Foundation Engineering
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Lecture – 49
Retaining Wall – II

So, last class I have discussed about the two checks that you have do to design a Retaining Wall, and now this class I will discuss about the two more checks that we have to perform during a design of retaining wall ok.

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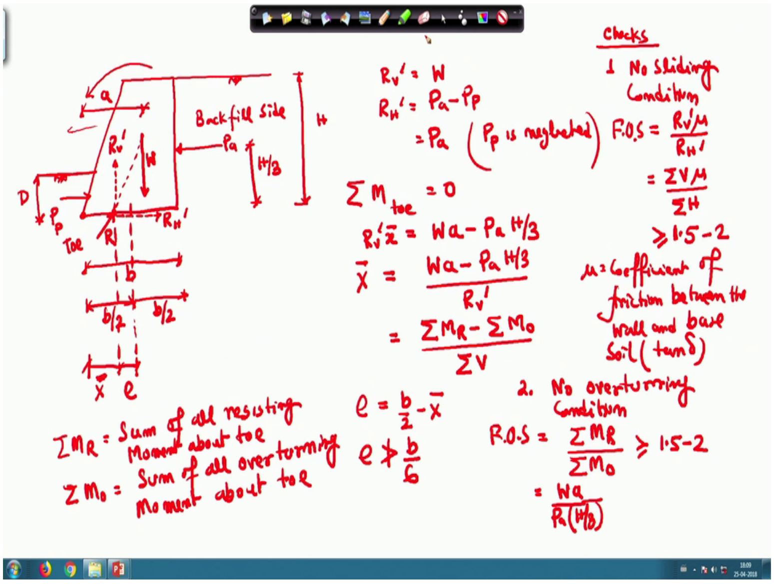

So, these are the things that as was I was discussed then this is the factor of safety and then no sliding condition, this is the factor of safety and no overturning condition.

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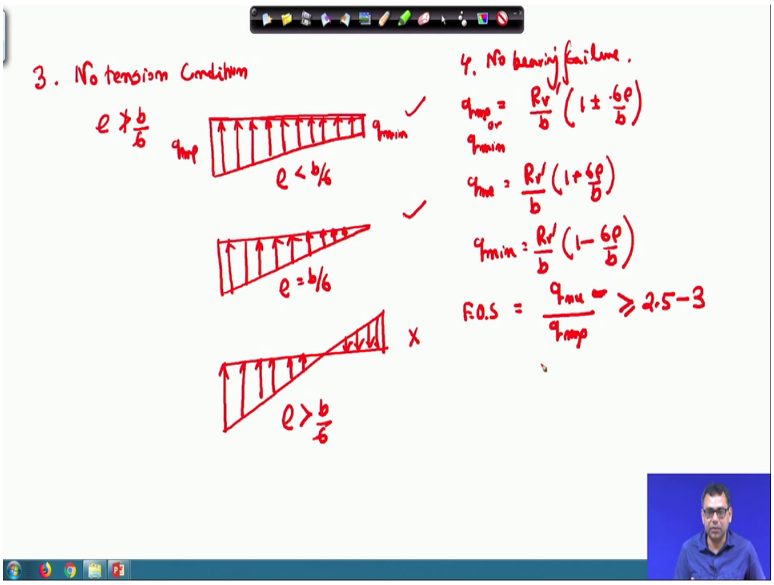

So, next one the third one is the no tension condition. So, there should not be any tension developed in the base of a retaining wall as I mentioned that you can see that there is eccentricity. So, that means, the stress distribution below the base of the foundation of retaining wall is not uniform, because the as there is a eccentricity. So, forces or stresses may be more will be more in one side and will be less in the other side.

So, that no tension condition you have to satisfy that your e cannot be greater than b by 6, ok. So, otherwise if as I have discussed this thing during the found a shallow foundation design also. So, this is the condition that q min and this is q max. So, this is the condition for e equal to less than b by 6, then this is the condition for e equal to b by 6 and this is the condition for this is the condition for e equal to e greater than b by 6.

