Advanced Foundation Engineering
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Lecture – 68
Well Foundation – IX

So, last class I have discussed that how we can determine the moment due to the friction force that is acting along the side of the well and then I discuss about the rectangular well. Now today I will discuss for the circular well first.

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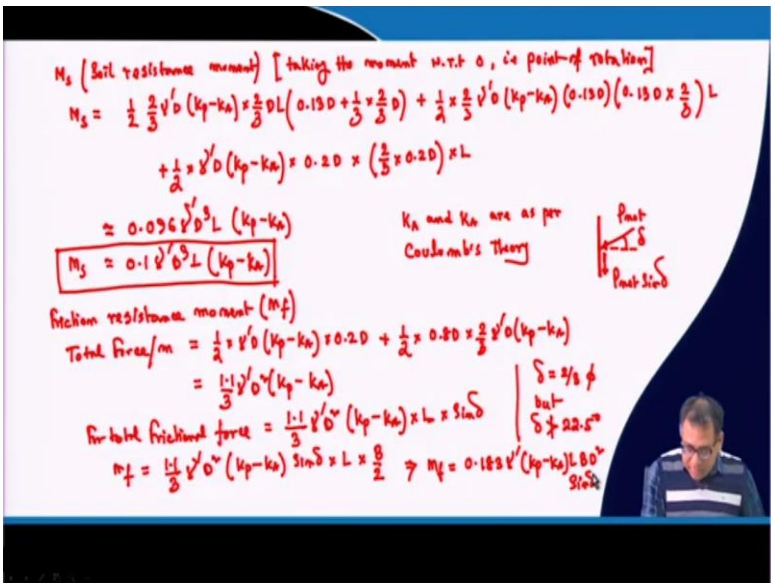

So, that means here the equation of the M_f, so that is 0.183 gamma dash because if this is 1.1 divided by 3 then also divided by 2. So, finally, it will be $0.183\gamma'(K_P - K_A)LBD^2 \sin\delta$.

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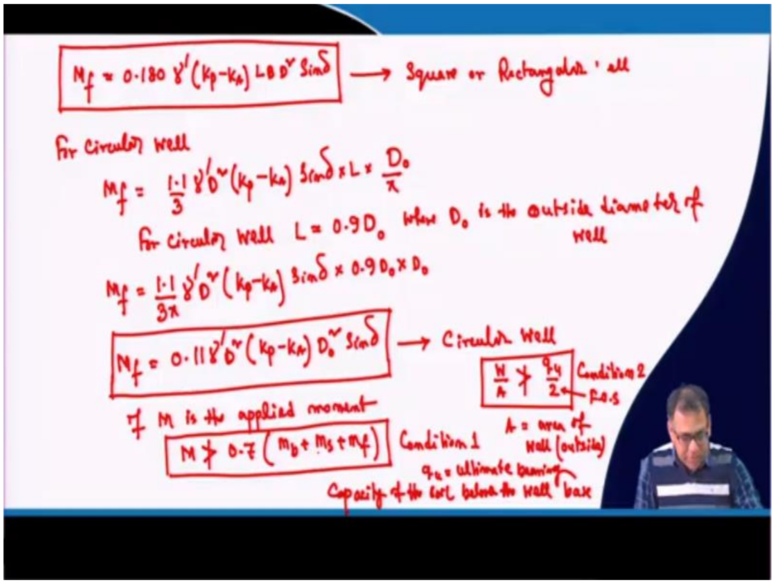

So, finally, I can write that M_f is roughly 0.183 I can write $0.180\gamma'(K_P - K_A)LBD^2 \sin\delta$, so this is one equation of M_f. So, this is for square or rectangular well. Now, for circular well $M_f = \frac{1.1}{3}\gamma' D^2(K_P - K_A) \times \sin\delta \times L \times \frac{D_o}{\pi}$, so that is the only difference, so this is $\frac{D_o}{\pi}$. Now, it is recommended that for circular well $L = 0.9D_o$.

So, this is D_o is the outside diam. So, this is the outside diam of the well, so in the previous cases we have considered in case of Terzaghi's analysis also the L is equal to the diam of the well if it is not circular well, but this time it is recommended that L should be the effective length or side length should be slightly less compared to the diam. So, that is $0.9D_o$.

Now, finally, if I put these values, then you will get $M_f = \frac{1.1}{3\pi}\gamma' D^2(K_P - K_A) \times \sin\delta \times 0.9D_o \times D_o$ and M_f will be roughly $0.11\gamma' D^2(K_P - K_A)D_o^2 \sin\delta$. So, this is for circular well. So, now this is M_f, then M_s and then M_b, these are the resisting moments.

