Advanced Foundation Engineering
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Lecture - 6
Shallow Foundation: Bearing Capacity-I

Hello, today I will start the second lecture of this module two that is on shallow foundation. Now, as I have already discussed that the bearing capacity and the settlement are the two main design criteria of a shallow foundation. So, that means the the soil the bearing capacity of the soil should be such that that it is adequate to carry the load that is coming from the super structure as well as the settlement should be within permissible limit. Now, today in this lecture, I will discuss about the bearing capacity how to calculate the bearing capacity of a shallow foundation.

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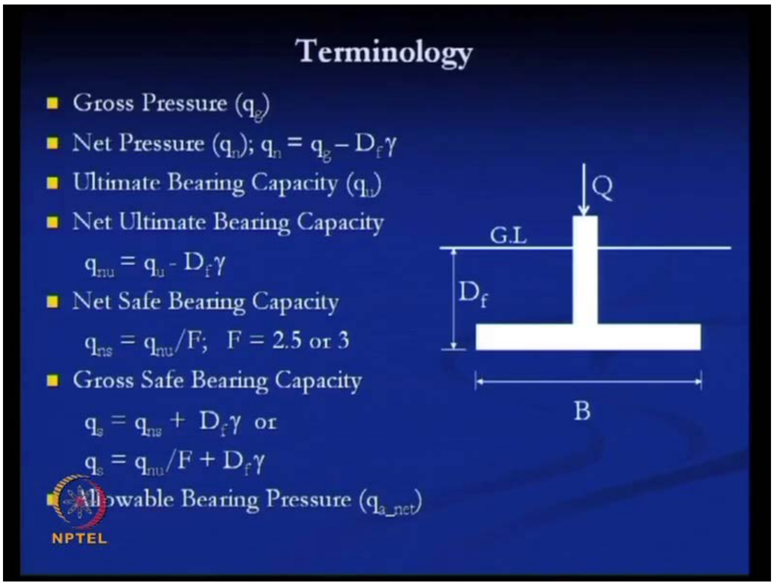

Now, first before I go to this calculation or the analysis part, I should discuss some terminology of this bearing capacity that first one is the gross pressure. Suppose this is the foundation, and this is the ground level and D f is the depth of foundation and B is the width of the foundation; and then this gross pressure is the pressure that is coming at the gross pressure that is coming at this base level of this foundation that means, the pressure that includes the load that is coming from the super structure, the self-weight of this foundation and the weight of the soil.

Now, next one is the net pressure as the settlement the soil will settle after because of this net pressure because this soil pressure is already existing in this soil because then we have to remove this soil, then then we place this soil. So that means, at the base of this foundation the pressure that is coming from due to this soil is already there. So, the settlement will start or this after due to this net pressure, that means, net pressure is the gross pressure minus the pressure that is coming due to this soil. That means, the if q g is the gross pressure then the net pressure will be q g minus depth of the foundation into the unit weight of this soil.

Let the ultimate bearing capacity of the soil, the ultimate bearing capacity of the soil that is the the ultimate load that this soil can carry before it fails. So, that means, this is the ultimate load carrying capacity of the soil. So, if we notice the q u for which is the ultimate bearing capacity of the soil. Next, will be the net ultimate bearing capacity of the soil. So, that means, the same again the net ultimate bearing capacity would be the ultimate bearing capacity of the soil minus D f into gamma where gamma is the unit weight of the soil then when we will get the ultimate bearing capacity and the net ultimate bearing capacity of the soil then we have to go for the net safe bearing capacity and or gross safe bearing capacity. For this net safe bearing capacity we have to apply a factor of safety, here F is the factor of safety that F varies either F will be either two point five or three.

So, if we divide this net ultimate bearing capacity by this factor of safety then we we can calculate the net safe bearing capacity of the foundation or the soil. Now, the gross safe bearing capacity similar as the if the net safe bearing capacity is n s then the gross safe bearing capacity will be n s plus D f into gamma. Now, again this will be n u divided by F plus gamma u. Now, the next one is the allowable bearing pressure. Now, as I have discussed that from the bearing capacity consideration basically we will get the two pressure. One is the bearing capacity consideration that the the net load that maximum load that soil can carry before it fails. So, that means that term will get the net safe bearing capacity and we have to apply the factor of safety there. So, we will get the get the net safe bearing capacity and from the settlement consideration we will get another pressure. That means that pressure is. So, that is within the permissible settlement. That means, if we apply that that pressure within the soil then settlement of that foundation will be within that permissible limit.

So, that if there is a permissible limit for the settlement that is a, that is corresponding that pressure is called the pressure for or the that is the maximum pressure the soil can carry for that settlement consideration. So, there is basically two criteria, one is settlement consideration another is bearing capacity consideration. So, that means, bearing capacity consideration that net safe bearing capacity. That means, it is a net safe bearing capacity of the soil and then another is the pressure that cause the maximum permissible limit. So, minimum of these two will give us the allowable bearing pressure that is q allowable net. So, one is from the net safe bearing capacity wherin bearing capacity consideration another is the we mean the that settlement consideration that the minimum of these two bearing and the settlement that will give us the allowable bearing capacity bearing pressure.

