Advanced Foundation Engineering
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Lecture – 61
Well Foundation - II

So, in my previous lecture I have discussed about different types of well foundation and how we can determine the depth of well foundation, discuss about the scour depth, maximum scour depth and the grip length and then ultimately the depth of well foundation.

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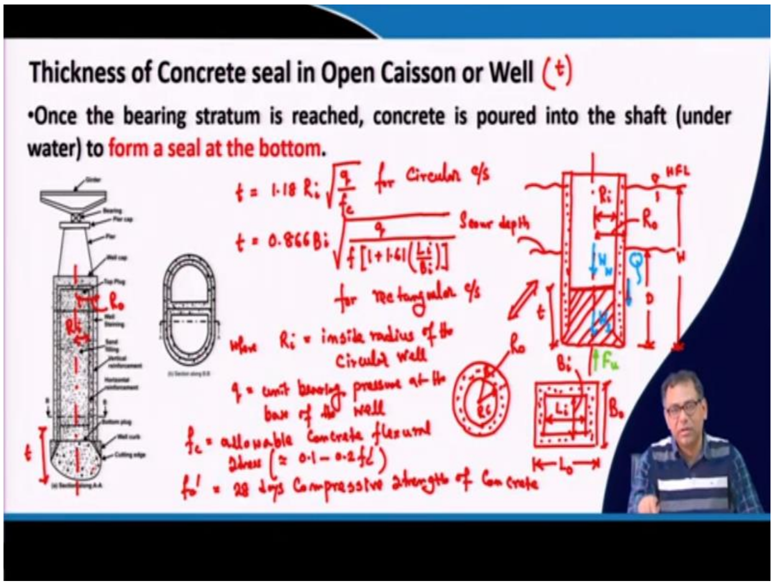

Now, today I will discuss that how we can determine the thickness of the concrete seal in open caisson or well. So, as in my previous lecture, I have already discussed that when the bearing strata is reached for open caisson when the concrete is poured inside the shaft under water to seal at the bottom, so that means, here you can see. So, this is the shaft and these are the places where the concreting is done to seal the bottom and then once the concrete hardens.

Then the shaft is filled with the sand or the concrete and then further constructions are done. So, that means, once this bottom seal is done, so you have to check whether that thickness of the concreting for the bottom seal is sufficient or not. So, why this thickness is important because in that case there will be buoyancy force which will act in the upward direction. So, that concrete is sufficient to take care that buoyancy force or not that you have to check.

Because in that situation we will not consider the weight of the water which is inside the shaft because we do not know what would be the depth of water inside the shaft. So, it is better to neglect that weight. So, we will consider only the concrete thickness weight to check that it can stand again that buoyancy force or not. So, here that thickness in this figure, you can see this bottom plug or this concreting that thickness we have to determine or if I draw a separate figure to calculate that thickness.

So, this is the shaft and here the concreting is done. And suppose that thickness is this one, so this portion of thickness of the concrete seal we have to determine. So, this is the water and this is the scour level or this is the HFL, this is the central line. So, this one is the scour level, scour depth or maximum scour depth and this is the HFL and this one is the depth of foundation below the scour level and that *t* thickness of the concrete seal that we have to determine

And we have two diameters of the shaft one is the inside diameter; another is the outside diameter. So, this R_i is the inside radius and this R_o is the outside radius or we are getting, so that means this is the radius. And suppose there can be two types of well that are commonly used. One is the circular cross section, so this is the circular cross section, which is the section that I have drawn. So, this is for the circular cross section or circular well.

So, this one is the inner radius R_i and this one is the outer radius R_o, so it can be a rectangular cross section also. So, this is the rectangular cross section of the well and where this outside length is L_o, inside length is L_i, outside width is B_o, and inside width is B_i. So, these are the particular wells, so for which we have to determine the thickness of the bottom seal.

So, the thickness of the concrete well or seal that is equal to *t* as for this figure this thickness or here you can see this thickness. So, this is the thickness of the bottom seal. So, that we have to determine. So, I have drawn a simplified section, so it is circular or it can be rectangular, but this section corresponding to this one these are the two sections. So, this is the plan of the circular cross section and this is the section and this can be rectangular also.

That mean the section that I have drawn is for the circular cross section, but it can be rectangular also that I want to say. So, now, that thickness of the concrete seal, $t = 1.18R_i\sqrt{\frac{q}{f_c}}$ for circular cross section. And $t = 0.8666B_i\sqrt{\frac{q}{f_c\left[1+1.61\left(\frac{L_i}{B_i}\right)\right]}}$ that is for rectangular cross section or rectangular caisson.