M_b is because of this friction force which is acting along the slip surface then M_s is because of the soil resistance that moment and then M_f is due to the friction between the soil and the side wall. So, these are the resisting moments. So, the condition should be that if M is the applied moment then this M should not be greater than $0.7(M_b + M_s + M_f)$.

So, and 0.7 times, 0.7 is the reduction factor in the strength, so you should say some factor of safety is applied. So, we have reduced the resisting moments, giving some factor of safety. So, that is the reduction of the strength or we have applied some factor of safety, so that means we have taken not the full resisting moment we have taken 70% of that.

So, that the applied moment should not be greater than the 0.7 times of the resisting moment or I should say 0.7 times of the resisting moment should not be less than M. So, this is the condition 1 and another condition that W/A the vertical force divided by total area of the well should not be greater than $q_u/2$. So, this is the condition 2.

Now, what is W? It is the total vertical weight; A is the area of well and definitely the outside area then q_u is the ultimate bearing capacity of the soil below the well base and this 2 is the factor of safety. So, this is condition 2 and here you can say this 2 is the factor of safety. So, these two conditions we have to check for the ultimate soil resistance method and then we have to check the three conditions that I have discussed for your elastic theory method.

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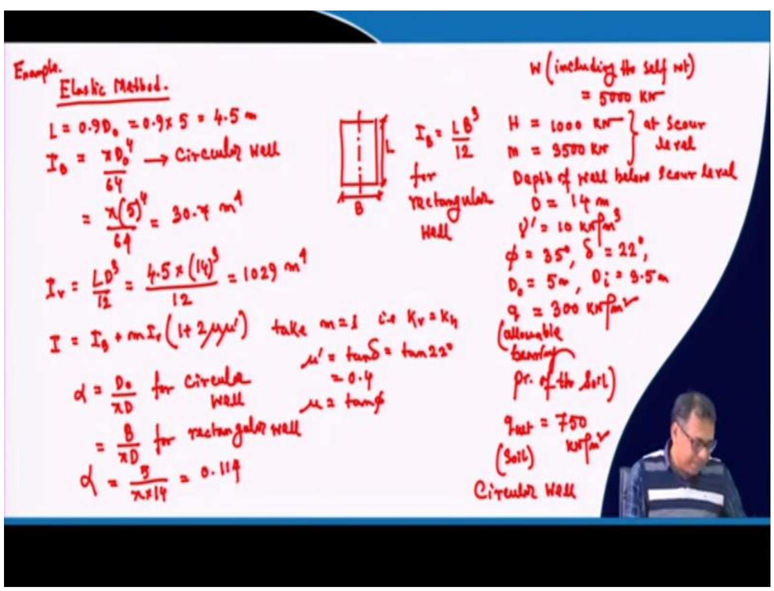

So, now I will solve one particular example problem and then I will show you how we can use these conditions. So, in the example problem the total vertical weight W including the self-weight that is equal to 5000 kN. The horizontal force H = 1000 kN and the moment at scour level that is equal to 3500 kN, so both are acting at scour level, then the depth of well below scour level that means, D = 14 m then submerged unit weight of the soil, γ' is 10 kN/m^3.

ϕ is given as 35°, δ is $\frac{2}{3}\phi$ but it should be restricted up to 22.5°. So, it is taken 22°. Now, outside diam of the well is 5 m, inside diam of the well is 3.5 m. Now, allowable bearing pressure of the soil is equal to 300 kN/m^2 and ultimate bearing capacity of the soil, q_u is equal to say if I apply a 2.5 factor of safety say it is 750 kN/m^2, so this is for the soil.

Now, we have to first do it by elastic method and we have to check whether these conditions are set or these values are sufficient to make the well stable. So, here it is given the $L = 0.9D_o$, so this is for the circular well. So, it is a circular well, $0.9D_o$. So, $0.9D_o = 5$, so this is 4.5 m. Similarly, the $I_B = \frac{\pi D_o^4}{64}$ that is for circular footing or circular well. Now for the rectangular well suppose this is B, this is L.

So, your I_B will be $\frac{LB^3}{12}$. This is for rectangular well. Now it is circular well, so, we will write $\frac{\pi \times 5^4}{64}$, so this is 30.7 m^4, then $I_v = \frac{LD^3}{12}$. Now, L is here 4.5, D is 14. So, $I_v = \frac{4.5 \times 14^3}{12}$, this is 1029 m^4. So, now $I = I_B + mI_V(1 + 2\mu\mu')$.

