Geology and Soil Mechanics
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Lecture - 64
Problems on Earth Pressure on Retaining Wall - 2

Welcome back. So, already we have seen a couple of numerical problems on the earth pressure theory in the last lecture and today we will be solving few more numerical problems on the earth pressure theory of soil and basically you will be getting the idea that how you can solve the different problems related to the earth pressure theory in soil okay. So, let us write down the problem.

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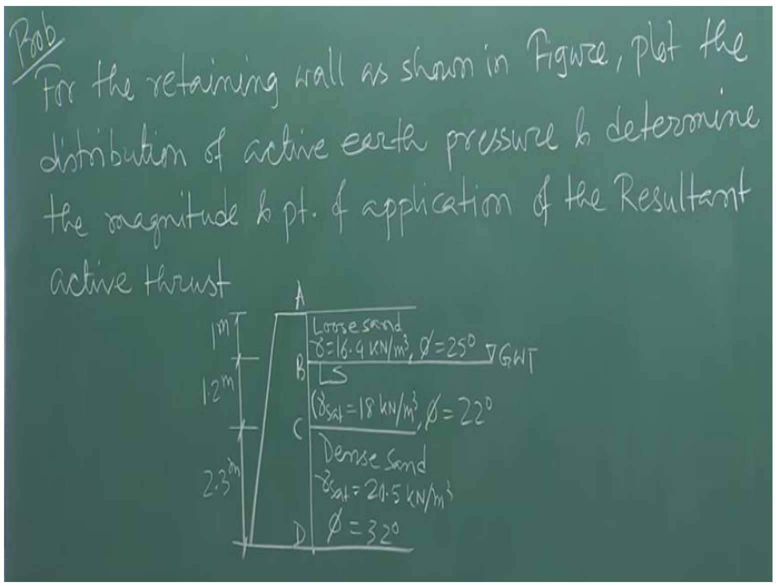

For the retaining wall as shown in figure plot the distribution of active earth pressure and determine the magnitude and point of application of the resultant active thrust okay. So, let us draw the figure first. This is your point A. This is the retaining wall okay. You have 3 layers of soil. This is point B. This is point C and this is point D okay. This is your loose sand gamma equal to 16.4 kN/m cube and phi equal to 25 degree so this is your ground water table is here at this level. So, let me write down the depths.

This is say 1 m this is 1.2 m and this is 2.3 m. This is also loose sand where gamma saturated equal to 18 kN/m cube and phi equal to 22 degree and this is your dense sand gamma saturated equal to 20.5 kN/m cube and phi equal to 32 degree. So, this is the problem okay. So, you have the retaining wall like this okay and you have 3 layers of backfill. The first layer is having loose sand.

That is the top layer is having loose sand which is having the depth of 1 m and this loose sand is having the unit weight 16.4 kN/m cube and phi equal to 25 degree and here is the ground water table that means ground water table is at 1 m below the ground level and second layer is also loose sand that is stratum 2 is also loose sand and that is having gamma saturated equal to 18 kN/m cube and phi equal to 22 degree.

Whereas the third layer that is the stratum 3 it is having dense sand and which is having gamma saturated equal to 20.5 degree 5 kN/m cube and phi equal to 32 degree okay. So, and you need to find out that first one is the plot the distribution of active earth pressure and determine the magnitude and point of application of the resultant active thrust. So, first we will find out the distribution of the active earth pressure and from the distribution we can find out the resultant active thrust as well as the point of application okay.

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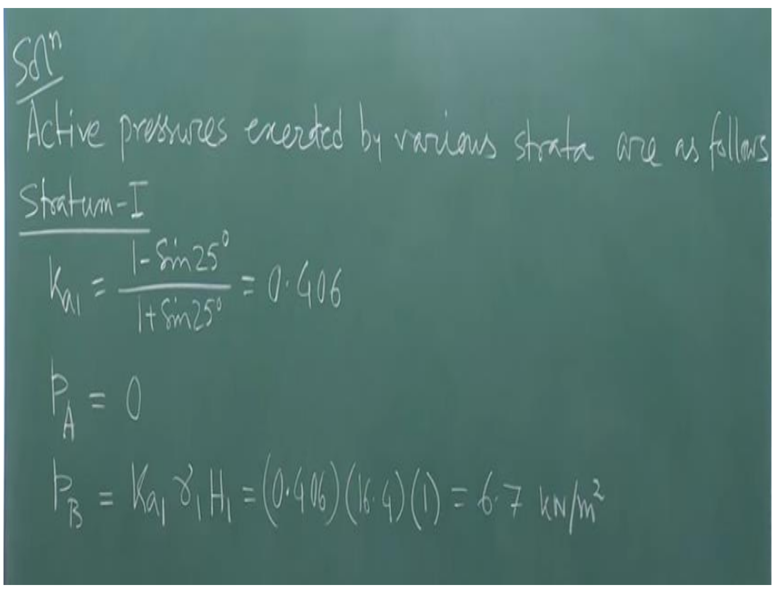

