Geotechnical Engineering II / Foundation Engineering
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Lecture - 33
Stability analysis of earth retaining wall

Hi, this is again once again let me continue with Foundation Engineering and or Geotechnical Engineering II and now we are discussing right now about Stability analysis of earth retaining wall. In fact, we are still doing earth pressure calculation, I have discussed various theories, how to find out active part pressure, how to find out passive pressure or how to find out earth pressure addressed also at the same time what will be the because of the active case active condition, what would be the total thrust on the wall and where it will act.

And whatever preliminary theories like Rankines and then Column we have discussed. And what are the advantage and disadvantage of the both the methods we have discussed also.

And we have taken a few problems in the previous lecture. Today I will also take a few more. And then after that I will try to explain how to do the stability analysis. Stability analysis means what? When you do design at a wall means design means what? Actually what should be the height and what should be the base width what should be the top width weather it is a gravity wall, whether it is a cantilever retaining wall or something else and based on that again if there is a particular wall, if you design; that means, suppose a 5 meter height or 10 meter height with some dimension and if it retains particular soil, then it may whether it is safe or not that to be verified.

How to verify that? It is general mechanism is to we have to find out that various failure modes and then we have to check each mode how much factor of safety. So, that will come later on.

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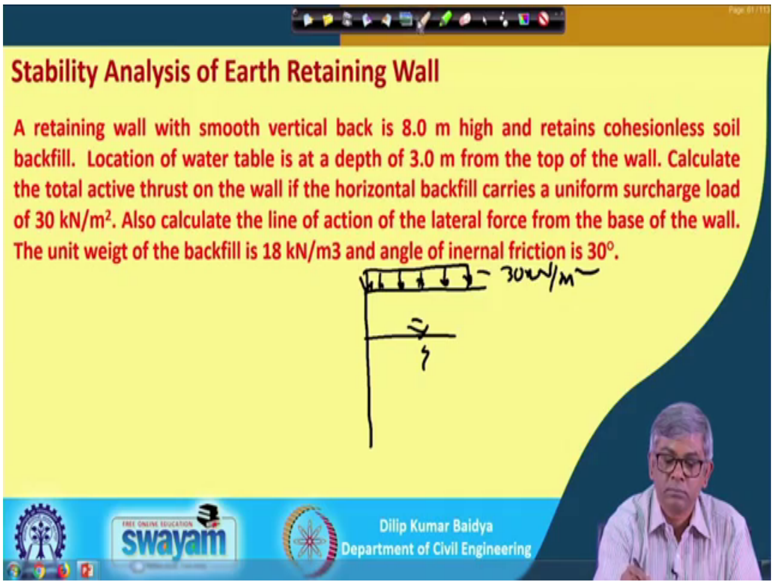

So, before that let me discuss about a few more problems and the problem first problem let me take that retaining wall with the smooth vertical back is 8 meter high and retains cohesion less soil backfill and location of water table is at a depth of 3 meter from the top of the wall, and calculate the total active thrust on the wall. If the horizontal backfill carries a uniform surcharge load of 30 kilo Newton per meter square also calculate the line of action of the lateral force from the base of the wall. The unit weight of the backfill is 18 kilometer per meter cube and angle of internal friction is 30 degrees.

So; that means, this is a problem basically I have to do suppose this retaining wall is suppose some height actually it is mentioned something like this and it retained backfill level backfill water table at 3 meter height, then calculate the total active thrust of the wall if the horizontal backfill carries uniform surcharge now of 330 kilo. So, far whatever problem we have considered, there was no surcharge now we will be giving surcharge of 30 kilo Newton per meter square something like this ok. So, this value is 30 kilo Newton per meter square.

So, this is the additional thing and this water table and all those things we have discussed before.