So, these two is for the design, this we will not accept because your because soil cannot take tension. So, there will be a separation between the soil and the wall base. So, that is not recommended. So, you have to check the no tension condition such that e cannot be greater than b by 6, because we will design under these two conditions only. And, the four one is the no bearing capacity failure or bearing failure. So, this p max or the q max you can calculate by using this expression. So, p max or q max or q min we can calculate that Rv dash divided by b 1 plus minus 6 e divided by b.

So, here your q max is equal to Rv dash divided by b 1 plus 6 e by b and q mean is Rv dash divided by b 1 minus 6 e by b. So, in this me if the this minimum if e is equal to b by 6 then it is 0, if e is equal to greater than b by 6 then it will be negative. So, that is not recommended that is why.

So, the factor of safety for this case will be the q net ultimate or net ultimate and divided by the this q max that is acting and that should be greater than equal to 2.5 to 3. So, this is the stress which is coming from the wall and this is the q max that we will calculate. And, so, these are the four checks that you have to do during design of a retaining wall.

And we will solve two problems considering this regarding this design of retaining wall, one is for the cantilever retaining wall another is for the gravity retaining wall and then those and there we will use these theories. And we will check these four conditions and I will we will we will try to satisfy those four conditions during what design ok.

The next one, another important thing that if I use Rankine theory during a design of retaining wall; and if I use Coulomb's theory during design of retaining wall what are the differences what are the things we will consider, what are the things you will not consider.

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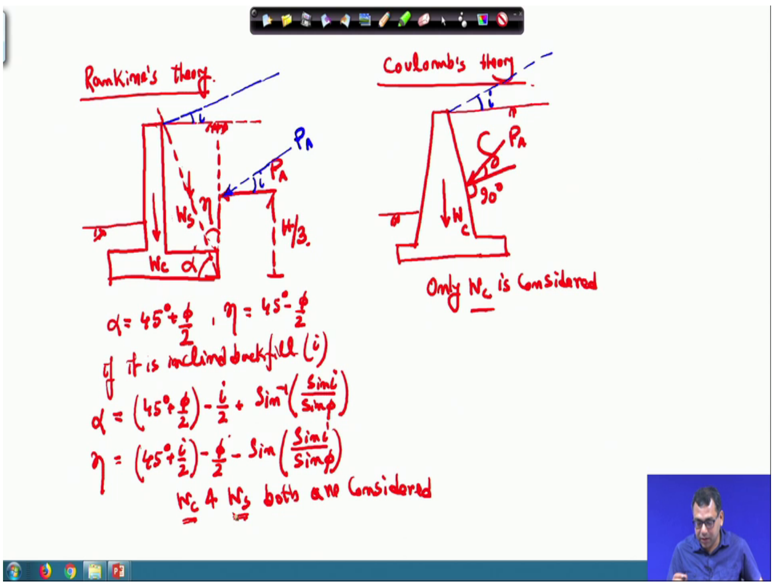

So, that is why it is very important to explain that for the first one that you have talking about that the Rankine's theory and this is Coulomb's theory.

So, I am considering similar type of wall for both the cases that sorry. So, we will consider we will take wall and then. So, this is the backfill surface which is horizontal and this is the wall and this is the foundation level. Similarly, I am using say rank Coulomb's theory for this type of wall this is also foundation, this is also the backfill and when you are talking about the Rankine and we are talking of the Coulomb, the first will discussed about Rankine's theory.

Now, when you would first check that you can apply Rankine theory or not. So, in the figure also I have shown that there is a line that and this case this angle is sorry; this will go from here. So, this is a line that will go up to here and this is the point alpha and this is the eta.

So, you check that your alpha value is 45 degree plus phi by 2. So, that means, you can apply Rankine's theory if this line passes within the back fill or this is the; I mean limit. So, this line this dotted line cannot pass through the stream of the wall. It will not pass through the wall ok, if it is passes through the wall then you cannot use the Rankine's theory, you have to go for the Coulomb's theory, ok. That is the first condition for Rankine's theory design. And if it is say inclined backfill, if it is the inclined backfill then the if it is inclined backfill with inclination of I then this value of alpha will be 45 degree plus phi by 2 minus i by 2 plus sin inverse sin i divided by sin phi or phi dash.

