Advanced Foundation Engineering
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Lecture-11
Shallow Foundation: Bearing Capacity V

In my previous lecture, I have discussed about the effect of soil compressibility on bearing capacity and today I will discuss another effect that is the effect of eccentricity on bearing capacity. That means, the loading is not acting at the center of the foundation, it is acting out from the center of foundation because application of moments or the column is not at the center of the footing. So, in such cases how the bearing capacity can be calculated will be discussed in this lecture.

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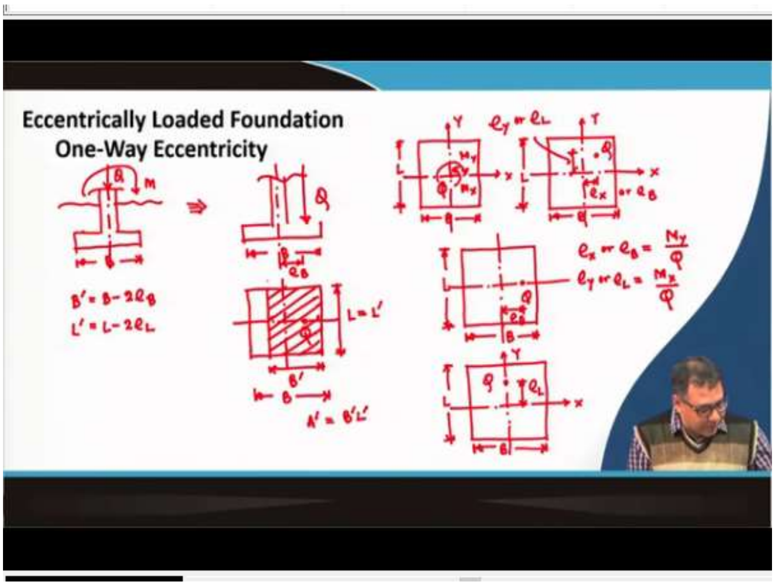

So, now first the eccentricity can mean 2 types, one is one-way centricity and another is that two-way centricity. One-way centricity means the load is acting away from the center to a particular direction either length direction or width direction and in the two-way centricity, it is acting away from the center with respect to both the directions. That means, it has some eccentricity in the width direction as well as in the length direction.

So, first I will discuss about the one-way eccentricity and then I will discuss about the two-way eccentricity. Now, for one-way eccentricity suppose, in general case this is my foundation and this is x or the width direction and this is say y direction or the length direction of the foundation. So, as I mentioned there may be a possibility that your moment is acting say, M_y.

Or in this way also the moment is acting which is M_x. So, now because of the load that will act at a distance *i* from the center. So, suppose this is in *x* as I mentioned and this is in *y* now, because we have M_x and M_y both are present. So, *Q* will act at this position, a distance e_x or sometimes we can write e_B because it is in width direction. And this one is e_y or e_L because it is in length direction.

But this is basically two-ways eccentricity. The figure that I have drawn. In one-way eccentricity either it will be e_x and e_y will be 0 or there will be e_y and e_x will be 0. So, that means in one-way eccentricity I can draw that loading is acting here with an e_B value, this is my width or *x* direction and this is length or *y* direction or there may be possibility that it can be like this also.

This is *x*, this is *y*. So, loading is acting here with an eccentricity e_L and this is length direction and this one is the width direction. So, that means in one-way cases either M_x is acting or M_y is acting or that is another possibility that the column itself is not at the center of the footing, it is away from the center of the footing. So, that means there can be either e_x or e_B or there can be a e_L or there can be both.

So, now, we can draw the effective area. So, suppose we have a one-way eccentricity. This is the plan and if I draw the section then I can draw in this way that this is my footing, this is ground surface. Now, here *Q* is acting at the same time a moment *M* is also acting and this is say width *B*. So, in final form this can be written in this way. So, this is my foundation.

