Ground Improvement
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Lecture 57
Geosynthetics in Ground Improvement (Contd.)

Hi, everyone. Let us start what I have mentioned in the previous lecture that one design example on MSE wall.

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And it is quite lengthy. Let, let us see whether I can do within half an hour.

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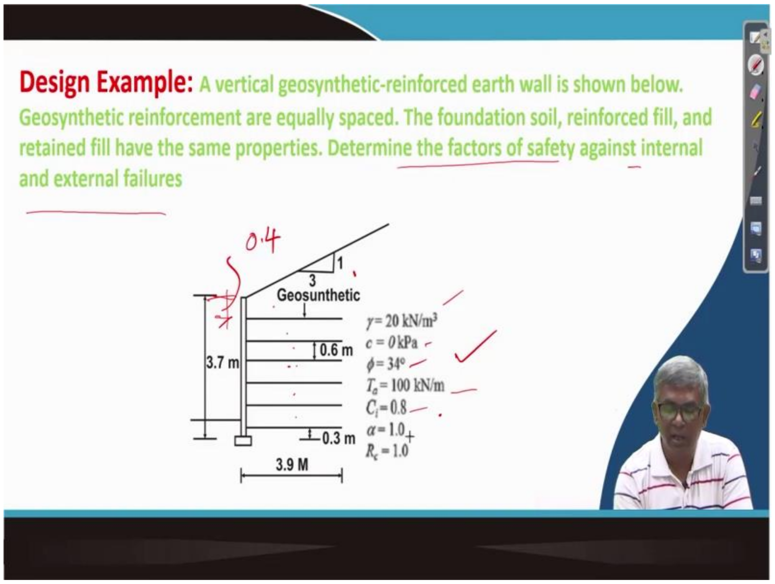

So let us come to the problem first. So, the problem is like this. A vertical geosynthetic reinforced earth wall is shown below. This is the one, is shown. What it is actually? The wall height is 3.7meter. And reinforcement initial, this is a trial design, suppose, and we have to check the factors of safety against internal and external. So, there are actually, 3.9meter long reinforcement is provided.

The backfill is sloped, 1 vertical, 3 horizontal and, and you can see that the vertical spacing between the reinforcement is 0.6meters. And the bottom most reinforcement actually started 0.3meter above. So, and that topmost reinforcement is applied, from the geometry if I calculate, I will see that this distance is 0.4. So, then 0.6. Then 5 into 0.6 is, 5 into 0.6, actually 3meter, 3.4meter and plus 3.7meter, is total height of wall.

And it is a geosynthetics, and it is mentioned, the foundation soil, the geosynthetic reinforcements are equally spaced, that means 3meter and laterally also equally spaced. The foundation soil, reinforced fill, retain fill have the same properties, that means, soil here, soil here all three soils are same. And determine the factor of safety against internal and external failure.

So, whatever we have discussed, by and large, same we would know, global analysis will be required. We will do factor of safety against sliding, overturning and bearing capacity, and pullout rupture, and connection strength is not given so will not be able to find out that factor of safety.

And here actually soil properties are given, here you can see gamma γ= 20 kilo Newton per meter, for c is 0, phi ϕ is 34°, T allowable actually, allowable strength of the reinforcement is 100 kilo Newton per, C_i is 0.8, alpha α is 1, R_c is 1. So, these are the things given. So, we have to design. So, for this, let us open a new page.