So, this is the equation I have already derived. So, now take $m = 1$ that is $K_v = K_h$. So that we have assumed and $\mu' = \tan\delta$ and δ is 22°, so $\tan 22°$. So, this is equal to 0.4 and μ is $\tan\phi$. So, now α because there is a term α is given how much because α is $\frac{D_0}{\pi D}$ that is for circular well and $\alpha = \frac{B}{\pi D}$ that is for rectangular well. Now, our case it is circular well, so this D_0 is 5 and D is 14, so this is 0.114.

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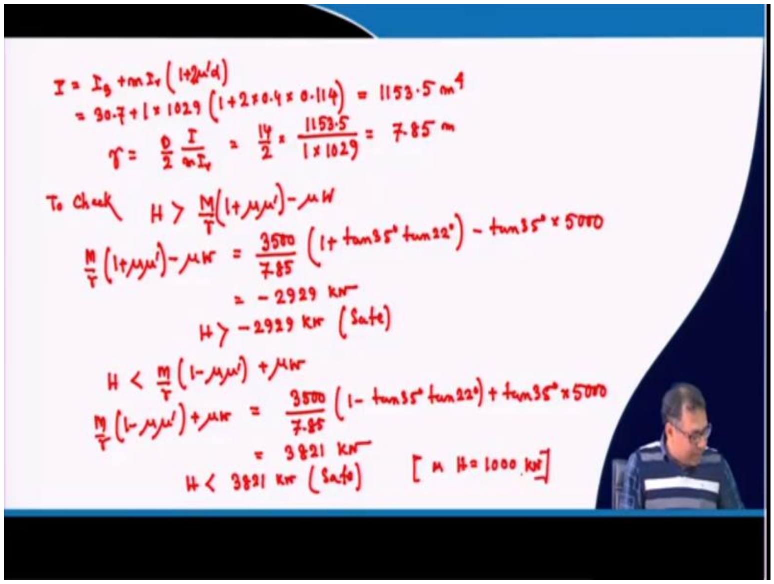

So, now I can write that $I = I_B + mI_V(1 + 2\mu'\alpha)$. So, this is the correction this will be the $2\mu'\alpha$. So, I will put these values, so I_B is 30.7, m is 1, I_V is 1029, μ' is 0.4, α is 0.114, so this is 1153.5 m^4. Now, $r = \frac{D}{2}\frac{I}{mI_V}$.

So, I can write D is 14 then I is 1153.5, m is 1, I_V is 1029. So, this is 7.85 m. Now, first check that H should be greater than $\frac{M}{r}(1 + \mu\mu') - \mu W$. So, now the applied moment M is 3500, r is 7.85, μ is $\tan\phi$ that means $\tan 35°$ and μ' is $\tan 22°$ or directly you can write 0.4 also.

So, W is 5000, so $\frac{M}{r}(1 + \mu\mu') - \mu W$ is -2929 kN. So, H is greater than -2929 kN, so it is safe, because H is 1000 kN. So, now I will do the second check. So, that check is H should be less than $\frac{M}{r}(1 - \mu\mu') + \mu W$. So, M is 3500, r is 7.85 then $1 - \tan 35° \times \tan 20° + \tan 35° \times 5000$. So, that is 3821 kN. So, H is less than 3821 kN. So, that means it is safe, because H is 1000 kN. So, it is safe.

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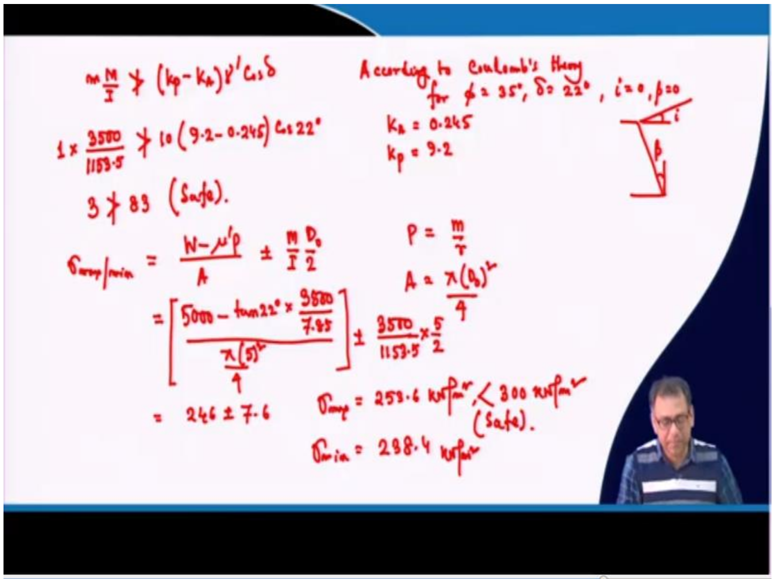

