Advanced Foundation Engineering
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Lecture-12
Shallow Foundation: Bearing Capacity VI

So, last class I was discussing about the two-way eccentricity. So, there are four cases, so I have discussed two of them the case 1 and case 2. Now this class I will discuss other two cases and then I will discuss few problems related to eccentric loading.

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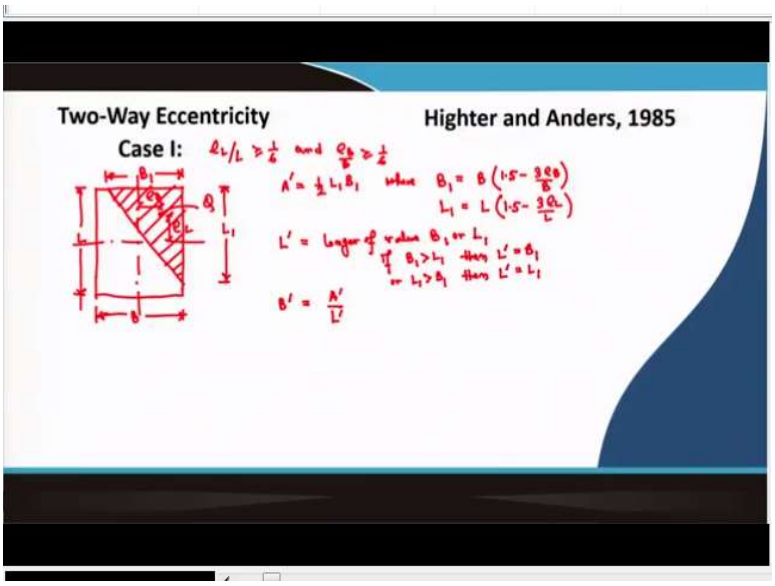

So, now this is my case 1 when $\frac{e_L}{L} \geq \frac{1}{6}$ and $\frac{e_B}{B} \geq \frac{1}{6}$.

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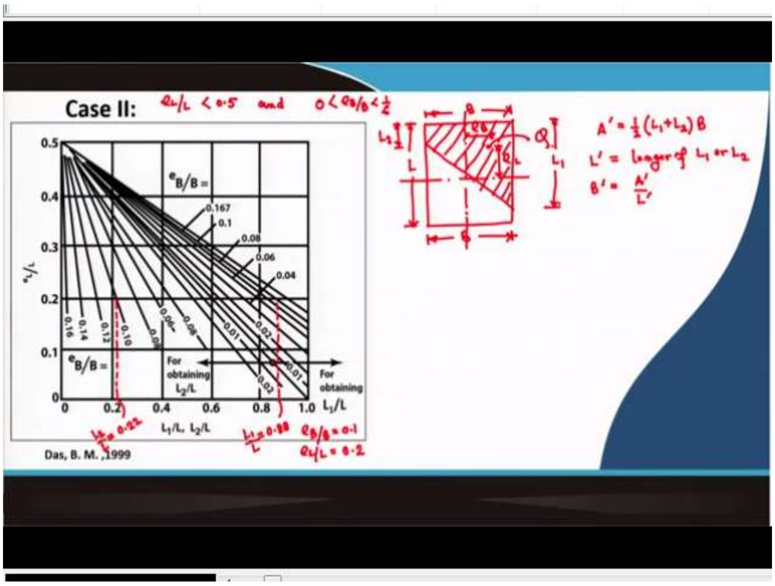

And this is the case 2 when $\frac{e_L}{L} < 0.5$ and $\frac{e_B}{B}$ is within $\frac{1}{6}$ to 0.

