Advanced Foundation Engineering
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Lecture - 7
Shallow Foundation: Bearing Capacity - II

Lecture three of the module two which is total, now this is the seventh lecture of this series. So, today I will explain about this shallow foundation and the last class I have explained about the bearing capacity of the shallow foundation in Terzaghi's bearing capacity analysis, how to determine the ultimate load carrying capacity of the soil. Those things I have discussed and then the effect of water table on the bearing capacity analysis those things are also discussed in the last class. So, now today this class I will discuss the other methods of analysis to find the bearing capacity of the soil. Now, first before we start the different methods of the bearing capacity analysis. Now, this section I will discuss about the factor of safety.

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How to apply the factor of safety on ultimate bearing capacity to determine the allowable load carrying capacity of the soil. In the last class I have discussed that we can apply a factor of safety 2.5 or 3 or even we can apply a factor of safety 4 to water bearing capacity, ultimate bearing capacity analysis to get the safe bearing capacity. Now, there is alternate method by which we can determine the, we can apply the factor of safety that is against shear.

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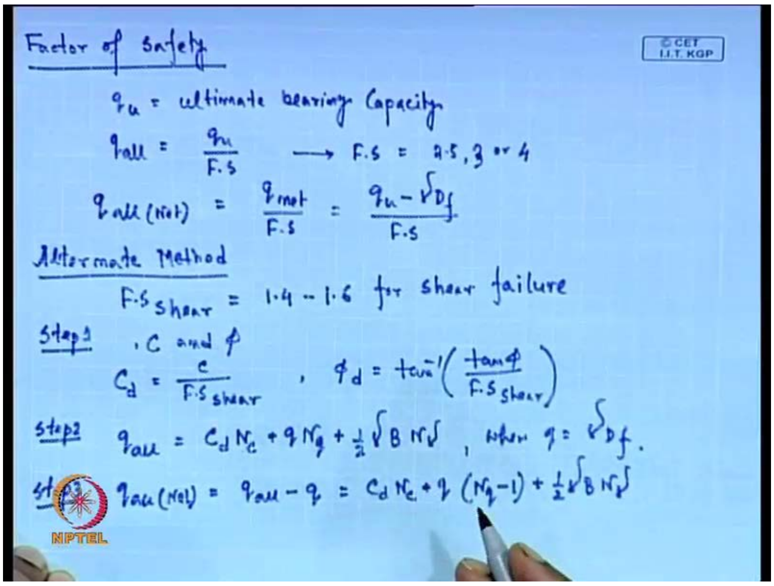

Now, first method that I will discuss that for the factor of safety. So, suppose if u is the, q u is the ultimate bearing capacity of the soil. This is the ultimate, if this is ultimate bearing capacity and then we can get the allowable bearing capacity or the safe bearing capacity by dividing factor of safety in this q, that means q allowable is q ultimate divided by factor of safety. Now, this factor of safety as I have mentioned already that we can take a factor of safety around say 2.5 or 2, 3 or even 4 also we can apply. So, now, and this is 3 and or even 4 we can apply.

Now, sometimes it is recommended that we can apply the net allowable bearing capacity of the soil. That means, that is q allowable in net, it is in practice that most, some of the cases this net allowable bearing capacity is used. That means, in that case this will be the q net divided by factor of safety.

Now, here we can determine the q net is q ultimate minus gamma into D f is factor of safety. So, these are the things that I have already explained. So, how to determine this these D f is the depth of the footing, gamma is the unit weight of the soil. So, this is the net bearing capacity, if we apply the factor of safety then we will get the q allowable net. Now, there is alternate method. So, there is another alternate method is there where we can apply a factor of safety F s against shear. So, generally it is applied this value 1.4 to

1.6 for shear failure. So, which nearly this against this footing load the soil is fail, is failed against shear. So, in another alternate method we are applying this factor of safety against shear. Because in the first method this is where we are applying a overall factor of safety. Say 2.5 to 4 or here we are applying a factor of safety against shear. That is normally 1.4 to 1.6.

Now, how to calculate this things here for the step one, then we can suppose C and phi are the two shear parameters, C is the coefficient of the soil, phi is the friction angle of the soil. Then first we have to modify this C by applying this factor of safety shear. In this process that we have to determine this C d by dividing this C into factor of safety shear. So, C divided by factor of safety again shear.

Similarly, we can determine this phi d that will be tan inverse tan phi against factor safety shear. So, first in this apply, when we are applying this factor of safety, that means, divide this C with this factor of safety against shear and then determine the new phi with tan inverse tan phi factor of safety against shear. Now, in step two when we calculate this q allowable that expression will be C d N c plus q N q plus half gamma B N gamma, Now, where q is gamma into D f. Now, here in place of in the in the Terzaghi's expression that we know that value C N c plus q N q plus half gamma n gamma where C is replaced by this C d and this q is the gamma into D f and when we will calculate these N C N gamma N q from the table of this table that was given in the last class in the Terzaghi's analysis or any other methods that we will, I will discuss later on.

So, where, if we want to find this bearing capacity factor by using those tables, so where those tables are values are given with respect to phi, but when we apply this shear factor of safety against shear then instead of using phi we have to use phi d when we calculate this bearing capacity factor. That means, when we determine the N c N q N gamma then we have to use phi d. That means, corresponding to phi d value we have to determine this N N N q N c and N gamma, this bearing capacity factors. So, then we need not apply any additional factor of safety over overall factor of safety. If we adopt this process then this expression itself will give us the q allowable.

