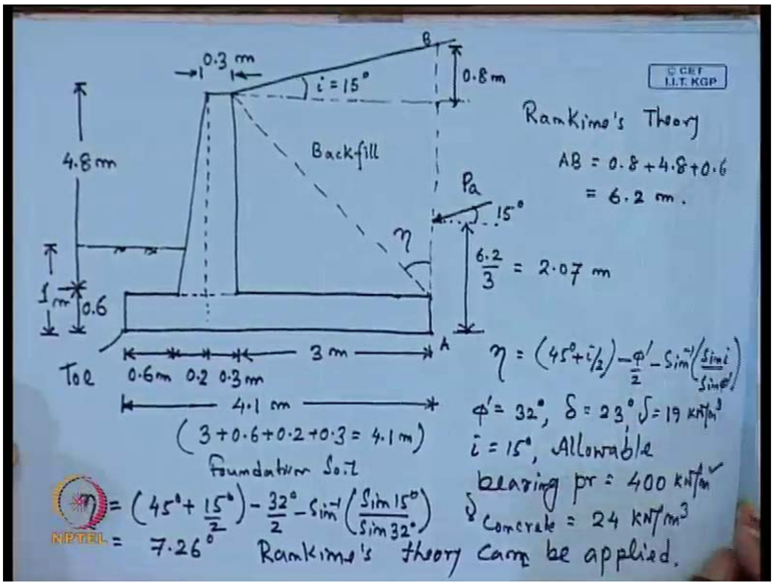
Advanced Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 24
Design of Retaining Wall (contd.)

In last class, I have discussed about the various aspect of design of retaining wall, and then different types of retaining wall, that is gravity retaining wall, semi gravity retaining wall, then cantilever retaining wall, then counter fort retaining wall. Now, in this class, I will basically solve one example of cantilever retaining wall, to show that how this the dimension of this retaining wall, is decided. And what are the factors of safety, or the safety that we have to check, during the design of this retaining wall.

(Refer Slide Time: 01:02)



Now, first if I go for the problem, now suppose if we take one retaining structure, which is cantilever retaining wall, in this form. Suppose, this is the retaining wall and ground surface is this one. Now this ground surface or the backfill side, which is making an angle i equal to 15 degree with horizontal and this is backfill side, and this one is the existing ground surface. Now, this first, for the first trail based on the guidelines, that I have given in the last class. I have chosen this dimension of this retaining wall, that for this job portion, I have taken this is 0.3 meter. Then, and this height of this retaining wall, from this, here to here that height is 4.8 meter, and this thickness that I have taken, thickness of this base slab is 0.6 meter.

So, below this ground level, the total distance below this ground level, is one meter basically, to the base of the slab. Now, what are the other dimensions that is taken, like if we extend this, because this triangular portion. So, the dimension of this portion, as I have mentioned that, this distance from here to here is taken as 0.6 meter; that means, from here to here, this is the toe; then this distance, if I extend this triangular part, so this distance is taken 0.2 meter. Now as usual as I have mentioned that top portion is 0.3 meter, so this one is also 0.3 meter. And this total slab distance or length is taken as 3 meter. So, the total base width of this retaining wall, of this, distance is 3 plus 0.6, plus 0.2, plus 0.3; that is 4.1 meter. So, that is basically 0.3, plus 0.6, plus 0.2, plus 0.3, which is equal to 4.1 meter. Now, the other distance, or this things, we can take, we can take the, extend this vertical lines, which is passing through this edge of this retaining wall.

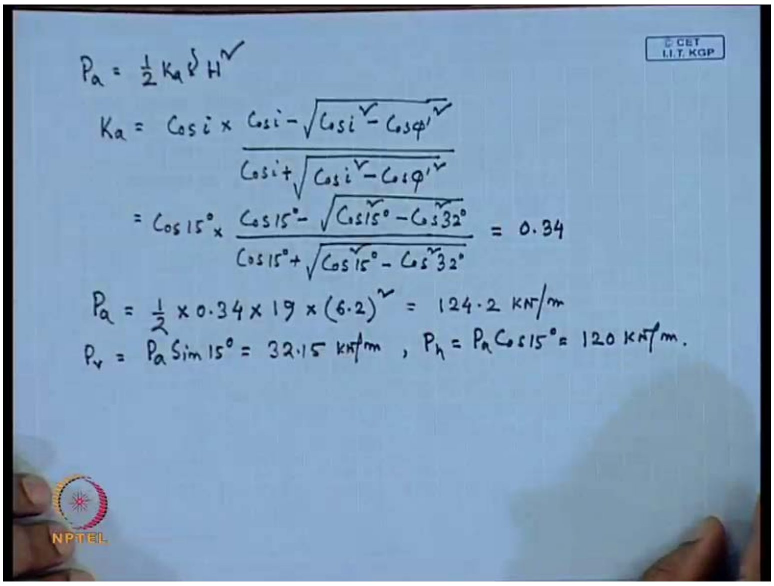
Then we divide this total retaining wall, as we will solve this problem, particular this problem by using, this is Rankine's theory, that we will solve this problem by using Rankine's theory. So, as I have mentioned that, we will consider the weight of this soil also. So, first we consider that, our active earth pressure which will act, at an angle of 15 degree with horizontal. And the pointer application that will act, resistance of this total vertical line, to the one third. Now, the distance of this total vertical line before we start, we can determine the distance of this portion. So, this portion is, this is tan 15 into 3. So, distance from this point to this point is 0.8 meter; that is come from tan 15 into 3. So, the total height of this vertical line, from; say A to B. So, distance A B, that will give us the distance of this height is 0.8, for this one. Then 4.8 for from here to here then additional 0.6 meter, the thickness of base slab. So, total distance that your height is 6.2 meter.