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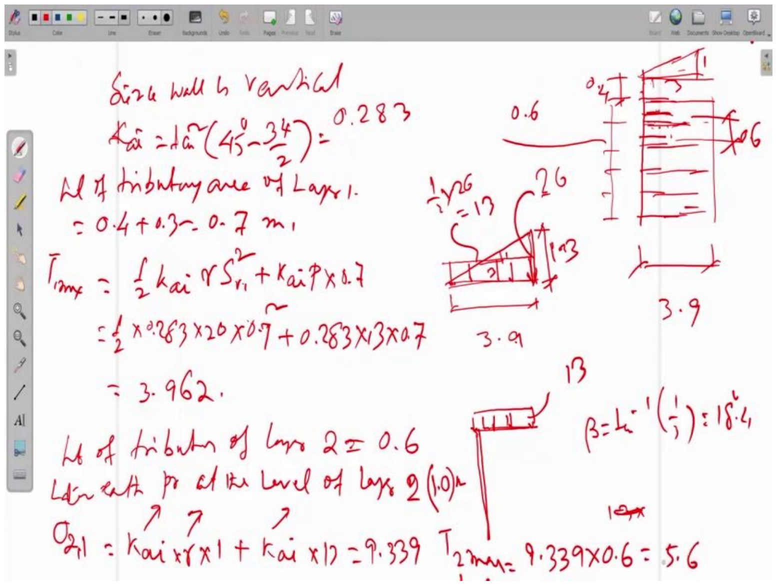

And here actually, so let me draw the wall first. There may be wall is something like this, some, 1, 2, 3, 4, 5, 6. So, these are the reinforcement. And this distance is 0.4, and these are all, 0.6 each, and this is actually 3.9. And this angle is 1 vertical, 3 horizontal, that means that beta is actually tan inverse 1 by 3, it gives you 18.4°.

And since the wall is vertical, then what we can do, I can take, two things I can assume, this one actually, the sloping portion, so sloping portion let me draw here. This is 3.9 meter, and then if it goes 1 is to 3, so it is 3.9, then it becomes 1.3. So, 1.3 multiplied by 20, so this pressure, here actually pressure will be 1.3 multiplied by, this will be 26, it will be, pressure will be 26.

If I consider average pressure over that, if I consider over, average pressure over here, so the average pressure will be half of 26, so it will be 13. I will consider, that means instead of sloped wall so now, I consider the wall is like this with a surcharge of 13 and then it becomes leveled surface, and this is also vertical. Then I can find out K_{ai} .

So, it is a vertical wall, and again if I assume this average pressure, then I can assume level back fill, will be equal to 10 square 45 degrees minus 34 by 2. So, that gives you 0.283.

And the, then height of the tributary area of the first one, so this is the reinforcement, so these two-reinforcement half, this will be 0.3, and this side is 0.4, so 0.7. Height of tributary area of layer 1 will be equal to 0.4 plus 0.3 equal to 0.7meter.

And if it is so, the required tensile strength of layer 1, so $T_{1\max}$ will be equal to half K_{ai} γ and S_{v1} square. So, so this is actually starting from here up to this, that pressure has to be there, plus K_{ai} multiplied by this, average pressure is 13, P, multiplied by actually your K_{ai} into P and again multiplied by 0.7.

So, this if you do, then it will become half multiplied by K_{ai} actually is 0.283, multiplied by 20 multiplied by S_{vi} is 0.7 square plus 0.283 multiplied by 13 multiplied by 0.7. So, if I do, calculate this one, this will be 3.962.

And height of the tributary of layer 2 will be equal to 0.6 because, if this is the layer so here and up to these, it will be nothing but 0.6. So, if it is 0.6, the lateral earth pressure at the level of layer 2, lateral earth pressure at the level of layer 2, what is the level? Level is, here actually 0.7 plus 3, so it will be 0.6 plus 0.4, that is 1 meter.

So, σ_z 1 meter will be equal to K_{ai} multiplied by gamma multiplied by z, actually, is 1, and plus this will be K_{ai} multiplied by 13. So, this becomes the pressure. So, if γ (gamma) equal to 20, this is 2.283, and this is again 2.283, this pressure comes, actually 9.339. In that case $T_{2\max}$ will be equal to 9.339 multiplied by 0.6 equal to, this is 5.6.