Now, if we want to find in the step three, if we want to find that q allowable net, then just q allowable minus q that will give us the q allowable net, so where this q will give us C d

N c plus q N q minus 1 plus half gamma B N gamma, so in this process. So, there is the two methods, one is where we are applying the overall factor of safety. And one is where we are applying this factor of safety against shear. So, in this two method here we are applying overall factor of safety 2.5 to 4 or 3 2.5 or 3 or 4 or here we are applying the factor of safety against shear 1.4 and 1.6. So, for any expression by using trial and error method we can determine what will be the factor of safety against shear. So, that these two values are same or otherwise these factor of safety value these are the range, but this factor of safety value that we have to use during our design that depends on the side condition the risk of this structure and the importance of the structure. So, those effects are very important.

So, by considering those effect we have to decide how much value of the factor of safety overall or against shear that we will choose. That is the important issues. So, these two methods are written one and two method second method two that we can used to determine the allowable bearing capacity of the soil or net allowable bearing capacity of the soil, during our design.

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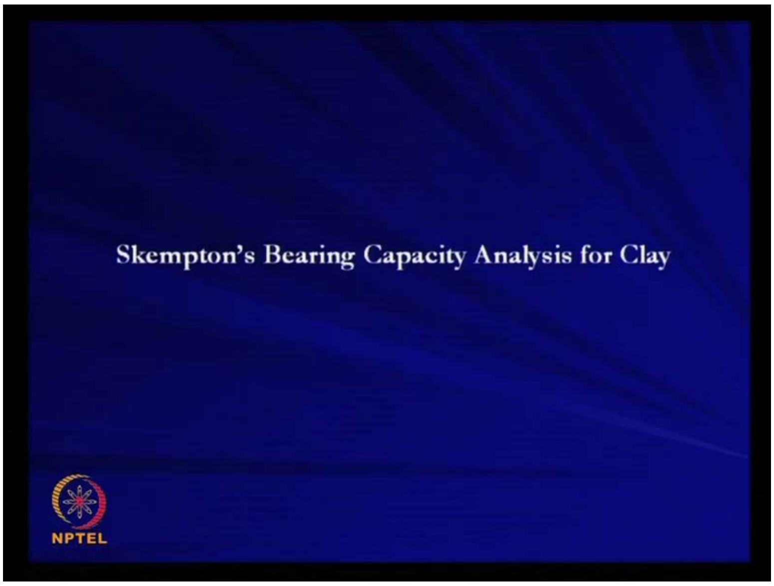

Now, the next one is the Skempton's Bearing Capacity Analysis for the clay because the till now we are discussing about this C phi soil. So, this Skempton's bearing capacity analysis, this is applicable only for clay soil because in Terzaghi's theory that I have already explained that is applicable for N C type of soil or even for purely cohesive soil or purely cohesionless soil. Now, this Skempton's bearing capacity analysis. This is applicable only for clay. Now, these recommendation that is recommended by Skempton's is such that for this Skempton's bearing capacity analysis, This is for bearing capacity analysis. So, this is valid for only for case. So, that is why we can write that here phi 0 phi u is 0. So, this is valid for only clay soil, is purely cohesive soil. So that means, phi u will be 0.

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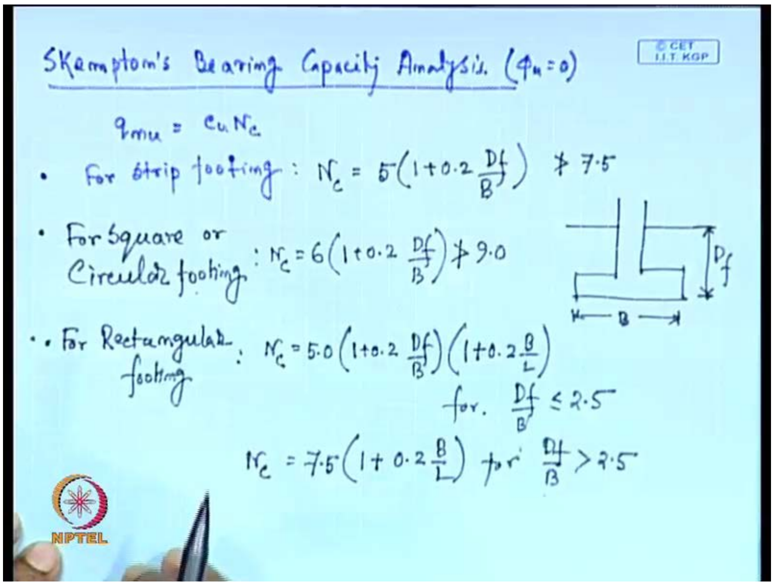

Now, recommendation is that that we can calculate q net ultimate. So, this is q net ultimate by using C u and N c. N c is the bearing capacity factor and C u is the undrained coefficient of the soil. Now, how to these are different cases where we can use this N c value. Now, for the strip footing we can write this N c for that strip footing, this N C value we can write this is 5 into 1 plus 0.2 D f by B and which cannot be greater than 7.5. So, here for the strip footing this N c is 5 into 1 plus 0.2 D f by B where D D f is the depth of the foundation and B is the width of the foundation and that is limited to 7.5. That means, the minimum of these two have to consider. Either if this value is calculated value is greater than 7.5 then we have to consider 7.5. If this calculated value is less than 7.5 then we have to consider this calculated value.

Where we as we know this if this is the foundation then this will be the B width of the foundation and this one will be the depth of the foundation. Now, similarly for square footing, square or circular footing the expression that is given for N c is 6 into 1 plus 0.2

D f by B which is limited to 9. So, here this value is 6 into 1.5 into 2 1 plus 0.2 d f by B which is limited to maximum value 9.

Now, similarly for the rectangular footing this N c value that we will get is 5 1 plus 0.2 D f by B into 1 plus 0.2 B by L for this value D f by B less than equal to 2.5. So, that means, if we will see rectangular footing then for D f by B less than equal to 2.5 we can use this N c expression.