So, the pointer application, of this lateral earth pressure is 6.2 divided by 3, which is 2.07 meter, from the base of the retaining wall. Now as from this design we are neglecting, neglect the effect of this passive resistance, but for this can also be included in the calculation, but for the first case, this problem will be solved by neglecting this passive pressure. So now, if I want to solve this problem by Rankine's theory, so as we have to check, whether Rankine's theory can be applicable or not. So, if I determine this angle. So, this angle we can determine the expression is 45 degree, plus i by 2, minus phi dash by 2, minus sin inverse, sin i divided by sin phi dash. So, now the values which is given, for this problem; that phi dash is 32 degree, delta is 23 degree. Delta is the friction angle between this concrete retaining wall and the soil. And here for the simplicity, that it is assume that, this is the foundations and this is backfill, and this is a foundation soil.

And assume the properties of same wall both the soil, the foundation soil, and backfill soil, but is some cases, this property may not be same. So, in that case, we have to consider different properties, for different conditions. So, for the foundation soil calculation, we have to, then the delta of the base of the retaining wall, and the soil. That friction angle will be based on the foundation soil properties, and this friction angle delta, which is with backfill and the retaining wall, that will also change, and that will depend on the backfill properties, soil properties. So, in that case, the delta of this two may not be same. So, that consideration, we have to take care into our calculation, if this soil properties are different, for the foundation soil and backfill soil. But for this problem we consider the both the properties are same, for this soil total system. So, now the delta all the system is 23 degree, now unit weight is 19 kilonewton per meter cube, i which is 15 degree, and the allowable bearing pressure, is 400 kilonewton per meter square.

So, now we have to solve this, another the unit weight of concrete, is taken 24 kilonewton meter cube. And weight of soil is taken, as 19 kilonewton per meter cube. So, first we have to determine this angle, so that we can check, whether this value, ranking theory can be applicable or not. This angle we can determine by 45 degree plus 15 degree by 2, minus 32 degree by 2, minus sin inverse, sin 15 degree divided by sin 32 degree. So, this value is coming out to be 7.26 degree. So, if this value is 7.26 degree, so this line we will pass, through the backfill soil. It will not pass through the vertical steam of the retaining wall as this angle is very small. So, we can consider that, the Rankine’s theory can be applied. So, this is the first theory we have done, that there we can use the Rankine’s theory. Now we will proceed for the other sections.

(Refer Slide Time: 11:56)



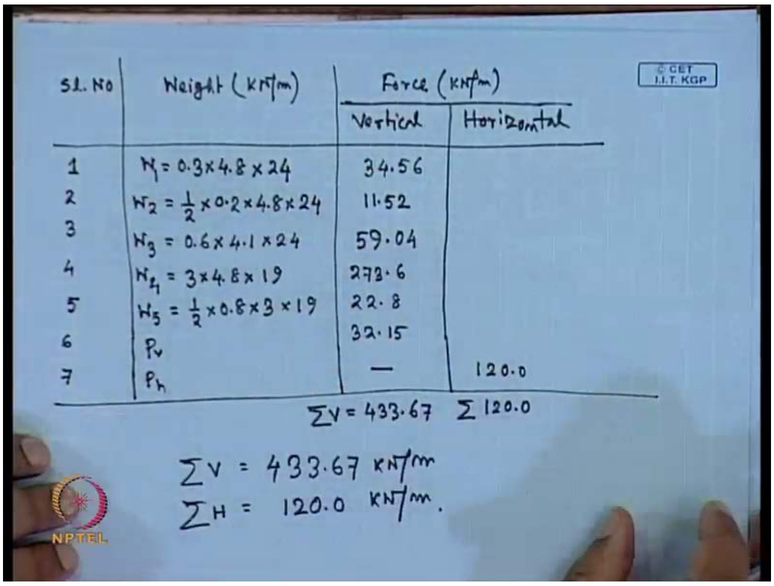
Now, first we will calculate what is the active earth pressure, that will act into this soil or into this retaining wall. So, first we will calculate this p a; that is equal to half into k a into gamma epsilon into H square. Now H we are taking this as I have mentioned that, H we are now taking the total vertical distance from A to B. the total height we are taking, and that a b is 6.2 meter. So, if I take this 6.2 meter, then k a by using Rankine's theory, if we can consider this k a is cos i into cos i minus root over cos i square, minus cos phi dash square, divided by cos i plus root over cos i square, minus cos phi dash square. So, if I put this value, so then this is cos 15 degree, into cos 15 degree minus, root over cos 15 degree square, minus cos 32 degree square, divided by cos 15 degree, plus root over cos 15 degree square, minus cos 32 degree square. So, this k a value, if i solve this thing, this k value is coming 0.34, so this is 0.34. So, the p a value is equal to half, into 0.34 into gamma is 19, into H is 6.2 square.