Now, where R_i is the inside radius of the circular caisson, circular well or the caisson, q is equal to the unit bearing pressure or unit pressure at the base of the well or caisson f_c is equal to allowable concrete flexural stress that is equal to $(0.1 - 0.2)f_c'$, where f_c' = 28 days compressive strength of concrete. Similarly, the B_i and L_i are the inside width and length of the caisson for the rectangular caisson.

So, this way we can determine what would be the thickness of that concrete seal and this depth D is the below the scour level. So, now next is how we can calculate that? So, for that or here I can write one more thing that q is equal to here.

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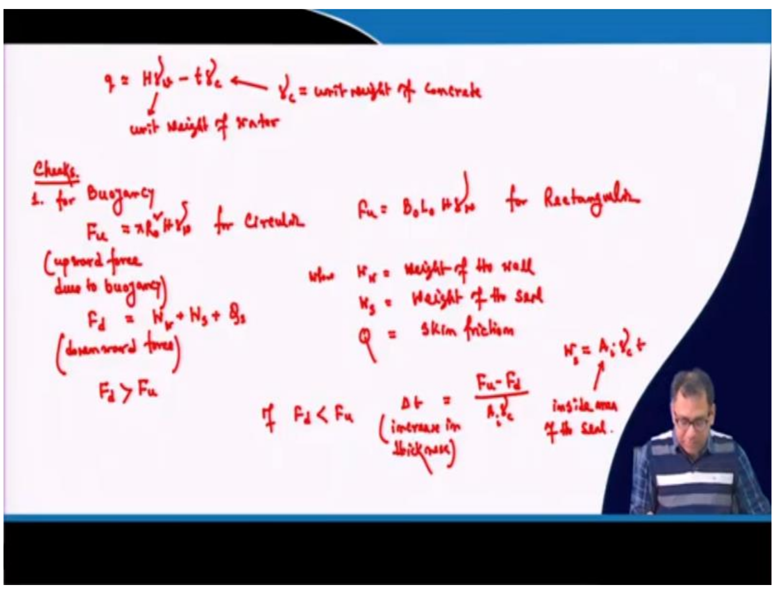

So, in this equation the q is roughly we can write that q is the in this base what is the pressure which is acting here. So, what are the pressures which are acting at the base that the downward stress that is acting due to the concrete seal and the upward stress which is acting due to the buoyancy force. So, the net stress which is acting at the base of this well that is equal to q again the stress or bearing pressure or you can say the pressure which is acting at the base net pressure.

So, that means here the net pressure as I mentioned there will be a buoyancy force that is acting in the upward direction and or the buoyancy stress or the pressure due to the buoyancy and there will be a pressure due to the concrete seal self for it. So, that means we can write that the q is roughly is equal to the buoyancy stress due to the buoyancy will be $H \times \gamma_w$ and minus the t is the thickness of the seal into unit weight of the concrete.

Now, what is H? H is that total water height from the HFL to the base of the well, so that is total one is equal to H. So, that is the height of the water at the base of the well. So, that means here this is the height and this γ_w is the unit weight of the water and this is γ_c is the unit of concrete. So, this way once we know that q and f_c we will get from the 28 days compressive strength of the concrete then we can determine the thickness of the well.

So, all here that thickness again I should write, so this will be the thickness of the well for this particular figure and here this is the thickness of the well and here also you have internal radius, R_i and the external radius, R_o. So, now, we have to done few checks, what are those checks that mean the thickness that we have provided is sufficient or not that check we have to do.

So, a first check is for the buoyancy. So, for the buoyancy that uplift force or you can write this is the upward force due to buoyancy will be how much, so that uplift pressure due to the buoyancy $H \times \gamma_w$, so that you have to multiply with the base area. So, that area is πR_o^2, so this is for circular cross section or circular well and F_u will be equal to for rectangular it will be $B_o \times L_o$B that is the area $\times H \times \gamma_w$ that is for rectangular well.

Now what is the downward force, F_d is the downward force or the total downward force, so that will be weight of the well + weight of the seal + skin friction. So, what is skin friction because when there is a soil here and well is placed here, so there will be a skin friction between the soil and the well, so that force due to that skin friction is Q. So, that is acting in the downward direction.

Why it will act in a downward direction? When this buoyancy force will try to push this well in an upward direction. So, the skin friction between the soil and well that will act in the downward direction. So, that is why this Q will act in the downward direction now the weight of this seal that will act in the downward direction, so this is the weight of the seal and there will be a weight of the well that will also act in the downward direction.

So, I should write weight of the well or W_w, so that means, these three forces will act in the downward direction and the force due to the buoyancy that will act in the upward direction. So, that force due to the buoyancy F_u, so that will act in the upward direction. So, buoyancy force will act in the upward direction and due to that buoyancy force, friction will generate do between the soil and the wall.