Now, similarly if D f by B is greater than 2.5 then we can use N c value is 7.5 plus 0.2 B by L for D f by B greater than 2.5. So, these are the different cases where we can use this Skempton bearing capacity analysis for the square or circular footing or rectangular footing or this is for strip footing, for the strip footing these expression we have to use which is limited to 7.5, for square or circular footing this N c is this expression which limited to 9, for the rectangular footing if D f by B is less than equal 2.5 then you can use this expression. Now, if D f by B greater than equal to greater than 2.5 then we can use this last expression. Now, once we get this N c from this expression from different cases then by using this q n u value, I mean net ultimate value by using C u and then multiplying this N c with the undrained coefficient of the soil. So, this is Skempton's analysis bearing capacity analysis for this purely cohesive soil.

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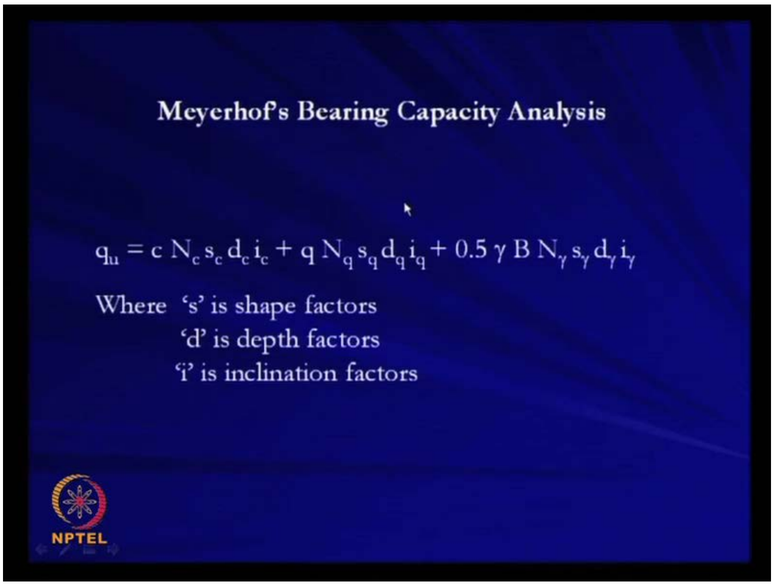

Now, the next one that we will discuss about the Meyerhof's bearing capacity analysis. Now, in this Terzaghi's bearing capacity analysis that it is assumed that this failure surface is extended up to the base of the footing, but in the Meyerhof's analysis it is assumed that this failure surface is extended up to the surface of the ground up to ground surface. So, then the contribution from this above soil above the base of the footing that is also incorporated in this analysis, and another thing that is this Meyerhof's analysis more general in nature because here the difference factor that is the shape of the footing then inclination of loading and then the depth of the footing those things are incorporated in this expression. Because in the Terzaghi's analysis that is for pure of vertical purely vertical loading and where this is a, this which is assumed that we are taking this load surcharge load above the base of the footing. So, it is more or less the surface footing or the footing resting on the ground surface with a surcharge. And then this is the shape different shape because this Terzaghi's analysis that is valid for either strip footing or circular footing or square footing those expressions are available.

Now, for the rectangular footing type of footing those expressions are not available. So, for these consideration the Meyerhof's proposed bearing capacity analysis with these expression this c N c s c d c i c where this s term denotes the shape factors now d which denotes the depth factors and i is the inclination factors. The shape factors where s is the shape of the footing and d is the depth of the footing and i is the inclination, loading inclination of the footing. So, these are the expression. This is for the first term this N c with term, this is for the surcharge term u and this is for the density term. So, these are the different factors.

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Meyerhof's Bearing Capacity Factors

ϕ (degrees)	N_c	N_q	$N\gamma$
0	5.14	1.0	0.0
5	6.5	1.6	0.07
10	8.3	2.5	0.37
15	11.0	3.9	1.2
20	14.8	6.4	2.9
25	20.7	10.7	6.8
30	30.1	18.4	16.7
32	35.5	23.2	22.0
34	42.2	29.4	31.1
36	50.6	37.8	44.5
38	61.4	48.9	64.0
40	75.3	64.2	93.7
45	133.9	134.9	262.8
50	266.9	319.1	874.0

Now, here Meyerhof's bearing capacity factor, these are suggested in this table because the similar expressions are as the Terzaghi has suggested various expression for N c N q and N gamma.

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Meyerhof's Corrections Factors

Factors	Expression
S_c, S_q, S_γ	1 for strip footings
S_c	$1+0.2\frac{B}{L}\tan^2(45^\circ+\phi/2)$
S_q, S_γ	$1+0.1\frac{B}{L}\tan^2\left[45^\circ+\frac{\phi}{2}\right]$ for $\phi>10^\circ$ 1 for $\phi=0$
d_c	$1+0.2\frac{D}{B}\tan\left(45^\circ+\frac{\phi}{2}\right)$
d_q, d_γ	$1+0.1\frac{D}{B}\tan\left(45^\circ+\frac{\phi}{2} \text{ for } \phi>10^\circ\right)$ 1 for $\phi=0$
i_c, i_q	$\left[1-\frac{\alpha}{90}\right]^2$ α in degrees
i_γ	$\left[1-\frac{\beta}{\phi}\right]^2$

α Is the inclination of the of the resultant load from vertical or α=tan (H/V). Where H and V are the horizontal and vertical loads at the base of the foundation.

Similarly, Meyerhof's has also suggested the expression for N q N c and N gamma where N if we can find the, this bearing capacity factors for different phi values for and these things are presented in this table. So, this from 0 to 50 degree angles of this internal friction angle then what will be the N c N q and N gamma value. Then similarly this Meyerhof's correction factor, this is the depth correction, shape correction and the inclination correction, those things are also present presented in this table, where S c S q S gamma is one for strip footing. If it is strip footing these three shape factors are one if S c will be 1 plus 0.2 B by L tan square 45 degree plus phi by 2 where B is the width of the footing, L is the length of the footing and phi is the friction angle of the soil. So, this is the S c value. Similarly by using this expression if phi is greater than 10 degree then S q S gamma we can determine. Now, if phi is 0 then S q and s gamma is 1.