So, now. So, these are the different terms that we will use for this analysis. Now, there are now we have to calculate the bearing capacity of the foundation. The first expression that I will the analysis I will I will explain that is given by the Terzaghi. So, that means, this is the Terzaghi's Bearing Capacity Theory.

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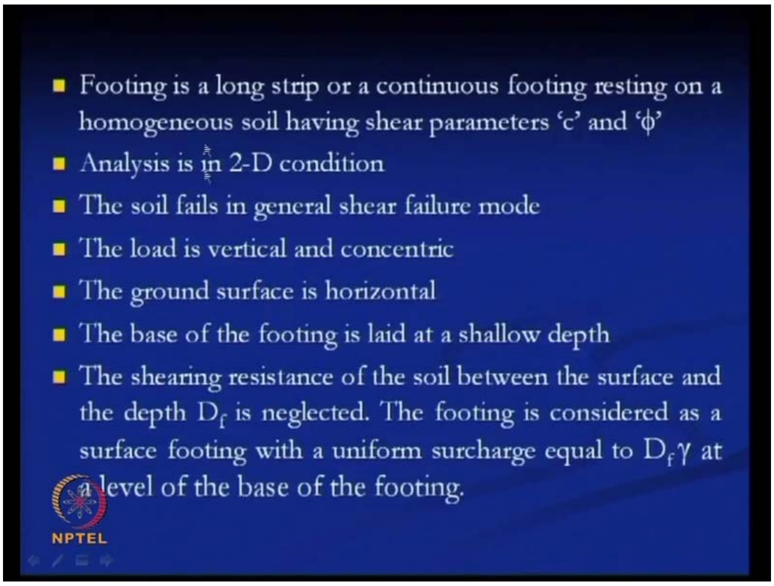

Now, Terzaghi proposed this bearing capacity theory. So, it is, this is the this bearing capacity theory. So, there is the some assumptions are there. So, before we start this analysis part or the bearing capacity analysis part, we will go for this assumptions or the that means, the footing is loaded, footing is a long strip or continuous footing resting on a homogeneous soil having shear parameters c and phi. So, that means, the soil is homogeneous with shear parameter c and phi and it is a strip footing or continuous footing. Now, as this is the strip footing or continuous footing. That means, the analysis is 2D analysis. Now, soil fails in general shear failure. So, last class I have discussed the different types of failure. One is general shear failure then the local shear failure and the punching shear failure. Now, this particular analysis of Terzaghi Bearing Capacity Theory is valid for the general shear failure for this one.

Now, the the load is vertical and concentric, the ground surface is horizontal, the base of footing is laid at a shallow depth. Now, this is for the shallow foundation. So, that means, this is the base of the footing laid at the shallow depth. Now, shearing resistance of the soil between the surface and the depth of footing D f is neglected. So, the footing is considered as a surface footing with uniform surcharge equal to depth of footing into unit weight of the soil at a level of the base of footing. So, the the resistance coming from the the soil that is within between the surface ground surface and the base of the footing is basically neglected, in place of that the it is considered that one surcharge that is equal to the pressure that is coming due to that soil part is acting at that base level.

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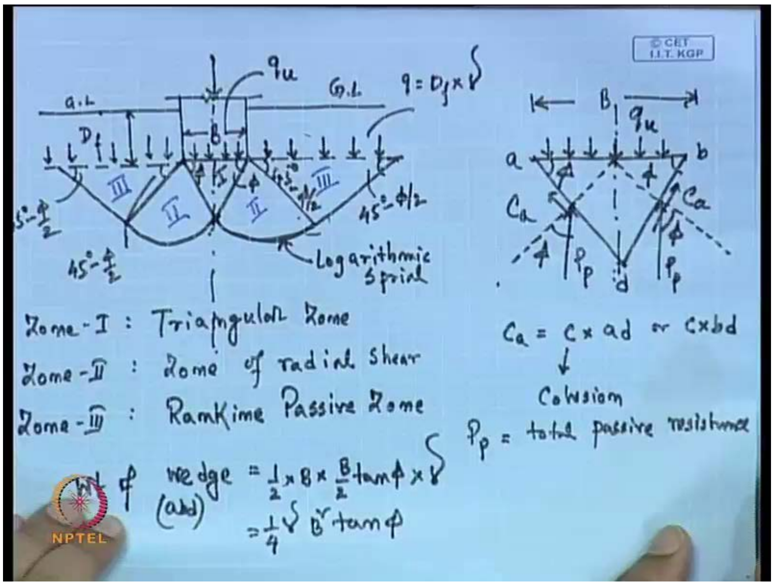

So, now if we go for this Terzaghi Bearing Capacity part now, if we draw the failure surface for this. Suppose, this is the ground surface and this is the foundation width say. So, this is ground level now where width is B, B is the width of the footing and this is the base level of the foundation. Now, this depth of foundation is D f, D f is the depth of foundation, B is the width of foundation and say we are talk calculating this pressure that is acting of the base of the foundation that is this pressure is q u. That means ultimate bearing capacity of this soil; so q u that is the ultimate load that this footing can carry. So, now as in the first assumption this is the footing is the strip footing. So, that means, this is the 2D analysis.

