Geotechnical Engineering - II

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Lecture No. 40

Analysis of Sheet Piles- II

So, you must have realized that I introduced the concept of the tie rod with the anchorage. These systems are known as anchored bulkhead. Sometimes, we also call them as the propped sheet pile. What is Propping? Propping is nothing but putting a tie rod or a prop material or in simple possible forms these are also known as anchored sheet piles.

Now, the issue is how I am going to analyse this type of situation. First of all, understand why propping has been done or why tie rod has been included. You must have realized that the bending moment is a function of H^3. So, the higher you go, what is going to happen? The bending moments are going to become extremely high; we want to avoid this type of situation in the field.

So, the moment I put a tie rod, this point it starts behaving like a pin. So, that means what I am doing is this becomes a pin joint and by propping it from here, I am reducing the bending moments, that is the mechanistic model. So, the moment you pull it from the side, the deflections can be controlled. That is what the whole philosophy is all about.

Now, you must have seen the bow and arrows. So, a typical bow will look like this and then somewhere here would be the arrow. So, what normally we will do? We will try to pull it back. So, what is happening to the bow it deflects, correct? Inside. The same is the logic over here. The moment you apply a tension from the backside, you are stopping the deflections.

Now, there are two ways, you must have seen some of the sportsmen in archery. What do they do? They will put a leg over here. If the height or the length of the bow is too much, and that is advisable that means by putting a leg over here what they are doing, they are inducing a resistance. Watch it closely. In the second situation, we do not apply any constraint over here, there is no restraint for the motion, or the movement and we say R=0. So, depending upon these two logics two methods have been created for analysing the propped sheet piles or anchored bulkheads.

The second one which I have talked about here is known as a free earth support method. And the first one which I talked about is known as fixed earth support method. So, these are the two methods which are normally applied to obtain or to analyse the anchored bulkheads. In this case, which is free earth support method, the value of R is going to be 0 in this case, the sheet pile is free to rotate at the bottom point at this point.

In the second case $R \neq 0$ is fixed there is a reaction you are putting a constraint. So, this is free to deflect and rotate. This one is fixed because of the reaction which is imposed on this. So, these are the two methods. Now, let us see how the analysis will be done.

So, for analysing the situation, if I consider this is the ground surface, this is the dredged level, somewhere here you have a tension component which is coming over because of the tie rod or the propping. We normally assume this to be a depth *a* sometimes you have to assume *a* when you are designing or sometimes *a* might be provided there is no issues.

Now, the question is draw the deflected shape of this type of a sheet pile and draw the pressure distribution. So, the pressure distribution is very simple. Yes, that is what we did. Active earth pressure and then how about the passive earth pressure, pressure diagram is done. This is active earth pressure, this is passive earth pressure at this point R is 0, why? Because we are assuming that this is a free earth support method.

Draw the deflected shape in this case. It should start like this. Because once you are pulling it back the deflection is going to be inside the backfill. Deflected shape? Have you understood this. So, this is the deflected shape of the sheet pile. What we do is as we were discussing earlier, we put a factor of safety F over here, why? We are assuming that the full passive earth pressure is not getting mobilized intentionally. So, we are designing it for the worst possible situation.

Now, suppose if I take moment about point T. So, that means, is this okay or not? I can put a condition, because this happens to be a pin joint. I have shown deflection to be 0 at this point. So, the more and more anchors you add the more and more pin joints would get created. What about the second condition? The second condition I can get by equilibrating the forces. So, that means T plus P_p over F equal to P_a.

$$T + \frac{P_p}{F} = P_a$$

What is the principal unknown? The value of d. And this is the height of the wall. So, the problem statements could be like this that I want to design a retaining wall of height H prefixed, because H happens to be a finished product. This is our main objective.

So, for a given H value, what would be the value of d and we are analysing this situation by assuming free earth support method for a propped system. The advantage of propping is I can go for a very high, higher heights as compared to the initial height.

So, suppose if this is H_1 and if I keep it an H. H is going to be higher than H_1 this is the advantage I am going to get. Any questions regarding this? Can you draw the bending moment diagram? Try drawing the bending moment diagram for this case. Where is the prop here? How would bending moment diagram will look like? Good. Next? It gets it reverses its direction. Why? There is no constraint on this there is no restriction on this correct.