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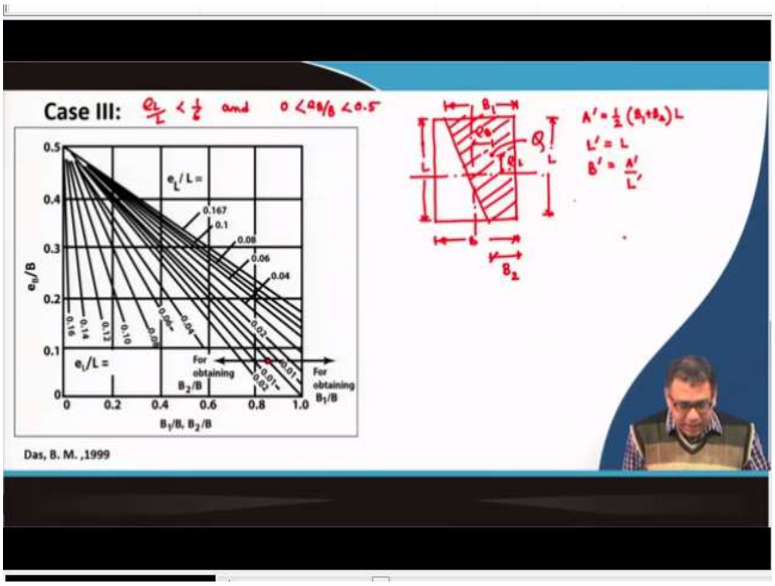

So, now the third case this is case 3 when $\frac{e_L}{L} < \frac{1}{6}$ and $\frac{e_B}{B}$ is in between 0.5 to 0. So, in such case this is the foundation ok. So, this is the width of the foundation and this is the length of the foundation and in such case the effective area is like this ok. So, this load is acting here say this is my e_L.

And this one is e_B and Q is acting here and this shaded area is the effective area, ok. So, in this case this is say B_2 and this one is B_1 ok and now I can say again the effective area is $\frac{1}{2}(B_1 + B_2) \times L$ ok and the effective length $L' = L$ because this is your L and $B' = \frac{A'}{L'}$ ok. Now this value of B_1 and B_2 will be obtained from this curve from this chart.

Again this is $\frac{B_1}{B}$ this is $\frac{B_2}{B}$ and this is $\frac{e_B}{B}$, this is $\frac{e_L}{B}$. So, $\frac{e_L}{L} < \frac{1}{6}$. So, that is why $\frac{e_L}{L}$ is given up to 0.167 and this $\frac{e_B}{B}$ is from 0 to 0.5. So, this is 0 to 0.5. So, again if you go this is the line if you go above this line then you will find values or towards the right side then you will get $\frac{B_1}{B}$ and if you go towards the left side or below the values of this line then you will get $\frac{B_2}{B}$. So, this is $\frac{B_2}{B}$ and this is $\frac{B_1}{B}$ similar to the case 2.

So, in this way you will get B_2 and B_1 and $L' = L$ you will get the effective area by using this equation and you will get the B'. So, now this L' and this procedure will tell that how we can determine the effective area A' and or effective width, B' or effective length, L' . Now these effective width or length or the effective area we have to use in our bearing capacity equation to determine the bearing capacity of the foundation, that I will discuss in example problem. Now we have the last case.

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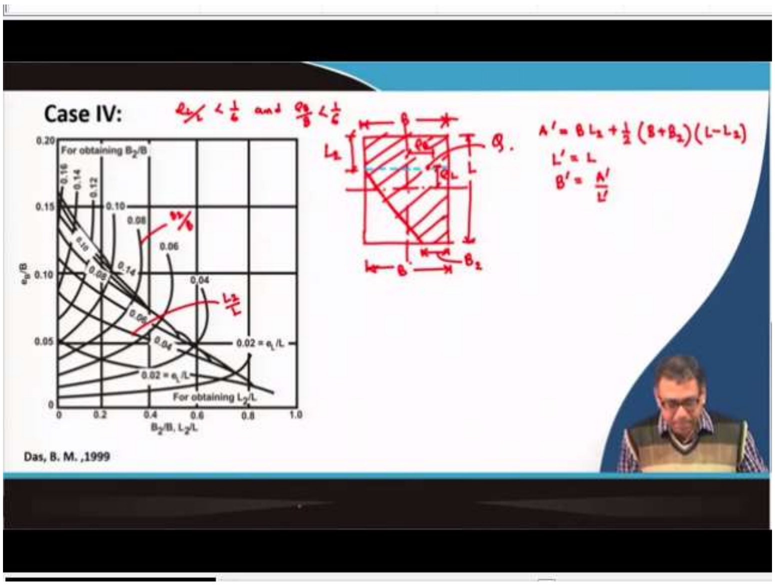

