Geotechnical Engineering - II

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Lecture No. 32

Gravity walls Supporting Cohesive Soil Mass (Backfill)

So, we have been talking a lot about the Rankine wall, where we have assumed that the backfill happens to be pure granular material. In practice many times it happens that you have to retain cohesive size because of the lack of availability of a pure granular material. So, under these conditions though it is not advisable to have a backfill material as a cohesive material, please make it very sure, all right. So, we are just doing a hypothetical analysis to make ourselves understand that if cohesion is present in the backfill what would be its implications, all right?

Otherwise by definition, backfill material should always be a freely draining material of very high permeability so that consolidation does not become a problem. Long-term consolidation should not become a problem, water retention should not become a problem. The type of analysis which we have done in the previous modules where we have shown purged water table and the submerged situation where the water gets logged into the retaining wall, these types of situations can be avoided by using highly permeable granular material. So, let us do analysis of a situation where the backfill happens to be a cohesive soil, it's a c-ϕ soil let us say.

And it will be very interesting to see the case of a passive earth pressure. So, if this is the trial wedge and we have all those conditions which we have considered earlier, there is a q_s, height of the wall is H, inclination of the slip surface is θ. We are trying to find out the passive earth pressure on the system. This is W, weight and this material happens to be a c-ϕ material. That is the only difference. Draw the free body diagram of the forces which are going to act on the system.

So, this part you are very well conversant with. You have the normal force acting on this system. Then we have a component of the shear. Now, this happens to be a passive earth pressure, so shear force is acting downwards and then the component of c comes into the picture, all right. So, the component of the c is getting mobilized in this form which will be equal to c' multiplied by length of AB, is this. So, this is the only difference which we have made, and L_{AB} is known, this is H upon sinθ.

Now, we can solve this problem by using the simple trial wedge analysis. So, try to work out the magnitude of P_P. What this should be equal to? The first component is, suppose if I take a worst situation, here also if I allow water logging, so the first one would be the effect of water. If I take it on the left-hand side this becomes P_P minus half $\gamma_w H^2$, P_P' effective earth pressure under passive conditions plus what is the contribution from the soil? Buoyant force H^2 into K_p term plus what is the contribution from the c?

So, this will be equal to $2.c'H.\sqrt{K_P}$ and what else is remaining? The surcharge, so the surcharge will be in the form of q_s into H into K_p, is this fine?

$$P_P = \left[\frac{1}{2}\gamma_w H^2 + \frac{1}{2}.\gamma_b H^2 K_P + 2c'H\sqrt{K_P} + q_s H K_P\right]$$

Try to solve this problem or this situation by using trial wedge analysis. You know all the forces which are acting on the system and then compute this, all right? Any questions?

Now, let me introduce the concept of tension crack in a c-ϕ soil which you have studied already and if you remember we had talked about the soil mass of height H and if this happens to be a c-ϕ type of soil with unit weight of γ, what we did? We drew the pressure diagram, and this is how the pressure diagram looked like and this is the z_0, the depth of tension crack. So, here the tension is prevailing here the compression is prevailing in the soil mass, this is all right and the z_0 value we computed as $2c/\gamma\sqrt{K_a}$.

$$z_0 = \frac{2c}{\gamma\sqrt{K_a}}$$

If you are working in pure cohesive soils, K_a term disappears this becomes 2c upon γ. If you are working in a c-ϕ soil, this is the contribution of c, this is a contribution of ϕ in the form of K_a. So, we get the value as 2c upon γ $\sqrt{K_a}$. And if I multiply this by 2, so $2z_0$ is equal to the critical height of unsupported cut. So, this concept we are now going to use for analysing the stability of the walls for finding out active and passive earth pressures. Is this part, okay?

So, if I extend this logic to the stability block over here. What you will realize is, now this is the slip surface, this tension crack I am depicting as a crack over here. So, this becomes C, no

C is this D and E. So, this is the tension crack which is developing because of the inherent property of the soil mass being cohesive. What is going to happen during rains? The water will seep through, water gets logged over here and then the water pressure is going to act on the block and which is going to destabilize the entire system, you remember all these things.

Another property of E and D is this happens to be a free surface. Now, what is the attribute of the free surface? This surface has got detached from the parent block, from the parent wedge. That means this is an atmospheric surface, there is no reaction which is going to come on the surface in the form of the normal stress. That means, if you look at the free body diagram of EBD, here the normal stress is 0 and the shear stress is 0. It is a free surface, clear?

