Geotechnical Engineering - II

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Lecture No. 41

Anchored Bulkheads

So, in the previous lecture, I have discussed in detail about the sheet pile walls particularly the anchored bulkheads. I have also discussed about the analysis of anchored bulkheads by using different methods. The first one that you discuss was the simplified method and the second one was the free earth support method and the fixed support method, and the statement of the problem is for a given height of the bulkhead or the retaining wall or the sheet pile wall, you are supposed to find out the depth of embedment.

And at the same time, I also introduced the concept of how anchoring is done by using tie rods or the cables attached to the anchorage systems to enhance the stability of the sheet pile walls or the anchored bulkheads. I will go a bit more into the details of the analysis of anchored bulkheads because these systems are becoming very contemporary in today's infrastructure development. And I wish that all of you should become an expert in this subject for analysing the anchored bulkheads.

So, by definition an anchored bulkhead is you have a retaining wall, say this is the sheet pile and this is the dredged level. We call it as DL. This is the ground surface, and this is the backfill. So, the whole idea was to attain much higher heights of H above the dredged level. So, that I can make a higher wall and with can retain lot of soil mass. So, what we did is, we introduced a tie rod or anchorage. So, this is the tie rod or the bar at the depth of say about *a* from the top of the bulkhead.

Now, without having an anchor this tie rod or the bar is not going to be effective. So, what is done is, this tie rod is connected to an anchor. So, this becomes an anchor. Now, these anchors could be the independent units. This could be an anchor, a block and this block will be connected to the tie rod like this let us say. This could also be a beam of length *l*. So, this could be a continuous beam of length *l* also.

So, otherwise the spacing between the two blocks. So, if I consider another block over here, the spacing could be *S*. So, *S* is the spacing between the anchors and in case you are having a continuous beam then the length is the length of the beam is *l*. Now, one of the most critical questions here is what should be the length of the tie rod? In other words, where this block should be located within the backfill? why it is so? As far as analysis is concerned what we have done is, we have obtained the *d* value the depth of embedment by using different methods. We can obtain *t* also. We can optimize *a* also depending upon the parameter which are known and unknown.

Now, the question is where should be the anchor placed in the backfill? Why this question is being asked? Suppose if this anchor is very close to the tie rod in such a way that this sits in the active wedge. So, suppose if this is the failure slip surface and this becomes the active wedge. So, if this is the active edge, do you think that this anchor is going to be active or going to be useful? No. Why? At the time of failure this entire rigid body is going to fail by deflecting the wall excessively. So, what you have to do is you have to make sure that this anchor is sitting in the passive block, not in the active block. That means, what I have to do is graphically I should find out what is the zone of active earth pressure and what is the zone of passive earth pressure.

And then locate the anchor in the passive earth pressure zone. Big question is what this point through with the slip surface is passing. So, this point normally defined as x could be at the tip of the wall we can obtain from d or this could be 75% of the d value is obtained by fixed earth method. So, there are two ways of obtaining the value of x or the point x. So, the location of x is, either this is d which you get from free earth support method, or this could be 0.75 times d when we are using a fixed earth support method.

Now, once the point x is fixed, what I can do? I can draw the location of the active earth pressure zone. This would be $45+\phi/2$. So, say this is the active earth pressure zone. So, ABX is the active earth pressure zone. What will be this angle? Angle this angle will be $45+\phi/2$. Remember the Mohr circle? If I want to find out the conjugate plane on which the passive earth pressure conditions are acting, what I should be doing?

From this line if I draw a perpendicular so, this angle is 90°, what will be the inclination of this line? This will be 45-ϕ/2. So, this block BC, C not be there. B and B onwards let us say. So, this goes up to BC, so, this zone is going to be the passive earth pressure zone. So, this is 45-ϕ/2. So, what we have done is by using the simple concepts of analysis of the sheet pile walls, anchored bulkhead, we have obtained the value of d.

I can take either d as the location of x that could become the pile tip or 0.75 d the location of x starts from here, draw a horizontal line 45-ϕ/2. This becomes the active earth pressure zone and having obtained this perpendicular to this plane would be the slip surface for passive earth pressure one. What about the zone in between X B and C? So, all these zones which you are seeing over here this is K_a condition this is K_p condition, so what about the in between zone, this becomes K_0. So, this is how we analyze the anchorage and position of the tie bar with the anchors.

There is one more thing I suppose, if I consider that *b* is the height of the block and depth of embedment is let us say normally, we define this as the d_a. The free body diagram is like this. Now, suppose if I magnify the pressure which are acting on the anchors, I hope you will realize that this now I can draw the anchor. This is the ground surface. Anchor is being pulled up towards the left-hand side with respect to horizontal what would be the surface this zone, active zone, correct?

So, this is equal to 45+ϕ/2 and what about the passive zone? When you are pulling the anchor on the left-hand side this soil mass is trying to resist the moment of the anchor block. So, this is going to be 45-ϕ/2, is this, okay? The height of the anchorage is b which should be not less than $d_a/2$ where d_a is this whole thing. This is the first condition that means there should be enough overburden on the anchor, so, that active and passive earth pressures mobilize.