So, it is a free earth support the pile is free to rotate, bending moment is going to be 0 at this point. And then you are seeing that there is a point of contraflexure also which is going to come which we can analyse subsequently. Now, if you have followed this, the fixed earth support method becomes very easy to follow. What we do is in free earth support method, we do not impose a factor of safety but yes that the d value will be incremented by 20%.

So, in this case, this is the propping which has been done. Draw the deflected shape first. There will be a concept of point of contraflexure. Contraflexure will come somewhere over here. This is normally at a certain depth below the dredged level. So, we define this as Y. And Y is dependent upon friction angle, and I will give you the values.

So, if ϕ' is known, you can get the value of Y as if it is 25° sorry 20° is the standard value. 20° this is 0.25 H, if it is 30° than it is 0.08 H and if it is 40° it is -0.007 H. What is that you are observing? The more the compacted the material would be below the dredge line, the point of contraflexure has a tendency to pop up. In fact, for 40°, what you are observing is? The point of contraflexure would be above the dredged line.

So, what is the significance of this? If there is no surcharge over here that is why you must have noticed, when we construct the sheet pile walls to take care of the point of contraflexure popping out of the dredge line, normally this portion is overloaded with surcharge. So, the moment surcharge is overloaded over here, the Y value will still remain as positive. You have to practice it a bit.

So, if you draw the deflected shape now, how it will look like? Try doing it yourself. This portion remains common. At point of contraflexure what is going to happen? The bending moment is going to be 0 at this point, now, somewhere here is the point d which we have taken and then this portion is 0.2 times the value of d.

So, if I complete this, this is how it will look like. This continues. But what should have happened at point ‘d’? Where you are imposing R, if you are imposing R then at point d the deflection should be 0. So, this is where your net resultant R is acting, you can draw the pressure diagrams. This portion up to R is passive earth pressure. From here up to R is active earth pressure and this point contraflexure which is at depth of Y is somewhere in between.

Now, the question is how are we going to solve this? Of course, draw the bending moment diagram also here. So, what will happen to the bending moment diagram? In this figure this will get slightly modified because we will be having a point C which is the point of contraflexure. So, at point C the bending moment becomes 0 and where is the point C? Somewhere here. You can make it smooth. This corresponds to the R value.

Now, there is something known as equivalent beam method you must have studied also. So, the moment only difference between fixed earth support method and free earth support method in terms of the mobilization of passive earth pressures is, here we have put a penalty on passive earth pressure in the form of factor of safety. Here we do not put, and then we use the concepts of equilibrium of the forces which are acting on the beam. And now I have an advantage. I can cut the beam to make an equivalent beam about point C.

So, I can cut the beam about this point. So, this becomes my section number 1, and this is the section number 2 of the beam. This is what is fixed earth support method, equivalent beam method.

So, what we have done? We have taken two portions of the beam one is from A, this is let us say a B, C, D, E and F. So, from A to C, we have one beam. Draw the free body diagram of A to C or I can rub this. So, this is the complete section, and this is the point d, this is C, this is somewhere D, this is B, this is A, this is one active earth pressure. This is the Y value, the depth of contraflexure, passive earth pressure.

If I cut the beam over here, now, what is going to happen? The moment you cut, there will be one reaction R1 bending moment is 0, so, moment about C is also 0. And then what I can do? I can go up to point number this point and I can take another section of the pressure which is acting like this.

And this is our extra 20%. So, I can get rid of this. At the bottom portion you have external imposed R. If this is R_1 acting over here, we will have equal and opposite R_1 acting over here, this is the P_P rest of the portion of this length that is CE and this one is going to be P_a of CE. You can create different conditions for moments at point B there is a tension occurring. I can take moment about point B=0 moment about point C as 0.

So, depending upon how many unknowns you have, and then force equilibrium I can have P_{a1} equal to P_P plus R_1. And similarly, here you have $(P_a)_{CE} – (P_P)_{CE} + R_1 + R$ equal to 0 and hence you can solve this equation, will have to practice this to understand how the analysis is done.

$$P_{a1} = P_p + R_1$$

$$(P_a)_{CE} - \left(P_p\right)_{CE} + R_1 + R = 0$$