So, that is the case 4. So, in the case 4 both the eccentricities are less than $\frac{1}{6}$ i.e. $\frac{e_L}{L} < \frac{1}{6}$ and $\frac{e_B}{B} < \frac{1}{6}$ ok. So, this is $\frac{1}{6}$ means 0.167. So, that is why this is drawn up to here 0.16, here also it is 0.16 ok. So, now in such case the loading area or effective area of the foundation can be obtained as, this is my L, this is B and this is the value ok or this is the area or this is L_2 and this is B_2 ok.

And load is acting here this is e_L and this is e_B, Q is acting here, this shaded line is the effective area, ok. So, now how I will calculate the area of the loading or the effective area, then the effective area A' is equal to because we can now divide it in one rectangle and one trapezoidal. So one rectangle whose length is B and width is L_2. So, suppose now if I divide it into one rectangle and one triangle and one trapezoidal.

So, this is the rectangle and this is the trapezoidal. Now for the rectangle the area is $B \times L_2$, and for the trapezoidal the area is $\frac{1}{2}(B + B_2) \times$ this length will be $(L - L_2)$ ok. So, this way I can calculate the effective area and then we know the L and B, then we have to determine the L_2 and B_2. So, how I will get the L_2 and B_2?

So, this is the chart. So, you can see this is the value of $\frac{e_B}{B}$ and this is x axis and these values are $\frac{e_L}{L}$ and this y axis is $\frac{B_2}{B}$ and $\frac{L_2}{L}$. Now if I use the upward curve that means these curves the upward curves ok. So, then if I use these curves then I will get $\frac{B_2}{B}$ ok. So, if I use this curve then I will get $\frac{B_2}{B}$. Now if I use the downward curve, so if I use the downward curves that means this curves, these downward values ok.

This charts or this curves then I will get $\frac{L_2}{L}$. So, upward values, this upward curve will give me $\frac{B_2}{B}$ and this downward curves will give me the value $\frac{L_2}{L}$ ok and then once I get this L_2 and B_2 then I will get the effective area and then I know this is the length. So, effective length will be equal to L and effective width, $B' = \frac{A'}{L'}$ ok. So, this way we can determine the effective area, effective length or effective width for two-way eccentricity.

Now there is a question that when I talked about the one-way eccentricity I have used one expression, that is my $L' = L - 2e_L$ and $' = B - 2e_B$. So, now the question is that few researchers have suggested that you can use that expression also in these cases but my personal suggestion is that you use those expressions for one-way eccentricity and for two-way eccentricity you use these four cases that I have discussed ok.

So, I prefer to use these things because those expressions are perfect if we are using within the distance $\frac{1}{6}$ i.e. e_B by width or e_L by length is less than $\frac{1}{6}$ or equal to less than $\frac{1}{6}$, but here some cases it is more than that so I would prefer that you use one-way eccentricity to calculate effective width and effective length. But you use the procedure that is discussed for four cases for two-way eccentricity that you should use to calculate the effective width and length for two-way eccentricity.

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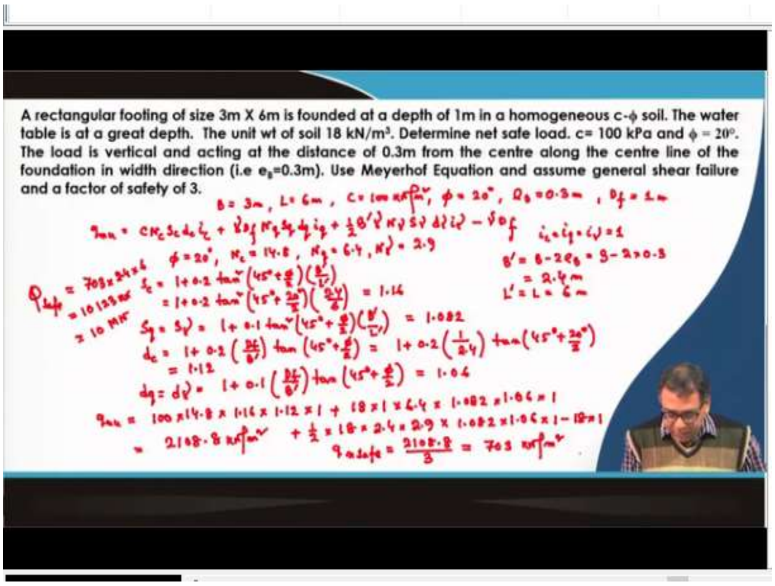