Now, the loading is acting here with eccentricity *e*, this is the center line, because a moment is acting and sometimes directly that column will act at a certain distance from the center. So, this is *B*. So, finally, as the loading is acting away from the center, then my effective area of the footing will decrease. So, this is a center. So, this will be now the effective area.

The hatch portion will be now, the effective area in this case, because here eccentricity in the width direction. So, I can write this is my *L* length of the footing or I can write this is L' and now initially width was B, now effective width has been reduced to B'. So, initially it was B. Now, the B', because now the footing will not get the total area that is A and B now it will be reduced to an effective area which is A' and B'.

So, the effective area A' is $B' \times L'$, and original area was $B \times L$. Now, when we calculate the bearing capacity and other factors, then we have to consider this effective area and I have discussed in my previous lectures that as per different theories the different factors we have to calculate by considering either A or B or A' and B', those things are mentioned.

So, what is the B' value? B' value is equal to $B - 2e_x$ or e_B, I should write e_B because this is my e_B, which is how much distance the load is acting away from the center towards the width direction. Similarly e_L is how much distance the load is acting away from the center towards the length direction. So, now basically my load is acting here.

So, that is why this effective area is reduced in this left hand side. So, now this is the one case now, if the loading is acting away from the center towards the length direction, because we are talking about the one-way eccentricity. So, in such case my $L' = L - 2e_L$, e_L is again the same distance that I have discussed. So, now, how in terms of moment we can calculate the values, suppose we have a moment M_x and M_y.

So, my e_x or $e_B = \frac{M_y}{Q}$ that means, if there is a moment acting with respect to y axis and there is a load Q acting then we can determine the e_B and or e_x in this way and sometimes the e_x can be directly be given if the load is itself acting from away the center. So, similarly, I can write that e_y or $e_L = \frac{M_x}{Q}$.

So, a Q is also acting here and two moments are acting. There can be two moments or one moment because in one-way eccentricity and one moment is acting, in two-way eccentricities both the moments can act. So, now, I can calculate in this way e_x or e_B and then the effective length and width I can calculate by using these expressions. Now, this is in case of one-way eccentricity where I can calculate B' and L'.

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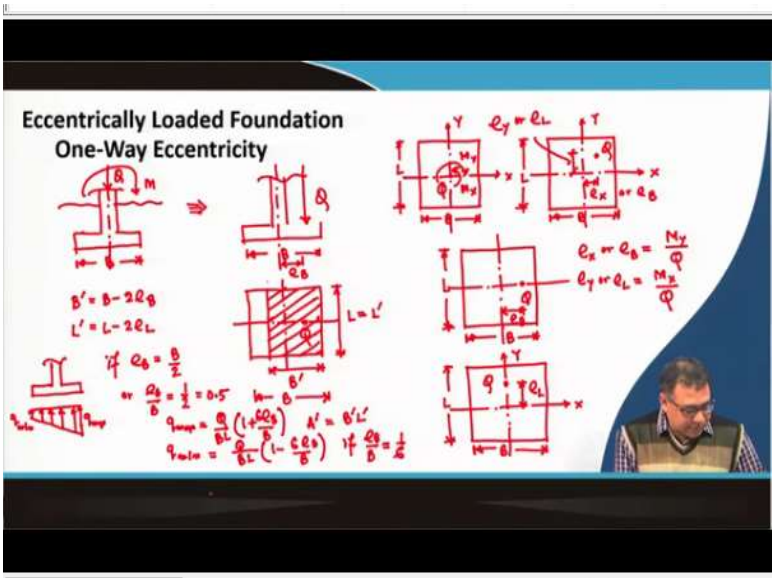

So, now, if I go to the two-way eccentricity, so, in such case in two-way eccentricity how I can calculate the eccentricity value that I will discuss here. Now, in the two-way eccentricity, four cases are discussed which are proposed by these two authors in 1985. So, first case that now if you go back to that previous expression those are given. So, now, here you can see that if my $e_B = \frac{B}{2}$.

