Geotechnical Engineering II / Foundation Engineering

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Lecture - 35
Stability analysis of earth retaining wall (Contd.)

Good morning. Once again, I welcome you all to the Foundation Engineering course. And we actually discussing on Stability analysis of earth retaining wall and for that before going for stability analysis whatever necessary things, essential things are actually earth pressure and different types of earth pressure like earth pressure addressed or pressure at active condition, earth pressure at passive condition all those things we have done and we have taken some problem to calculate earth pressure for different condition. Also, I have taken some problem for stability analysis.

Now, for stability analysis means what actually we have to find out factor of safety against different failure modes like factor safety against sliding factor, of safety against overturning, factor safety against bearing capacity failure etcetera. And I have taken one problem in my previous lecture and once again I will take one more problem and were actually I have taken little problem of involvement of everything but exam generally expect little simpler. But I will highlight where actually we can simplify, but I am taking the problem little complicated mainly because to I want to show the application of everything ok.

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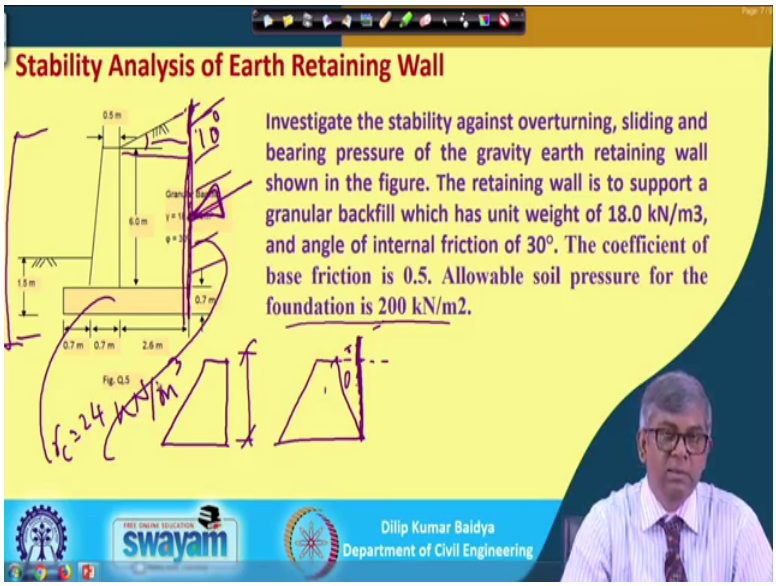

So, let me start with the second problem of stability analysis. It is the problem is like this, this there is a cantilever retaining wall and this cantilever retaining wall is your you can see that it is a concrete part and these and these are concrete part and this is having a backfill and that backfill is again inclined. So, this angle is not shown suppose it is 10 degrees slope. And generally, whatever earth pressure theories we have learned, that is actually for horizontal backfill and particularly Rankines and that is simple which we use commonly. But however, we have also discussed if there is a backfill is slow how to handle this how to modify the Rankines theory that also we have discussed.

And now, this problem actually you can see that this type of problem as I have told you before yesterday. Actually I have taken a problem something like this and the back was vertical ok. So, whatever height of the wall this is the wall height, but when this type of slope backfill then in that case actually what we do from the edge of the end of the vertical wall actually draw the vertical line from here and you can see, it is it is meeting the backfill soil surface at here so; that means, I will imagine now the wall from here to hear this is the wall height.

This is the wall height, I will imagine. So, while discussing the problem the previous lecture if the wall was something like this and something like this, then also I have told that if there is a backfill soil here like this. Then if I extend your, you have to imagine the wall equal to this is the wall. I have to imagine this is the wall.

And if it is a backfill, then I have to go up to this and you have to imagine this as a wall. So, and while doing this then this soil weight this soil weight coming on to the this retaining wall. So, because of that when I will consider this wall actually initially wall height is suppose this is given 6 meter and this is 7 7.7. So, it is 6.7 from here to here, it is 6.7.

But for the calculation purpose earth pressure calculation purpose, I will find out actual modified or imaginary height which will be this height to be calculated. So, this angle is known this length is known. So, I can find out by 10 formula this height. So, after getting these height, then I have to find out imagining these has a wall and I had to find out earth pressure first. And when I will find out the earth pressure, I have to imagine that earth pressure are inclined parallel to this surface and so thrust will be something like this.

So, for calculating this again, I have to follow step by step by step procedure and which I will try to show you the detail calculation and here actually what are the things are not given let me see; unit weight is given 18 here and angle of internal friction is given 30 degrees. I think, I have taken 30 degrees and the coefficient of base friction 0.5 allowable pressure for foundation is 200. All those thing and concrete unit rate is not given you can imagine gamma c equal to 24 kilo Newton per meter cube. This is the only thing you can additionally assume otherwise this is the problem.