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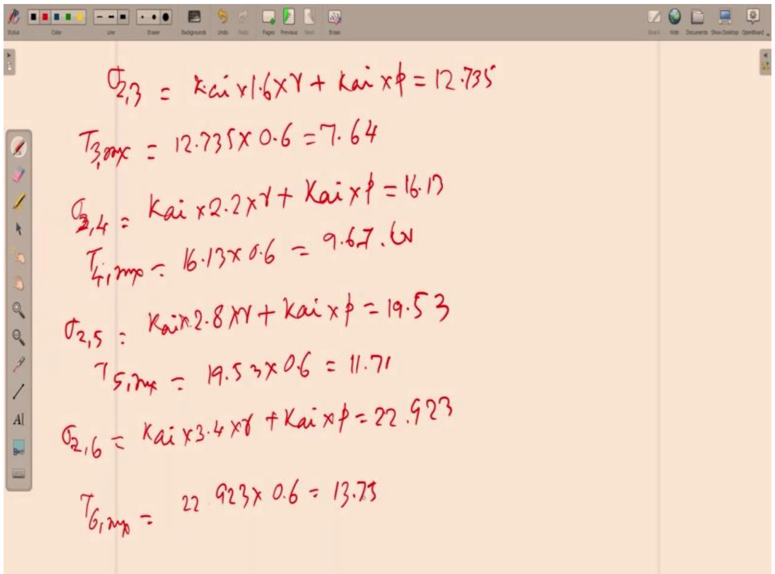

Similarly, you can find out your σ_z actually layer 3, so that will be equal to, again, it was 1 meter, so next layer will be 0.6 meter below, so it will be K_{ai} multiplied by 1.6, that is z, multiplied by γ plus, this will be again K_{ai}, multiplied by P. So, if I put those values, this comes actually σ_{3H}, that is actually coming 12.735, and then $T_{3\max}$ comes 12.735 multiplied by 0.6, tributary area is again same, so it will be equal to 7.64.

Again, σ_{z4} it will be what? Multiplied by K_{ai} again, next layer will be 0.6 meter below, so it will be 2.2 multiplied by γ plus K_{ai} multiplied by P. So, if I put all those values this, this value comes actually approximately equal to, it will be 16.13, and then $T_{4\max}$ will be called to 16.13 multiplied by 0.6. This gives you 9.67, so kilo Newton.

And then next one is sigma z 5, or σ_{z5}. That will be again K_{ai} multiplied by 2.2 plus 1, plus 0.6, so 2.8 multiplied by gamma γ plus K_{ai} multiplied by P. If I put the values, then it will be, it will give you 19.53. And if, that means T_{5max} will be equal to 19.53 multiplied by 0.6, that is S_{v5} that is again equal to 11.71.

And then next one is σ_{z6} that, means sixth reinforcement position will be K_{ai} multiplied by, 2.8 multiplied by, plus 6, that will be 3.4, multiplied by γ plus K_{ai} multiplied by P. If I put the values, all values then it will be coming 22.923. So, $T_{6\max}$ will be equal to 22.923

multiplied by 0.6. So, this will be equal to 13.75. So, I got the tensile force requirement in each level, T_{max}.

So next actually what do you have to do? We have to find out the, we have got a layout, based on that layout what do you have to do? You have to find out the length of the resisting portion. So, L_{ar}, L_{ar1}, L_{ar2}, L_{ar3} like that. So, like, we will go to the next page, maybe.

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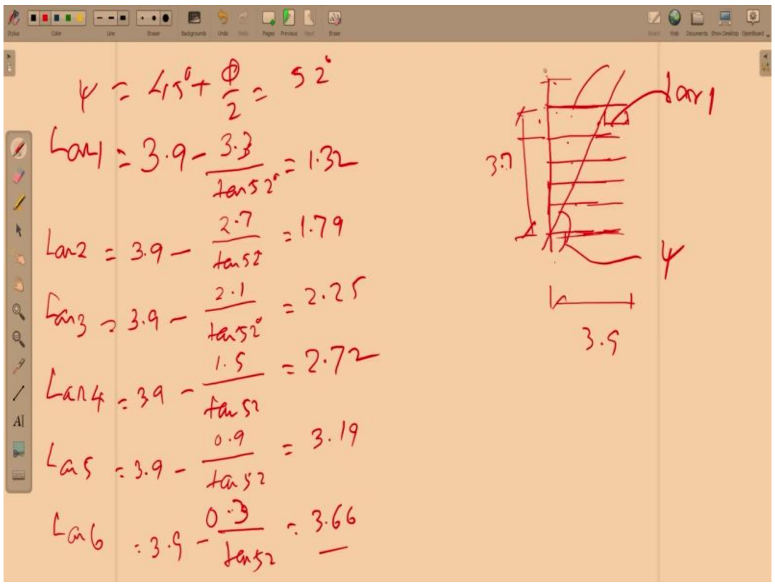