That means, if $e_B = \frac{B}{2}$ or $\frac{e_B}{B} = \frac{1}{2}$ or 0.5, and then the $B' = 0$. So, that means that in such case this $B' = 0$ that means, the load will act at the edge of the footing. Similarly, if the $e_L = \frac{L}{2}$, I mean the load will act at the edge of the footing. So, theoretically I can write the maximum limit of e_B or e_L is $\frac{1}{2}$ of the width or the length.

That is theoretically I can write that. So, now here I have given four expressions. So, those four cases the first case that if $\frac{e_L}{L} \geq \frac{1}{6}$ and $\frac{e_B}{B} \geq \frac{1}{6}$, why $\frac{1}{6}$ is given because if the footing has eccentricity greater than $\frac{1}{6}$ then this is my pressure distribution, because as the loading is now eccentric, so, this will be the pressure distribution. So, this is the pressure distribution. So, now I can write that this is my q_{max} and this is q_{min}. So, that q_{max} this can be written as $\frac{Q}{BL}\left(1 + \frac{6e_B}{B}\right)$ and in case of L this will be e_L and the q_{min} will be $\frac{Q}{BL}\left(1 - \frac{6e_B}{B}\right)$.

If eccentricity is in the length direction then it will be e_L. So, you can see that sorry this will be e_B if $\frac{e_B}{B} = \frac{1}{6}$, then the e_{mean} value will be 0. So, that means if $\frac{e_B}{B} < \frac{1}{6}$, then a negative pressure will be developed below the footing. So, that is why these $\frac{1}{6}$ is a value that we have to keep in mind. So, that is why if for one-way eccentricity, if we put that $\frac{e_B}{B} < \frac{1}{6}$, then a negative pressure will be developed.

So, that is why you have to keep this $\frac{1}{6}$ in mind during our selection of the eccentricity. So, that is why the other four cases are taken according to that. That means we have now talking about two values, one is 0.5 theoretically, that can be the maximum value of any eccentricity e_B or e_L because in such cases the load will act at the edge of the foundation and another is $\frac{e_B}{B} = \frac{1}{6}$. That means the e_B or e_L is $\frac{1}{6}$ times B or L. So, that there will be no negative pressure below the foundation base.

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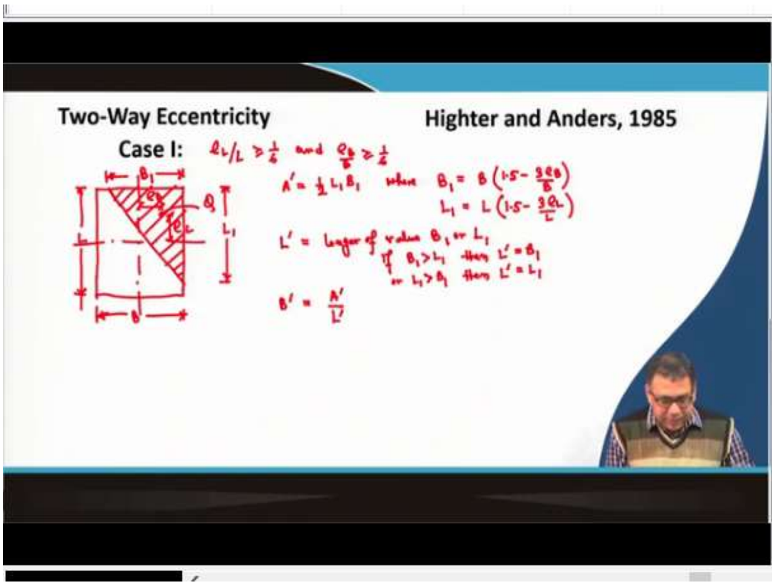

So, now I can write other cases that is why the first case is taken as $\frac{e_L}{L} \geq \frac{1}{6}$ and $\frac{e_B}{B} \geq \frac{1}{6}$ because that is why this limit is considered because as I mentioned, this is the important thing that these two values 0.5 and $\frac{1}{6}$. So, now in case one if this is the loading condition, now this is the footing. This is the center line and this will be the width of the footing and this is the length of the footing.