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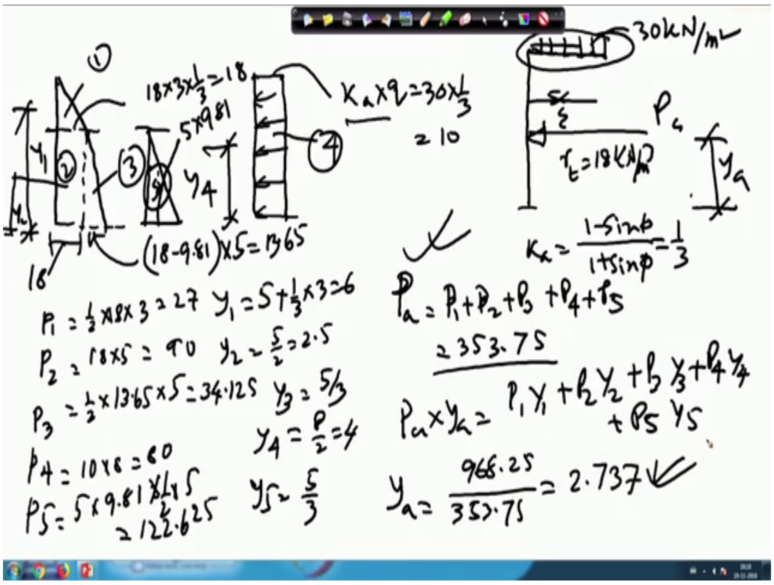

So, let me take a new page and try to solve this problem and you can see now the problem was it was 8 meter height wall 8 meter high wall and it is level backfill with surcharge the 30 kilo Newton per meter square and at 3 meter depth water table and so, first thing actually you have to calculate the your gamma t is given 18 kilo Newton per meter cube gamma t equal to 18 kilo Newton per meter cube.

And your k a will be if you calculate k a equal to 1 minus sin phi by 1 plus sin phi and phi equal to 30 degree if you put it will be 1 by 3.

And so, now, we can draw pressure diagram one by one. So, I will draw from here suppose it is 8 meter suppose this is 8 meter high and then I will draw the pressure diagram first of all earth pressure diagram up to 3 meter depth because of this soil pressure. So, this is the pressure diagram. So, this value will be it will be 18 multiplied by 3 multiplied by 1 by 3. So, this value will be equal to your it will be 3 3 get cancel. So, it will be 18. So, somewhere I have written.

And then you will have then because of the water table here actually the pressure diagram will be changing from here to here and so, these 18 will be remaining so; that means, this one is 18 and we have to find out this one. So, this one will be equal to 18 minus 9.81 multiplied by your this will be a 8 meter. So, 8 minus 3. So, it will be 5 and so, this will be equal to 13.65 ok.

So, this is 13.65. So, this is because of the soil we have drawn, now because of the surcharge I have told you that it will be throughout the depth it will be constant that value will be equal to. So, it will be k a times q. So, that will be 30 multiplied by 1 by 3 it will be 10. So, it will be a 10 kiloNewton per meter square. So, I can divide in to this is 1, this is 2, this is 3 and this is now 4 actually. So, if I divided 4 parts. So, then I can find out P 1 will be equal to half multiplied by 18 multiplied by 3. So, it will be 27 and what about y 1? y 1 from here to here. So, this will be 5 plus 1 by 3 of three. So, it will be 6.

Similarly, P 2 will be equal to it will be 18 multiplied by 5. So, it will be 90 and y 2 will be equal to actually y 2 will be up to middle of this. So, this will be y 2 this is y 1. So, y 2 will be equal to 5 by 2 equal to 2.5 similarly P 3 will be equal to this triangle. So, this triangle will be half multiplied by 13.65 multiplied by 5. So, this will be equal to 34.125.

And y 3 will be one third of 5. So, it will be 5 by 3 and P 4 will be equal to this diagram. So, it will be 10 multiplied by 8. So, it will be 80 and y 4 y 4 will be how much? That means, from here to mid height of the area. So, that will be y 4 that means, this will be equal to 8 by 2; that means, 4.

So, total active thrust Pa, P a will be equal to P 1 plus P 2 P 1 plus P 2 plus P 3 plus P 4 and if you add them that it will become a sorry I have missed one more.

Because of this water table, they are supposed to be another water pressure and that will be equal to 5 multiplied by 9.81. So, this would be P 5 will be 5 multiplied by 9.81. So, that will be equal to suppose on twenty 2 point. So, P 5 will 5 into 9 multiplied by half multiplied by five. So, that will become 122 points 122.625 and your y 5. So, this is suppose 5 I give this is 5 y 5 will be again one third of 5. So, it will be 5 by 3.