Similarly for the depth factor we can define this d is the depth of the foundation, v is the width of the foundation and we can determine the d c value. Similarly for d q and d gamma value also we can determine for phi equal to greater than 10 degree and for phi equal to 1 this value is 1. Similarly, inclination factor i c i q we can determine from this expression, where alpha is degree and i gamma is can be determined by using this expression, now1 minus alpha by phi whole square.

Now, here alpha is the inclination of that resultant load from vertical. So, that means, the alpha angle is measure from the vertical axis which is the inclination of the resultant load or in other hand alpha can be determined by tan inverse H by V, where H and V are the horizontal and vertical components of the load which is acting at the base of the foundation. So, these there is two components of loading and acting one is horizontal, one is vertical then as the base of the footing then if we know this horizontal vertical components then we can determine this alpha by using this tan inverse horizontal by vertical components of the load or in otherwise, if we know the direction of the resultant force then the angle, this resultant force is making with the vertical axis that is denoted as alpha. So, if we know this thing alpha value and other different properties then the then the dimension of the footing then we can determine this correction factor and by using this table we can corresponding to phi value we can determine the bearing capacity factor and if we know this correction factors and bearing capacity factor then finally, by using this expression we can determine the ultimate load carrying capacity of the soil by considering this shape factor, depth factor, inclination factor of the footing.

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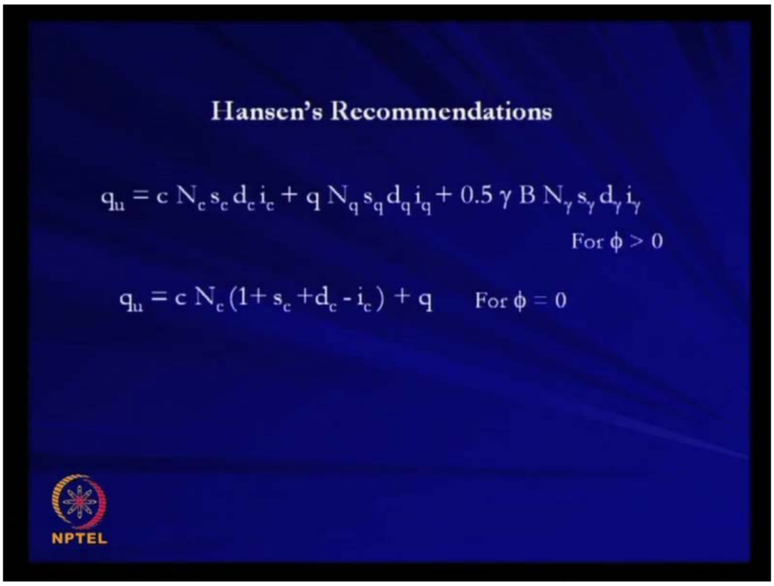

The next one is the Hansen's recommendation which is similar to this Meyerhof's recommendations and where this if phi is greater than 0 then this expressional use where this s d i is the same as shape factor, depth factor and inclination factor. Now, for the if phi is 0 then we can use this expressions, where again s c d c i c is the shape depth and inclination factor. Now, in this Hansen's recommendations is mentioned that the N c and N q these two bearing capacity factor, these are determined similar to the Meyerhof's N c and N q value. That means, by using this Meyerhof's table we can determine this N c and N q for Hansen's analysis also.

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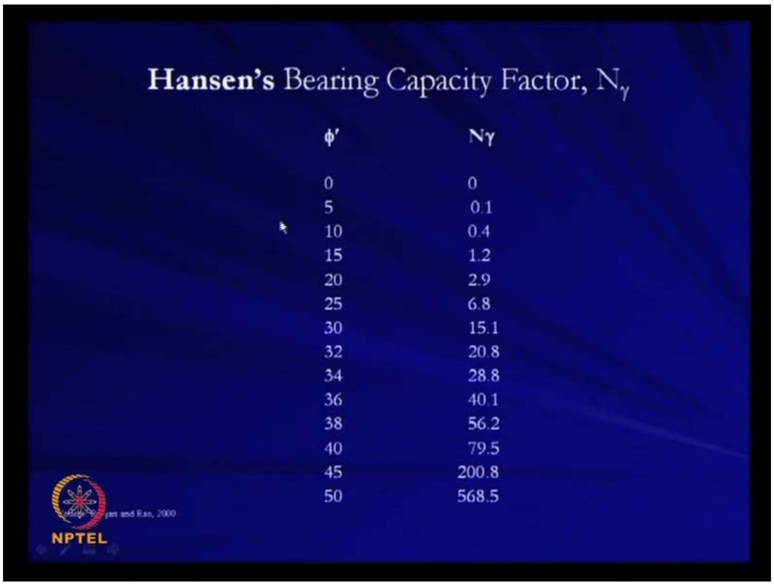

But for this n gamma factor Hansen's has recommended one table, that is to determine this corresponding to the phi value, then we can determine this n gamma factors for different phi value. This is varies from 0 degree to 50 degrees, these are the values of N q. So, by using the Meyerhof's table for Hansen's recommendation we can determine the N c and N q bearing capacity factor and by using this table we can determine the N gamma bearing capacity factor.