So, now the first problem is a rectangular footing of size 3 m × 6 m is placed at a depth of 1 m in a homogeneous c-ϕ soil is subjected to eccentric loading. The water table is at a great depth, the unit weight of soil is 18 kN/m^3, determine the net safe load. Net safe load that means the net ultimate load divided by the factor of safety. If c = 100 kPa, ϕ = 20°, the load is vertical and acting at a distance of 0.3 m from the center in width direction.

That means that e_B is 0.3 m. So, sometimes you will get this type of value that means load is itself acting on the foundation at a distance of say e_B or e_L from the center of the footing ok. But sometimes the moment will be given and we have to calculate the eccentricity. Then the moment and the vertical load will be given. So, we have to calculate the eccentricity as I have discussed.

So, in two ways you can do either the eccentricity value e_B or e_L will be directly given or the M_x or M_y will be given and the Q value or the vertical load will be given. So, we have to calculate the e_L or e_B based on the value M_x and M_y. Now you use Meyerhof's equation and assume general shear failure and a factor of safety as 3. So, now here in the solution we know that B = 3 m, L = 6 m.

Now, c is given as 100 kN/m^2, ϕ is given as 20° and e_B is given as 0.3 m, ok and this is towards the width so that is why e_B. So, now the q_{nu} is $cN_cs_cd_ci_c + \gamma D_fN_qs_qd_qi_q + \frac{1}{2}B'\gamma N_\gamma s_\gamma d_\gamma i_\gamma - \gamma D_f$ because here it is eccentric loading. So and if you remember that I have discussed that if

I use Meyerhof's bearing capacity equation then all the factors those shape factors and this factors we have to use B' and L'.

And for the third term of the bearing capacity equation you have to use B' so that is $\frac{1}{2}B'\gamma N_\gamma s_\gamma d_\gamma i_\gamma$. So and that is the net so γD_f. Now as the load is not inclined so this i_q, i_c, i_γ all will be equal to 1. So, that is why $i_c = i_q = i_\gamma = 1$ and but no data is available to check or to incorporate the compressibility effect.

So, that is why the compressibility effect is not considered as the data is not available so you can consider the compressibility factors also equal to 1, okay. So, now you can see that for $\phi = 0$ general shear failure is considered and no compressibility data are available. So, we consider that all those factors are 1 and we consider the N_c value as 14.8 and N_q value as 6.4 and N_γ value as 2.9 for Meyerhof's bearing capacity factors.

Now as per Meyerhof this s_c is $1 + 0.2\tan^2\left(45° + \frac{\phi}{2}\right)\times$ now here instead of B, I will use $\frac{B'}{L'}$ ok. So, now what is B' here? So, this is one-way eccentricity as I mentioned so I will use the expression that I have given that is $B - 2e_B$. So, B is 3 m - 2 × 0.3 so this will be 2.4 m, but there is no eccentricity along the length direction.

So, $L' = L = 6$ m. So, now B' is 2.4 m and L' = 6 m. So, that value if I put here $1 + 0.2\tan^2\left(45° + \frac{20°}{2}\right)\left(\frac{2.4}{6}\right)$. So, this is equal to 1.16. Now similarly the s_q and s_γ value those are equal to $1 + 0.1\tan^2\left(45° + \frac{\phi}{2}\right)\left(\frac{B'}{L'}\right)$. So, if I put those values I will get the factor as 1.082 ok.

