Geotechnical Engineering II / Foundation Engineering
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Lecture - 32
Earth Pressure Theories (Contd.)

Let me continue with Earth Pressure Theories, in fact I could have used the title stability analysis because stability analysis main component is the earth pressure calculation. And I have in the 3-4 modules I have discussed about that pressure theories, how to calculate earth pressure and first of all we have considered active case, passive case, address condition then cohesion less then soil cohesive soil, level backfill, inclined backfill then vertical wall, inclined wall all sorts of things we have discussed. So, what are the different ways it can be calculated we have discussed.

Now, I will take a few problem, numerical problems to illustrate how to use those whatever we have discussed. Today I will try to take three problems one by one and let me see the first problem.

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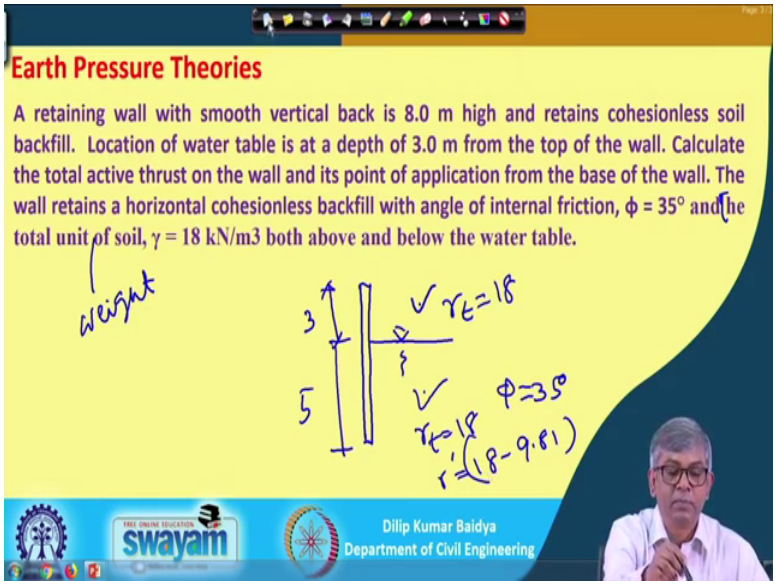

You can see that retaining wall with smooth vertical back 8 meter high and retains cohesion less soil backfill. Location of water table is at a depth of 3 meter from the top of the wall. Calculate the total active thrust on the wall and its point of application from the base of the wall. The wall retains a horizontal cohesion less backfill with the angle of

internal friction and phi equal to 35 degrees and the total this is actually t is missing and the total unit when unit weight of soil ok; unit weight of soil gamma equal to 18 kilo Newton per meter cube both above and below the water table. That means, the wall is something like this and it is 8 meter height and it is water table at 3 meter depth; that means, this is 3 meter and this is 5 meter. So, total 8 meters so, water this is the water table and this is throughout 5 cohesion less soil phi equal to 35 degrees.

But you need to add actually though below water table above water table supposed to be sometime maybe different, but here in this problem it is mentioned that gamma t for here and here will be same, but when you consider this zone you have to use summers unit weight that is there; we will show that application. So, this is the only difference. So, otherwise for calculation operation gamma t total gamma it will be here whatever value here also same value. It can be different, but for the simplicity we have taken the same value here gamma t equal to 18 here gamma t is 18 here, but actually in the calculation here it will be use gamma summers which will b 18 minus 9.81.

So, that I will show you the while solving the problem in the next slide. So, let me sorry, let me take a board. So, these problem suppose we have a wall of 8 meter height.

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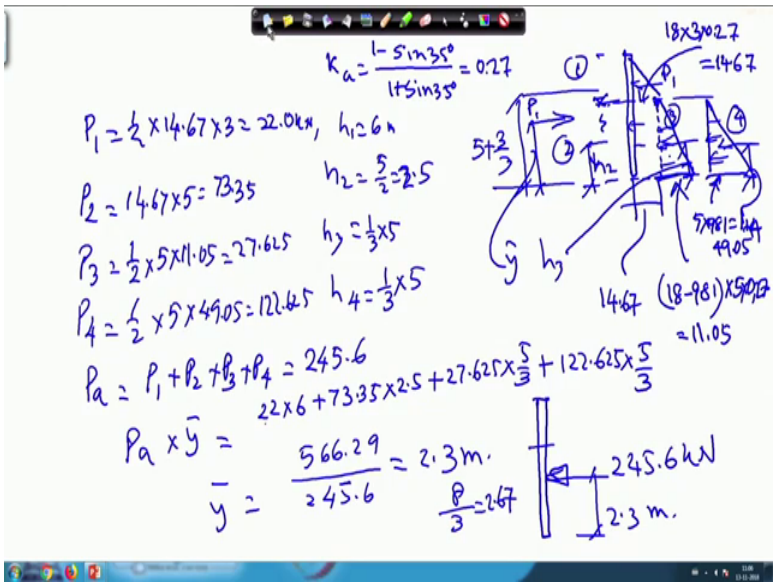