So, this value is coming 124.2 kilonewton per meter, as we are calculating this thing per meter distance, so this is per meter. Now, as from this figure, we can see that p is acting as angle of 15 degree. So, we can take the vertical component and horizontal component of this p a; that we can write like this is p v, and this is p h. So, this is the vertical component of p a p v, and p h is the horizontal component of p a. So, we can calculate that, p v is p a into sin 15 degree; that is equal to 32.15 kilonewton per meter. Similarly p h is p a into cos 15 degree, which is equal to 120 kilonewton per meter. So, the vertical force and horizontal force; that is coming due to the lateral earth pressure of the backfill;

that we can calculated. Now we have to calculate the other parts of this problem. So, now, for the other parts, suppose if I take the previous figure, our main figure, then in this total retaining wall, we can take a several parts of the retaining wall.

So, we can take this is number one. This number one means, this rectangular is our first component. Then this triangle is number two; that means, this triangular zone is number two. Then this total base slab is third zone, and this total rectangular soil portion is fourth zone, and this triangular soil portion is zone five. Now, we have to determine the individual weight of this five zones. There centroid, where these weights are acting actually, and then the moment with respect to two. So, all these things we have to calculate, because this five zone, these loads are giving the vertical force, and that will also give the resistive moment. And this p a, due to this p a we will get the overturning moment. So, first we have to calculate, the weight of different portion, of this total system.

(Refer Slide Time: 17:27)



Sl. No	Weight (kN/m)	Force (kN/m)	
		Vertical	Horizontal
1	$W_1 = 0.3 \times 4.8 \times 24$	34.56	
2	$W_2 = \frac{1}{2} \times 0.2 \times 4.8 \times 24$	11.52	
3	$W_3 = 0.6 \times 4.1 \times 24$	59.04	
4	$W_4 = 3 \times 4.8 \times 19$	273.6	
5	$W_5 = \frac{1}{2} \times 0.8 \times 3 \times 19$	22.8	
6	P_v	32.15	
7	P_h	—	120.0
		$\Sigma V = 433.67$	Σ 120.0

$\Sigma V = 433.67$ kN/m

$\Sigma H = 120.0$ kN/m.

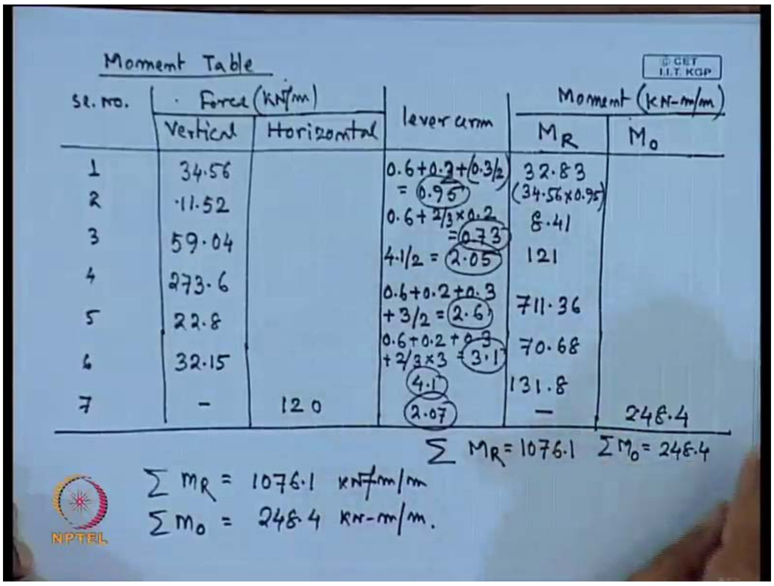
Now, first if we calculate this weight, we can take the, for weight calculation, we can take this table; we can make this table; that is our serial number. Then weight calculation; that is kilonewton per meter. Then the force that we will calculate that is also kilonewton per meter; and this force can be vertical, and this can be horizontal. So, this is for the weight calculation table; that we will calculate. The first serial number one, the first segment weight that we will calculate; so for this first segment, this is for the first segment; the weight will be this area into the unit weight of the concrete. So, this area will be 4.8 meter into 0.3 into 24.

So, if in this way, if we calculate the weight of every section, then weight one for the first section, is 0.3 into 4.8 into 24; that is the unit weight of the concrete. So, this will act in the vertical direction. So, vertical direction we can write the total weight w 1, that is equal to 34.56 kilonewton per meter; similarly, if we calculate the weight of second portion; that is a triangle; so that we can write half into 0.2, into 4.8 height, and then 24. So, we will get this value is 11.52, and this will also act in the vertical direction. So, we will get this is also 11.52. Similarly, the third weight, if we calculate the weight of the third segment, so that is 0.6 into 4.1 into 24, because for the third segment means, this total base slab. So, that is 4.1 into 0.6 into 24, 0.6 is this distance and to 4.1 is total base slab width, and then for 24 is the unit weight of the concrete.