Similarly I will get d_c which is $1 + 0.2\frac{D_f}{B'}\tan\left(45° + \frac{\phi}{2}\right)$ ok. So, now if I put D_f is 1 m because the foundation is 1 m below the ground surface and then B' is 2.4 then $\tan\left(45° + \frac{20°}{2}\right)$. So, that is coming out to be 1.12. So, similarly I can write d_q and d_γ which is $1 + 0.1 \times \frac{D_f}{B'}\tan\left(45° + \frac{\phi}{2}\right)$ ok.

So, if I put this value I will get the correction factor 1.06. Again I mentioned here water table is not considered. So, if the water table is here then you have to consider the water table effect as per the procedure that I have discussed in my previous lectures. So, now finally the q_{nu} will be c is 100, then this is 14.8 × 1.16 then d_c is 1.12, then that i_c is 1, then + 18 × 1 × 6.4 × s_q is 1.082, d_q is 1.06 + 1 × 1 + $\frac{1}{2}$ × unit weight is 18 × now it is B'.

B' is 2.4, then it is 2.9 is the bearing capacity factor, then the shape factor is 1.082, depth factor is 1.06, inclination factor is 1 - 18 × 1. So, the final value is coming out to be 2108.8 kN/m^2. So, now I can write that $q_{n,\text{safe}}$ will be equal to because we have a factor of safety of 3. So, I can write that $\frac{2108.8}{3}$. So, that will give me the value 703 kN/m^2. So, 703 kN/m^2.

So, finally the safe load that I can put on this foundation is $q_{n,\text{safe}}$ × the effective area so, $q_{n,\text{safe}}$ is 703 × effective area is 2.4 × 6 which is equal to 10123 kN or roughly 10 mN. So, the load that I can apply on the foundation is roughly equal to 10000 kN or 10 mN. But here I have considered the one-way eccentricity along the width direction and I have used Meyerhof's equation ok.

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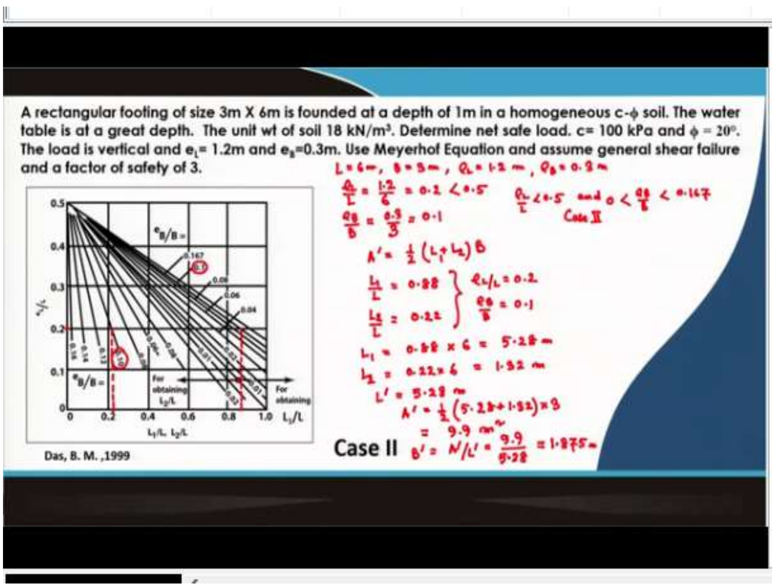

So, now next question that I will solve that if I have a two-way eccentricity, then how I can solve or I can determine the bearing capacity. So, what I have considered that I have taken a rectangular footing of same dimension and more or less all the values are same as in previous problem only I have taken one-way eccentricity, here I have taken the two-way eccentricity.

So, footing is 3 m × 6 m and it is a depth of foundation is 1 m and it is in the homogeneous soil, water table is at a great depth, unit weight of the soil is 18 kN/m^3 to determine the net safe load when the c is 100 kPa and ϕ = 20°, the load is vertical. But e_L = 1.2 m and e_B is 0.3 m. So, now there is two-way eccentricity and so two eccentricity or e values are given.