The more and more passive earth pressure gets mobilized the anchor is going to be more effective. I think now you can realize the tension in the anchorage comes because of two things. One is because of the deflection of the sheet pile which is not acceptable. So, how is going to come? It is going to come because of the passive resistance which is being mobilized by the soil mass. So, that means the net pressure which is acting on the bar would be T multiplied by S, S is the spacing between the two anchor blocks and T is normally in kN/m tension per unit

length of the wire. And that length defines how much these blocks are going to be spaced with each other.

So, this is T, and this is T. I hope you can realize we can go for the equivalent forces which are going to act on the anchor. So, I can take S/2 and S/2 one T. So, T into S is the total force in the tie bar, and this will be equal to what is the net pressure? Half K_p minus K_a unit weight of the soil into d_a^2 depth of embedment multiplied by l.

$$(S.T) = \left[\frac{1}{2}\frac{(K_p - K_a)}{F}\gamma d_a^2\right] \times l$$

Now, one thing is missing over here we are not very sure about how much the passive earth pressures getting mobilized. In fact, we are not sure about how much K_p get mobilized. So, put a penalty function or put a factor of safety on this. So, so far what we did? We applied only factor of safety uncertainty in terms to K_p only. Now, the net K_p - K_a we are applying a factor of safety of F and hence, we are equilibrating the forces which are going to come in the tie rod and the force which is getting exerted onto the anchor system.

So, I hope you can realize if it is a continuous beam what is going to happen? S will be equal to l. So, this part normally gets cancelled out and we are left with total tension equal to this term. Now, I can convert it into a design problem. For a given tension which I am expecting for an anchored bulkhead to mobilize would depend upon the K_p, K_a that means, in other terms phi value. The unit weight we can be obtained by compacting the soil mass or by changing the water table correct.

So, there could be a situation where you have a water table over here. Only thing is going to change is that your γ term is going to change and depth of embedment or burial. So, this is the depth of burial. We have discussed lot of concepts over here regarding the anchored bulkheads.

Now, few more concepts before I switch over to another topic. You must have realized that installation of this anchored tie bar is not so easy. It is correct? What we have to do is we have to keep on filling the file. If you are doing stage wise construction, which is not possible you are doing dredging let us say. You brought the soil mass by cutting from this level to this level is extremely difficult to put an anchor bar over here or an anchorage system over here.

So, this type of systems can be done only when you are backfilling something stage by the layers. And then you can lay the system over here and again bury it and then compact it. Hope you are realizing. So, a better way would be what, any idea? Next time when you pass by a highway or in the hilly terrain or maybe sometimes the systems where you are seeing a retention of the soil mass. Nowadays what is being practiced is people are inserting nails. Now, this is what is known as nailing. The purpose is same, to stabilize the retaining wall.

So, these red systems what I have shown are the soil nails? What you must have realized is intentionally I have been lowering down or decreasing the length of the soil nails, why? Look at the zone of influence of active earth pressure. These nails are going to be effective once they are extending beyond the active earth pressure zone. So, as if you are stitching, this block ABX with the parent body, the stitching, if you remove this, what is going to happen? This block has a tendency to get detached from the system.

So, soil nailing is quite prevalent in today's infrastructure development projects. What is normally done is you define the angle of inclination with respect to horizontal and the length of the anchor or the soil nails. So, length of nails and their inclination is normally fixed. I could show you some of the videos in this case.

So, in the simple form. This is how a soil nail wall looks like. This is an existing road and you wanted to widen it, so, you have cut down the hill. This portion has been cut and then there is a fascia and then the entire slope has been nailed followed by grouts. In most of the airport projects, tunnelling projects, retaining wall projects, highway projects, these types of structures are being designed.

This is a typical anchor where after creating a cavity, you put the steel bar, grout it, use a nut and bolt and fix it at the face of the fascia. This is how the installation is done.

And this is how the finished product looks like. So, sometimes there is a wire mesh which is placed over here, not for the vertical section but for the inclined section. So, sometimes a heavy-duty steel mesh is also provided which gives more strength to the retention. Several projects are being executed by using these concepts.

I would also like to show you a video on a typical sheet pile failure which causes excessive loss of up to the time, money and populi and could be fatal even. So, systematically if I explained that there is a deep excavation very close to multi-storey buildings. Suppose you are constructing a swimming pool quite deep or maybe some car park area in the basement. So, you can see the caving in has already started. The soil mass is almost on the verge of failure such type of failures are quite challenging to control and they could be disastrous.

Few years back there was a major failure which was in the national network very close to IIT, Bombay during the rains. I am sure you must have come across that. One has to be very very careful while designing such systems. You see the infrastructure, road, parking lot or the facility which has been created has already collapsed and fortunately these buildings are not sitting on this pad or the foundation was not provided within this pad. Otherwise, this would have been really fatal. You can type on net and see several failures which have occurred in the recent past.