Suppose, if your wall is something like this and reinforcement is here. So, 1, 2, 3, 4, 5, suppose, 6, like this, all are equal. And this is all 3, 3.9 meter. So, another thing it is vertical wall, and horizontal level we have considered, that failure plane, that actually, zone, there is that, this is p_{si}, actually, the value of p_{si} can be calculated, 45 degrees plus 5 by 2, so that it will be 52°.

So, if I do that, then this is, total length is 3.9, so this portion is only L_{ar} this is actually L_{ar1}. So, L_{ar1} will be equal to 3.9 minus this length. So, if this angle is p_{si} $\tan 52^0$, from the trigonometry I can find out this length which will be equal to, so up to this, 63.7, so this is 0.4, up to this length is 3.3. So, this is 3.3. So, it is 3.3 divided by $\tan 52^0$. So, if I do that, then it comes 1.32.

So, you can see that though we have provided, now, that, 3.9 meter of length of reinforcement, but it is effective for developing, or development of resistance only 1.32 meter. Rest of the things actually it is only to reach the connection. So, this is the one.

Similarly, I can find out L_{ar2}, which will be equal to 3.9 minus, up to this will be again how much? 3.9, so it will become 2.7, divided by $\tan 52^0$. So, this length will become, if I do, this will be 1.79, then L_{ar} so this will be again 3.9 minus 2.7 minus 0.6, so I will be 2.1 divided by $\tan 52^0$ So, it will be 3. It will be 2.25. L_{ar4} Which will be again 3.9 minus 2.1 minus 0.6, this will be 1.5 divided by $\tan 52^0$. So, this gives you 4. It will be 2.72. And L_{ar5} which will be equal to 3.9 minus 1.5 minus 0.6, it will be 0.9 divided by $\tan 52^0$. So, this gives you 3.19. And L_{ar6} will be equal to 3.9 minus 0.9 minus 0.6. So, it will be 0.3 divided by $\tan 52^0$. It will be equal to 3.66.

So, it is obvious, the bottom most reinforcement will have more resisting length. But it is not required actually. If I draw again the vertical force diagram, so that, I will come later on, that one. For the time being we have got the length of different layer, what is the length of, resisting length. We have to find out now T_{po}, that means what is the pullout capacity of the, each layer.

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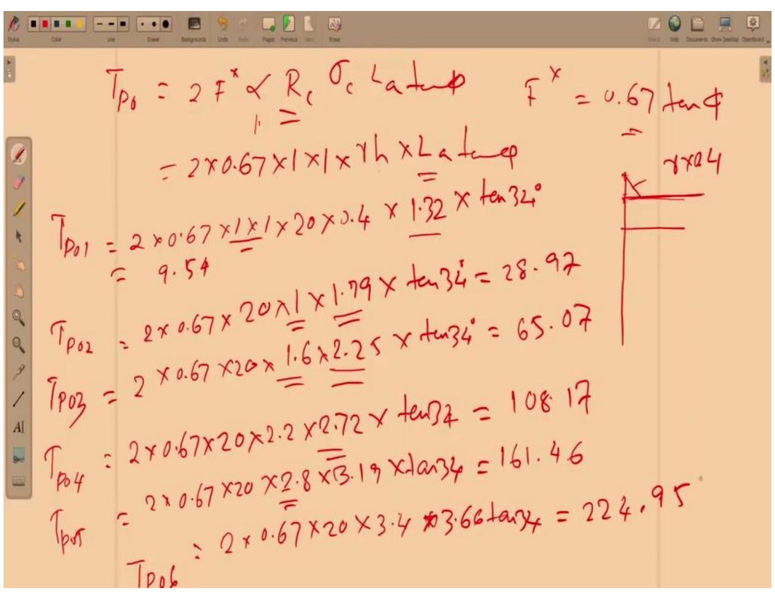

