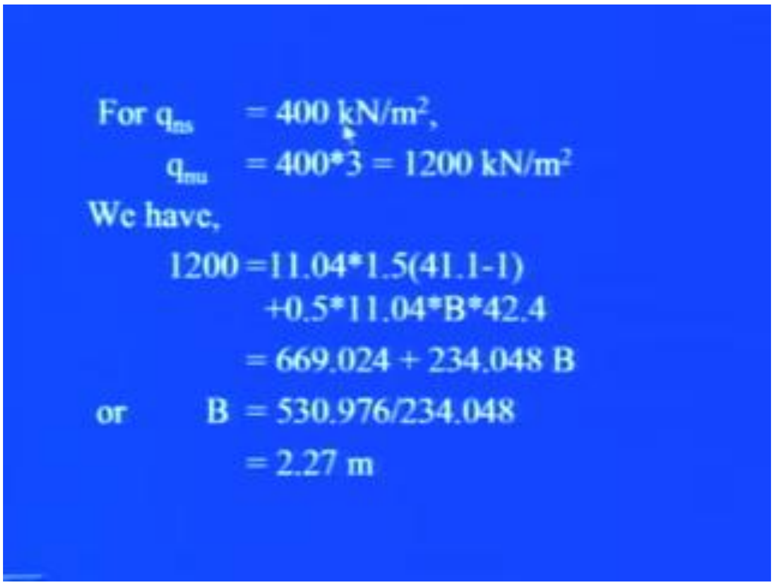

And this net ultimate is compared with the net ultimate which we obtained from the bearing capacity equation. So, when we substitute this then the unknown parameter in this case is the width of the footing when we solve it we will get the width of the footing as 2.27 meters.

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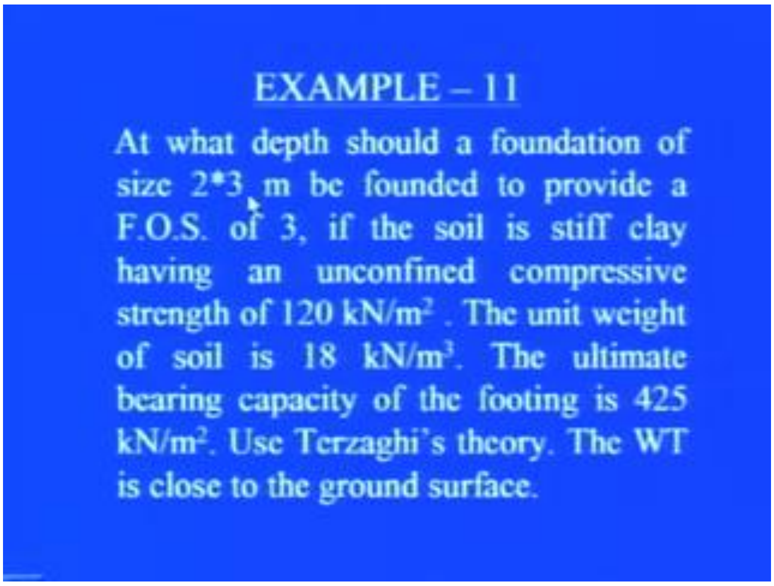

Now, this is another example at what depth should a foundation of size 2 meter by 3 meter be founded to provide a factor of safety equal to 3. The soil is stiff clay having an unconfined compressive strength of 120 kilonewton per meter square. The unit weight of soil is 18 kilonewton per meter cube the ultimate bearing capacity of the foundation is 425 kilonewton per meter square again using Terzaghi theory and water table considering very close to the ground surface. Now, using Terzaghi theory for the case phi equal to 0.