Now, soil fail in general shear failure, now load is vertical. So, that load that is applying this is the vertical and concentric that means it is centrally loaded. Now, suppose this is the center line. Now, base of the footing laid is the shallow depth. So, D f is the shallow depth and the shearing resistance. So, as I have mentioned the shearing resistance of the soil between this zone that means, the ground this is also a ground level ground level in the base of soil base of the footing is neglected. So, in place of that it is assumed that this the load, that means, the total pressure that is acting in this point or the base of the foundation that will be equal to q, that will be gamma D f into gamma where D is the depth of foundation and gamma is the unit weight of the soil. So, that is the pressure that is acting at the foundation base level.

If we draw the failure surface that is assumed for this analysis that is general shear failure. So, this is the triangular portion, then there is a logarithmic spiral and then it is a straight portion. Similarly, here this triangular portion, then logarithmic spiral portion and the straight portion. So, this is the failure surface that is considered for this analysis. Now, basically in this this is the symmetric. So, this part, so we can say it is a three zone. So, the first zone or we can say this is three zone, this is first zone. Now, this is second zone this is also second zone and this one is the third zone.

So, three zones are there. So, one is this triangular portion this is the first zone. So, zone one this is called the triangular zone. Now, similarly zone two this is called zone of radial shear. Now, the zone three is Rankine Passive Zone. So, there is a three zone one is, first zone is triangular zone, this this triangular part. The second zone is zone of radial shear from this zone and this zone and third zone is the Rankine Passive Zone.

So, now the angle which is considered for this analysis, that means, this angle is 45 degree minus phi by 2 where phi is the friction angle of the soil. Now, this is also 45 degree minus phi by 2. Similarly, this angle is also 45 degree minus phi by 2 and this angle is also 45 degree minus phi by 2. Now, this angle is considered phi and this angle is also consider as phi. So, now here this portion this part is logarithmic spiral part, it is considered. This is logarithmic spiral in the straight portion. So, triangular part then the logarithmic spiral then the straight portion. So, this straight portion is passive Rankine Passive Zone, this angle is 45 minus phi by 2 and this angle is also 45 minus phi by 2. Similarly, these two angles are 45 minus phi by 2. In the triangular part this angle is phi, this angle is also phi.

Now, if I draw this free body diagram of this triangular portion. So, if I draw this free body diagram of the triangular portion. So, here we can say this is a, b and d. So, and this is the center line and this is the width of the footing that is B. So, this triangular portion we are drawing here and this load that is acting that will be q u ultimate bearing capacity or load carrying capacity. So, I have this considered this angle is phi and this angle is also phi. Now, here a d and b d act as a rough back of the rigid wall. Suppose, it is considered here a d and b d, it acts as a rough back of rigid wall. So, where the c and the phi this two parameter c and phi are the equivalent of the wall addition c is equivalent to the this wall addition and phi is equivalent to the angle of wall friction.

So, now for this mean that suppose this is the free body diagram and this is the perpendicular line, perpendicular to this a d and perpendicular to b d. So, this dotted line. So, the perpendicular line perpendicular to a d and perpendicular to b d. Now, here that is the P p, P p is the passive resistance that is coming from this zone 2 and 3. So, that means, this portion resistance in this triangular portion is coming from this zone two and these two other zones and so, this is the passive resistance that is coming from this zone that is a P p, P p is the passive resistance. So, which is acting at an angle phi with this vertical line?

Similarly, here also P p is acting at a angle phi and this C a. So, because as now this phi is equivalent to this wall friction angle; so now, P p is acting as a angle of phi with this perpendicular line of this wall. Similarly, here also P p is acting as a angle phi the perpendicular line of this wall.

Now, this C a is the addition that is acting for a d and b d line. So, where C a is the addition it is acting this two line. Now, we can say this C a that is equal to C into a d or C into b d where C is the addition. So, similarly C will be the cohesion and P p is equal to the total passive resistance. So, P p is the total passive resistance that is acting here. So, this is the passive resistance, C is the cohesion. Now, in this figure if we calculate the weight of this triangular portion, that means, weight of wedge this triangular portion a b d, if you want to calculate the weight. So, that weight will be this is the half the area this means this is the B and then this height.

Now, this height is basically B by 2 into tan phi. So, with this base of this triangle is B height is B by 2 into tan phi and then the unit weight of the soil. So, this will be the weight. So, finally, we can write 1 by 4 gamma B square into tan phi. So, this is the weight of this triangular wedge. The next we have to calculate the different components of this triangular wedge. So, if we take the different components then we can write. So, if we take this figure again we can see.

So, there is a in the vertical direction if we take the different components. So, one is P p that is acting in the upward direction, then q u it is acting in the downward direction, then addition it has one component in the upward direction and one component in the horizontal direction. Similarly, here also one component in the upward direction, and one component in the horizontal direction.