So, similarly this is it here eta will be 90 minus 45 degree minus phi by 2 this will be 45 degree minus phi by 2. And, for the inclined backfill this will be 45 degree plus i by 2 minus phi by 2 minus sin inverse sin i sin phi. So, you have to satisfy this condition before we apply this Rankine theory, that this line this dotted line should not pass to this wall. It will always pass to the through the backfill and this is the limit ok, that is the first condition. Suppose, if it is satisfied you go for the Rankine, if it is not satisfied you go for the Coulomb.

Now, if it is satisfied you are applying the Rankine's theory, then this remember that this Rankine's theory this force will act at the age of this base. So, you have to apply this force and which is parallel to the wall parallel to the backfill with a height of H by 3, but in case of Coulomb's you have to apply here and within angle delta this is the normal. So, this is 90 degree.

So, this is the first difference that you have to apply these force here and he here you have for the Coulomb's you have to apply on the wall surface and it is on the soil surface. If it is inclined say suppose; if your backfill is inclined then this force will also be inclined, but even if here it is inclined still it will act with an angle of delta. So, both the cases within angle of delta with the normal to the wall so, both the cases it will act in the similar condition, but here the direction will change.

Now, the next one is that when you use the Coulomb's theory, then you will only consider weight of the wall do not consider the weight of the soil during the stability calculation, but when you use the Rankine's theory you use the weight of the concrete as well as the weight of the soil. So, here only W c is considered, ok. Here the W c and W s both are consider. So, remember that these things are very important, ok.

So, when you use the Coulomb's theory we will use only you will you use only the W c during stability calculation, but when we are talking about we are using about the Rankine's theory then you have to consider both U c and W c and W s. So, these are the basic difference between the Coulomb's theory and the Rankine's theory.

And, now, I will solve one problem which is related to the gravity retaining wall and then we will solve the problem for a cantilever retaining wall also.

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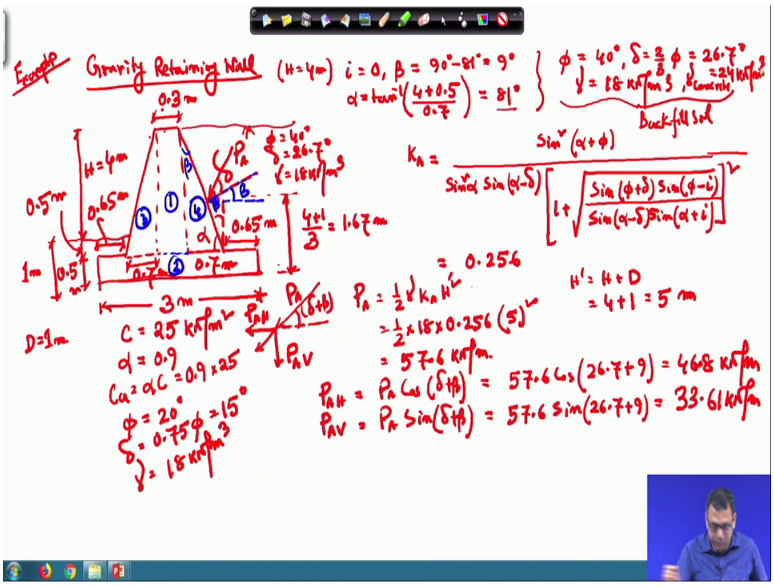

So, first when we are taking example problem ok; so this is for the gravity retaining wall. So, I have taken because in the gravity retaining wall, I have given you the tentative dimensions. So, I have followed that thing and I have chosen one particular dimension for the first wall where the weight of the wall H value height of the wall is 4 meter ok.