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Hansen's Corrections Factors

Shape Factors	Depth Factors	Inclination Factors
$S_c = 0.2 i_c \frac{B}{L}$ for $\phi = 0$	$d_c = 0.4 \frac{D}{B}$ for $D \le B$ and $\phi = 0$	$i_c = 1 - \left[\frac{H}{2BLc}\right]$ for $\phi = 0$; $i_c = 0.5\left[1 + \left\{\frac{1-H}{BLS_u}\right\}^{1/2}\right]$
$S_c = 0.2(1 - 2i_c)\frac{B}{L}$ *for* $\phi > 0$	$d_c = 0.4 \tan^{-1}\frac{D}{B}$ *for* $D > B$ *and* $\phi = 0$; $d_c = 1 + 0.4\frac{D}{B}$ *for* $D \le B$ *and* $\phi > 0$; $d_c = 1 + 0.4 \tan^{-1}\frac{D}{B}$ *for* $D > B$ *and* $\phi > 0$	for $\phi > 0$
$S_q = 1 + i_q\left(\frac{B}{L}\right)\sin\phi$	$dLq = 1 + 2\tan\phi(1 - \sin\phi^2)\tan^{-1}\left(\frac{D}{B}\right)$ *for* $D \le B$; $d_q = 1 + 2\tan\phi(1 - \sin\phi)^2\tan^{-1}\left(\frac{D}{B}\right)$ *for* $D > B$	$i_q = \left[1 - \left\{\frac{0.5H}{V + BLc\cot\phi}\right\}\right]^5$
$S_\gamma = 1 - 0.4 i_\gamma\left(\frac{B}{L}\right)$	$D_\gamma = 1$	$i_\gamma = \left[1 - \left\{\frac{0.7H}{V + Lc\cot\phi}\right\}\right]^5$

Now, this Hansen's correction factor is similar to the bearing Meyerhof's correction factor. This is the table which is presented for the Hansen's correction factors. So, this is for the shape factors, these are the shape factors for phi equal to 0, this is for phi greater than 0, then this is these are the two shape factors S c and this is S q. Now, similarly S gamma, this is similar to depth factor if phi equal to 0 and d equal to less than equal to B and then for phi equal to 0 d greater than B this is the depth factor and if d less than equal to B and phi greater than 0 then this is the depth factor. Now, if D greater than B and phi also greater than B then this is the depth factor D c. Similarly, for D q we can determine by using this expression and for different condition if D is greater than B then this expression, if D is less than equal to B then this expression.

Now, where D is the depth of the foundation B is the width of the foundation and D gamma is 1. Similarly, for the inclination factor also we can determine. This is the inclination factor expression where this H and V these are the horizontal and vertical components of the load that is acting at the base of the footing respectively. And c c is the coefficient and phi is the friction angle of the soil. So, this is the different inclination factor we can determine by using different conditions for Hansen's correction factors. So, if we know the this correction factors for Hansen's and then the bearing capacity factors, then by using these expression of different condition we can determine what would be the ultimate load carrying capacity of the soil.

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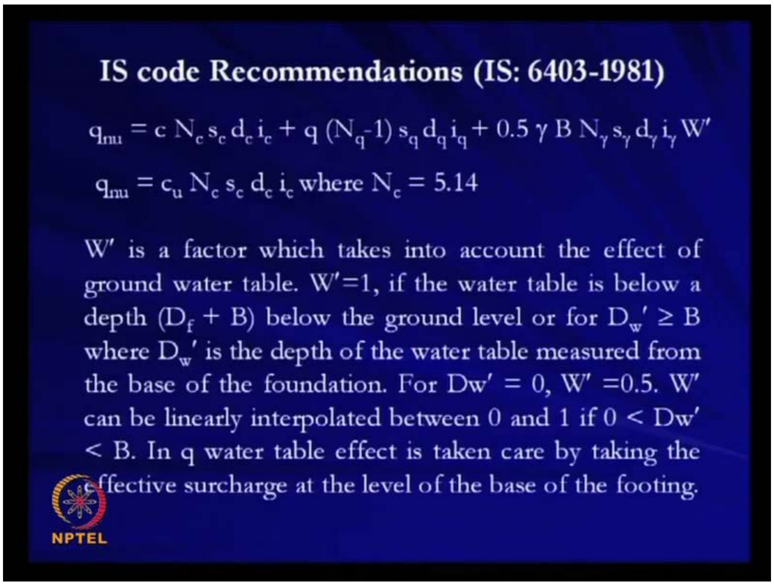

Now, next one is the our I S code recommendation, where I S 6403 or 1981 these are the recommendation that this is similar to the analysis which is presented by Vesic. So, this is the, here we can determine that net ultimate bearing capacity of the soil. By using this expression on the by using this expression we can determine the net ultimate bearing capacity, where previous expression we are getting this ultimate bearing capacity for Terzaghi, for Meyerhof's and for Hansen's. And for the Skempton's analysis also that is also net ultimate bearing capacity. Similar to this one I S code recommendation this is also for net ultimate bearing capacity of the soil.

Now, here one factor this is similar to again this s c d c i c is for shape factor, depth factor and the inclination factor. Now, this expression is for valid for this phi greater than 0 condition, and this expressions second one is valid for phi equal to 0 condition. So, if this is phi equal greater than 0 and this is phi equal to 0 condition, where N c is 5.14 and this is the, at 5 equal to 0 condition, this will be the net ultimate bearing capacity of the soil. Here in this expression this is the one term W dash which takes into account the effect of water ground, water table position. So, this W dash is used for apply the corrections for basically water table. Now, if this water table is below at a depth of D f by B below the ground level. So, where this D f is the depth of the foundation and B is the width of the foundation or D w dash greater than equal to B, if D w is measured from the base of the foundation. Then this W dash is 1, basically if the position of water table is equal to or greater than the width equal to depth which is greater than or equal to width of the foundation. If this depth is measured from the base of the foundation then this correction for water table is equal to 1.