8 meter height and this is 3 meters and this is 5 meters and then you can find out the k a actually k a equal to 1 minus sin 35 degrees divided by 1 plus sin 35 degree. If I calculate then we get a value equal to 0.27. Now if I find out the earth pressure; that means, from

here 0 to suppose 3 meter. So, this value will become gamma times; that means, 18 multiplied by 3 multiplied by k a; that means, 0.27. So, that value if I calculate it comes at 14.67.

Now so, up to this pressure; so, this pressure already came. So, this pressure will be constant throughout depth. Now you can imagine the wall start from here and because of that with the increase of the wall height how pressure will vary. So, again that will be linear for how to find out that one. So, that one will be can be calculated. So, this one actually the these value is 14.67 and these value will be equal to 18 minus 9.81 multiplied by 5 multiplied by 0.27; that means, this will be equal to your this will be equal to your 11.05. So, this is 11.05 this is 14.67 and as I have told you the water table is here and we have considered submerge unit weight of the soil for calculation of earth pressure.

Now, if this is the case then the water also will give a pressure on the wall. So, this one will be considered these pressure will be water pressure and this will be equal to 5 multiplied by 9.81. So, this will be equal to 49.05; that is 49.05 all are kilo Newton per meter square. So now, this is the pressure diagram is done. So, all pressure will be on the wall like this, this will be like this will be like this.

So, like this ok. So, now, I can imagine; that means, there will be one triangle, one rectangle, another rectangle triangle; that means, three triangles and your one rectangle. So, these I can consider as 1, the rectangle can be considered as it 2, this triangle can be considered is 3 and this triangle consider as 4. So, I can find out now P 1, P 1 will be how much actually half multiplied by base is actually 14.67 multiplied by height is 3. So, it will be equal to P 1 actually will be equal to 22 22.0 kilo Newton.

And h 1 means actually what this if I consider this triangle and this P 1 will be acting somewhere here. So, it is 3 meter; that means, one-third of from here so; that means, 1 meter from here; that means, at the base actually it will be 3 meter, 5 meter plus 3 by 3 so; that means, it will be h 1 it will be equal to 6 meter. Similarly P 2; P 2 will be equal to it is a rectangle. So, it is having 14.67 and height is 5. So, that gives you 73.35 and your P 2 will be acting as the middle of this so, 5. So, this will be P 2. So, this will be this is h 2. So, h 2 we be equal to 5 by 2; that means, 2.5.

Then P 3 will be equal to this triangle, this will be half multiplied by 5 multiplied by the basis 11.05. So, this will be equal to 27.625 and h 3; that means, it is acting somewhere here. So, this height is 3. So, this is h 3. So, h 3 will be equal to one-third of 5 so; that means, 5 by 3 and then P 4 will be equal to area of this triangle that will be half multiplied by 5 multiplied by 49.05. So, that will be equal to 122.625 and h 4; that means, it will be equal to that means, it is acting here. So, h 4 will be this distance. So, this will be h 4 this will be h 4. So, this h 4 will be again 1 by 3 multiplied by 5.

So; that means, the total P active I can say P 1 plus P 2 plus P 3 plus P 4 if I sum all them then I will get total P a actually 245.6 and if I assume that total active thrust acting somewhere here P a then these height is suppose y bar. Then you will be having P a multiplied by y bar will be equal to P 1 multiplied by h 1. So, directly I will write here P 1 multiplied by h 1. So, P 1 is 22 sorry 22 multiplied by 6 plus P 2 actually 73.35 multiplied by 2 is 2.5 plus P 3 actually 27.625 multiplied by 5 by 3 plus P 4 actually 122.625 multiplied by 5 by 3.