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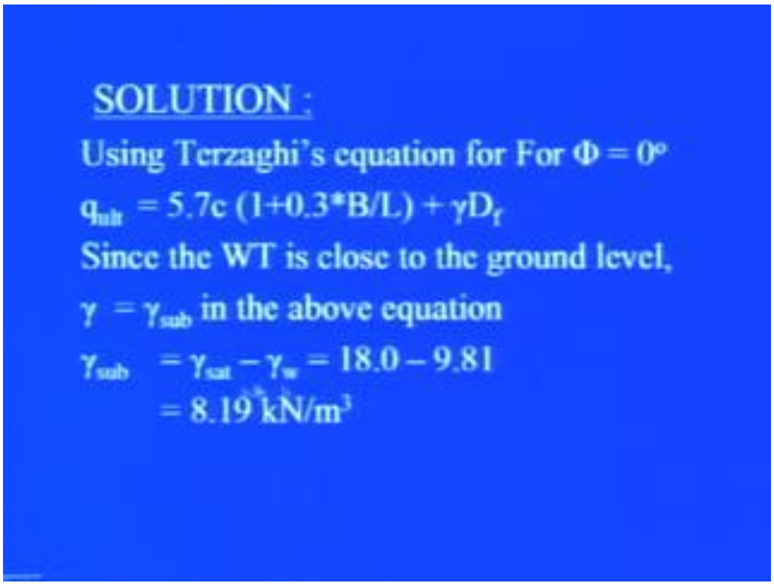

For the rectangular foundation we have this q ultimate equal to 5.7 that this five 0.57 is the N c parameter c 1 plus 0.3B upon L plus gamma D f. Since the water table is close to the ground level gamma which we use again that will be the gamma submerged in the above equation. And gamma submerged is equal to gamma saturated minus gamma w that comes out to be 8.19 kilo kilonewton per meter cubed.

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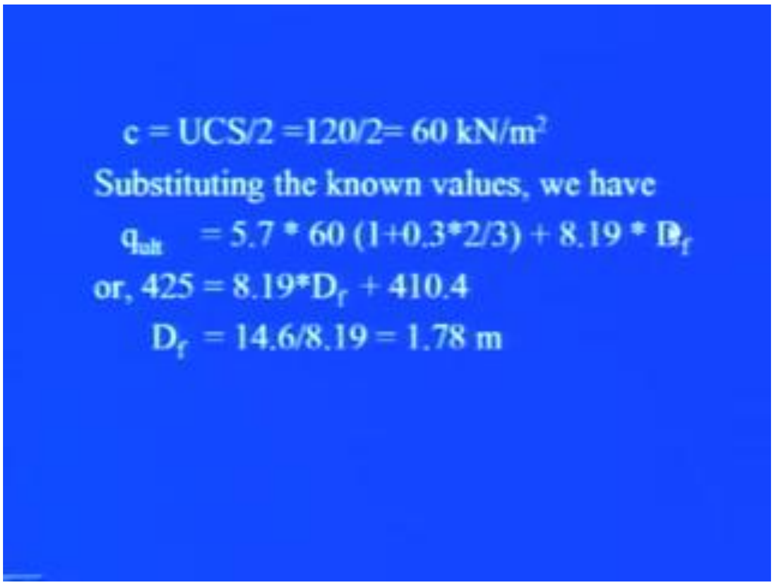

Now, the cohesion is the unconfined compressive strength divided by 2 and unconfined compressive strength in this particular case is given as 120 kilonewton per meter square. So, cohesion comes out to be 60 kilonewton per meter square now when we substitute these values we can obtain. The unknown parameter that is the depth of foundation where the foundation should be placed for this particular case and when we solve it we get depth of foundation as 1.78 meters. Now in another example that is the case of a rectangular foundation which is to be founded at a depth of 2 meter below the ground surface.