Now, D w dash if this is 0, that means the position of the water table at the base of the foundation, then this W dash is equal to 0.5. Now, if this W dash can be linearly inter interpolated between 0 to 1. So, that means, we can say this W dash is linearly interpolated between 0 to 1 if D w is greater than 0 or less than B. So, in between this because this at the B position this W dash is 1 and 0 position, this W dash is 0.5 so that means, this can be linearly interpolated between this range. Now, then. So, in this by applying this W dash correction we can corrected this terms for the water table.

Now, for the second term this q in q water table effect is taken care into the effect of effective surcharge at the level of the base of the footing. So, when we will. So, incorporate the corrections for the water table if the second term. So, when we calculate the q we have to take the effective overburden pressure q so that we can incorporate the water table effect in the second term also.

In the first term there is no effect of the water table, in the second term incorporate the water table we have to take the effective overburden such pressure of surcharge. When we calculate this q and for the third term we have to depending upon the position of the water table this W dash value also we have to use, that means, if it is the base of the foundation then this W dash is 0.5. If it is at a distance of B from the base of the foundation water table position then W dash is 1 and if it, if it is within that range from the base of the foundation or at a depth of B from base of foundation. Then by linearly interpolated if we linearly interpolate N point these value at the, at one range and to another end, one end to another end. Then we can get the correction for this water table which is located any position from base to at a depth of B from the base below the foundation.

Now, this here when we we have to calculate the N c N q and N gamma because similarly which is which is similar to the Vesic recommendation and the Vesic recommendation it is recommended that N c N q, these two value we can calculate by using Meyerhof’s bearing capacity factor table. So, that means, the N c and N q for the I S recommendation these value are as same as Meyerhof’s bearing capacity factor value or Hansen's bearing capacity factor value, this N c and N gamma, N c and N q these 2 N c and N q.

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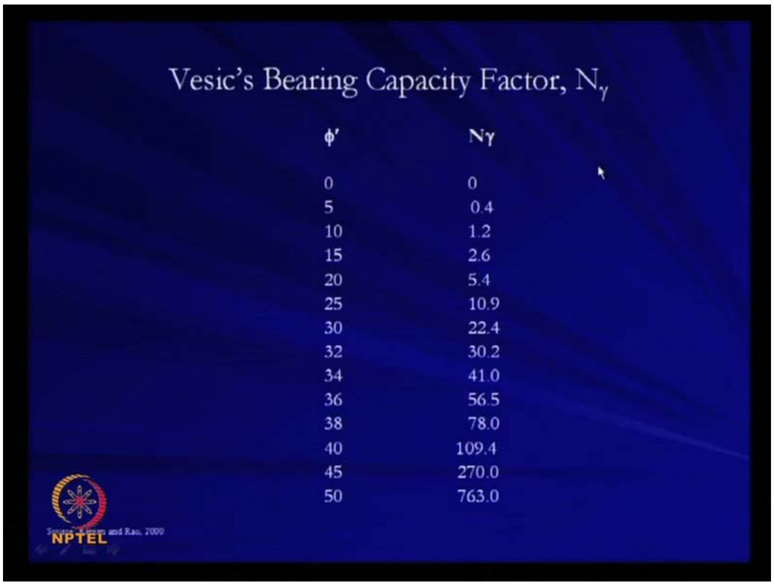

So, here to determine the N c and N q you have to go you can take the help of Meyerhof's bearing capacity table by the, but to calculate the N gamma we have to go for this table we can from this table this is Vesic's bearing capacity factor N gamma by using this table, we can determine the N gamma for value for different friction angle. So, it varies from 0 degree to 50 degree and value varies from 0 to 763.

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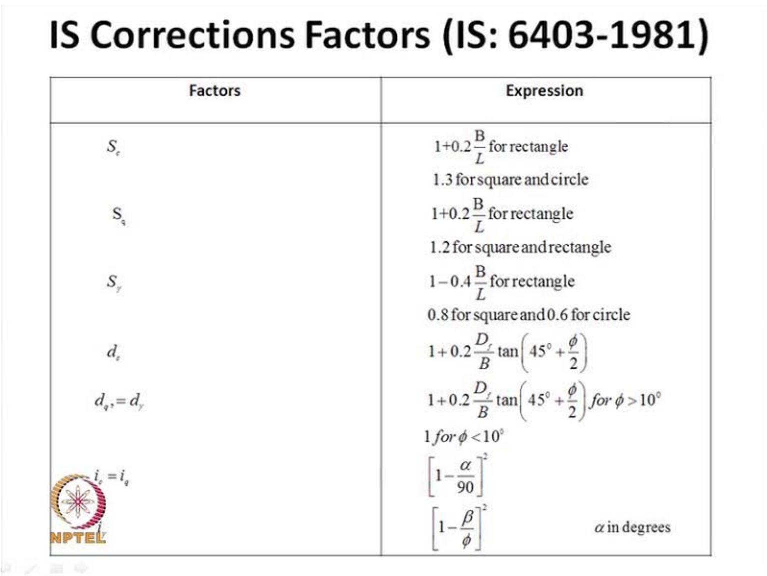

So, by this by using this table we will get the N gamma and by using Meyerhof's bearing capacity factor table we will get N c and N q and by this using this table by as a we can get we will get the I S recommendations corrections factors. So, for the I S correction factors we have to go use this table where we will get the S c shape factors for this rectangle square or circular footings and for the depth factor for different phi conditions and for the inclination factor this alpha is same as the Meyerhof's inclination factors alpha, that means, alpha is the angle making by the resultant load with respect to the vertical axis.

So, in this table we will get the corrections and this table we will get the N q and from the Meyerhof's this table we will get the N gamma and from the Meyerhof's correction factor, bearing capacity factor table. That means, by using Meyerhof's table we will get the N c and N q, so N c and N q N gamma from this Vesic's table. So, if you know this value if you put this on this expression or I S recommendation expression then we will get the net ultimate bearing capacity of the soil.