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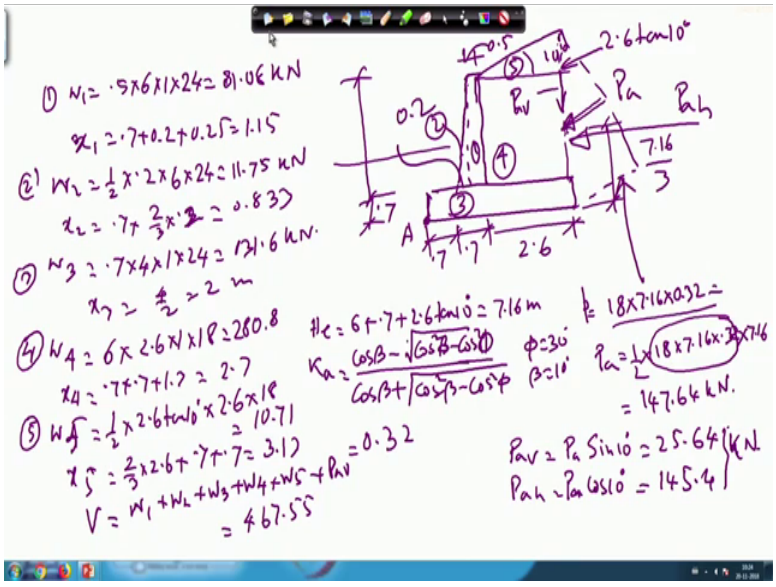

And so, this problem let me take a fresh page and then let us try to do. So, problem was something like this, you have a wall and this is little sloped here and this side vertical and this is something like this. So, this is again 10 degrees and if I joined from here and this is actually these dimensions and now I have to put. This is 0.7, this is 0.7 and this is 2.6. And you can see and this is actually 0.5, this is 0.5; that means, if I draw a vertical line, so this small portion that will be 0.2 ok. So, this is the wall. So, this distance; that means, I can find out this will be nothing but these distances from here to here 2.6.

So, these distance will be 2.6, this will be 2.6 tan 10 degrees and whatever it comes. And so that will be equal to; that means, we had that means, wall height actual effective wall height, he suppose effective wall height it will be 6 plus this is 6 actually and this is 0.7. So, 6 plus 0.7 plus 2.6 tan 10 degrees and that gives you 7.16 meter. So, instead of 6.7, I will take 7.16 meter. And your K a will be equal to cos beta minus under root cos square beta minus cos square phi divided by cos beta plus under root cos square beta minus cos square phi and here, phi equal to 30 degrees and beta equal to 10 degrees and if a put these value comes actually approximately 0.32.

Now, for earth pressure calculation, earth pressure calculation actually you have to find out the thrust. So, this will be acting somewhere something like this thrust and these height will be suppose your 7.16 by 3. So, it will be there, so what will be the pressure? How to find out and of course, 7.16 pressure at this point will be pressure at this point. Suppose if I draw if I imagine a pressure diagram, pressure diagram will be something like this.

So, this pressure diagram will be gamma means 18 multiplied by he equal to 7.16 multiplied by K a means 0.32. So, this will be whatever it comes, this will be. So, this will be pressure and now I can if I can find out P a. So, this is suppose intensity pressure P at this point. So, P a this is P a suppose, then these will be a half multiplied by again entire thing 18 multiplied by 7.16 multiplied by 0.32 multiplied by once again 18 no once again 7.16 ok.

Because this height, so this is base multiplied by half multiplied, but this is base multiplied by height. So, these if you calculate, it comes around 147.64 kilo Newton. And then, I can imagine this inclined force I can imagine is acting vertically. So, that I can say as P active vertical and I can consider around horizontal, that is P active

horizontal. So, if I do that. So, this will be; that means, it will be component of cos 10 degrees. So, P a v will becoming P av will be P a sin 10 degrees and h equal to P a cos 10 degrees. So, this will be 25.64 and this will be 145.4. These are all kilo Newton.

So, this is actually earth pressure calculation. Now, in addition to that what are the other calculation, I have to do that for stability analysis. You have to calculate the gravity load and gravity load that we can see that now, I have imagine this is the wall so; that means, this soil will be there this soil will be there, this concrete will be there and another thing I have missed actually there is a this side, there was a embedment some height actually. And as I have told you that to be in surfer side this can be ignored that is this side will be passive and disabled we active and if not the passive pressure, generally we will be in surfer side.