So, if I use this value, then it is come 59.05. Then for the fourth; that is for the soil, fourth and fifth portion; that is the fourth and fifth portion. Fourth; this rectangular portion, and fifth, this triangular portion, this is for the weight of the soil. So, for the fourth portion, we can write this is three into 4.8 into 19, as the unit weight of this soil is 19. And for the triangular section, it will be half into 0.8 into into 3 into 19. So, in that way, if I write fourth section; that is 3 into 4.8 into 19. So, vertical force again this soil pressure will act in vertical direction, that 273.6. Now, for the fifth segment, for the triangular one, for the soil; that is equal to half into 0.8 into 3 into 19. So, that value is 22.8 kilonewton per meter. So, these are the vertical load, vertical force; that is acting due to the concrete and the soil.

Now, we can write the next two forces; that is the horizontal and vertical force, is acting due to the lateral earth pressure. So, sixth segment we can write, this is p v; that will also act in vertical direction, so that p v value is 32.15. And the seventh one is p h, horizontal force. So, that means, p h will act in horizontal direction, so that is 120 kilonewton per meter. So, we can write the total vertical force, summation of v; that is equal to the summation of this vertical column, is 432.67. Similarly, summation of this horizontal force, total 102 kilonewton per meter. So, summation of total vertical force, is 433.67 kilonewton per meter, and summation of horizontal force is 120 kilonewton per meter. So, this is force table. Now, we will calculate the moment table. So, once we calculate the moment table. So, this table will calculate.

(Refer Slide Time: 23:23)



So, this is the force table, the next one is the moment table. So, again this is also serial number, then we will consider the vertical and horizontal force; that is force. So, now we can write the next column is. This is serial number, we can write the next column is lever arm, with respect to two. The next one is the moment. Now this moment can be over resistive moment M R, and this can be overturning moment M O, this is kilonewton per meter per meter. So, first we will go for, again this seven force that we have taken; first, second, third, fourth, fifth, sixth, seventh. So, from the force table, we can write the value of these forces. So, for the force table, first vertical force for the first seven is 34.56, then second one is 11.52, then third one is 59.04, then fourth one is 273.6, fifth one is 22.8, then the sixth one is 32.15, and seventh one is 120, which is horizontal.

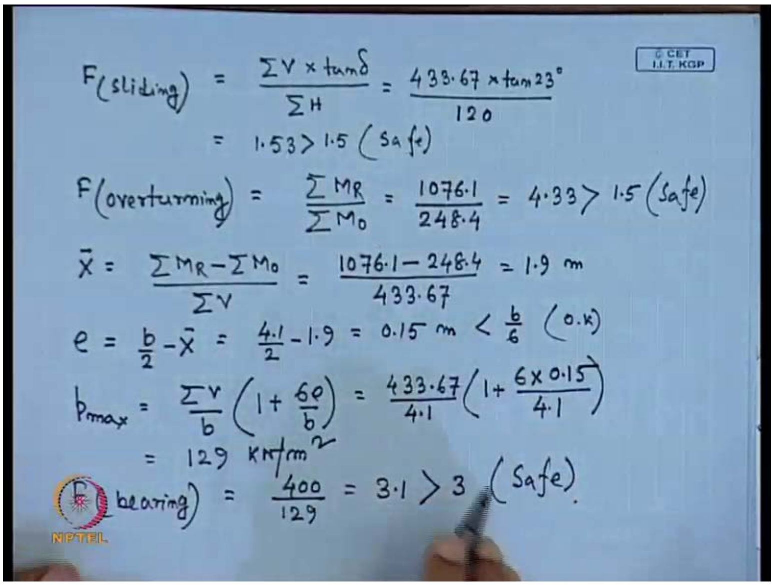
Now, for a each segment, we have to calculate the lever arm. So, now, if I consider the first segment, this is the first segment, so it is a rectangular. So, this will act the center of this rectangle. So, lever arm from the toe will be 0.6, plus 0.2, plus 0.3 divided by 2, so that as it will act the center of this rectangle. So, the 0.6, 0.2, 0.6 plus 0.2 plus 0.3 divided by 2. So, now if I write in this form, so the lever arm will be. For this first segment is 0.6 plus 0.3 sorry 0.2, plus 0.3 divided by 2. So, this will give us the value 0.95. Similarly for the second one; second is a triangle, so second segment is a triangle. So, here lever arm will be 0.6 plus two-third of 0.2.