Actually the T_{po}, we can calculate T_{po} will be equal to, 2 multiplied by F star multiplied by α alpha multiplied by R_c, multiplied σ_z, L_a. This was the formula. And F star actually can be taken as 0.67 multiplied by $\tan\varphi$. And if I do that is actually, ϕ value is given 1, and I can take 0.67.

So, I take 2 multiplied by 0.67 multiplied by 1 multiplied by, R_c is full coverage 1 multiplied by σ_z actually γ_t h multiplied by L_a. So, this is like that, T_{po} will be calculated.

So, if I now calculate T_{po1} then here 2 multiplied by 0.67 multiplied by 1 multiplied by gamma γ is 20, multiplied by h, h actually the height and L, it is $\tan\varphi$, γh actually how much, for the layer 1 so at this level what is the vertical pressure? This is the pressure, so gamma times multiplied by 0.4. So, it will be 0.4 multiplied by, L_a is how much, 1.32 multiplied by tan 34°. So, if I calculate this T_{po1}, it will come 9.54.

Similarly, T_{po2} if I calculate, 2 multiplied by 0.67 multiplied by, this 2 I will not write, 20 multiplied by, next level actually 0.4 plus 0.6, so it will become 1, and multiplied by L_a actually, that, L_{ar2}, that is actually 1.79, so this will be 1.79 multiplied by tan 34°. So, if I calculate this it will come 6, 28.97.

And then T_{po3}, everything is same, only you will change this and this. So, 2 multiplied by 0.67 multiplied by 20 multiplied by, this will be 1.6, and this length will be for the third layer, what is the length? This is 2.25, 2.25 multiplied by tan 34°. It will be 3, so it will be 65point, 65.07.

Then T_{po4}. This will give you 2 multiplied by 0.67 multiplied by 20, and this will be next level, so 0.6 will be added, so 2.2 multiplied by, the length of this will be your 2.72 multiplied by tan 34. So, this will give you a 108.17.

And T_{po5}, that will be 2 multiplied by 0.67 multiplied by 20 multiplied by 2.2 plus 0.6, it will be 2.8, multiplied by, this length will be 5, this length was 3.19, multiplied by tan 34. So, this gives you the result 161.46.

And T_{po6} will be equal to 2 multiplied by 0.67 multiplied by 20 multiplied by 2.8 plus 6.6, it will be 3point, 3.4, 3plus, not plus, multiplied by, length was 3.66, multiplied by tan34°. So, then it will give you a value equal to 224.95. So, these are actually, we are getting a T_{max}, T_{1max}, T_{2max}, T_{3max} and then we are getting capacity. So, capacity by the tensile force that will give you the factor of safety against pullout.

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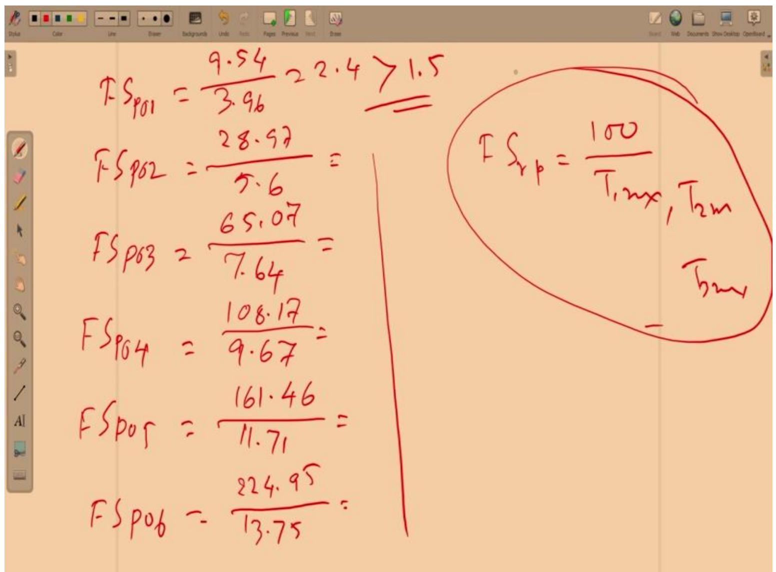