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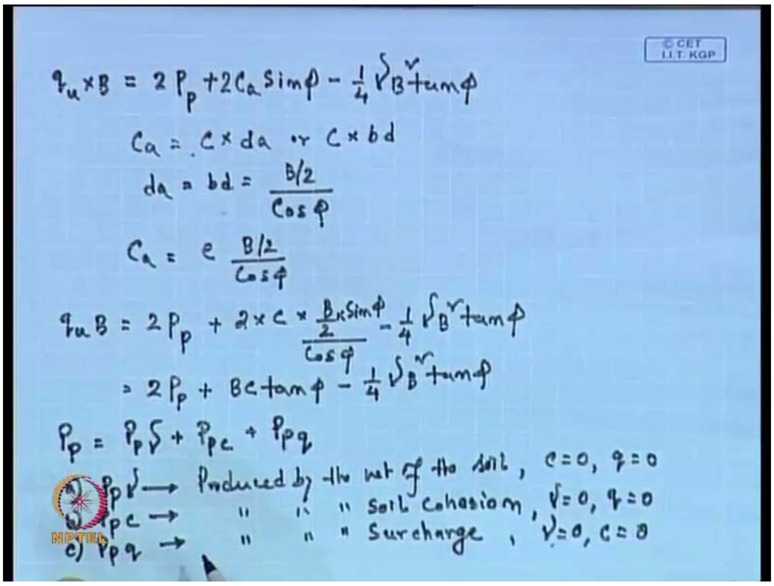

So, if we take these vertical components of the all the forces then we can write let q u into B. So, q u is the total load that is acting in the downward direction that will be equal to it is the load bearing capacity of the soil, that means, two P p this passive resistance both are acting in the upward direction plus C a this addition in the vertical component this C a into sin phi as it is acting in the both the sides. So, this will be two into C a into sin, sin phi sin phi we multiply with this a, we will get the vertical components; then this weight of this edge that is acting. So, this is the passive resistance component, this is the ultimate load carrying capacity of the bearing capacity of the soil and this is the addition components and this weight of the wedge that is acting in the downward direction.

So, this this this will be minus 1 by 4 gamma B square into tan phi. So, these are the total forces here this these two this one and this one was acting in the downward direction and this P p and this C a components this is acting in the upward directions. So, now we can see now here as we have mentioned that C a is equal to C into d a or C into b d. Now, from this figure we can write this d a is equal to b d that will be equal to B by 2 divided by cos phi. So, here in this figure we can write this d a as this height is d by two into tan phi similarly this side a d or b d is B by 2 divided by cos phi. So, we can replace this value here in the C a. So, we will get C a is equal to C into B by 2 divided by cos phi. Now, if we put this C a value here in this equation. So, this will be q u into B equal to 2 P p plus 2 into C into B divided by 2 divided by cos phi minus 1 by 4 gamma into B square into tan phi.

So, further simplify we can get this two P p plus B into C there is another term here that is sin phi because this is two C a is replaced by C into B by 2 cos phi and sin phi is there. So, this two two cancel. So, this will be this B C into sin phi by cos phi this will be tan phi, so minus one fourth gamma B square into tan phi. So, now just consider this P p, this total passive resistance it has three components basically. So, this P p is the summation of P p gamma plus P p C plus P p q. So, these resistance are coming from three parts one is for the weight of the soil this gamma C is due to the cohesion and q is due to the surcharge. So, that surcharge we have considered here for this part. So, this q is the surcharge that we have considered here. So, that means, this q that is replaced the surcharge, that means, gamma D f D f into gamma.

So, now here P p will get this P p gamma that will get. So, first component is P p gamma. So, this is produced by the weight of the soil in which it is assumed the soil is cohesionless and negligible surcharge. So, this is the contribution because of the weight of the soil this is produced by the weight of the soil in shear zone and it is assumed that soil is cohesionless, that means, C is equal to 0 and negligible surcharge. So, q is also equal to 0. So, that q and C both are 0 in this condition the resistance that is produced by the weight of the soil is called as P p gamma. Second one, this second resistance this is P p C which is the produced by the soil cohesion, this is produced by the soil cohesion assume that this soil is weightless and negligible surcharge. So, assuming that weightless soil and negligible surcharge.

Similarly, the third component that is P p q it is also produced by the surcharge assuming that the soil is weightless and also cohesionless. So, here in this third condition soil is weightless and cohesionless that contribution due to the surcharge is called P p gamma.

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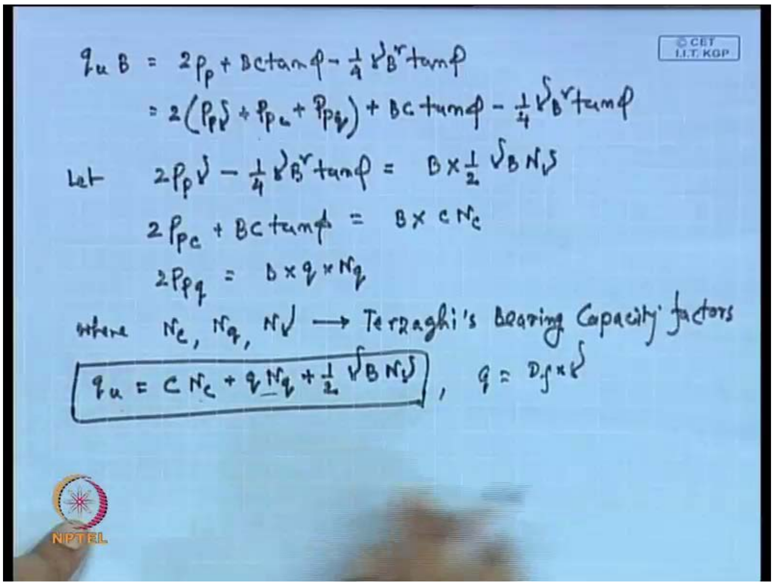