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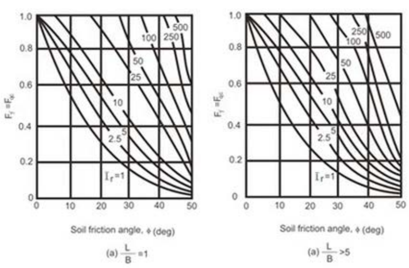
Effect of Soil Compressibility

Variation of $I_{r(cr)}$ with and ϕ B/L

ϕ (deg)	$I_r(cr)$ $\frac{B}{L}=0$	$I_r(cr)$ $\frac{B}{L}=1$
0	13	8
5	18	11
10	25	15
15	37	20
20	55	30
25	89	44
30	152	70
35	283	120
40	592	225
45	1442	482
50	4330	1258

After Vesic

Variation F_{qc} of $F_{\gamma c}$ and I_r B/L ϕ



Now, next section is the effect of soil compressibility. So, we will get this effect of soil compressibility, so how to determine the compressibility effect of the soil in different conditions.

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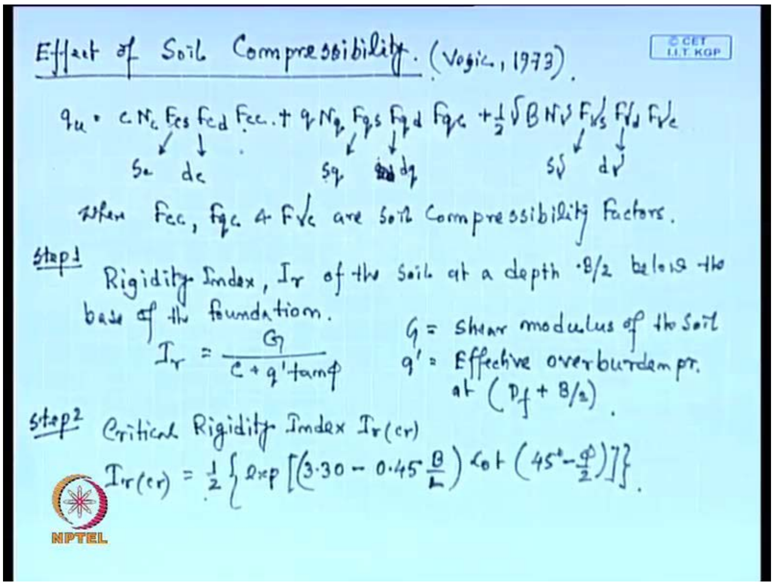

So, first we will go for the effect of this soil compressibility. Now, in when I was discussing about the Terzaghi's bearing capacity analysis. So, that is those analysis is developed initially for the general shear failure then it is modified for the local shear failure. So, that means, this general shear failure and local shear failure condition that depends on the compressibility of the soil. Now, those things we can incorporate in detail for these effect and soil compressibility in this section by this process.

Now, here suppose this is the, its suggested by Vesic in 1973, now our expression is q ultimate that is C N c into F c s F c d or F c c, this F c s basically correction factor for the safe factor that is S c and this is d c and this is the new corrections. So, this F c s is the shape correction factor for shape factor. This is depth factor F d c and F c c is the compressibility factors. So, similarly this is plus q N q F q s F q d F q c plus half gamma B N gamma F gamma s F gamma d and F gamma c. So, similarly here this is S q, this is S d sorry this is d q, similarly this one s gamma and this one d gamma. So, these are the here, I am was I am using F c s which is basically S c that is used in a previous expressions. And this is F c d actually this is d c. Similarly, this is s gamma d gamma S q and d q. Now, where this is new term F c c F q c and F gamma c are soil compressibility factors.

So, those value. So, this S c D c S q d q s gamma d gamma or F c s F c d F q s F q d F s a F gamma d these are the this is correction factors for the shape factor shape factor this F c s F q s F gamma s and this is depth factor F c d F q d F gamma D these shape factor and depth factors we can determine by using the tables or the presented tables for different cases, even for the table is the that I have already shown, from there we can get this shape factor and depth factor, but now the new term this compressibility factors those value we have to calculate for to incorporate the effect of compressibility in the bearing capacity analysis.

Now, first step that calculate we have to calculate the rigidity index I r where I r is the rigidity index of the soil at a depth of B by 2 approximately below the base of the foundation. So, first we have to calculate this rigidity index I r of the soil at a depth of B by 2 approximately B by 2 below the base of the foundation. Now, this expression of I r is given by G by C into q dash tan phi where C and phi are the coefficient and friction angle of the soil respectively. Now, G is shear modulus of the soil and q dash is the effective overburden pressure at D f plus B by 2. So, G is the shear modulus of the soil and q dash is the effective overburden pressure at the depth D f plus B by 2 where D f is the depth of the foundation B is the width of the foundation.

So, point will be somewhere below the base of the foundation at a distance B by 2 from the base. So, now the next step, in the first step we will calculate the I r rigidity index and next step we have to calculate the critical rigidity index. That is, c r critical the expression for I r critical, this is critical rigidity index I r critical will get is the half exponential 3.30 minus 0.45 B by L cot 45 degree minus phi by 2. So, these are the critical rigidity index value or the expressions. So, by using this expression we can determine the critical rigidity of the soil.

For any phi and B by L condition where B is the width of the foundation, L is the length of the foundation. Now, here table is presented in these slide where which is the variation of I r the critical rigidity index with phi and B L. Now from this table we can determine this is the table which is variation of critical rigidity index I r critical with different phi and B L. So, this is the phi value and this is the critical rigidity index value for B L B by L equal to 0 and B by L equal to 1 condition. Now, if B by L is equal to 1. So, these are the critical rigidity index value for different phi values, which is varies from 0 to 50 for 0 it is 8 and for 50 it is 1258.