So, I time for the timing being I am of ignoring. So, if I do that, then at least what are the things you have to calculate? I have to calculate different part this suppose 1, this suppose 2, this supposed 3, this suppose 4 and this suppose 5. So, there are five component of gravity weight and so one will be for one suppose w 1 will be equal to nothing but 0.5 multiplied by 6 multiplied by 1 multiplied by 24 and that will be equal to 81.08, 81.08 kilo Newton. And it will be if I imagine that with the if I consider how far from this point A and that distance will be your this distance will be your 0.7 plus point 0.9 plus 0.9 plus 0.25. So, this d 1 lever arm actually distance lever arm suppose x x 1, suppose I if I say; that means, 0.7 plus 0.2 plus 0.25. So, this will be equal to 1.15.

So, similarly 2, the means w 2 if I do that will be nothing but half multiplied by 0.2 multiplied by 6 multiplied by 24. That gives you approximately 11.75 kilo Newton and that distance will be suppose x 2 that will be 0.7 plus this will be two third of, two third 0.3, 0.22 third of 2 point. So, that would be your 0.8330, 0. 833. Now, component three; that means, this entire this one, so this will be w 3, suppose then it will be 0.7 multiplied by 4, multiplied by 1 multiplied by 24 that gives you weight actually 131.6, 131.6 kilo Newton and it is lever arm the it is acting at the midpoint. So, it will be x 3 will be equal to since it is a 4 meter. So, it will be 4 by 2 equal to 2 meter.

Then forth part forth part actually this soil. So, this will be that is nothing but w 4 will be equal to your 6 multiplied by 2.6 multiplied by 1 multiplied by 18. So, that will give you 18. So, that will be equal to 2.72 no 2 281, 281.8 and suppose x 4, x 4 will be equal to

you can see 1.3 plus 0.7 plus 0.7 plus half of these 1.3. So, that will be equal to 2.7. And suppose x 5, 5 component 5 that is supposed w 4 and that w 5 that will be equal to half multiplied by 2.6 tan 10 degrees multiplied by 2.6. And that will be area multiplied by 18. So, that gives you your 10.71 and your lever arm will become, suppose x 5 lever arm will become this will be two third of 2.6 two third of 2.6 plus 0.7 plus 0.7. So, that will give you approximately 3.13.

So, now, all force calculation is done. And now, we have to what you have to do, we have to calculate total vertical force; that means, total b suppose or P vertical total vertical force suppose that will be w 1 w 2, w 1 plus w 2 plus 3 plus w 4 plus w 5 plus P a v. And if I do that, that will become 467.55. And then, we can now after that I can do one by one calculation and what I can do? This is actually your first of all first factor of safety against overturning factor of safety against overturning.

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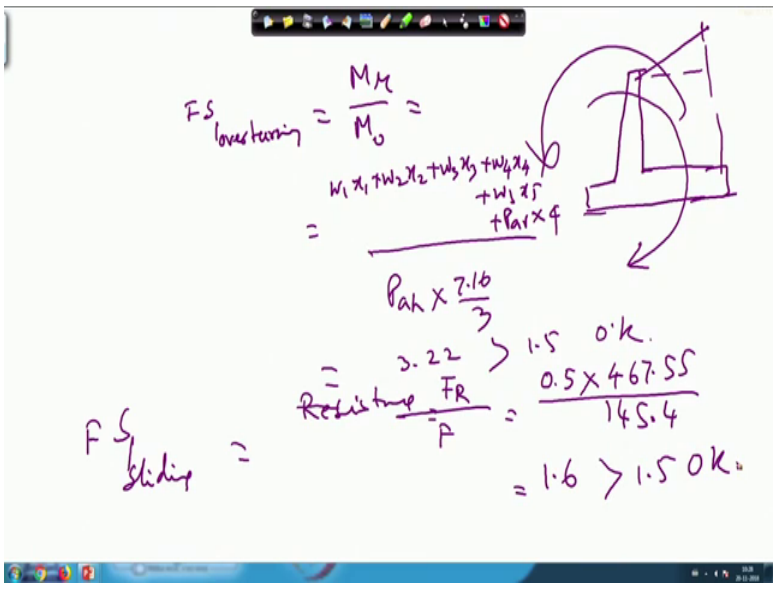

That will be equal to a your M r by M naught, M r by M naught. So, that will be a M r is what wall weight if the wall is something like this. So, you can see because of the 1, 2, 3, 4, 5 because of the all the weights all the weights, actually creating restoring moment resisting moment. And all the P h is giving you movement in this direction. So, for overturning, so, overturning M r will be all forces w 1 h 1 w 1 x 1 plus w 2 x 2 plus w 3 x 3 plus w 4 x 4 plus w 5 x 5 plus P a v multiplied by P a v multiplied by that was at a

distance here actually. So, it will be 4 divided by M resistance will be what P a h multiplied by because 7.16 by 3.