So, now if we put this value in the final expression, so our expression was q u B is equal to 2 P p plus B C into tan phi minus 1 by 4 gamma B square into tan phi. So, if P p is the summation of three parts. So, if we replace this equation by this is two P p gamma plus P p C plus P p q plus B C into tan phi minus 1 by 4 gamma B square into tan phi

Now, let we consider that two P p gamma minus one by four gamma B square tan phi is equal to B into half gamma B N gamma. So, we replace this term two P p gamma minus 1 by 4 gamma B square into tan phi by this expression B half gamma into B into N gamma and two P p C plus B C into tan phi is replaced by B into C N c where C is the cohesion, arrange two P p q is replaced by B into q into N q. Now, where this N c N q N gamma these are Terzaghi's Bearing Capacity factor. So, this is the Terzaghi's bearing capacity factors. So, finally, if we write this, replace this expression by these terms then the final expression will be q u. So, if we put this, in these expressions. So, this will be q u is equal to C N c plus q N q plus half gamma B N gamma. So, where C is the cohesion of the soil, N c is the bearing capacity factor Terzaghi Bearing Capacity, q is we can write that q is equal to gamma D f if D f into gamma.

So, gamma is the unit weight of the soil and this is half B is the width of the foundation. So, this is the three components. So, three parts this is the contribution due to the cohesion, this contribution due to the surcharge and this is the contribution due to the weight of the soil. So, ultimately this is the final expression where we will get the ultimate load carrying capacity of the foundation. So, this q u is the ultimate load carrying capacity of the foundation that is q u equal to C N c plus q N q plus half gamma B N gamma.

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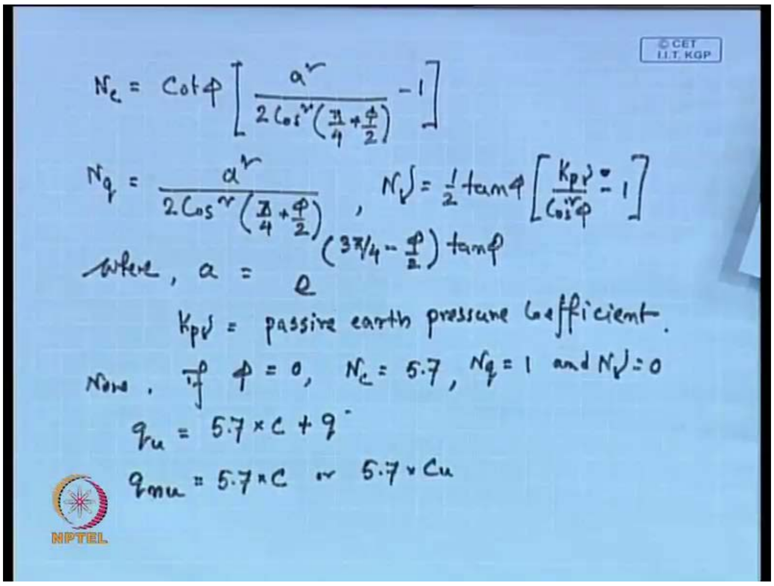

Now, where we can write this terms, this bearing capacity terms that we can write that N c Terzaghi has given this bearing capacity factors value this is cot phi into a square divided by 2 cos square pi by 4 plus phi by 2 minus 1, this is N c. Similarly, N q would be a square divided by 2 cos square pi by 4 plus phi by 2 and N gamma you can write this is half tan phi K p gamma minus K p gamma divided by cos square phi is total minus 1. So, where this a is equal to e to the power 3 pi by 4 minus phi by 2 into tan phi and K p gamma is equal to passive earth pressure coefficient. So, this is passive earth pressure coefficient.

Now, if phi is equal to 0, then N C will be 5.7, N q will be 1 and N gamma will be 0; so from this expression we can write q u will be N C 5.7 into C plus N q part is 1. So, into q and the N gamma part is 0. So, this is the ultimate load carrying capacity of the soil and then q net ultimate that will be q ultimate minus q. So, this will be 5.7 into C or 5.7 into C u and then correlation of the soil. So, now by using this expression we can determine what will be the this load varying capacity of this soil or this foundation. Now, this is the basic expression. This expression now where C q gamma B these we can this gamma is the unit weight of the soil.

So, B is the width of the if we know this. So, from this expression we can see this bearing capacity of the soil, this depends on the soil property that is C and phi of the soil, then this surcharge of the depth of the soil, depth of the foundation and width of the foundation, that means, the geometry of the foundation then the soil properties also. So, now this is the basic expression which is derived for the vertical and concentrating loading condition, it is for homogeneous soil and so, this is simplified expression. So, now, in the next lecture I will discuss about the different condition the general type. So, for incline loading or for if if there is a moment is there then how we will determine this bearing capacity.

So, this is the simple expression that we can use. So, here one thing that this N C N q N gamma expressions are given, because this are the N C N q N gamma expressions. So, by using this expression we can calculate the this bearing Terzaghi's Bearing Capacity factors for different see different phi values. Now, Terzaghi has also proposed or given this bearing capacity factor in a tabular form for different phi values. So, that expression values are given here.