So, now, I will do the next checking. So, next one is that $m\frac{M}{I}$ should not be greater than $(K_P - K_A)\gamma' \cos\delta$. So, that is the equation. Now, according to Coulomb's theory that for $\phi = 35°$, $\delta = 22°$ that $K_A = 0.245$. So, you can calculate this because we know the equation for Coulomb's active earth pressure and passive earth pressure coefficient you put these values and $i = 0$ because it is not incline.

So, i is also 0 then β this is the vertical plane, so β will also be 0. So, that means here it is not inclined. So, this is vertical plane I am talking about this is β for a wall. So, this β is now 0, because the sidewall of the well is perfectly vertical. So, that means here this β will be 0. So, β is 0, i is 0, I mean that this inclination of the backfill. So, here backfill is also flat, so i is 0, β is 0, $\delta = 22°$, $\phi = 35°$.

If you put these values in the Coulomb's equation you will get $K_A = 0.245$ and $K_P = 9.2$. So, now, if I put that $m = 1$, M is 3500 applied moment and I is 1153.5. So, I is 1153.5, so that should not be greater than γ' is 10 K_P is $9.2 - 0.245 \cos\delta$, so $\cos 22°$. So, this is equal to 3 and that is not greater than 83. So, this side is 83, so it is safe. Now, I will calculate the next one that is $\sigma_{\max}$ and $\sigma_{\min}$.

So, $\sigma_{\text{max/min}} = \frac{W-\mu' P}{A} \pm \frac{M}{I}\frac{D_0}{2}$ because here it is circular. Now we know that $P = \frac{M}{r}$. So, now if I replace P with $\frac{M}{r}$ and $A = \frac{\pi D_0^2}{4}$. So, I can write, so this is equal to W is 5000 - μ' is $\tan 22°$ and P is $\frac{M}{r}$, M is 3500 - r is 7.85. So, this is 7.85 then divided by $\frac{\pi \times 5^2}{4}$ then $\pm m$ is 3500 and I is 1153.5 then D_0 divided by 2 is 5 divided by 2.

So, $\frac{5000 - \tan 22° \times \frac{3500}{7.85}}{\frac{\pi \times 5^2}{4}}$ because we have replaced P with $\frac{M}{r}$ then $\pm \frac{3500}{1153.5} \times \frac{5}{2}$. So, that is equal to 246 ± 7.6, so σ_{max} is 253.6 kN/m^2 and so which is less than 300 kN/m^2. So, that is the allowable bearing pressure of the soil, so it is safe and σ_{min} is also 238.4 kN/m^2 negative pressure is also not developed. So, that means, we have done all the checks and under these conditions or these values or these configurations that well is stable.

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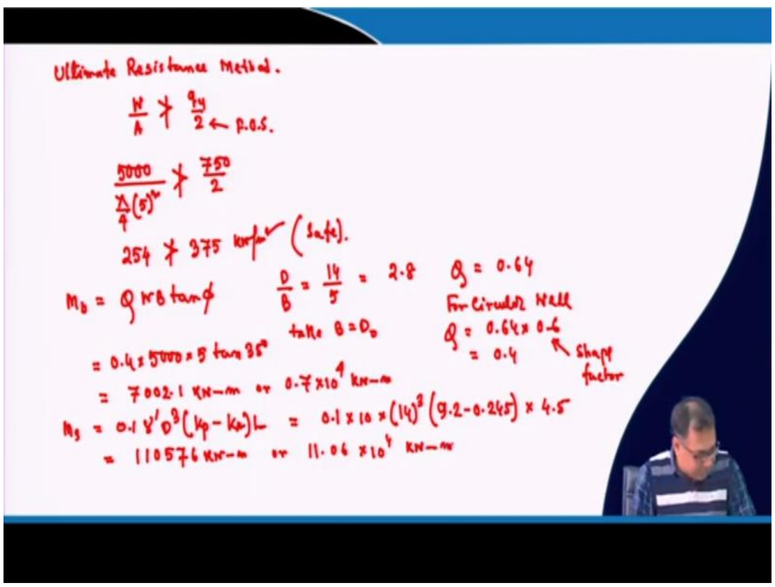

Now, we will do the same problem by the ultimate resistance method. So, in ultimate shear resistance method two conditions you have to satisfy that W/A should not be greater than $q_u/2$ where 2 is the factor of safety. So, W is here 5000, A is $\frac{\pi \times 5^2}{4}$, so $\frac{5000}{\frac{\pi \times 5^2}{4}}$ should not be greater than $\frac{750}{2}$ because I have given q_u is 750 kN/m^2 so, $\frac{5000}{\frac{\pi \times 5^2}{4}} = 254 \ngtr 375$ kN/m^2, so it is safe.