So, this is the wall dimension that I have chosen this is the backfill surface which is horizontal this is the foundation and foundation depth minimum was point 6. So, I have taken 1 meter as a foundation depth. So, D value is equal to 1 meter. And, this height is 4 meter. So, this height is 4 meters. So, H value is 4 meter. So, this is two third of H.

So, I have taken these value is around this is 3 meter. I am first taking this is 3 meter and this is minimum point 3. So, I have taken 0.3 meter and this value I have taken 0.5 meter. So, that mean this one is also 0.5 meter and this value I have taken 0.65 meter that is H by 6 you can choose. So, I have taken 0.65 meter, this one for the first trial also I have taken 0.65 meter.

So, this is 3 meter this is 0.65, 0.6 s this is 3. So, finally, this portion this is point 7 meter and this is also 0.7 meter. So, this is 0.7 meter, this is 4 meters. So, the alpha value is I can calculate. So, the properties are given i is equal to 0, with no inclination. So, beta value is we can calculate that the alpha value is this is the tan inverse alpha value tan inverse this is 4 meter up to here this is another 0.5. So, 4.4 meter plus 0.5 divided by this is 0.7. So, this is the tan inverse. So, this value is coming out to be 81 degrees. So, beta value is 90 minus 81 degree. So, this will be 9 degree, ok. So, beta is this one, fine.

So, beta is 9 degree alpha is 81 degree. So, properties are given phi of the backfill is 40 degree, and delta is given generally is taken two third of phi. So, that is 26.7 delta value is given to is nothing is mentioned you take two third of phi, but here two third of phi of phi is the delta is given unit weight of the soil is 18 kilo Newton per meter cube. So, these all properties are backfill soil property.

So, actually this properties I am talking about these are the properties is 40 degree phi, delta is 26.7 degree and you need weight is 18 kilo Newton per meter cube, but the base soil can be different properties also. Here the base soil properties is are given C is equal to 25 kilo Newton per meter square, alpha is equal to; alpha is the adhesion factor here, this is the adhesion factor is 0.9. So, your C equals C a is equal to alpha into C. So, this is 0.9 into 25 and phi value is given 20 degree and delta is given 0.75 of phi that is 15 degree and unit weight of soil is again kilo 18 kilo Newton per meter cube.

So, this is the soil properties and we have to design a retaining wall and this and we are using the Coulomb's theory here ok. So, we are using Coulomb's theory. So, that is why it will act here this is the perpendicular line with an angle delta this will be the P A and this point of application is from here it is. So, this total height is 4 plus 1 divided by 3.

So, it will act at the height of 1.67. So, this is 1.67 meter. So, this is the total geometry and the properties of the soil now we have to design it. So, I have taking this dimension for the first time. So, what I am doing? I am first I have to calculate K A and K A expression is given sin square alpha plus phi divided by sin square alpha sin alpha minus delta 1 plus root over sin phi plus delta sin phi minus i sin alpha minus delta and sin alpha plus i that is whole square.

So, if you put these values you put alpha is equal to 81 degree phi is equal to 40 degree because when you calculate K you use backfill phi. So, this is the 40 degree and sin alpha delta is 26.7. So, if you put this value. So, ultimately this is K A is coming out to be 2.256 you delta is given 26.7 I is 0 alpha is 81. So, you put all these values it is 0.256.

So, my P A value is half gamma K A into H square. So, this is half, but here it is H dash you are saying because your H is 4 meter. Now, I am taking from the base of the wall to the top. So, your H dash is H plus D and this will be 4 plus 1, 5 meter. So, I can write this is equal to half into unit weight is here unit weight is 18 k is 0.256 and this is 5 square.

So, this value is 57.6 kilo Newton per meter. Now, it has two components is acting in this direction. So, it has two components one is horizontal and one is vertical. So, this is making an angle with this horizontal is this is also beta if this is beta this angle is beta and this angle is beta then this angle is also beta, ok. This is 90 degree because this value is 90 degree and this is also beta.