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Terzaghi’s Bearing Capacity Factors

ϕ	N_c	N_q	N_γ^a	ϕ	N_c	N_q	N_γ^a
0	5.70	1.00	0.00	26	27.09	14.21	9.84
1	6.00	1.1	0.01	27	29.24	15.90	11.60
2	6.30	1.22	0.04	28	31.61	17.81	13.70
3	6.62	1.35	0.06	29	34.24	19.98	6.18
4	6.97	1.49	0.10	30	37.16	22.46	19.13
5	7.34	1.64	0.14	31	40.41	25.28	22.65
6	7.73	1.81	0.20	32	44.04	28.52	26.87
7	8.15	2.00	0.27	33	48.09	32.23	31.94
8	8.60	2.21	0.35	34	52.64	36.50	38.04
9	9.09	2.44	0.44	35	57.75	41.44	45.41
10	9.61	2.69	0.56	36	63.53	47.16	54.36
11	10.16	2.98	0.69	37	70.01	53.80	65.27
12	10.76	3.29	0.85	38	77.50	61.55	78.61
13	11.41	3.63	1.04	39	85.97	70.61	95.03
14	12.11	4.02	1.26	40	95.66	81.27	115.31
15	12.86	4.45	1.52	41	106.81	93.85	140.51
16	13.68	4.92	1.82	42	119.67	108.75	171.99
17	14.60	5.45	2.18	43	134.58	126.50	211.56
18	15.12	6.04	2.59	44	151.95	147.74	261.60
19	16.56	6.70	3.07	45	172.28	173.28	325.34
20	7.69	7.44	3.64	46	196.22	204.19	407.11
21	18.92	8.26	4.31	47	224.55	241.80	512.84
22	20.27	9.19	5.09	48	258.28	287.85	650.67
23	21.75	10.23	6.00	49	298.71	344.63	831.99
24	23.36	11.40	7.08	50	347.50	415.14	1072.80
25	25.13	12.72	8.34				

* From Kumbhojkar (1993)

So, here we can see this is the Terzaghi’s bearing capacity factors this is the table for different phi’s starting from 0, 0 this is what as I have mentioned for the 0 this is phi value this N C is 5.7 and Nq is 1 and N gamma is 0. So, it starts from 0 to 50 degree; so corresponding N C value N q value N gamma value; so these values are given. So, by using these charts we can determine. So, if we know the geometry of this foundation and width of the foundation then the depth of the foundation and we know those if we know the soil properties then by using this table we can determine this bearing capacity factor then we can use this bearing capacity factor in this our general expression and then we can calculate the ultimate load bearing capacity of this foundation.

Now, another thing is given that this expression that is derived is valid for general shear failure. So, that are mentioned. Now, if soil fails in local shear failure then how to incorporate those effects in these expressions. Now, that is also possible in these expressions.

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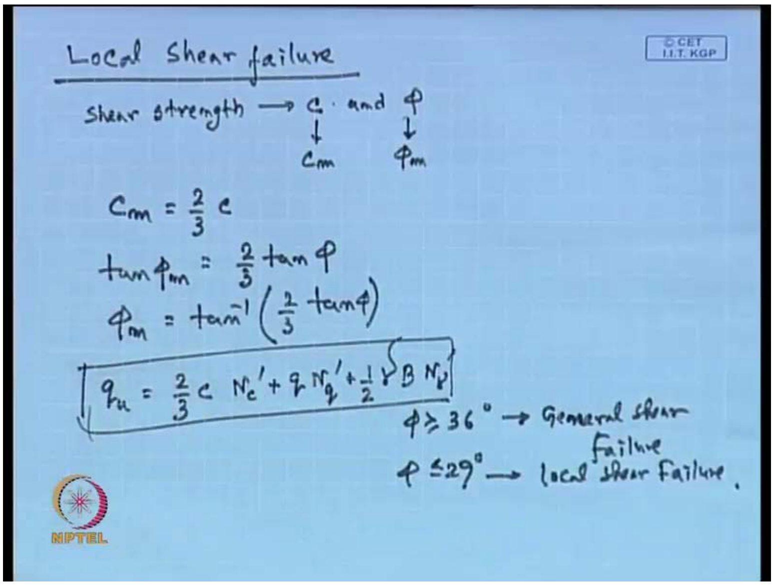

So, suppose this is for the for the previous one was for the general shear failure and this is for local shear failure. Now, local shear failure Terzaghi's as recommended that the shear strength parameters, this parameter which is C is converted to C m and phi is also converted to phi m. Now, how this? So, this is this C is for cohesion for the general shear failure and C m is the cohesion for local shear failure and phi is the cohesion friction angle for general shear failure and phi m is the friction angle for local shear failure.

Now, how to convert this thing? Now, C m will be two third of C and tan phi m that will be equal to two third of tan phi. So, phi m value, it will be tan inverse two third of tan phi. So, now, in place of phi and C you have to use this phi m and C m when we calculate the load bearing capacity of the soil in case of local shear failure. So, now, we have to use this expression in case of local shear failure, that means, q u ultimate this will be two third of C N c dash plus q N q dash plus half gamma B N gamma dash. So, let this N c dash N q dash N gamma dash are the bearing capacity factors in case of local shear failure whereas, whereas, N C N q N gamma is where the bearing capacity factors for general shear failure. So, this N c dash N q dash N gamma dash are determined using the same expression, but you have to replace phi by phi m and then we can determine this N c dash N q dash N gamma dash by suing the same expressions.