So, that will give you the lever arm of the, second triangle portion. So, for the second portion the lever arm is 0.6 plus two third of 0.2. So, that will give 0.73. Similarly for the third section; that is the base of this rectangle. So, that will give us the straight forward. This will at the center of this rectangle, so 4.1 divided by 2. So, lever arm for this third portion is 4.1 divided by 2; that is equal to 2.05. Now, lever arms similarly for the fourth section that is the rectangle of this backfill soil. So, that is 0.6, plus 0.2, plus 0.3, plus 3 divided by 2; that is, equal to. So, that means, here, this is 0.6, 0.2 plus 0.2, plus 0.3, plus it will act as the center of this 3, so plus 3 by 2. So, now this lever arm is 2.6. Similarly for the fifth segment; that is for the triangular zone, so that lever arm is 0.6 plus 0.2 plus 0.3, then it is a triangle. So, triangle means plus two third of 3, so it will give 3.1.

So, these are the lever arm value 0.951, 0.73, 2.05 then 2.6, then 3.1, and for the sixth one that is acting vertically, at the distance of 4.1 meter. So, that is 4.1 meter for the sixth one, and as we have calculated that the horizontal one; that is the vertical one will act 4.1 meter from the toe, and the horizontal will act 2.07 meter from the toe. So, that distance is 2.07. So, these are the, all rounded values are the lever arm. Now, these, from this, this is vertical force is corresponding to that moment will give the resistive moment. And the moment corresponding to this horizontal force that will give the overturning moment. Now if I calculate this moment, so this is simply 34 0.56 into 0.95. So, this will give resistive moment is 32.83. So, this is actually 34.56 into 0.59; that give you 32.82. Similarly, for the second one is 11.52 into 0.73, so that value is 8.4.

Similarly for the third one is 59.05 into 2.05, so this will give 121, the fourth one is 273.6 into 2.6; that is given 711.36. The fifth one is 22.8 into 3.1, so this will give 70.68. Sixth one is 32.15 into 4.1, so this will give 131.8, and the seventh one is 120 into 2.07, so this will give 248.4. So, these are the resistive moment and the overturning moments. Now, if I take the summation of all these moments, so that means summation of M R that is equal to summation of this column; that is 1076.1, and summation of overturning moment is 248.4. So, we can write that M R is 1076.1 kilonewton meter per meter, and M O is 248.4 kilonewton meter per meter. Now, we have completed the force table, I have written the moment table. Then we will calculate the, for which we will check the factor of safety for different condition. The first factor safety that we will check, that is for the sliding.

(Refer Slide Time: 32:32)

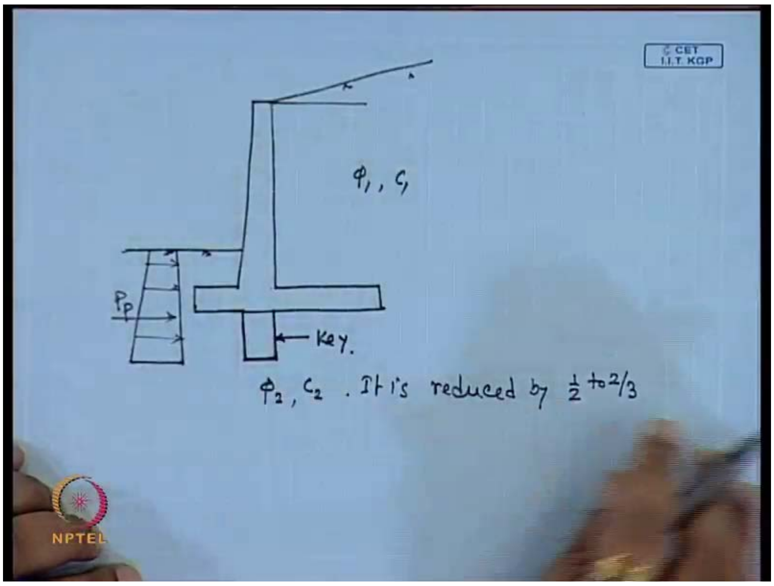


So, factor of safety for sliding; and that is the expression rule, total vertical force into tan delta, divided by all horizontal force. Now here total vertical force summation is 433.67, and tan delta that we have taken is 23 degree, so into tan 23 degree, and summation of all vertical or horizontal force is 120. So, this value is equal to 1.53, which is greater than 1.5, so that means, it is safe. So, now next check that we will do, for the overturning moment, factor of safety for the overturning, and that is summation of resistive moment divided by, summation of overturning. So, summation of all resistive moment is 1076.1 divided by 248.4, so that will give us 4.33, which is greater than 1.5. So, that means, it is safe. The first two check, we have done and it is safe, against this sliding and overturning.

Next we will calculate the e value or the no tension condition. So, first we calculate the x bar, that expression I have given; that x bar is summation of M R minus summation of M O divided by summation of all vertical force. So, summation of M R is 1076.1, M O is 248.4 divided by, vertical force is 433.67. So, it is coming 1.9 meter. So, e we can, eccentricity we can calculate, it is the b divided by 2 minus x bar, b is the total base width. here total base width is 4.1 divided by 2 minus 1.9. So, it is coming 0.15 meter, and definitely which is less than b by 6. So, this no tension condition will occur, so this is 5. So, next check we will calculate for the bearing capacity calculation, we have done the three checks; that is the sliding, overturning, and the no tension condition. Now for the bearing; for bearing calculate first p max, and that expression is all vertical force, divided by base width; 1 plus 6 e divided by total base width.