So, this is the case which is defying the law of mechanics. The weight is acting downwards and suppose if this happens to be pure cohesive material, this cohesion is going to balance. So, we have two forces and under which the body cannot remain in equilibrium. So, what is the way out? We have to assume that this block is of infinitesimal weight where weight is tending to 0 then only it is possible, is this part clear? So, because the weight is the component which was dealing with the induced cohesion and the way to justify this would be, if EDB is infinitesimal that means the weight of the block is tending to 0 then only the equilibration can take place. That means 0 weight no question gets mobilized.

I can extend this idealization in such a way that I can assume that the mobilization of the cohesion at point B is 0. When you reach the point D, it becomes the full mobilization of the cohesion. So, this is the c' value, the maximum cohesion. And beyond this point what is going to happen? The c' remains uniform.

So, this is the variation of c'. Starting from c equal to 0 attaining the maximum value at the tip of the crack which is known as tension crack and beyond which c' remains constant. So, what we will do is we will try to utilize these properties in such a manner that they could be useful to us. The total length of the wall is, or height of the wall is H. This we have computed as $z_{critical}$, is this, okay? So, this is your $z_{critical}$ which I had defined as z_0 or let it be z_0 and this is equal to $2c'/\gamma\sqrt{K_a}$.

Now, can I find out the average c which is going to act on the surface AB. So, $c_{average}$ which is acting on surface AB. This will be equal to how would you compute the average c value? total length of the surface, is this okay? I am assuming this as theta so H/sinθ is the total length? What about this triangle? This will be half c' into this value. So, this will be half c' into z_{cr} or z_0 upon, let it be z_{cr} then because standard term is z_{cr}. So, z_{cr} divided by sinθ plus the rectangular portion.

So, this will be equal to c' H minus this portion goes out z_{cr} upon sinθ, is this okay?

$$c_{avg} = \left[\frac{\frac{1}{2}.c'.\frac{z_{cr}}{\sin\theta} + c'.\frac{(H - z_{cr})}{\sin\theta}}{\frac{H}{\sin\theta}}\right] = c'\left(1 - \frac{z_{cr}}{2H}\right)$$

So, if you solve this expression what is that you are going to get? Solve it quickly. So, this will be equal to c' 1 minus z_{cr} open divided by 2H, this is right? Is this, okay? So, this is the average value of the question which is going to get mobilized on this surface. Why have we done all these analyses? We have done this analysis to make sure that we are using the right value of cohesion which is getting mobilized on the slip surface of a c-ϕ retained soil mass for finding out the earth pressures.

Suppose the soil happens to be pure frictional, clear? What is going to happen? Pure frictional soil no tension cracks, c' is equal to 0 that Z_{cr} equal to 0, if z_{cr} equal to 0 that means the average c is equal to the mobilized c', this is part, okay? And c' can be neglected because what we are doing is we are assuming c' to be tending to 0 for pure frictional material. So, value of c_{avg} will also be 0. So, this becomes a sort of a correction factor that is the critical depth of the tension crack divided by two times the height of the wall.

Now, using this concept, we can find out the active earth pressures and passive pressures, both. So, suppose if I give you the value of c_{avg}, now can you write the expression for active earth pressure case because that is more interesting. So, this will be half into γ_w H^2 plus buoyant weight plus half $\gamma_b H^2$.

Now, what is going to happen to the c' case? That c' gets replaced by the value which we have obtained. So, this becomes we are doing active earth pressure case. So, this will be 2c' or average value and average value is equal to $2c'.\left(1 - \frac{z_{cr}}{2H}\right) H\sqrt{K_a}$).

$$P_a = \frac{1}{2}.\gamma_w.H^2 + \frac{1}{2}.K_a.\gamma_b.H^2 - 2c'\left(1 - \frac{z_{cr}}{2H}\right).H.\sqrt{K_a}$$

So, this term becomes what? How would you define this term? This is basically average effective cohesion, which is exhibited by the soil mass. Similarly, you try to find out the P_P also so there is no difference. I think you can just substitute the terms accordingly and you will see that most of the parameters remain same in this expression, and we can obtain from P_P also. So, this will become plus $2c'.\left(1 - \frac{z_{cr}}{2H}\right) H\sqrt{K_p}$) and then these terms will also, we have done a mistake over here, so, this should have been K_a. This will also become K_p, fine?

$$P_P = \frac{1}{2}.\gamma_w.H^2 + \frac{1}{2}.K_p.\gamma_b.H^2 + 2c'\left(1 - \frac{z_{cr}}{2H}\right).H.\sqrt{K_p}$$