So, that will act in the downward direction that is Q, then that now, the weight of the well will act in the downward direction and the weight of the seal that will also act in the downward direction. So, I can write what are the different components? So, these were W_w is weight of the well or caisson, W_s weight of the seal. So, this is weight of the seal and then Q is equal to skin friction.

So, for stability purpose, that F_d should be greater than F_u such that, the total downward force can nullify that upward force due to buoyancy. So, for the stability purpose, this F_d should be equal to F_u. Now, if F_d is less than F_u, then we have to change the thickness. So, how we will change the thickness, then Δt is the increase in thickness. So, if F_d is less than F_u that means the upward force is greater than downward force, then we have to increase the thickness of the seal.

So, that increase is equal to the difference between these two forces divided by the inside area of the seal into the unit weight of the concrete, because the weight of the seal is equal to what? Weight of the seal is equal to inside area of the seal × unit weight of concrete × thickness. So, this is inside area of the seal. So, if this condition is not satisfied F_d is not greater than F_u then you have to increase the thickness by this amount.

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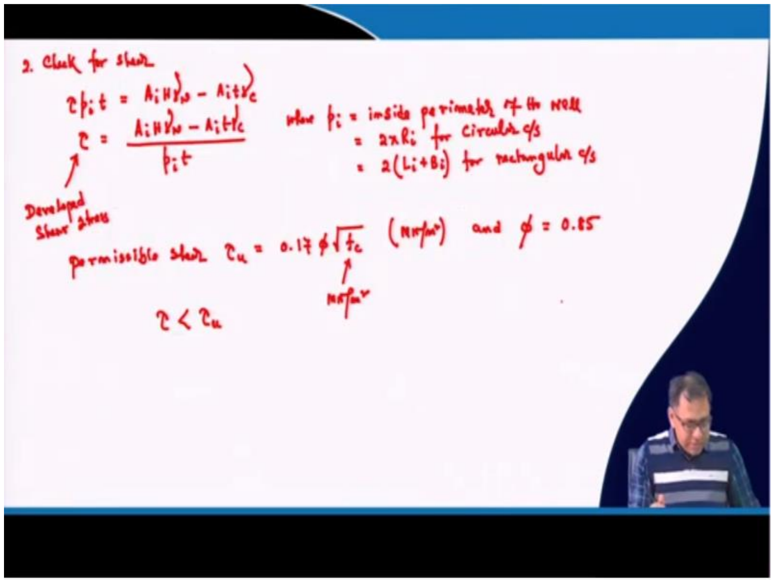

Now, the next check that we have to do is check for shear what is that? The shear stress that will develop because there will be buoyancy force which is acting in the upward direction, so that will be there and some downward forces will also act. So, here stress due to shearing will develop between this concrete seal and the shaft well. So, that also you have to check whether the developed shear stress is less than the permissible shear stress or not.

First, we will calculate inside the well. So, total shear force will be the shear stress that is developed × inside perimeter of the seal × thickness of the seal. So, inside perimeter that we have shear stress or shearing will develop the outside surface of the seal. So, that means here we can write the inside this perimeter of the seal into thickness into the shear stress that is developed.

So, that will be equal to the shear stress that is developed due to the upward force and that is $A_i \times H \times \gamma_w$ that means the inside area, so that is the force which is acting in the upward direction. So, and then $A_i \times t \times \gamma_c$, where, γ_c is the unit weight of concrete. So, that is the force which is acting in downward direction due to the weight of the well. So, that means, how these forces will develop.

So, that means there will be upward force due to the buoyancy that will push this well in the upward direction and the self-weight of the seal that is acting in the downward direction. So, difference of these two will give you the amount of shear force that is developed within the inside perimeter of the well or between the seal and the shaft. So, that is equal to the shear stress that is developed.

So, finally, τ will be the upward force due to the buoyancy minus downward force due to the seal divided by perimeter into thickness. So, this is the developed shear stress, so now A_i is the inside area of the seal or the area of the seal because the seal does not have any inside or outside you can say the inside area of the well that is equal to the area of the seal or this should be the area of the seal or I should write this is inside area of the well this A_i.

Similarly, the P_i is equal to inside perimeter of the well and that is also equal to the perimeter of the seal. So, that is equal to $2\pi R_i$ for circular cross section and equal to $2(L_i + B_i)$ for rectangle cross section. So, this is the shear stress which is developed, so the shear stress which is developed should be less than the permissible shear stress. So, that permissible shear is equal to τ_{ultimate} that is $\tau_u = 0.17\phi\sqrt{f_c}$.