Now, for vertical force is 433.67 divided by base width is 4.1, into 1 plus 6 into e is 0.15, and divided by 4.1. So, this p max value is 129 kilonewton per meter square. So, now factor of safety for the bearing, is the allowable force; that is 400 kilonewton per meter square, divided by is allowable bearing pressure is 400 kilonewton per meter square divided by 129. So, that value is 3.1, which is greater than 3; so safe. So, this way we have checked all the factor of safety; that is for the sliding, overturning then for the no tension condition, and a factor of safety for the bearing. So, all the checks are satisfied. So, the dimension that we have chosen; that is, for all the condition, it has satisfied all the factor of safety; so we calculate, use these dimension for our purpose. Now, there are few things that we have to mention that, suppose this problem is partially unsafe or slightly unsafe, by the sliding. In that case one thing we can do, that if this problem is not satisfied.

(Refer Slide Time: 38:00)



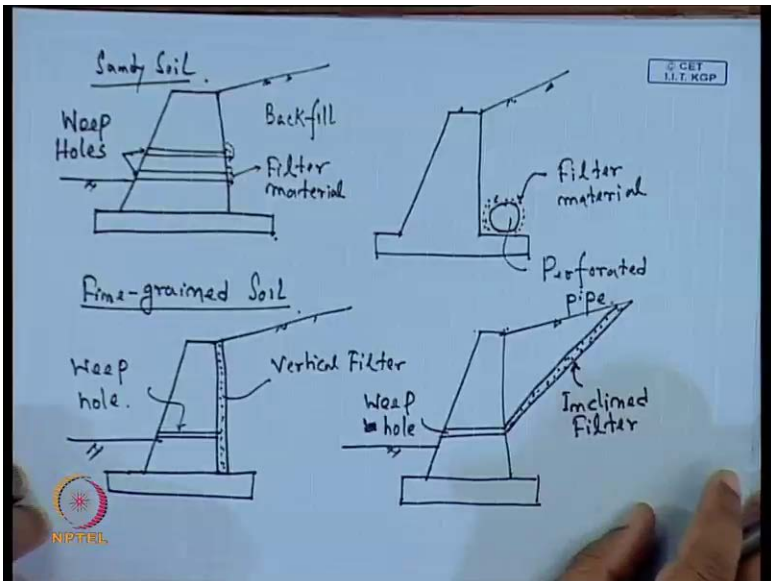
Suppose, this is our retaining wall structure. So, this is the retaining wall structure, ground surface, this is ground surface. Now, say this retaining wall is, unsafe against the sliding. Then one thing we can do that, we can provide one key here, in this form, just to increase this another portion, that we can exchange, it is called key. The idea of this key, this will give the additional resistance against the sliding. So, an another thing is that, when you calculate the passive resistance, that passive resistance part, the depth will also increase, because here we will get calculate the passive resistance; say p p. So, that passive resistance depth; that will also increase. But one thing, for the factor of safety, so this will give increase the passive resistance for this design, which we have, although we have not consider in our calculation, previous calculation, but this passive resistance that can increase, and this will give the additional resistance against the sliding.

So, if it is marginally unsafe against sliding, we can provide keys. Now, when we can provide key, one thing for the size this situation; that the properties for the soil, for this portion; say phi 2 is the base soil property, c 2 is the foundation soil property. And say phi 1 is the backfill soil property, c 1 is the backfill soil cohesion. This is friction, this is the foundation soil. Now, instead of taking the full, in the situation when key is used, instead of taking full phi 2 and c two, generally it is reduced by half to two third of the value of, for the extra safety, as for the full passive resistance, because in this case, as this key we are applying for the for this portion only. So, it is doubtful that, whether the full passive resistance will develop or not.

So, that just to the for additional factor of safety. This soil property c and phi is reduced by half to two third, for the additional factor of safety. So, now this is the function of key. Now another thing is that, if we solve this problem, that we have solved this problem, and where this, the soil properties are same for both the cases. And another one; that when we are talking about this theory, that we have use the Rankine’s theory. Now, we can solve this problem for Coulomb’s theory also. Now this is the home assignment for you, if you want to, you can try to solve this problem by Coulomb’s theory, by applying the Coulomb’s theory, and you can see, what is the difference, we are getting by if we use the two difference theory. Another one, that we are neglecting this passive resistance.

Now if we can solve this problem by using this passive resistance, that also you can try, to solve this one, with use of a passive resistance, you can see how much extra factor of safety you will get, when you consider this passive resistance. By these two things considering passive resistance and using a different theory, you can try to solve this problem, same problem. Now, when you are talking about the retaining wall, the next segment; that we are talking about the retaining wall; it is most of the cases, this the backfill material which is used, mostly it is used for the granular soil, to avoid the water pressure, because when you design the retaining wall, you always try to avoid the indo of water pressure, so that, this additional water pressure will not come into retaining wall. So, that to avoid this water pressure, there are few things we can do, that we can provide some holes in the retaining wall, so that water can pass through that hole, so that the water pressure can be neglected.