Here also Terzaghi's has given this N c dash N gamma dash N q dash values in a tabular form. So, here, so this is the Terzaghi bearing capacity factors under this local shear failure where this is the phi value from 0 to 50 degree. So, corresponding phi value what will be the value of N c dash, N q dash and N gamma dash. So, these values are given here. So, if you know the phi value and if the soil fails in local shear failure then we need to use N c dash, N q dash, N gamma dash instead of N C N q and N gamma. So, here we will get the different value of N c dash N q dash and N gamma dash. Now, generally it is observed that if phi is greater than equal to 36 degrees then it indicates that this is general shear failure and if phi less than equal to 29 degrees then it is local shear failure.

So, if soil fails in general shear failure or if it is a dense soil or strip then we can use this previous expression for the general shear failure and if soil fails in local shear failure, then this medium dense or moderate sign then we have to use this expression we have to convert this C to C m and phi to phi m then we have to use this expression. So, this final expression is for the local shear failure.

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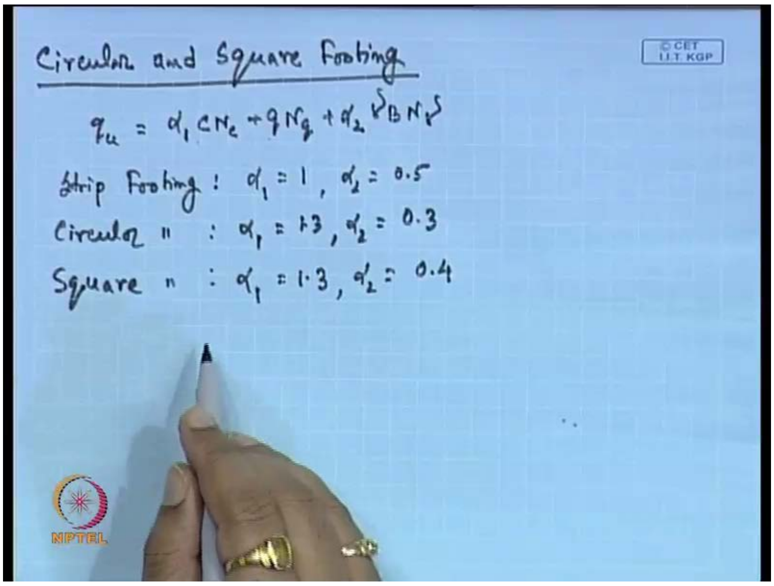

Now, the next thing is that these expressions are derived for strip footing. So, these expressions are derived for the strip footing. Now, if soil this footing is circular and square footing then also we can use this expression, but with some modifications. So, Terzaghi has recommended that how we will use, because these expressions general expression is valid for the strip footing. So, how we will use this expression for the circular footing or square footing? Now, if the so that the general expression for any type of footing. So, we can write this is alpha 1 C N c plus q N q plus alpha 2 gamma B N gamma. Now, as I have already mention that for the strip footing this alpha 1 is equal to 1 and alpha 2 is equal to 0.5 fine now for the circular footing this alpha 1 is equal to 1.3 and alpha 2 is equal to 0.3.

So, alpha 1 is 1.3 and alpha 2 is 0.3 now. So, for the square footing alpha 1 is also 1.3 and alpha 2 is equal to 0.4. So, for the square footing the expression will be 1.3 C N c plus q N q plus 0.4 gamma B N gamma. So, N q N c N gamma values that we will get from this table if we know the phi value. So, here also for different other type of footing the circular square we can use this expression also. Now, one thing that in these expressions that we have derived, I have derived so in this expression we have not considered the effect of water table. So, that effect we have to consider here.

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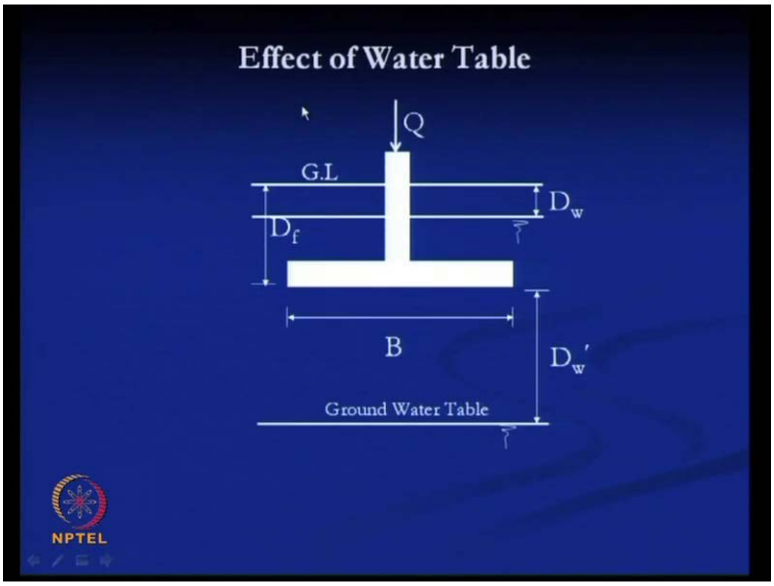

Now, here see if we take the effect of water table suppose this is the footing with width is B and depth is D f. Now, these are the position of water table suppose this is the. So, water table can be above the base of footing or below the base of footing. So, there now we have taken the different we will consider the different cases where we put this water table. So, that can be above the base of footing. So, this is the position of the water table. Well, that can be below the base of footing. So, this is the base of the footing that can be below the base of the footing.