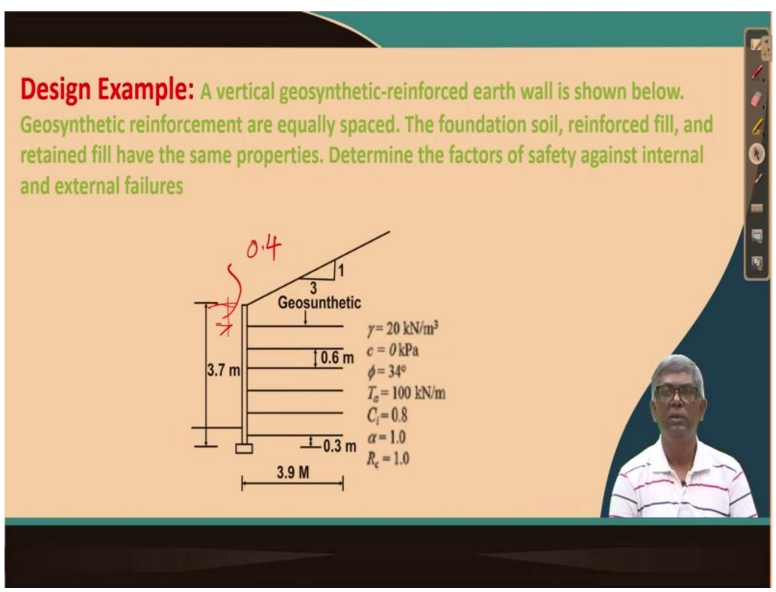

So let us take one more page. Factor of safety against pullout, and that too level 1 will be equal to, so 9.54, which is the capacity. And what was the tensile? 3.96. This gives you some value. It will be 2.4 greater than 1.5. So, performance requirement is 1.5 but we are getting more than that.

Similarly, FS_{po2} that will be equal to 28.97 divided by 5.6. I will, I have not calculated. It will be much bigger than 1.5. Then FS_{po3}, so this will be 65.07 divided by 7.64, which I have calculated already. And that also, if I calculate, it will be much, much bigger than 1.5.

Factor of safety against $po4$, that will be again 108.17, 108.17 divided by 9.67. This also, I have not calculated. It will very big value. FS_{po5}, so there also it will be 161.46 divided by 1, 11.71. This also will be a very large value. Then FS_{po6} then again it will be 224.95 divided by 13.75. So, this will also give you a very large value. Everywhere you can see that performance requirement is 1.5 but we will be getting much, much bigger than that.

That means, according to pullout, this design is satisfactory, that 3 point, for 3.7 meter height wall with some inclined back, slope and then 6.6 meter spacing, all those things, then this is the, pullout capacity is satisfactory.

And I think it is given, let me go back to the problem, T allowable is given 100, and so it is a tearing that actually, factor of safety against tearing. So, we can go back. Factor of safety against rapture, RP gain, there are, 100 is there, and T_{max}, T_{1max}, then T_{2max} then T_{3max} etc., You can find out and see that and nowhere, everywhere it is a factor of safety it is quite large. It is in the order of 9 or 10. So, rupture failure also will not happen. So, this is, these two are checked.

Now, what you have to do, and, next thing actually you to do that, we have done internal stability analysis, that means whether it is rupture is taking place or pullout is taking place, is not taking place.