So, this one this two will be equal and P a is already known. So, y bar will be equal to y bar will be equal to your 566.29 divided by 245 point 245.6. So, if I calculate this one it get it get a value 2.3 meter; that means, the wall actually this is the wall 8 meter height wall and it has water table somewhere here. Now, ultimately I am getting a thrust P a on the wall, which will be acting at 2.3 meter from the base; that means, here 2.3 meter and P a value equal to actually is your 245.6 kilo Newton. So, this is meter.

So, now in the 8 meter wall if it is no water table would have been there then where it should have been there, the point of application? That should have been 8 by 3. So, it will be equal to 2.67 so; that means, because of the water table and the water weight at the bottom. So, it actually pull down the point of application lower side, but if it is a we would have been a dry soil then the point of application could have been 2.67. So, that is the difference actually through the calculation he can find out. So, with this let me go to next slide then let me go to second problem.

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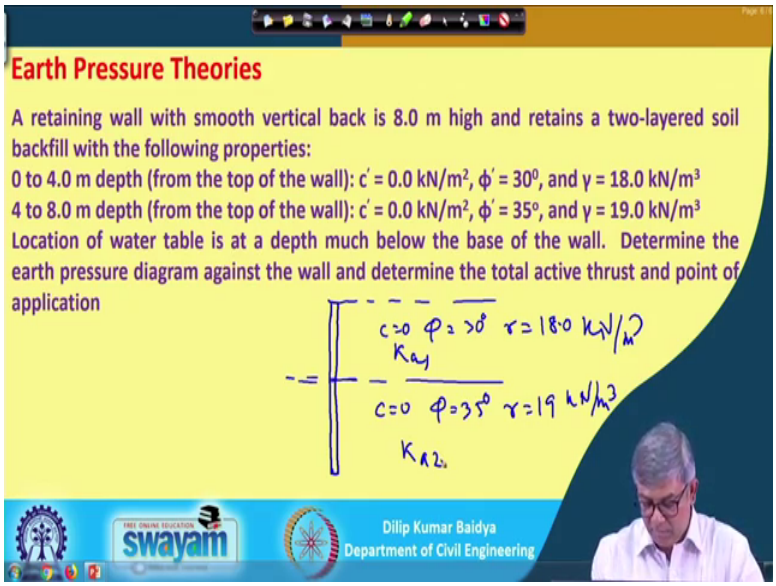

And you can see that here you can as I have told you that the water table one case then another case I have told you that the backfill may be layered and layered means top surface will having little lose or soft soil and bottom towards bottom maybe the dense soil. So, you can similar situation is shown here actually can see that retaining wall with smooth vertical back is 8 meter high retains a two-layered soil backfill with the following properties: 0 to 4 meter depth then from the top is c 0 530 degrees and gamma 18 and 4 to 8 meter depth from the top of the wall c is actually 0 c c is 0 phi is 35 degrees and gamma is 19.

Location of water level is a great depth; that means, your this is the this is the wall and this is a cohesion less level backfill and at the just up to mid height the soil having c equal to 0, phi equal to 30 degrees and gamma equal to 18.0 and here actually c equal to 0 5 to 35 gamma equal to 19. So, because of these two layered soil I have to find out now what will be the pressure and what is the total thrust, what is the point of application. So, here; that means, I have to find out what is the k a here k a 1 I had to find out what is the value of k a 2 hear. So, this is the way we have to find out so I will go to the next slide and do it; suppose now you can see that 8 meter height wall.

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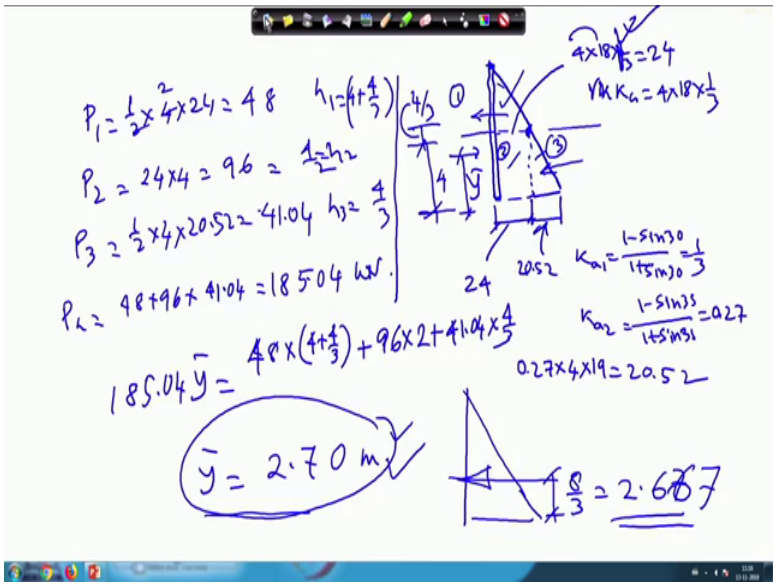