So, plus P 5 if I add them together then it will become 353 point 353.75. And now if I want to find out the point of applicants; that means, ultimately where that active thrust will act support this is pa acting, this is height from here suppose ya so; that means, P a multiplied by y a equal to P 1 y 1 plus P 2 y 2 plus P 3 y 3 plus P 4 y 4 plus P 5 y 5.

And if I put all P 1 y on P 2 its all listed here, P 1, P 2, P 3, P 4 5 etcetera all if I put here and then and pa also here already I have got 353.75, then y a will be equal to ultimately you have to calculate and then to become 968.25 divided by 353.75 this is P a, and then you will get a value equal to you can say here that value will be equal 2 point 2.737.

So, this problems perhaps I have taken before; that means, only water table except this one then the problem will be ended here and this P 4 will be missing. And when that is surcharge is there level are surcharge of uniform intensity then we know the pressure active pressure will be uniform which will be equal 2 ka times q and that will be throughout the depth it will same intensity of pressure will be there active pressure. So, you have to find out area of that then you will get the total thrust, because of this surcharge and then if you sum all those then you get total thrust and then you take moment with respect to that point with from the base then I will get the ya like this ok.

So, this is about the first problem.

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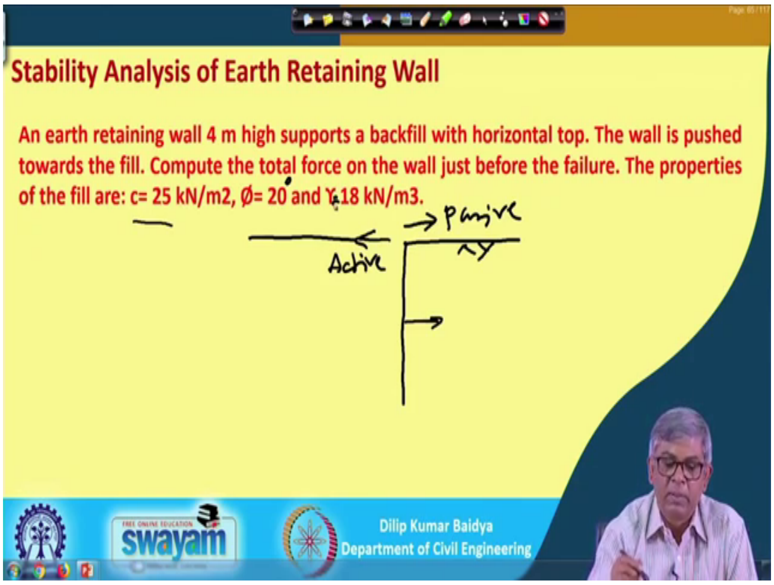

Let me go to the second problem. Second problem is again let me you can see this is a problem. So, far we are discussing the problem about the active earth pressure and when it become instead of active it will become passive or something else, there is no difference except you have to calculate kp and which is nothing but 1 by ka that straightforward that is one thing.

And you have to while finding out the pressure active earth pressure was the depth. When it is the active pressure we have multiplied by ka multiplied by the vertical pressure, and when it will be passive case you have to do what you have to do? I have to multiply the kp with the vertical pressure. So, with that actually I can complete earth pressure diagram. Once the diagram is done the diagram will be whether the active and passive whatever may be the situation ultimately thrust will be equal to area of the diagram.

So, I will take this problem now that is passive case instead of active and you can see this that. So, this problem actually we can see that an earth retaining wall 4 meter high, supports a backfill with horizontal top ok; that means, the backfill 4 meter and it is horizontal backfill. So, it is the backfill ground like this, the wall is pushed towards the fill. So, as definition actually what you have done that when the wall is pushed towards the backfill, then it is a passive and when the wall moves away from the backfill that is active and when it is pushed towards this is passive and when it is no movement that is addressed.