So, let us solve this problem. So, active pressure exerted by various strata are as follows. First one is stratum one okay. So, where your first we need to calculate the magnitude of coefficient of active earth pressure coefficient for first stratum so K a 1 which is defined by 1 - sin phi 1 what is phi, phi 1 is 25 degree by 1 + sin 25 degree that comes as 0.406 okay. Now what is the pressure at point A. What is point A? Point A is at the top of the wall.

So, what is the pressure what is the active earth pressure at point A? That is 0 right fine. Now what is the pressure at point B when you are considering stratum 1 please remember because at point B you are having the interface between stratum 1 and stratum 2. That means when you are within stratum 1 at that time you will be getting some pressure at point B and when you are considering stratum 2 at that time also you will be getting some pressure at point B.

So, basically at the interface you will be getting some jump right already discontinuity already we have seen in some problem in the last class okay. So, P B is nothing but K a 1 gamma 1 and H 1 that comes as 0.406 multiplied by gamma 1 is 16.4 multiplied by H 1 is that is the depth of stratum, stratum 1 is 1 m. So, that comes as 6.7 kN/m square.

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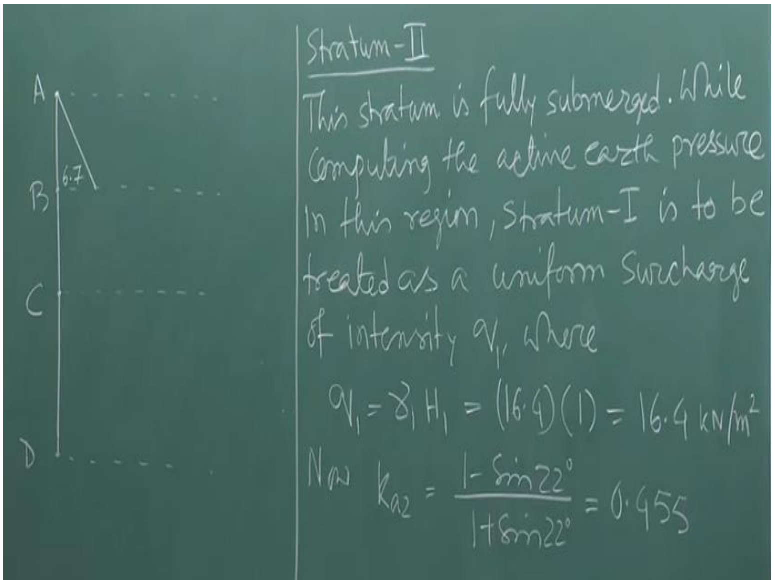

So, we can plot this distribution. So, this is your different points, point A this is your point B this is your point C and this is your say point D okay. So, from this whatever calculation we have done so far based on that what is the pressure at point A P a is 0 so that is 0 here okay and what is the pressure at point B when you are considering stratum 1 that is coming as 6.7 kN/m square. So, I will be getting linear distribution and this is my say 6.7.

So, I am not writing kilo newton per meter square everywhere because it will be congested then the figure will be congested so I am writing only the numerical value. However, all numerical values will be having the unit of kilo newton per meter square okay. Now we are going to calculate stratum II okay.

This stratum is fully submerged while computing the active earth pressure in this region stratum I is to be treated as a uniform surcharge of intensity q where say q 1 where q 1 is equal to gamma 1 H 1 that is nothing but 16.4 is the gamma 1 that is the unit weight of the stratum I and depth of stratum I is 1 so it comes as 16.4 kN/m square. Now what does it mean?

So, when you are considering stratum II so basically the active earth pressure in this region in stratum II when you are finding out stratum I is to be treated as a uniform surcharge of intensity q. That means when you are considering stratum II stratum II is spanning from point B to point C right. So, at point B whatever you will be getting or I mean at point C or point B or in between whatever point you are considering in stratum II basically this stratum 1 will be giving you some uniform surcharge loading okay on top of that point right.