So, my P; so I can write P A H horizontal part is P A cos P A cos delta plus beta. So, I can write this is 57.6 cos delta is 26.7 and beta is 9 degree. So, this is 46.8 kilo Newton per meter 46.8.

Similarly, the vertical part P A V because now what we are doing this P A as this, is the P A and it is making an angle delta plus beta with the horizontal. So, it has two components; you can write this is one component and this is another component. So, this is called P A V this is called P A H.

Now, similarly P A V is P A into sin delta plus beta. So, this is 57.6 into sin 26.7 plus 9. So, this is 33.61 kilo Newton per meter ok. So, now, I am using the Coulomb's theory. So, I will not consider the weight of the soil during the during the force calculation. So, I am taking the various component. So, this is the segment 1, this is segment 2, 3, and 4. So, this is a triangle this is a rectangle this is a triangle and this one is the rectangle. So, that I am taking for the force calculation.

So, now I will calculate the forces. So now, I will calculate the forces.

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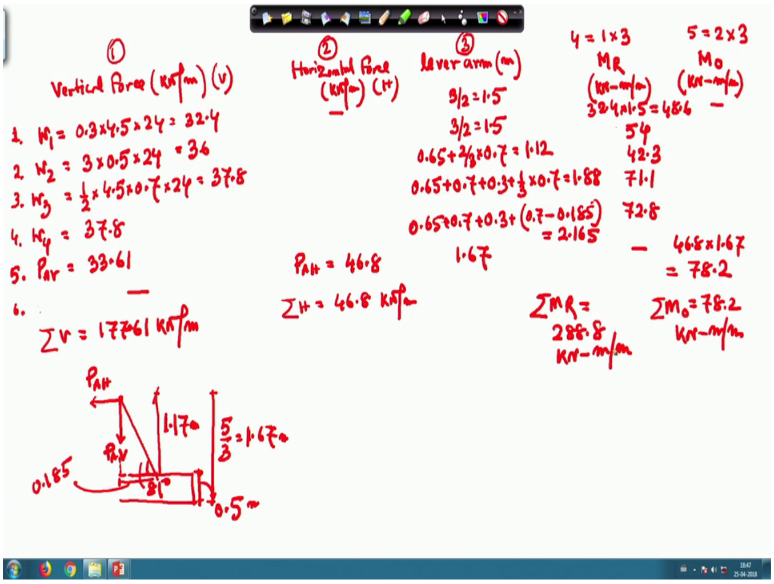

And so, I will make a table with the first I will make a vertical forces. The unit is kilo Newton per meter, then the horizontal forces unit is again kilo Newton per meter then I will take lever arm lever arm is meter. Then I will take MR that is a resisting moment kilo Newton meter per meter and MO over turning moment kilo Newton meter per meter.

So, this is the table because serial number 1 for the W 1. W 1 is the for the first part and first part is this one whose height will be 4 meter 4 meter is up to here, this is up to here it is 4 meter then plus 0.5 meter. So, this is also 0.5. So, this will be 4.5 and this is 0.3 and the unit weight of concrete is given concrete is given 24 kilo Newton per meter cube. So, I can write here for the first one will be 0.3 into 4.5 into 24 that will be 32.4, where 24 the unit weight of concrete. So, I can write the unit weight of concrete is 24

Then, it is perfectly vertical. So, horizontal is no forces second one the W 2 I will calculate for this one whose length is 3 meter and this height is 0.5 that is also concrete. So, this will be 3 into 0.5 into 24. So, this will be 36 then I will go for the W 3, ok. W 3 is this triangular portion whose height is 4.5 and this width is 0.7.

So, I can write this is half into 4.5 into 0.7 into 24 that is equal to 37.8 number 4 is the W 4 which is the same as W 1 37.8 because W W 4 is same as W 3. So, it is 37.8 ok. Then number 5 is the horizontal force that or number 5, I can take this vertical component ok; so this vertical component P AV. So, P AV is 33.61. So, I am taking P AV 36 point. So, this is P V that is 33.6 and number 6 I am taking P this is the horizontal one. So, this will be the P AH that is equal to because here only horizontal force is this one P AH that is 46.8 other all other forces are vertical forces ok.