So, now, in this problem it is mentioned the wall is pushed towards the backfill. So, because towards the fill that wins this side by some means because of some reason. So, it is pushed towards this then if you do that then compute the total force on the wall just before the failure; that means, if I push, if I give little push passive pressure will be there you further increase the push still passive pressure will be there, but pressure will be will be increasing then it will further increase like that it will pressure will be increasing, but at some stage that instead of further increase the soil will fail. So, that means, that full passive condition what is the maximum; that is at the full passive when the full passive conditional achieve that time we will get the total maximum pressure on the wall.

So, because of that so, that means, it is mentioned compute the total force on the wall just before the failure; that means, it is pushing, but pushing means just pushing is not enough, but if I push enough, then it will achieve a failure and at that point what is the maximum pressure that is what we have to find out. So, if I want to do these and then we required what? A property of the soil; that means, here actually see so, far we have done actually cohesion less soil; that means, without any c value here the soil is having value of c equal to 25 kilo Newton per meter square and 5 equal to 20 degrees and degrees is missing here you can put and gamma equal to equal sign also missing here gamma equal to 18 kilo Newton per meter cube.

So, this problem let us do with step by step.

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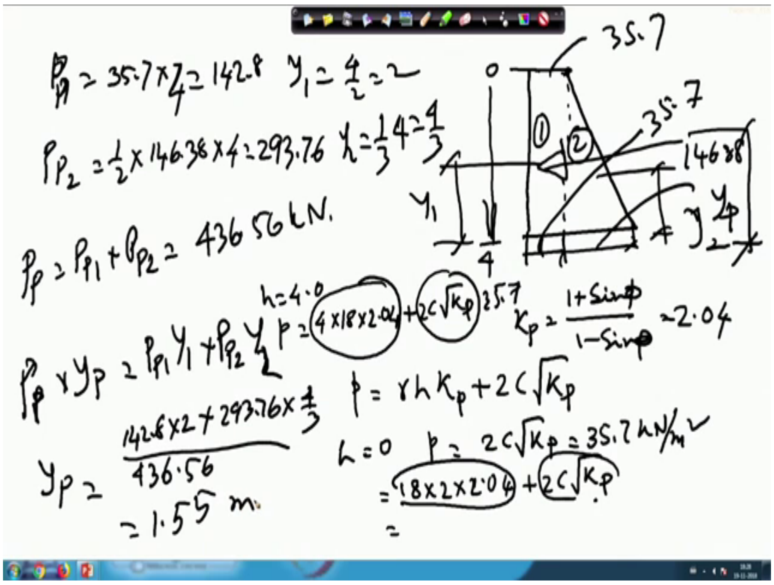

So, I will do like this suppose a 4 meter high wall level backfill, and we know that it is a kp condition; that means, passive condition since it is moving towards the backfill. So, kp will be equal to one plus sin phi by 1 minus sin phi and the phi value is given here 20 degrees and if I put this value here this value comes 2.04 kp value comes 2.04.

And when the when the wall retains when the wall retained c phi soil, then we know the active pressure sorry passive pressure at any depth p will be equal to gamma h k p plus 2 c root kp. So, this is the formula we know; that means, with the depth increase of depth with the increase of the. So, this is h equal to 0 here and h equal to 4 meter here. So, you are increasing this direction. So, when h equal to 0, then your p will be equal to 2 c root kp and that value if I calculate kp value root if I take and see value if I put 25.

So, it is 50 multiplied by under root 2 and this value comes up approximately 35.7 kilo Newton per meter square so; that means, I will get a some value. So, far when we are drawing the earth pressure diagram we are getting 0. Now instead of 0 we are getting some value and now if I put h equal to some value any value we can see that somewhere h equal to 2 meter. So, it will be equal to gamma is actually is 18. So, 18 multiplied by 2 multiplied by kp actually 2.04 plus 2 c root kp this will not change so; that means, it will be whatever it may be. So, this calculate this 1 plus this one. So, it will be value so; that means, these values constants. So, it will be constant. So, this will be constant and because of these will be increasing linearly like this.