And this is a mid height; so, k a 1 k a 1 equal to 1 minus sin 30 divided by 1 plus sin 30 that will be equal to 1 by 3 and k a 2 it will be 1 minus sin 35 divided by 1 plus sin 35. So, that gives you 0.27. So, now actually I can find out from here 0 linearly it will be increasing and this value will be equal to 4 multiplied by 18 multiplied by 1 by 3. So, it will be so, P 1 will be equal to 6 it will be 24. And now this will be constant throughout to depth and then if I am imagine wall start from here because, of the second layer of the soil what is the value will be there, how it will be varying? So, it will suppose like this. So, I have to find out this is actually your 24 and this one will be equal to your 0.27 multiplied by 4 multiplied by 19.

So, this is actually is giving you this is give 4 19 point; so, 20.52 this is actually 20.52. So, this is equal to 20.52 and this is 24. So, this is 24. So, I can now think of three diagram this will be one rectangle, this will be one rectangle that is 2 and this is again another triangle 3. So, I can find out now P 1 will be equal to half multiplied by 4 multiplied by 24 gamma gamma times h multiplied by a sorry this is why I have done one-third. So, this is not yeah one-third k a. So, gamma h k a gamma h ka so, that will be actually 4 multiplied by 8 multiplied by 1 by 3. So, it will be a 24.

So now, area will be half into 4 into 24 it will be 2. So, it will be 48 and your P 2 will become your 24 multiplied by 4 it will be 96 and P 3 will be equal to half multiplied by 4 multiplied by 20.52. So, it will be it will be half 20.5 52. So, will be this will be 48 and

this will be 95 per 0 4 this will be 96 and this will be 41.04 this will be 41.04 and then h 1 will be equal to h 1 actually what it will be acting somewhere here. So, it will be from here actually this is actually 4 meter and this distance will be 4 by 3 so; that means, your h one will be equal to 4 plus 4 by 3 and h 2 will be equal to 4 by 2 and h 3; that means, h 2 will be equal 4 by 2 and h 3 will be equal to again it will be acting somewhere here. So, it will be 4 by 3.

So, we can find out P a will be equal to P a will be equal to 48 plus 96 plus 41.04. So, it will be something like 498 point 498 or so. Sorry 185.04 or something like that kilo Newton. And then you will have y bar suppose the thrust is acting somewhere here at this height is y bar then you will have 185.04 into y bar will be equal to 48 multiplied by 4 plus 4 by 3 plus 96 multiplied by 2 plus 41 point 41.04 multiplied by 4 by 3. So, if I simplify then y bar will come approximately this will be I can do this, but it will come approximately 2.7 meter ok.

So, this for this calculation y bar; that means, at a; that means, point of application of the of the of the active thrust will be 2.7 from meter from the base, but if it is a single layer then the 8 meter height then, then what should have been the height? It should have been see it is 8 and. So, so, if the triangular diagram. So, it will be one-third height from the so; that means, it could have been 8 by 3 then it could have been 2.67 2.667. So, instead of 2.667 because of this two layers and minor variation so, height of the point of application of the it is becoming 2.7meters.

So, this is actually how to follow up to, how to proceed then you have to draw the pressure diagram one by one and then finally, you have to divide into parts. So, that you know the area see if I can take this area like this then this area somewhat the regular and find out difficult to find out area and point of c c. Instead of that I can divide this one this part and this part and this is another part. All three parts which is consisting of triangle and rectangle for which c c is known and if we know that then step by step calculation I can do to find out the point of application and this. So, let us next go to the third problem.