(Refer Slide Time: 43:05)



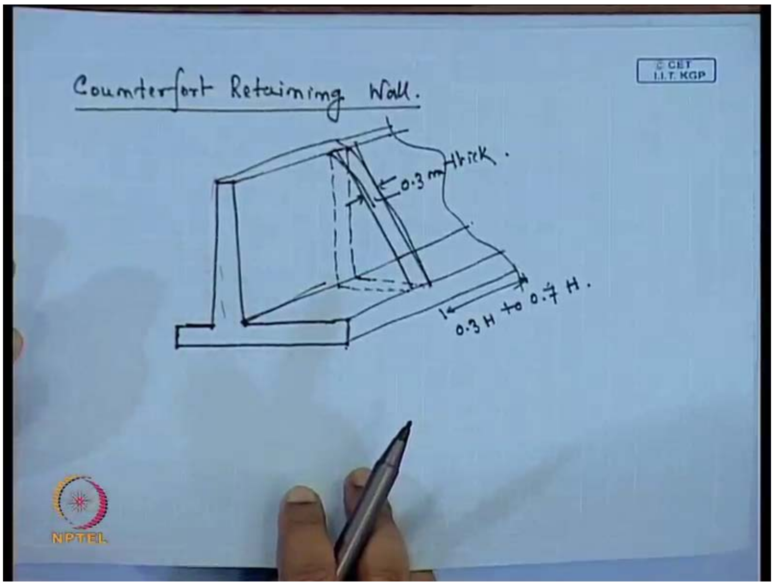
Suppose if this is one retaining wall structure. Let suppose this is one retaining wall structure. This is base, this is the ground surface. So, we can provide a hole, or a water body can pass through this portion, this is called weep holes; w double e p weep holes. So, we can provide some filter material, we can provide some filter material here, in the weep holes. So, suppose this is backfill material, so this is filter material. now this filter material, this weep holes, this diameter is around 0.1 meter, spacing is around 1.5 meter 23 meter in horizontal direction. So, now this use of this weep holes, is to reduce the pore water pressure develop, due to the water. Now this pore water pressure, if we can reduce this, if all water can pass through this weep holes, then we can reduce the pore water pressure.

So, that pore water. So that, the additional lateral earth pressure, that we can reduce, by this way. Now, another one, that we can consider, this different types of weep holes that. This is suppose the retaining wall, we can provide a perforated pipe here, with filter material surrounding this. So, that water can collect here, and it can pass through from the retaining structure. So, that is our perforated pipe, and this is filter material. Now, if this is for the granular soil or sandy soil, now for the clay soil, when fine grained soil is used, because we always try to use, this is for the sandy soil or granular soil. Now case two, if for the clay soil or fine grained soil, we always use, we always try to avoid the use of this fine grained soil. Now some time if it is not possible to avoid this fine grained soil, then what we can do.

Suppose this is our retaining structure, is existing around, this is the ground surface. Then we can provide a filter material, along the vertical surface, or we can provide, and then we can provide a path, so that water can collect here and it can pass through. So, this is weep hole. So, this is our filter material, or vertical filter. So, this filter material can be inclined also. Suppose this is the mid retaining wall. So, that material can be inclined, and then we can provide the weep holes here. So, this vertical material can be. This is inclined material, filter material………………..

So, in this way we can reduce the water pressure, this is for the fine grained soil, the inclined or vertical filter, then the water can be collected through this filter and passed through the weep holes. Or this is for the sandy material, where we can provide the weep holes or we can provide the filter material.

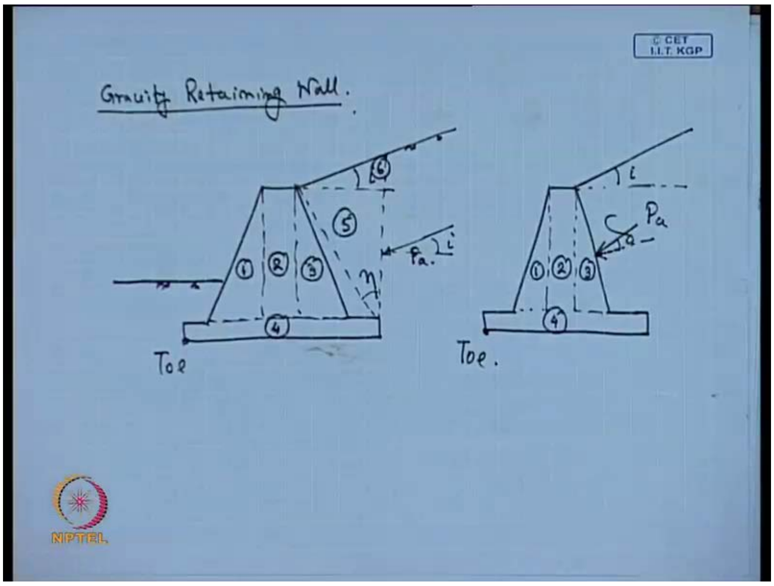
(Refer Slide Time: 48:24)