One is 1.2 m towards the length direction and another is 0.3 m towards the width direction. Use Meyerhof's equation and assume general shear failure and a factor of safety of 3 ok. So, now I will go to that case. So, that example the similar type of problem that my L = 6 m, B = 3 m and e_L = 1.2 m and e_B = 0.3 m ok. So, now $\frac{e_L}{L}$ is what? $\frac{e_L}{L}$ is $\frac{1.2}{6} = 0.2$ and which is less than 0.5, ok .

Remember that theoretically as I mentioned the maximum value of $\frac{e_L}{L}$ or $\frac{e_B}{B}$ can be 0.5, but it is very rare in the field that $\frac{e_B}{B}$ or $\frac{e_L}{L}$ is greater than 0.2. So, maximum it can be taken or used in the field as 0.2. So, that means the maximum eccentricity used in the field is 20% of the length or width from the center. That means 0.2 times of length or width.

So, it is rare that these values are taken greater than 0.2. So, that is why I have taken 0.2 and in most of the cases it is limited to 0.167 or $< \frac{1}{6}$. Most of the cases it is limited to 0.167 or within the $\frac{1}{6}$ or 0.167 value but really it is beyond 0.2. So, remember that but I have discussed theoretically you can go up to 0.5, but actually in the field it is not usually up to 0.5.

It is generally limited to within 0.167 or it can go around 0.2 and so not more than that. So, that means this is my 0.5 and then $\frac{e_B}{B} = \frac{0.3}{3} = 0.1$. So, in this case $\frac{e_L}{L} < 0.5$. So, that means my $\frac{e_L}{L} < 0.5$ and $\frac{e_B}{B}$ is within $\frac{1}{6}$ means I can say 0.167 to 0. So, that means it is case 2 that I have discussed in among those four cases.

So, this is case 2. So, this is the chart for the case 2. So, let me calculate the effective area. So, effective area for the case 2 is $\frac{1}{2}(L_1 + L_2) \times B$ ok. Now, $\frac{e_L}{L}$ is 0.2 and $\frac{e_B}{B}$ is 0.1. So, let us do that $\frac{e_L}{L}$ is 0.2. This is the value and $\frac{e_B}{B}$ is 0.1. So, that means this is the 0.1, this is the 0.1, here also this is 0.1. So, as I mentioned if I go above this line or towards the right side then I will get the $\frac{L_1}{L}$.

And towards the left I will get the $\frac{L_2}{L}$. So, let us first calculate the L_1. So, this is my 0.2 line. So, this will go to this line. So, this is the value ok. So, as I mentioned this is 0.9 and this will be 0.88. So, from the chart I will get that $\frac{L_1}{L}$ because this will give you the $\frac{L_1}{L} = 0.88$ and for the $\frac{L_2}{L}$. So, this is 0.1. So, this direction $\frac{L_2}{L}$.

So, this is the value which is 0.22. So, from the figure this $\frac{L_2}{L}$ is 0.22 corresponding to $\frac{e_L}{L} = 0.2$ and $\frac{e_B}{B} = 0.1$. So, I will get the L_1 and L_2. So, my $L_1 = 0.88 \times 6$ because $L = 6$. So, 0.88×6, this is 5.28 m and $L_2 = 0.22 \times 6$. So, this will be 1.32 m. So, as I mentioned the longer of this L_1 and L_2 will be the L'. So, the $L' = 5.28$, ok.

So, $L' = 5.28$. Now what is the A' value? A' value is $\frac{1}{2} \times (5.28 + 1.32) \times 3$. So, that is equal to 9.9 m^2. So, this is the effective area. So, my the effective width will be $\frac{A'}{L'}$ which is $\frac{9.9}{5.28}$. So, that is equal to 1.875 m. So, now I have already calculated the L' value. L' value is 5.28 m.

And B' value is 1.875 m. So, now I have calculated the L' and B' and the effective area. So, next class I will use this effective length and width and then I will put these values to calculate the bearing capacity factors and or the correction factors and then the bearing capacity of the foundation by using Meyerhof's bearing capacity equation. So, I will solve the remaining part of this problem in the next class, thank you.