So, τ_u should be in MN/m^2 where f_c is in MN/m^2 and we can calculate that ϕ or you can take ϕ = 0.85. Now, for the stability purpose this τ should be less than τ_u. So, that means, we have to do these two checks to see whether the thickness that we are providing is sufficient or not. One check is the buoyancy force which is acting in the upward direction.

So, this buoyancy force should be taken care of and that weight of the well, weight of the seal and the friction force. So, the weight of the well means, because that is the weight of the well without that seal because sealing is done once it is reached at the base of the well or at the hard strata or the bearing strata. Now, in addition to the seal that well has a shaft, so that shaft has its own weight.

So, those weight we have to consider. So, that weight is the weight of the well because in that situation only that shaft is present, because after that when the sealing is done then there will be sand filling then there will be further concreting for that top plug. So, those things will be done later on, but when this buoyancy check is done to provide the sufficient thickness at that moment that will be only that well shaft and bottom seal.

At that condition we are checking whether that seal is sufficient or not or what that mean that shaft weight and the bottom seal weight and the friction between soil and the well that these three forces will act only in the downward direction to take care of the upward buoyancy force. So, that check is required. And another check is when buoyancy force is acting in the upward direction and the weight of the well that is acting in the downward direction.

So, the friction that will generate between the shaft and the concrete for sealing. So, that friction that will generate should be within the permissible friction and that permissible friction is given as τ_u and this τ which is the developed friction or developed stress between the well and the shaft clear that means there will be shear stress that will be generated in this point between the shaft and the seal and there will be a buoyancy force and the weight. So, this shear that is developed we have to check whether that is within the permissible shear stress or not. So, these are the checks that we have to do.

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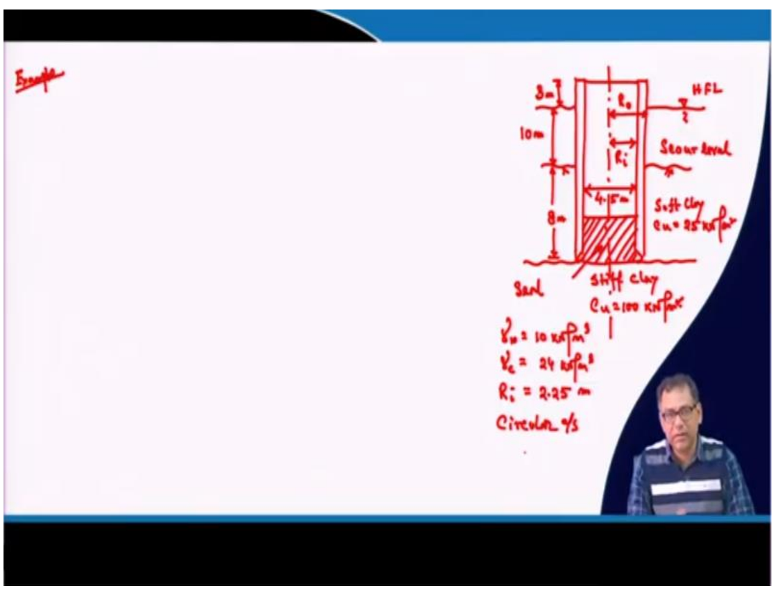

And then if I start one example problem, so I can give you what is the example problem and then I will solve this problem in the next class. So, this is a particular well which has a circular cross section and this is the HFL the height of the well above the HFL is 3 m and then this one is the scour depth and this distance from the scour depth to HFL is 10 m then the depth of the well is 8 m, because 10 m is the maximum scour depth.

And as I mentioned that there should be at least 30% of that means around 3.5 m, but here 8 m is provided. So, that mean it is okay. So, that means here this is 8 m and here the concreting is done and this is the seal. So, that seal thickness we have to determine. So, this is the seal and then the properties are, so this is the scour level, this is HFL and the properties that this portion it is soft clay whose C_u is 25 kN/m^2 and then it is resting on a bearing stratum.

This is stiff clay C_u = 100 kN/m^2, this is the center line and this is the inside radius R_i and this is the outside radius R_o. So, unit weight of water is taken as 10 kN/m^3, unit weight of concrete is 24 kN/m^3, then R_i, inside radius is 2.25 m and that means the total inside diameter is 4.5 m. Now, we have to determine what would be the thickness. So, this is circular cross section.

So, that means, it is passing through a soft clay layer of C_u = 25 kN/m^2 and resting on a stiff clay layer to C_u = 100 kN/m^2 and the grip length is 8 m and then the other properties are given and we have to determine what would be the thickness of the seal and then we have to do those two checks that I have discussed. So, in the next class I will solve these problems because this class I have given the input parameters.

So, I mean those are the parameters or the properties of the soil are known for that particular open well. So, next class I will discuss that how we can determine the thickness of this seal. Thank you.