Now, for this, so this can be done for the retaining wall design. Now when we are talking about the retaining wall design, so the design of counterfort retaining wall, that this counterfort, this basic difference of counterfort retaining wall, in case of reinforce. Suppose this is the retaining wall, that counterfort retaining wall. This is the retaining wall counter fort portion. So, when you determine the dimension of this front portion, this retaining wall. This is similar to the cantilever retaining wall. So, in base term that, as we have discussed for the cantilever retaining wall design procedure, we can determine the this dimension of this counter fort retaining wall also, but in case of reinforcement design; that is the difference between the retaining wall for the counter fort and the cantilever, that for the counter fort retaining wall, that counterfort are placed with certain spacing; say point.

So, this counterfort are about to this 0.3 meter thick. So, suppose this is 0.3 meter thick, and spacing between this counterfort is taken at 0.3 H to 0.7 H. And, when you are taking the reinforcement design, because when we were designing this retaining wall, then we have to design for this base slab. So, this idea to use of this counter fort as this spacing, a certain spacing, to reduce the induced bending moment and shear force in the base slab, as well as in the cantilever portion; this cantilever slab. So, that will, we have to design, when you consider this, when you design the reinforcement part. But for the dimension part, that is the main aim of this class, so that dimension we have to decide, based on the similar as we have discussed, for the cantilever retaining wall.

(Refer Slide Time: 51:49)



Now, another case, suppose we want to, that is for the counter force and the cantilever retaining wall. Now for the gravity retaining wall, suppose if we want to, this gravity retaining wall, so this is our ground surface, this is the base. So, here we can solve this example in two methods, as we have solved for the cantilever retaining wall also. Here the process is, we can solve if we want to solve it by Rankine's method, then we have to extend this part, then it will act at horizontal angle i. and then we have to consider the weight, and we have to, suppose if it is this form, then we divide this part. Suppose this is segment 1, segment 2, segment 3, segment 4, segment 5, segment 6. So, same process we have to follow, though when we choose the dimension. we have to first choose the dimension, based on the guideline that I have given, then we have to calculate the weight of individual section; it is first, second, third, fourth, fifth, sixth.

So, this is for the weight of the soil; this portion. And then, before that we have to check again, whether Rankine theory can be applied or not. So, then you calculate if it is applied Rankine theory, then we calculate the weight of this concrete blocks; four section then weight of the soil. Then with respect to toe, we have to take the moment, as we are neglecting the passive force here also. If you want, you can consider the passive force, in the calculation. Now, we take the moment, as I have solved for the cantilever retaining wall, then check all the factor safety. So, that is for the gravity retaining wall, same we can consider. Now if I consider the same problem, by Coulomb's theory. Then suppose this is i, so it will act with this perpendicular line, with an angle delta, this p a will act.

So, again we can take the different segment; this is say one, two, three, four, but here we will take the weight of this four section only, this concrete blocks, and then we will not consider the weight of this soil for this analysis. then the process is same, I will consider the, we will take the moment of this all the forces, with respect to toe, and then we have to check all the condition; that is for our sliding, then overturning, then no tension condition, then bearing. So, these are the design procedure that we have mentioned, for this class; that how this retaining wall, that basically the dimension of the retaining wall, can be chosen for different condition, and the basic difference of. And then what are the different types of retaining structure; that is for our gravity, semi gravity, cantilever and counterfort retaining wall. and in the design aspect, the difference in the cantilever retaining wall and the counter fort retaining wall that when, we are considering the reinforcement design, for they are the counterforts are used, so we have to counterforts, we have to design.

So, those things, but the dimension considerations, the dimension of this counter fort retaining wall, that approach is similar to the cantilever retaining wall. So, now we have discussed about how to reduce the water pressure, in the retaining wall by providing the weep holes. Then we have discussed that, if there is this retaining wall is slightly unsafe against sliding, then by providing key, we can increase the sliding bearing capacity. And then that the passive resistance; that is given that passive resistance will increase. But when we use the keys we have to keep in mind, that the full development of passive resistance that is, whether that will develop fully or not; that is the question. So, that is better for the safety purpose, if we reduce the soil property c or phi, by two half to two third, to its original value, so that we can reduce this value, because we do not know whether this resistance will fully occurred or not.

So, these are the things we have to keep in mind, when we consider design the retaining structure. So, next class we will discuss about the various other aspect, or various other types of retaining structure, in the geotechnical engineering. And then we will discuss about the how to choose the depth, because in this, there is another type of retaining structure, that is our sheet pile. So, what is sheet pile, then what is the difference between the sheet pile and the cantilever retaining structure, because sheet pile is also one type of retaining structure, and then how to differentiate between these two. Those things we will discuss in the next class, and then I will try to solve that, what are the different types of sheet pile, and then how to solve the, I have to choose the dimension of those sheet piles, that things we will discuss in the next class.

Thank you.