So, if I do that, then it will come factor of safety against overturning it will come something 3.22 and it is quite big value it is a expected value is 1.5, so greater than that. So, it will be generally. Similarly, factor of safety against sliding factor of safety against sliding that will be equal to resistance divided by disturbing horizontal force. So, fixed resistance or I can say F R divide by F. So, F R will be equal to friction is given 0.5 multiplied by vertical force that is actually 467.55 and that is actually below the wall.

Because your total vertical load multiplied by frictional coefficient that is actually resistance whereas, your horizontal force is actually will be by upward that horizontal force is you have already P h, we have calculated that was actually your P h was 144 145.4. So, this gives you a factor of safety will be equal to factor of safety will be equal to it will give you 1.6. Now, that is also greater than one point 5 and hence it is ok. So, now I have to see the factor of safety against bearing capacity.

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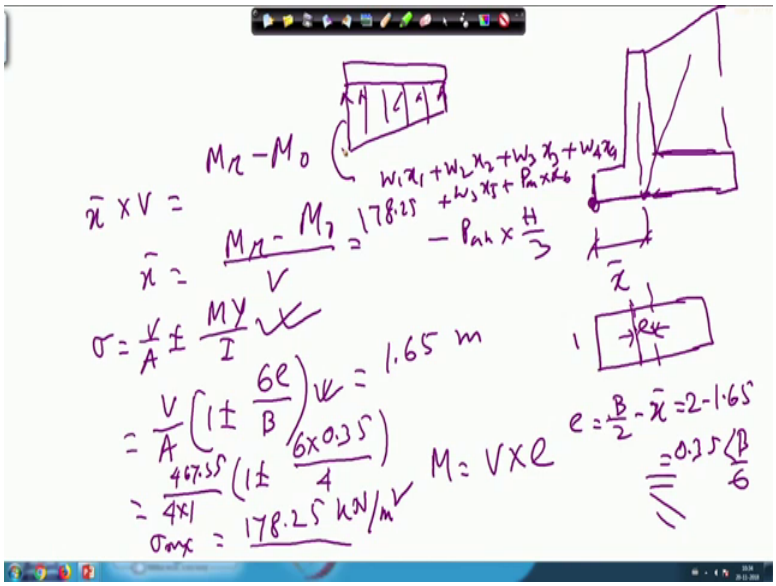

And for that, I will just take another new page and for that actually as I have told you that the wall is something like this. So, different forces are acting. Finally, the point of application of the resultant force may be somewhere here. If I take vertical and horizontal and take moment with respect to this, then I can find out that point of

application of these, these distance the actual x bar I can find out how to find out actually x bar multiplied by v will be equal to M r minus M naught ok.

And so, if I do this, then your x bar will be equal to M r minus M naught divided by V. And that M r already I have told you that w 1 x 1 plus w 2 x 2 plus w 3 x 3 plus w 4 x 4 plus w 5 x 5 plus P a v multiplied by the distance that is supposed x 6. And M r will be minus M r will be equal to how much, P h multiplied by H by 3 and if I put all those values and this finally, the x bar will come approximately 1.65 meter.

X bar means ultimately the point of application of this load on the base resultant force where it is acting. So, if I draw the base of the footing now, suppose this is 4 meter, this is some 1 meter and this is 4 meter. So, this is 2 meter. So, it is acting at 1.65, somewhere here. This is 2, so 1.6. So, this actually; that means, force is acting at eccentricity and that eccentricity can be calculated e can be calculated equal to B by 2 minus x bar and that is equal to 2 minus 1.65. So, that is actually equal to 0.35. And this is also in while doing bearing capacity, we have mentioned that to satisfy that no tension in the foundation we have this has to be less than B by 6 and that is also satisfied.

Now, after getting this you know that when there is a eccentric vertical load is acting eccentrically, then there will be a moment which will be equal to V multiplied by e. So, that means, in this foundation suppose in this rectangular area in this rectangular area, there is a vertical force and there is a moment. Then to find out the pressure actually we use a typical formula either sigma equal to actually sigma equal to V by a plus minus my by I. And, this rectangular area I if you substitute y if you substitute moment if you substitute then this formula can be also simplified as V by A and 1 plus minus 6 e by B. So, this actually if you substitute all those thing in terms of B and A all and then, eccentricity then this expression also can be modified to in this form.