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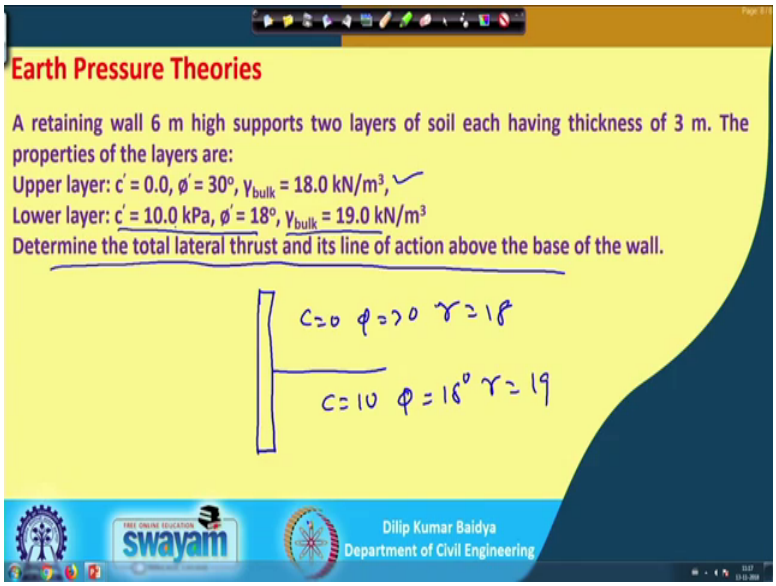

A problem is you can see that as I have mentioned that there can be two layers and the previous problem what I have taken the both the soil was cohesion less soil, but one soil suppose cohesion less and another soil layer is suppose cohesive. In that case or the c phi soil in that case how to do this. So, this problem you can see that retaining wall 6 meter high suppose two layer of soil each having thickness of 3 meter the properties of the layers actually upper layer actually c is 0 and phi 30 degree a gamma is 18 and second layer c 10 and phi 18.

So, you can see the c phi and gamma actually 19. Determine the total lateral thrust and its line of action of that thrust so; that means, it is the 6 meter high wall and on that you have here c equal to 0 phi equal to 30 gamma equal to 18 and here c equal to 10 phi equal to 18 and gamma equal to 19. So, you have to find out now the pressure diagram and total active thrust and then finally, you have to find out your point of application of the thrust. So, let me take a new page and do it you can draw you can see that a 8 meter 6 meter high wall.

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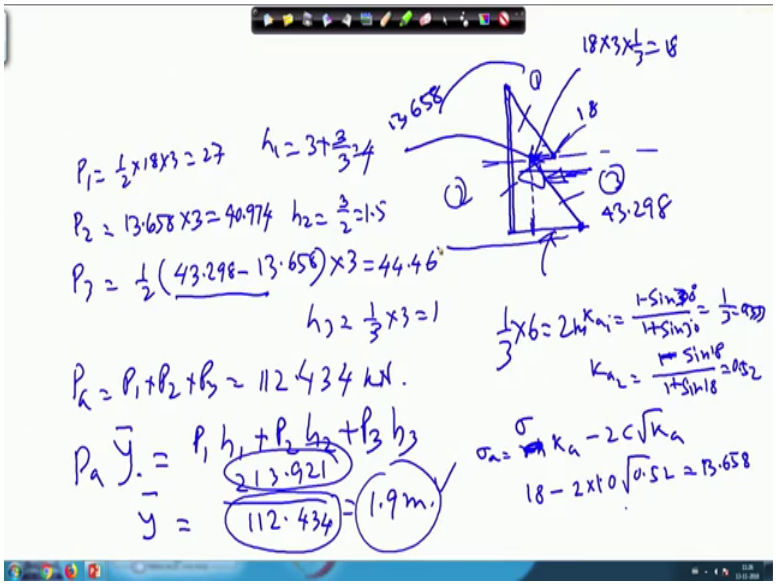

Suppose this is the wall and at the middle actually there is a layer and you can see that first layer. So, k a 1 I can find out k a 1 will be 1 minus sin phi by or 1 minus sin 30 actually by 1 plus sin 30. So, these become again 1 by 3 and k a 2 will be equal to 1 my 1 minus sin 18 divided by 1 plus sin 18. So, that become actually value 0.52, 0.52 and 1 by 3 means 0.3333 you can write like that.

Show, here actually since gamma is 18 and 3 meter. So, it will go it will go linearly for this value will be gamma means 18 h means 3 and k a means 1 by 3. So, these become a team at this point pressure intensity now when the second layer will start that second layer how to find out actually? Second are actually here to find out when two layer system your pressure diagram will be equal to sigma active will be equal to gamma h ka or you can say instead of these I can say sigma k a minus 2 c root k a.