So, this is the another position of the ground level. So, here this ground level we can look we can look at this ground level at distance of D w from the ground level and if it is below the base of the footing then we can look at this ground level position by D w dash is measured from the base of the footing. Now, we will consider the different cases. Now, for the first cases or first case now here we consider that above this soil level.

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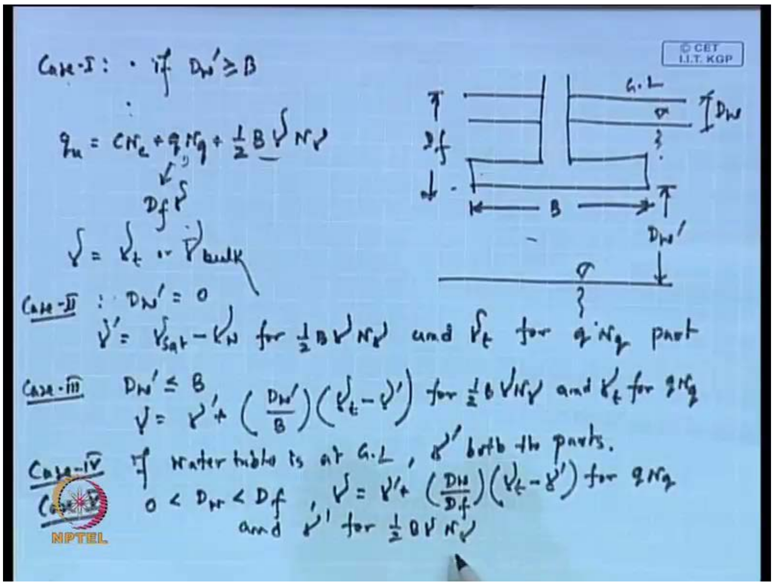

So, suppose if we take this figure. So, this is the ground level, this is the base of the footing, where B is the width, and D f is the depth of the foundation. Now, suppose this is the position of the ground level here, this is D w; and this is the another position of the ground level, ground water level; so this is D w dash. Now, first case that if case one, the first care if D w dash greater than equal to B. So, first case is that means, this position of this ground water table below the base is equal to or greater than width of the foundation.

So, now in this general expression, we can write our expression is q u C N c plus q N q plus half B gamma N gamma. In this N q term, this is D f is gamma. So, we can see that here this D f into gamma is there. So, these gamma is basically the unit weight of the soil above the foundation base; and this gamma, because it is two gammas in two parts. So, this gamma is the unit weight of the soil below the foundation base. So, this is the second first term, second term and third term. So, first term is unit weight that means, gamma less and in the second term, there is one gamma that gamma is basically above the foundation base and the next one is the below the foundation base, second one. In the case one if D w dash is greater than equal to B, then gamma will be gamma t or gamma bulk.

So, gamma will be gamma bulk whether this natural unit weight condition. So, both the case, that means, the water table will not effect these bearing capacity expressions. So, we will is the natural natural gamma is natural unit weight of the soil is gamma t or gamma bulk. So, in the both the cases where this expression also we have to use the gamma bulk and this expression also we have to use the gamma bulk. Now, if case two they will consider this D w dash is equal to 0. So, if D w dash is equal to 0 this case 2. That means, the water ground water table level is at the base of the footing then we have to consider the gamma sub that is gamma sat minus gamma w. So, this is gamma submerge gamma sat. So, this gamma we have to use for second term for half B gamma N gamma portion and gamma t or gamma bulk for q N q part. So, here if first case D w dash greater than equal to B then we will have to use gamma t for both the cases this part and this part.

Now, if D w dash is equal to 0 then we have to consider gamma sub for this this part this part we have to use the gamma sub and this part we have to use gamma bulk. Now, for the case three that D w dash is less than equal to B or less than equal to B or you can say this is greater than B then we have to use gamma is equal to gamma sub plus D w dash divided by B into gamma t minus gamma sub for half B gamma N gamma and gamma t for q N q. So, if D w dash is less than equal to B then you have to use this gamma value in this part and gamma t for this part. Now, case four that if water table is at G L. So, if water table is at G L then both the parts we have to use the gamma sub, here also we have to use the gamma sub here also we have to use the gamma sub; so here also for both the parts.

Now, for the case five that D w is greater than equal to 0 and less than equal to D f then gamma will be gamma sub plus D w by D f into gamma t minus gamma sub for q N q and for the second part, for this part we have to use the gamma sub and gamma sub for half B gamma N gamma. So, if the water table is greater than 0 and less than D f then we have to use this gamma for this this part and gamma sub for this part. So, these are the five cases, where we can improve the water table effect putting this water table position at different location and we can incorporate the water table effect with the different unit weight that is used in the expression. In the next lecture, I will explain the other effect that is the inclination loading inclination effect, then the then the shape and factor of shape of the foundation effect, depth of the foundation effect in this expression through general time. Those things I will explain in the next lecture,

Thank you.

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