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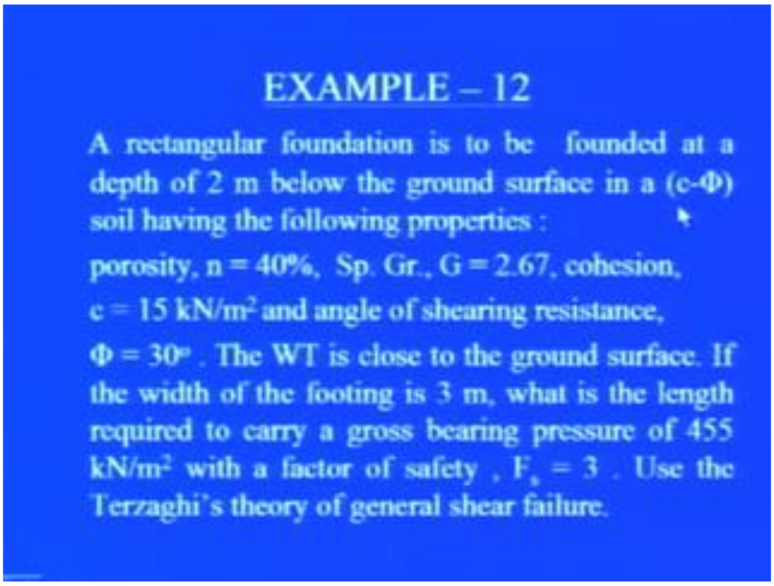

In c phi soil having the following properties the properties of the soil are porosity that is equal to 40 percent a specific gravity of soil solids that is given that is equal to 2.67. Cohesion c is given as 15 kilonewton per meter square and angle of shearing resistance is given as 30 degrees. The water table is closed to the ground surface if the width of footing is 3 meter. What is the length required to carry a gross bearing pressure of 455 kilonewton per meter square with the factor of safety equal to 3 using Terzaghi's theory of general shear failure. Now, again in this case our aim is to find out what should be the length of the footing?

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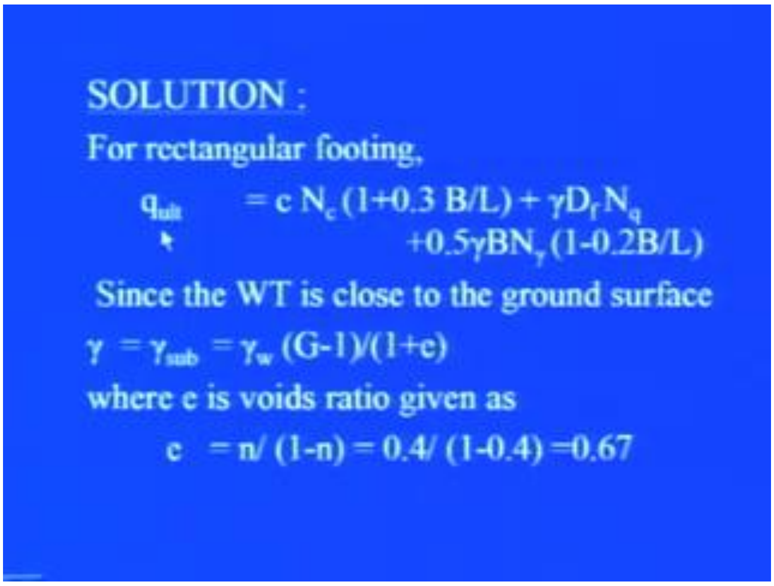

Now, for the rectangular footing ultimate bearing capacity given by Terzaghi is c N c plus 1 point 1 plus point three B upon L plus gamma D f N q 0.5 gamma BN gamma 1 minus 0.2 B by L. Since the water table is close to the ground surface we will have to first find out what is the unit weight. Now, as it is very close to the ground surface the unit weight will be the gamma submerged and gamma submerged can be determined if we know gamma w specific gravity of soil solids which is given in the ratio. This void ratio can be determined if we know porosity by the relationship e equal to n upon 1 minus n. So, when we substitute value of porosity which is 40 percent 0.4 divided by 1 minus 0.4 it will give the void ratio of this item comes out to be 0.67. Now, when we substitute this 0.67 in the submerged gamma submerged equation.