Similarly, for B by L equal to 0 condition for 0 it is 13 and for 50 degree this is 4330. So, these are the table which is presented to determine the critical rigidity index of the soil otherwise for different B by L condition and phi value, we can use this table to determine these critical rigidity on index or we can determine the expression that I have presented to determine the critical rigidity index.

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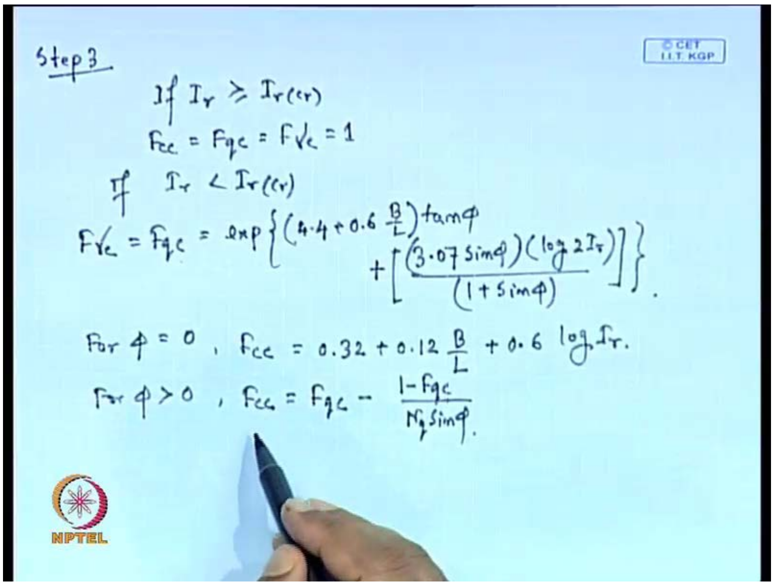

Now, the next step, the step three, in step three now if. So, in the first step we will calculate the rigidity index I r and in the second step by using this table or by using the expression we will determine the critical rigidity index. So, now, if I r rigidity index is greater than equal to critical rigidity index. Then F c c is equal to f q c is equal to f gamma c is 1. Now, if I r critical rigidity index is greater than equal to critical rigidity index then all the compressibility factors are 1. Now, if I r is less than I r c r or rigidity index is less than critical rigidity index then F gamma c is equal to F q c is equal to exponential term into 4.4 plus 0.6 B by L tan phi plus 3.07 sin phi and log 2 I r divided by 1 plus sin phi. So, these are the expression of F gamma c or F q c.

Now, for phi equal to 0 condition F c c is equal to 0.32 plus 0.12 into B by L plus 0.6 log I r. Now, if for phi greater than 0 then F c c is equal to F q c minus 1 minus F q c divided by N q into sin phi. So, now these are the different compressibility factors. Now for different conditions this value will be difference. So, now, if F critical F rigidity index is greater than equal to critical rigidity index, then all the compressibility factors value are

1. Now, if rigidity index is less than critical rigidity index then by using this expression we can determine the F gamma c and F q c. Now, under this head if phi is equal to 0 then F c c will be equal to this expression, by using this expression we will get the F c c value. Now, if phi greater than 0 then F c c will be F q c minus 1 minus F q c divided by N q sine phi. So, so if we…

So, first step we will get the rigidity index and if we know the width of the foundation, length of the foundation then we will get this expression for the phi 0 condition of F c c. Now, phi equal to greater than equal to 0 condition, we should know the value of q c F q c before we can, before we calculate the F c c value. So, for phi equal to greater than equal to 0 condition, we should know the F q c if we want to calculate the F c c value. Now this F q c and F gamma c these expressions for different condition are either I can use this expression or the table that I am going to show you by using this these tables also we can determine this F q c and F gamma c.

Now, this is the table that is presented the variation of F q c. So, in this table these 2 tables that presenting. So, these are the two tables where this is for L by B equal to phi and this is the L by B greater than phi. So, now here this table two tables are presented where this is the soil friction angle, this x axis represent the soil friction angle phi and these y axis represents the F gamma c that is equal to F q c. Now, this lines where these are the value 1 2.5 5 10 25 50 100 250 and 500 this is for rigidity index.

So, now if we know then say suppose a rigidity index of a soil is 25 and L by B is equal to 1 and 5 is 20 degree. Now, for the L by B equal to 1 phi is 20 degree and for L I r or rigidity index 25 or 2.5 this will be the value and corresponding F q c and F gamma c value will be 0.45 something. Now, for the phi equal to 20 and this I r value 25. So, this compressibility factors value will be around 0.95. So, in this fashion for different L by B value and if L by B is greater than phi then we have to use this chart.

Now, if these values are in between then by using linear interpolation we can determine these factors. Similarly for this figure also for this within this value we can determine thus by using linear interpolation to get the high critical. So, either we can use these tables or figures or by using the given expression we can determine the different compressibility factors of the soil. So, if we know the different compressibility factors and then the Vesic expression from the table we can determine the bearing capacity factor N c N q N gamma and by compressibility factors by using this expressions or the tables or figures and this others factors that is correction factors of this shape factors or depth factors that those we can calculate or determine from the table that is presented in this class.

So, from these things, from these tables or figures or expressions we can get all the parameters and then if we put it in the general expression then we will get the ultimate bearing capacity of the soil that will incorporate the effect of compressibility of the soil. So, in the next class that I will explain the different other conditions that is for because till now we have explained the we have mentioned that the loading is acting at the center of the footing, although it may be inclined or vertical, but is acted at the center of the footing, but if it is not acting at the center of the footing or if there is any movement we are not talking about the movement. So, if the is there any movement in the loading condition or then what will be the bearing capacity value. So, those things different cases that I will explain in the next class,

Thank you.