So,. So, if it is your if it is your height is 4 meter, then it will become. So, when h equal to 4 meter when h equal to 4 meter, then your p become 4 multiplied by 18 multiplied by 2.04 plus 35 point or and that means, actually 2 c 2 c root kp and which is nothing, but 35 point 57 35.7 this is 35.7. So, this value when it is there.

So, this 2. So, this is actually should be this one and this is this should be this one. So, this entire value this entire value is this. So, this value is constant so; that means, this portion is your this one. So, this is actually your if we calculate it comes 146 point 88 146.88 and this value is 35.7.

Now, what this is the earth pressure diagram? So, earth pressure diagram for passive case. And this passive case now I can again divided into 2 parts this is one and this is two. So, now, I can calculate P 1 that is P 1 that is passive or P p 1 I can say here now P p 1 that will be equal to because of the rectangular diagram that is actually 35.7 multiplied by 7. So, that will be equal not 7 it is 4 that will be equal to 142.8, 142.8 and y 1 that will be equal to mid height. So, this is y 1.

So, that will be equal to nothing, but 4 we divide by 2 equal 2 and similarly P p 2 I can find out P p 2 will be equal to half multiplied by 146.38, 146.38 multiplied by 4. So, that will be equal to your 293.76 293. 0 01and y 2 will be equal to one third of this is if it is y 2, then that will be one third of 4 so; that means, 4 by 3.

So, your; that means, total P p will be equal to P p 1 plus P p 2 and that will give you actually P p that is 436. 6 kilo Newton. And now if I want to find out what is the thrust the thrust actually acting. So, somewhere here suppose here acting and that is at a distance of all y a or y P suppose then P p P p multiplied by Y p equal to your P p 1 multiplied by y 1 plus P p 2 multiplied by y 2 if I do this.

And all values are known P p 1 P p 2 are known y 1 y to known if I put those values then Y p will become 142.8, 142.8 multiplied by 2 plus 293.76, 293.76 multiplied by 4 by 3 divided by that P p is actually 436.56.

So, if I calculate this one then it get 1.55 meter so; that means, this is a passive. So, whether it is passive or active, the calculation is similar; that means, first of all you have to draw the earth pressure diagram and if it is a cohesion less soil earth pressure diagram will be varying from 0 to linearly to a maximum value at the bottom of the wall, will be triangular diagram and when it is a c phi soil, then you have to remember the pressure equation for active and passive pressure in terms of c.

And phi and for the passive pressure this is the equation gamma h kp plus 2 c root kp and if it is active case then it could have been gamma hka minus 2 c root ka. So, since it is a passive condition. So, we have taken this diagram, initially I put h is equal to 0 then what is the value of the surface, what is that pressure then increasing the h we have got the value and then at putting at 4 meter putting h equal to 4 meter, I have got the maximum earth pressure at the bottom.

Now, in this diagram you can see is a diagram become a trapezium, but instead of using the whole trapezium I can if I if you remember the size of or trapezium I do not have any issue, but easily remember rectangle triangle. So, all because of that I can divide into 2 parts one rectangle and one triangle and then I know the of them, and then I can find out the area of them then I have calculated area of the first diagram I have denoted as P p 1, area of second diagram I have written as a P p 2 and size of their of that those diagram also I have given as y 1 y 2 and P p will be equal to P p 1 plus P p 2 that also I have done and finally, to suppose to resultant acting as a distance Y p then P p multiplied by Y p will be equal to P p 1multiplied by y 1 plus P p 2 multiply by y 2 and putting all those value finally, I get the Y p equal to 1.55 meter ok.