So, I have to find out now what is a sigma here, the sigma here actually is nothing, but this 18. So, if I do that. So, if I do this at this point for the second layer this will be 18 minus 2 multiplied by a c was actually how much? 10 and root 0.52; so, these become actually the value become it become actually this value become something like 13 point become 13.658 658 13.658.

So, this was 18 this is 18. So, 13.658 will be somewhere have. So, this will be 13,658. now from here actually the second layer pressure diagram will be again if I increase the h further then it will be increasing this way these value will become this value will become

43.298, this value will become 43.298. So, this is that that this is the typical diagram for two layer soil this will be increasing. So, though it this transition it looks to different intensity, but for the through to calculation purposes, but it should be something in between actually the actual, but for the calculation purpose we will take these diagrams.

So, these value 18 and this is 13.658. So, now, what I can do I can also divide this diagram into three parts, you can see here and that is 1 this is 2 and this is 3 and then based on that I can find out P 1 equal to half multiplied by 18 multiplied by 3. So, it will be 27 and then what will be the y or h 1? h 1 will be this is 3 meter so and this is 3 meter. So, it will be 3 plus 3 by 3; so, it will be 4 meters and similarly P 2 will be equal to P 2 means this one. So, this is unit 13.658. So, 13.658 multiplied by 3.

So, that becomes the value so it is 40.974 and what about h 2? It will be 3 meter; so, 3 by 2 that will 1.5. And, what about P 3? P 3 will be this diagram. So, this is this value actually 43.298. So, that will be equal to half 43.298 minus already taken this value 13.658 this is base multiplied by h so half base into height. So, this gives you a value equal to 44 point 44.46 and what about h 3? h 3 will be one-third from these base. So, it will be 1 by 3 multiplied by 3; that means, 1 meters.

h 3 equal to 1 meter. So, now, your P a will be equal to P 1 plus P 2 plus P 3. So, this if you do then it will become 112 this will become 112.434 kilo Newton these become base value. So, that way now if I if I consider that resulted acting at a height y bar from the base. So, it would be P a multiplied by y bar equal to P 1 multiplied by h 1 plus P 2 multiplied by h 2 plus P 3 multiplied by h 3 all P 1 P 2 P 3 h 1 h 2 h 3 all value are or there.

So, I simply I can get y bar equal to you can say that will be equal to 213.921 divided by 112.434 and that gives you a value equal to 1.9 meter ok. So; that means, the thrust final thrust will be acting somewhere here 1 meter 1.9 meter from the base of the wall. So, this is actually there, but if the if the 6 meter wall is there the single layer; where should it should have been? 6; that means, 1 by 3 multiplied by 6; that means, 2 meter so; that means, because of this layering its point of application is came toward bottom actually by 10 centimeter actually can see, it should have been 2 meter, but it become 1.9 meters.

So, this is a step by step procedure, first of all whatever you have learned through Rankine's theory; that means, for cohesion less you find out active pressure diagram or

passively. Here actually all problem I have solved in terms of active pressure, it could have been passive pressure wherever I have used k a I should have used k p then these values could have been bigger actually, other no other difference or not then the magnitude will change.

So, I have shown the application in terms of active pressure, but it could have been done in passive pressure instead of k a I could have taken k p. So, now, that means, by using the active Rankine's theory you have to draw the diagram and once you got a draw the diagram you have to break the entire diagram into a number of parts for which you know the area; that means, triangle rectangle like that you have to divide. And then find out the all component area of the all component that becomes the component force beyond P 2 P 3 P 4 and then if you add them that become the total thrust.

That is one part and then find out the individual point of application from the base and then you find out the individual force multiple an individual distance and then sum up that and then divided by the total active thrust then you will get the point of application from the bottom of the base of the footing. So, that is the way. So, this is actually P 1 h 1 P 2 h 2 P 3 h 3 and this is the total thrust. So, by that I could get the point of application of the loading is 1.9 meter from the base.

So, that is three application I have shown, some more I will show and then finally, I will try to show the how to using this you can do the stability. So, this is a simple wall I have you see it will give a thrust then it will have tendency to topple or it may tendency to slide. So, there this many things will happen. So, how to find out that factor of safety so those calculation analysis I will do in the subsequent lecture.

Thank you.