If we want to do now external stability, then what you have to do? You have to do the force diagram and then based on that force diagram you have to find out the driving force, resisting force, driving moment, resisting moment, and then you find out eccentricity and then find out the normal force.

Now, find out the effective width, and then find out the effective, average contract pressure under this loading condition. And if that average contract pressure is greater than the allowable pressure, then that that will be, your, your factor of safety will be satisfied, and it should be greater than 2.5. That has to be checked. So, this problem, maybe I will continue in our next class, but for the time being I will just do the, so that I do not have to do in the next class, I will draw the force diagram.

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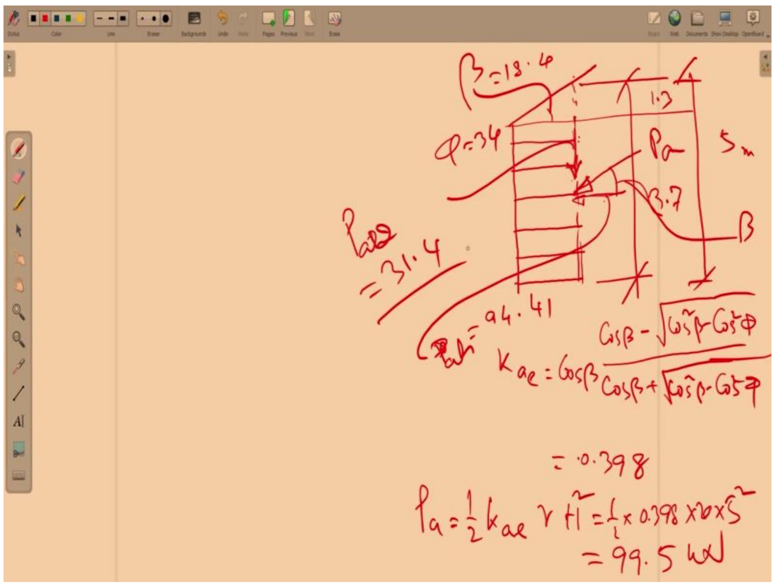

So how it will be? Wall will be something like this. Now I will be taking the sloped, okay, I will be taking the wall like this, and then I have one reinforcement, two reinforcement, three reinforcement, fourth reinforcement, fifth reinforcement, and six reinforcements.

So, they are all 3.9. Then it is sloped. And now I have to find out the height. This is the actual wall height for external stability analysis. So, this one will, this much, this will be how much? 1.3, already we have got, and this is 3.7. So, total height is 5 meters.

And now, your K_{ae} when it is a vertical wall, as per and Rankine, β and then cosβ minus under root cos square beta minus cos square phi divided by cos beta plus under root cos square beta minus cos square phi, where beta is this angle, this is beta, and phi is the friction angle of the soil.

So, if I put this value and calculate then I will see this value comes around, beta equal to actually 18.4 and phi equal to 34. And then I will get K_{ae} , actually, coefficient of earth pressure for external analysis that gives you a value equal to 0.398. And how it will act? If this is the wall, now I assume, and it will be acting parallel to this. So, like this. This is supposed p_a .

Now this P a can have two component. One is vertical component, so this, this angle is beta, this angle is beta. So, this will be sin, p_a sin beta, and this will be p_a cosβ. So, this value I can find out. So, p_a can be calculated as, p_a will be equal to half K_{ae} multiplied by γ multiplied by H square.

So, H become now 5, so half multiplied by 0.398 multiplied by 20 multiplied by 5 square. So, this gives you 990 point, 95, 90, 99.5 kilo Newton. So, this one, sin and cos, so this I can denote as p_{ah} and this p_{ab}, and this I can denote as p_{ah}. p_{ah} will become 94.41, and p_{ab} will be equal to 31.4.

So, then this, lot of other calculations are there. So, better I will close here. I will continue with, from here in the next class. And then I will try to show you that how to find out the factor of safety against sliding, factor of safety against overturning and bearing capacity failure. And then some discussion in the next class. With this, let me stop today. Thank you.