Then the effective area will be like this, because now my load will act here. Here the Q will act and this one is e_L and this one is e_B. And both are greater than or equal to $\frac{1}{6}$. So, now the effective area will be this one. So, now effective area will be this one and then I can write that this is equal to L_1 and this one is equal to B_1. So, how we can calculate these L_1 and B_1 because that is important.

So, this effective area is A'. This is a triangle the shaded portion is a triangle. So, this will be $\frac{1}{2} \times L_1 \times B_1$. So, now, where B_1 I can calculate by using these expressions $B\left(1.5 - 3\frac{e_B}{B}\right)$ remember that and L_1 I can calculate by $L\left(1.5 - 3\frac{e_L}{L}\right)$. So, now, the effective length L' will be equal to the longer of value B_1 or L_1.

That means, the L' effective length will be now, the larger value of B_1 or L_1 that means, which one is the higher value that we have to consider as L'. If $L_1 > B_1$ then L' is L_1. If B_1 is greater than L_1 then L' will be the B_1. So, that means, if $B_1 > L_1$ then $L' = B_1$ or if $L_1 > B_1$ then $L' = L_1$.

So, now the effective width B' you can calculate. Now, I know I can calculate L_1 and B_1 from these two equations. So, I know the effective area A'. So, once I will get the A' and L' will be the longer value of B_1 or L_1 then my $B' = \frac{A'}{L'}$. So, in this way I will get the effective area as well as the effective width and length in case of two-way eccentricity case.

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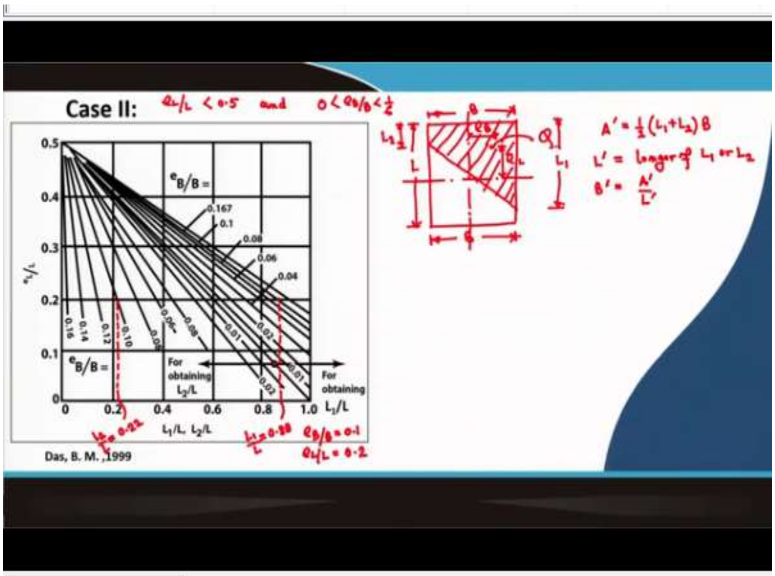

Now, I will go to the case 2, where the condition is that $\frac{e_L}{L} < 0.5$, that I mentioned these 2 are the very important values $\frac{1}{6}$ and 0. 5 and $\frac{e_B}{B}$ is in between 0 and $\frac{1}{6}$. So, $\frac{e_B}{B}$ is in between 0 and $\frac{1}{6}$. So, this will be the foundation. Now, this one is B and this one is L. This is center line, and your load is acting here.