And now, if we know that V actually value of V, I know that is actually your already I have shown V was 467.55, 467.55 and area actually is nothing but 4 meter by 1 meter. And so, this is 1 plus minus 6 multiplied by B is here 0.35 divided by B is here your 4 meter. So, this one if I do then, you can do sigma max will be equal to sigma max will be equal to coming this 1 plus these multiplied by these this is coming 17.25 kilo Newton per meter square. So, that is similarly, I can find out sigma minimum also and this value 178.25, 170.25 kilo Newton per meter square.

This is value maximum value; that means, below the footing below the footing if I draw the elevation if the footing is like this elevation if I do elevation and below the footing actually pressure diagram will be something like this. So, this side is maximum and this side is minimum and this maximum value is coming 178 point, 178.25 kilo Newton per meter square. And it is given that that foundation pressure maximum foundation pressure is it can be to 200 kilometers. So, it is less than that so, it is also, so that means, it is ok. In fact, actually we need to find out this and whatever value is there given you have to compare.

So, here it is given 200. So, if you compare, then it is coming less than that. So; that means, looks like ok, but sometime it may desire that you have to give a factor of safety of 1.5 or 2 also. In that case, we have to find out that ratio of that should be 1.5 or 1.6 or 2 whatever expected. So, like, so these are the problem; that means, we have got we have started from. So, all three problems are done. So, this problem is done. Now, as I have mentioned that we have we may have to you may expect little simpler problem in the exam. What is simpler actually?

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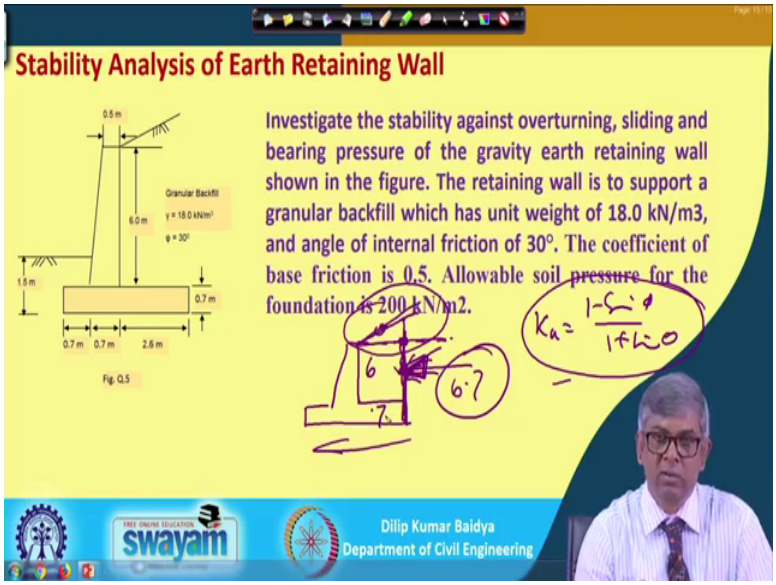

So, this wall suppose this is the wall here and this is the wall. So, this inclination is there. Instead of that instead of that, I may give I may we may express horizontal in that case your wall height will be only this much. You extend from here and this will be wall height. So, this will be wall height will not change here or wall height will change only

when there is a level backfill ok. So, here wall height would be it was 6 and it was 0.7. So, it be wall will be 6.7.

So, like that if I do that, little simplification will be there because your K a calculation in that case 1 minus sin phi by 1 plus sin phi instead of that cos beta minus under root cos square beta minus cos square phi divided by cos square beta plus plus under root cos square beta minus cos square phi. That was the expression that expression will be simplified like this. And addition additional thing is when there is a level backfill, your pressure was like and we have made a two, made two component P a v and P h and when this horizontal lack back whether straight will get the P a horizontal. So, that is the only horizontal force which will create overturning movement and also it will give you a sliding.

So, that that cos sliding. So, this two, this will be horizontal. So, this is a problem, I have taken to show application of everything, but in the exam sometimes you have to do in the less time. And then in that case, you may not have these type of things. But if it is there how to calculate that is the procedure I have shown that, I have to use the complicated formula, a little completed formula for K a calculation and after calculation of K a I can find out P a. And finally, direction of P a will be parallel to this backfill and when the force is parallel to backfill; that means, it is not neither vertical or horizontal.

But you have to work with horizontal and vertical force, then because of that you have to make 2 component one horizontal and vertical for the calculation. So, that is way we can do it ok. So, with this I will close this one.

Thank you.