So, because this is P AV vertical P AH is the horizontal force. So, I am taking P A H is 46.8 it is 46.8. So, now, the total summation of all horizontal forces that is giving again 46.8 kilo Newton per meter and summation of all vertical forces is you if you add this 1 2 3 4 5 five forces. So, this will coming out to be 177.61 this is 0.61 kilo Newton per meter. So, summation of all vertical forces; so vertical this is V and this is H.

Now, the lever arm: so, the lever arm part. So, first I am talking about the first vertical force and the lever arm. So, let us see that I am taking the moment from this toe this is the toe. So, first one lever arm will be. So, this will act at the center. So, 3 by 2 is the lever arm because it is acting because this is at the center point. So, this will act as the center of the wall. So, first lever arm for the first one will be one 3 divided by 2 1.5 ok, then the second one second one is also will act the center of the wall because that is the middle portion. So, this is also 3 by 2 1.5.

Now, for the third one: so, it will act from this side two third of 0.7 and this is 0.65; so 0.65 plus two third of 0.7 because this is the triangle. So, this side is one third of 0.7. So, I am calculating from this side. So, this would be 0.65 plus two third of 0.7. So, this will be 0.65 plus two third of 0.7 that is equal to 1.12 meter.

Now, for the fourth one is 0.65 plus 0.7 plus 0.3 plus one third of point 0.7. So, it will be 0.65 0.65 plus 0.7 plus 0.3 plus one third of 0.7 that is equal to 1.8 then for the this is the fourth and the fifth one P A V. So, now, P A V is P A V is acting here. So now, let us discuss that that P A V part. Now, P A V is acting. So, this is the wall and P A V vertical one is acting here. So, here this is the P A V and here it is P A H and this is P A V and this one from here to here it is 5 by 3 so, 1.67 meter.

So, I can write. So, this one is 0.5 meter. So, from here to here it is 1.17 meter 1.65 minus 0.5, 1.17 meter. So, I know this angle. So, this is 81 degree and these height is 1.17. So, I can determine that this height where it is of this distance where it is acting. So, this distance is 0.185, because you know this height you know this angle. So, you can calculate this one you know this height. So, this one is you can calculate, because this height I know this angle I know. So, I can calculate this is 0.185.

So, my P A V is acting as where it is acting? So, I can this is 0.65 plus 0.7 plus 0.3 then 0.7 minus 0.185 because it is acting from this side 0.85, 0.185. So, it will be this is the fifth 1.65 plus 0.7 plus 0.3 then plus 0.7 minus 0.185 ok. So, that is equal to 2.165 and where P H is acting P H is acting this height this 1.67.

So, P H is 1.67. So, these are the all lever arm. Now, you have to multiply this lever arm with the vertical force. So, this is in column number 1, this is column number 2. So, this is column number 3. So, column MR is column number 4 is equal to 1 into 3 and column number 5 this is equal to 2 into 3. So, I am just showing one calculation. So, for the first one I am showing that that this will be 32 point 32.4 into 1.5. So, this is equal to 48.6 and resisting moment will be nothing.

Similarly, for the W 2 also I can write this is 54 then W 3 it will be 42.3, then W 4 W 4 it will be 71.1 then P A V due to P A V it will be 72.8 and then for the last one this is the overturning the horizontal one is giving overturning moment and that is equal to 46.8 into 1.67. So, that is equal to 78.2 ok.

So, now I am taking the summation of all overturning moment. So, that is 78.2 kilo Newton per meter per meter and the summation of all resisting moment. So, that is equal to the summation of you add this column 4. So, you will get all the resisting moment is 288.8 kilo Newton per meter per meter. So, these are the all calculation that that have done for this problem.

So now, first I have done all the calculations. So, in the next class I will use these values to check the stability of this retaining walls against sliding, overturning, and then I also check the no tension condition and the bearing capacity.

Thank you.