Now, I will do the moment checking. So, I have to calculate the resisting moments. So, $M_b = QWB\tan\phi$. Now, $\frac{D}{D_0}$ I should say first because we have to use that table then you will convert it, so take $B = D_0$ so $\frac{D}{D_0} = \frac{D}{B} = \frac{14}{5}$. So, this is equal to 2.8 and this is beyond is 2.5. So, we have taken it close to 2.5. So, we are taking 0.64. So, we have taken 0.64.

So, $Q = 0.64$ this is for rectangular square footing. So, for the circular, rectangular, square well so for the circular well you have to multiply with a factor of 0.6, so that for circular well $Q = 0.64 \times 0.6 = 0.4$. So, this 0.6 is a shape factor. So, now if I put these values, so this is 0.4 W is 5000. Now, $B = D_0$, so that is $5 \times \tan 35°$. So, $M_b = 7002.1$ kN-m or 0.7×10^4 kN-m.

Now, for the circular well M_s is $0.1\gamma' D^3(K_P - K_A)L$. So, this is equal to 0.1 γ' is 10 then this is 14^3, then K_P is 9.2 $-K_A$ is 0.245. Now, L is 4.5 because we have already multiplied that and you will get 4.5. So, this is equal to 110576 kN-m or 11.06×10^4 kN-m.

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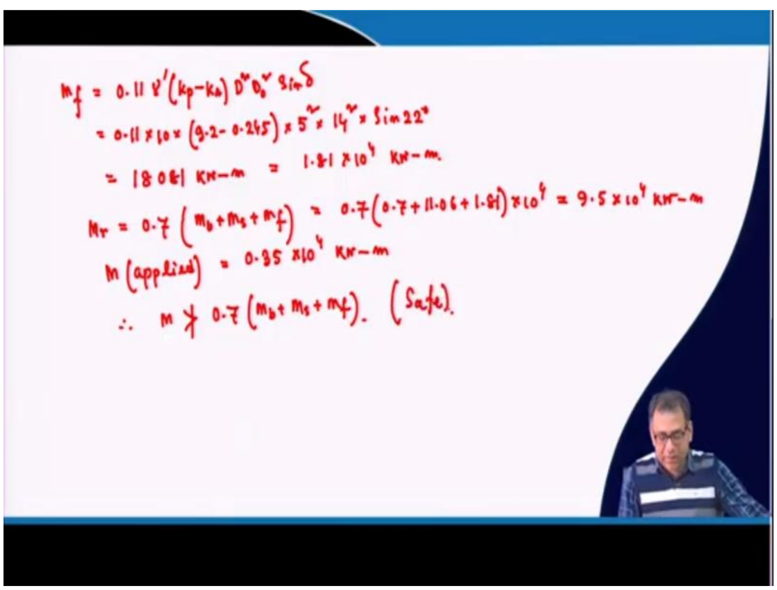

Now, we will calculate the moment due to the friction M_f and for the circular well this is $0.11\gamma'(K_P - K_A)D^2 D_0^2 \sin\delta$. So, this is $0.11 \times 10 \times (9.2 - 0.245) \times 14^2 \times 5^2 \times \sin 22°$. So, this is equal to 18081 kN-m or that is equal to 1.81×10^4 kN-m. So, the resisting moment $M_r = 0.7(M_b + M_s + M_f)$.

So, that is equal to $0.7(0.7 + 11.06 + 1.81) \times 10^4$ kN-m. So, that is 9.5×10^4 kN-m. And the moment which is applied, so that is equal to 0.35×10^4 kN-m. So, M is not greater than the $0.7(M_b + M_s + M_f)$ because M is 0.35×10^4 kN-m and we have a resisting moment of 9.5×10^4 kN-m and applied moment is 0.35×10^4 kN-m, so it is safe.

So, we have checked these well stability using both methods elastic analysis as well as the ultimate resistance method and both methods are giving the safe design. So, it is indicating that well is stable. So, this is the end of the well foundation. In the next class I will start new topic which will be a very small module. So that is the foundation on difficult soil. Thank you.