This is e_L and this one is e_B. This is the position of Q. Now the effective area in this case will be like this, okay. So, this will be the effective area in this case. So, you have this L_1 and this one L_2, now B is this side fully covered within the effective area. So, in such case the effective area you can calculate because this is a trapezoidal. So, I can calculate because this is equal to B.

So, this will be $\frac{1}{2}(L_1 + L_2) \times B$. Now, how I will calculate the B. I know the length and width of the footing, how I will calculate L_1 and L_2. So, L_1 and L_2 I will get from this figure. So, these figures you can see, it may be explained from these figures. So, first you will calculate what is $\frac{e_L}{L}$? So, you have to know the eccentricity then divide it with the length.

That means eccentricity along the length direction divided by the length of the footing, then you will get a value and that should be less than 0.5. So, that is why it is 0 to 0.5. So, this value is given and then we have to calculate $\frac{e_B}{B}$ because $\frac{e_B}{B}$ is in between 0 to $\frac{1}{6}$. So, $\frac{1}{6}$ is roughly 0.17 or something. So, that means 0.167 actually. So, that is why this is given from say 0.01 to 0.167 because $\frac{1}{6}$ is 0.167.

So, now, this x axis is giving the $\frac{L_1}{L}$ or $\frac{L_2}{L}$. So, I will get in terms of ratios $\frac{L_1}{L}$ and $\frac{L_2}{L}$. So, now, in this figure if you look at this figure here there is a straight line which is this line. Where this side also you can see $\frac{e_B}{B}$ is 0.01, 0.02, 0.04, 0.06, to 0.167 and this side also it is going 0.01, 0.02, 0.08 to 0.167 which is 0.167. So, that means both sides it is $\frac{e_B}{B}$.

This side also $\frac{e_B}{B}$ and this side also $\frac{e_B}{B}$, but if I go towards the right side direction that means if I go along this direction, then I will get $\frac{L_1}{L}$ and if I go towards the left direction, then I will get into $\frac{L_2}{L}$. So, for example, $\frac{e_L}{L}$ is 0.2 and $\frac{e_B}{B}$ is 0.1. So, I want to calculate L_1 and L_2. So, $\frac{e_L}{L}$ is 0.2 and $\frac{e_B}{B}$ is 0.1. So, 0.1 is this graph. So, 0.2 so, this is the value one value.

This is one value and that is corresponding to this graph I will get this value so this is 0.9. So, this will be around 0.88. So, that this 0.88 as I am going towards the right side direction, so, this will give me $\frac{L_1}{L}$. Now, if I go to this direction, that means below this straight line, if I go the other way I can say if I go to the above the straight line or the line that I have shown that the middle line above that, then I will get $\frac{L_1}{L}$.

If I go below I will get $\frac{L_2}{L}$. So $\frac{L_2}{L}$ will be how much this is 0.1, this is 0.2. So, this is the value. So, this value is 0.22, so that will be give me the $\frac{L_2}{L}$. So, $\frac{L_2}{L}$. So, in this way I will get the $\frac{L_1}{L}$, $\frac{L_2}{L}$. Now this is valid, these 2 values are valid. If I have considered $\frac{e_B}{B} = 0.1$ or $\frac{e_L}{L} = 0.2$. So, then this way I can calculate L_1 and L_2.

Now, if once I get the $\frac{L_1}{L}$ or $\frac{L_2}{L}$ then we have to multiply it with the L and I will get the L_1 and L_2. So, once I get the L_1 and L_2 I will get the A' value and the B' value is or I should say that first the L' is equal to longer of L_1 and L_2. That means, the longer value between L_1 and L_2 will be considered as a L' and the B' will be equal to $\frac{A'}{L'}$.

So, in this way you can calculate the effective area, effective length and effective width of the foundation. So, these are the two cases that I have discussed that case 1 and case 2, there are two more cases. So, in the next class I will discuss two more cases for this two-way eccentricity and then I will solve one particular or few problems related to eccentric loading to determine the bearing capacity of the foundation. Thank you.