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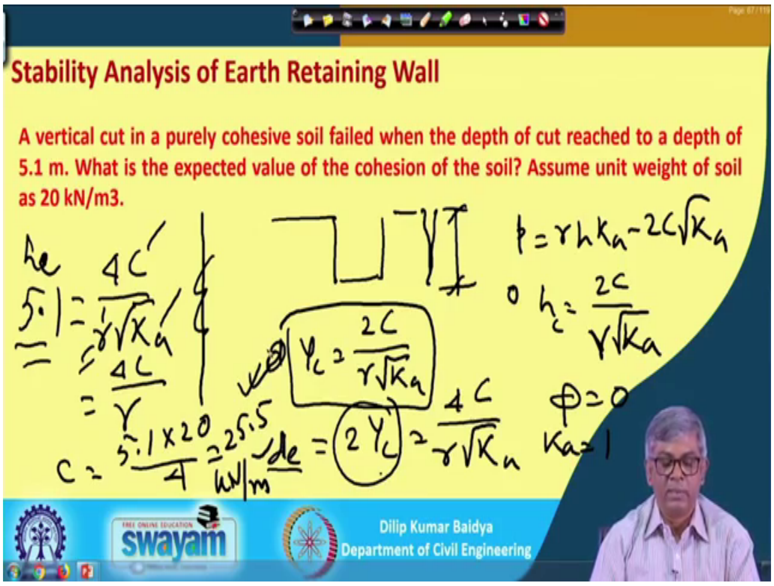

So, this is not new this is same thing ok. So, I will go back to the next problem suppose your third problem. You can see this, this is a problem also I have discussed and when is a active case and then the pressure diagram is can see a vertical cut, when in c phi soil or in a cohesive soil. Then I have shown that at the surface generally will be tension particularly when it is active case because in the active case wall will be like this wall moves this way and when wall moves this way when it is a sandy soil then it will flow, but when it is a cohesive soil, it will stand up to sometime, but beyond some movement it will crack will form. So, that what is the depth of crack maximum depth of crack that we have discussed theoretically and also we have discussed what to do the maximum depth up to which we can this excavate without any support which is nothing but double the depth of crack and we have done that.

So, now, this problem actually I will try to show that and you can see here you can see here that a vertical cut in a purely cohesive soil fail, when the depth of cut least to a depth of 5.1 meter, what is the expected value of the cohesion of the soil? Assume unit weight of the soil is 20 kilo Newton per meter cube and so, wall is something like this and not wall actually the soil is there and we are excavating suppose like this and after some depth of excavation soil failed. And we know that theoretical depth of theoretical depth of excavation without support actually we know what is the depth equation we know? Actually when there is a c phi soil and we know the depth of a crack suppose this is the soil depth of crack we know the formula actually if is dc or Y c if I say that was 2 c by gamma root k a ok.

And depth of escalation d e depth of escalation without supposed will be twice of Yc. So, that will be equal to 4 c by gamma root k a how it came actually? We know the pressure at any point actually gamma h k a minus 2 c root k a. So, where cracks forms there actually pressure will be 0, initially pressure is negative and then it is decreasing and becoming 0 if I put this equal to 0 then I will get h equal to or h equal to we can say hc which equal to 2 c by gamma root ka and which I have written as y as Yc and this is actually; that means, twice of that up to that tension curve is 0 the twice of that actually we can excavate without any support. So, because of that depth of support excavation without support twice of yc at 4 c by gamma root k a.

Now, we can see that this depth is given this depth is given actually when it is become 5.1 meter let me. So, at 5.1 meter it failed and which can be equated to 4 c by gamma root k a and you know that it is purely cohesive soil when c purely cohesive soil; that means, phi equal to 0 and; that means, your ka become 1.

So, if I put this one this equation will be reduced to 4 c by gamma. So, 4 c by gamma equal to 5.1 and gamma is given actually 20. So, c is equal to 5.1 multiplied by 20 divided by 4. So, that will become it will become 25.5 kilo Newton per meter square.

So; that means, sometime the problem will be c value phi value everything will be given one may ask you that what is our depth of unsupported excavation, then use this formula this will be in that case he and then with this formula put the value of c put the value of gamma put the then we will get the value, here actually problems asked in differently that why would while excavation it failed at 5.1 meter depth and it was seen that. So, I will ask only cohesive.

So, what is the expected value of cohesion? So, that actually; that means, I have just back calculating I know the depth, I know the gamma, I know the ka then what is the value of this. So, by putting this equation I the get the value of depth equation equal to 25.51. So, this is the problem actually. So, third problem and with this I will just stop here and in fact, I will next in my next session, I will try to discuss about the stability analysis. Then how to analyze the stability, that how to find out factor of safety against suppose over turning, sliding, bearing capacity all those things I will try to find out in the next slide next session ok.

Thank you.