Geotechnical Engineering - II
Professor D. N. Singh
Department of Civil Engineering
Indian Institute of Technology, Bombay
Lecture No. 35
Earth Pressure Analysis II

Now, what we will do is, we will go back to the analytical procedure for finding out the earth pressures which are going to act on the walls by assuming Coulomb's wedge. So, in the simple case, if I assume the backfill to be horizontal and if this wall is vertical, we now we are applying Coulomb's theory to the vertical wall.

This is a perpendicular. This is P_a. This is how the zone of influence will look like. This angle would be 45+ϕ/2 and this will also be 45+ϕ/2. In case of the passive earth pressure, these angles will become negative. So, this is the effect of the roughness of the wall on the block stability.

Now, one more thing you could do very interesting is- coming back to this, suppose if I asked you to find out the Pole. How will you obtain that? I think we have discussed this in the earlier classes, is it not? So, this happens to be the failure point and if I connect A to point F and if I connect this point to B, these are the two planes of failure. Is this alright?

And where would be the mirror image? This point would be a mirror image somewhere here also. So, if I complete the Mohr circle with two failure envelopes, this is going to be another failure surface. This angle is 45+ϕ/2, active earth pressure. This is going to be 45-ϕ/2, passive earth pressure.

So, you can superimpose these concepts over here to find out you know how the active and passive pressures are going to act. You can use the Mohr circle to obtain and to prove that the failure planes are inclined at an angle of 45+ϕ/2 and 45-ϕ/2. This part we have done earlier in the class.

So, continuing with this discussion, I will give you an idea about how to analyse wedges by using Coulomb's theory and I also intend to discuss in today's discussion about the graphical methods. Though I have been telling that, graphical methods have been phased out because of the advent of very powerful numerical methods but still it is a good idea to learn the basics which you can apply anywhere. We also say it as a wedge theory for a generalized situation.

So, for the generalized situation, the active block will look like, active earth pressure analysis. Let us assume that the wall and the backfill both are having inclinations. So, for that batter, this is the wall. This is the inclination of the backfill. In this case, what we do is we go by trial-and-error analysis by using the method of stability of wedge only.

So, the first slip surface we will assume to be like this. This will give me a weight of W_1. I know the direction of application of the active earth pressure. This is the perpendicular to the surface at an angle of δ and this happens to be a candidate slip surface which we want to find out by optimization.

So, in the first trial we will take as W_1. You can complete the force diagram over here; the forces which are acting on the block. So, this is the direction of the shear force. This is the normal which is acting on the surface. This is the reaction. Angle between N and R is going to be ϕ. The slip surface inclination is assumed to be θ and this is assumed as β.

We have done force diagrams earlier also for this type of situation. So, you can easily draw the force diagram. This is the P_a, W and then the balancing is R. Find out the inclination of these two forces with each other. So, when we were discussing earlier, I said that this angle is always going to be equal to what? θ-ϕ. Is this correct? I mean you can derive it also. And what about this angle? This angle is always the difference of the batter angle and the friction angle. So, this is β-δ. In this system of forces, what is the unknown? P_a. I want to find out P_a, is it not?

So, I can now compute P_a by using the sign law. That is, it. So, P_a can be obtained. Let us say this analysis corresponds to the first wedge. So, I am associating P_a with subscript 1. Now, what you should do next time is change the slip surface to 2. So, W_1 changes to W_2. Correct? Effectively what is happening? This W is increasing. So, from W_1, it goes to W_2 and from W_2 it goes to W_3. You keep on changing it. Try with different-different wedges.

So, I will be having a series of active earth pressures and so on. I can list them. And whenever we find out the active earth pressure, we try to maximize the function. Correct? So, find out the maximum out of these and that is going to be equal to $P_{a,max}$. You know how to compute

W. You can compute W. You can use graph paper also to compute the area and multiply by the unit weight and it gives you the weight of the system.

The case of passive earth pressure is going to be slightly tricky. But though we have done this analysis, when we were analysing the Rankine wall. So, passive pressure case. The concept will remain the same. How will the force diagram change? If this is the wedge, this is θ. Weight is W. This is the perpendicular to the wall surface, passive earth pressure. The batter is going to be negative, and this is going to be the δ value. What about this surface?

The block is moving up. So, the shear force is going to be opposite direction. Correct? That is the only catch. The normal to the surface is; this is the shear force and this is going to be the reaction. That is, it. So, we analysed all these situations earlier. Complete the force triangle. So, why I said tricky? Because imagination is going to be a bit difficult. How to; it is difficult to imagine you know how the force diagram is going to get created.

Start with W. What is the other force which is known? The direction of P_p is known; only the magnitude is not known. So, the direction is known and the moment you have done these two, this is the R, the reaction which is going to balance the two. Fine? Now, let us compute the angles. Which angle you are interested in? So, between P_a and W, and P_p and W, what will this angle now? If you go by this logic where we were taking the difference of the angles, this will be addition of the angles. Correct?

You should work out and check whether this thumb rule is correct or not. We do not just believe on this. You should work it out. And how about the W and R? The included angle is θ-ϕ. So, W and R the included angle would be θ+ϕ. Now, I think you can realize, graphically it appears to be an acute angle. But truly speaking, we are doing θ+ϕ over here. So, that imagination is important. Is it not? These are the trivialities.

So, anyway, I mean like it is good to remember these thumb rules also, but you should try to visualize how the figures and the force diagrams look like and what is the significance of these angles. Because I hope you will realize how β+δ itself is going to be a bigger angle because normally βs are of the order of 30°. It could be 40°; it could be 70° also if I am creating a wall like this, depends upon what type of construction I am doing. δ is limited from 10° to 2ϕ/3, ϕ/3 or $\phi/2$ depending upon the value which you have. So, I hope you have understood now how the situation would be.

So, now you compute P_p value. Only thing here would be you compute P_{p1}, P_{p2}, P_{pn} and what we need to do is we need to minimize. Find out the minimum value of this. So, this is all about Coulomb's earth pressure theory. If you want to write the expression, you can just see any book and you can write them. So, we have discussed about the earth pressure analysis for Rankine walls, non-Rankine walls, by assuming the inclination of the retaining wall and the backfill and you must have realized that non-Rankine wall analysis is slightly complicated particularly if the material properties are not cohesive at loan.

So, the moment the cohesion term gets added up to the backfill material, the triviality comes into the picture. So, we have done analysis to introduce the concept of how cohesion gets mobilized if you remember. And there I showed how cohesion gets mobilized and how tension crack develops in the backfill and because of that we do not assume uniform cohesion distribution on the slip surface. Fine?

Another case we did is we were talking about the capillary surcharge on the retaining wall, and we derived a parameter or a term for effective or apparent cohesion in case of, you know when tension cracks develop and when there is a surcharge because of capillary action. So, under any circumstances, people have realized that it becomes difficult if you are doing analytically the earth pressure which are going to generate on the system. So, there is a practice people follow graphical methods.

And with these graphical methods, I will finish the discussion on earth pressure theory, and then subsequently we will be talking about the application of earth pressure theories in case of let us say sheet piles, bracings, cuts and so on. So, this module is going to be the last discussion as far as the earth pressure theory is concerned. So, having done the Coulomb's earth pressure analysis, we will talk about now graphical methods. So, there are two methods which are normally used. Alright? The first one is known as Culmann's method, C-U-L-M-A-N-N-S, Culmann's method. The second one is Poncelet, Poncelet's method. This is also named as Rebhann's method. What I suggest is if you are interested, please follow a book and just go ahead with that. So, with this discussion, the earth pressure theory is completed.