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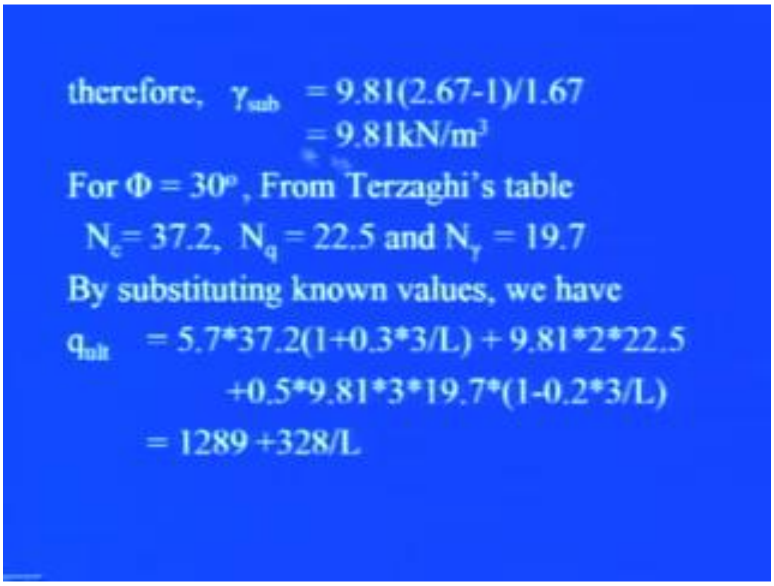

We will find that gamma submerged will come out to be equal to 9.81 kilonewton per meter cubed. Now, for phi equal to 30 degrees from Terzaghi's table we can find out what is Nc N q and N gamma? And these values are 37.2 22.5 and 19.7 respectively. Now, by substituting all these known values we can find out our relationships for ultimate bearing capacity which will have 1 unknown and that unknown is length of the foundation.

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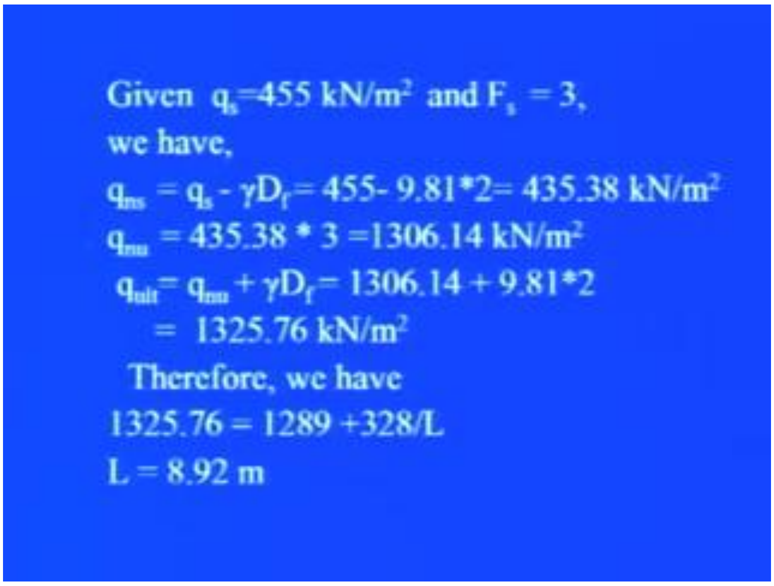

In the problem qs is given as four fifty five kilonewton per meter square and factor of safety is given as three. So, we know that q net safe equal to q as minus gamma Df. So, it will come out to be 455 minus 9.81 into 2 that is equal to 435.38 kilonewton per meter square. Then that net ultimate will be can we obtain by multiplying q n s with a factor of safety that comes out to be 1306.14 kilonewton per meter square. And q ultimate will be equal to q net ultimate plus gamma D f. So, that will come out to be 1325.76 kilonewton per meter square. And we have already obtained our, a relationship for q ultimate in which L was unknown. So, when we equate this value with the equation a we get value of length of the foundation.

That is 1325.76 equal to 1289 plus 328 by L and we solve it length of the foundation comes out to be 8.92 meter. So, in this particular lecture I had try to explained the use of safe bearing capacity equation given by Terzaghi. In order to solve problems related to strip footing a square footing circular footing rectangular footing. And in the conditions when the water table is at different locations below the ground surface and for the case of cohesion less soil and for the case of cohesive soil including the Skempton’s bearing capacity parameters. Now, in the next lecture, I will discuss few more worked examples to find out ultimate bearing capacity. And or in other way round to find out the unknowns like what should be the depth of foundation, what should be the width of foundation or length of foundation?

Thank you.