So, that will be always there okay. So, when you are considering stratum II basically so the stratum 1 will be considered as the uniform surcharge which is acting on that particular stratum okay. So, that q 1 that uniform surcharge is nothing but gamma 1 into H 1 that is the complete surcharge that is the total depth of stratum I okay which is lying over the stratum II. So, that will be considered as surcharge and that is given by 16.4 kN/m square okay. So, now I can find out other parameters like k a 2 that means active earth pressure coefficient for stratum 2 which is 1 - sin 22 degree by 1 + sin 22 degree. It comes as 0.455.

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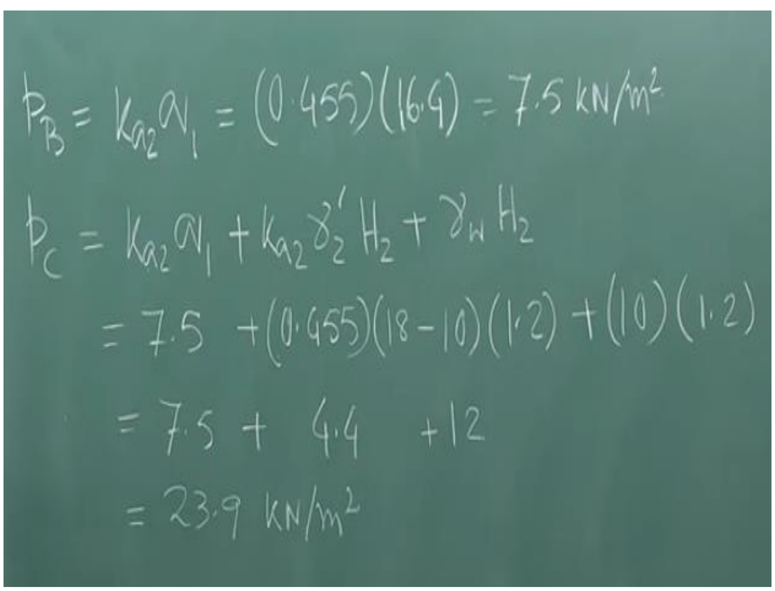

So, P B that means active earth pressure at B but when you are in stratum II. That means the point B is a crucial point. Point B is the interface between stratum I and stratum II. So, you have got some pressure what is that 6.7 kN/m square at point B when you are considering stratum 1 that means when you are coming from point A to B and now when you are starting from point B to C then also you are getting some pressure at point B and that pressure we are now going to calculate because you are now considering stratum II under consideration okay.

So, P B is equal to K a 2 into q 1 simple because you have the surcharge and that is surcharge is nothing but the vertical pressure. So, the lateral pressure will be K a into that surcharge amount okay. So, K a 2 into q 1 which is 0.455. Now what is q 1 already we have calculated 16.4 that comes as 7.5 kN/m square. So, you are getting some jump at point B right from 6.7 to 7.5 when you are considering from when u are travelling from stratum I to stratum II.

You are getting this discontinuity and the jump and what is P c? So, please remember point C is also another interface between stratum II and stratum III. So, we will be analyzing this thing very similar way that means now we are considering stratum II so we will be getting one pressure component at point C when you are considering stratum I. Now similarly when you will be considering stratum III at that time also you will be getting some jump or some pressure component at point C.

So, that will give me the discontinuity okay. So, P c is equal to how I can calculate K a 2 into q 1 that will be there plus K a 2 gamma 2 prime means the submerged unit weight because you see that ground water table is at this level right at this level you have the ground water table. So, anything which comes below point B will be completely submerged condition okay. So, therefore we have to use gamma 2 prime instead of gamma 2 or gamma saturated whatever I have got in the problem. So, gamma 2 prime into H 2 is that okay or is that all no right?

So, you will be getting some other parameters or some other component which will be coming completely based on the water pressure that is because hydrostatic pressure right. So, water is there. So, that part will be coming as gamma w into H 2. So, this is the lateral active earth pressure at point C when you are considering stratum II itself okay. So, we can calculate this. This is 7.5 already we have calculated okay plus K a 2 is 0.455 gamma 2 prime.

So, how I can find out gamma 2 prime? I have gamma saturated right. So, gamma saturated - gamma w will be equal to gamma prime that is gamma submerged. So, gamma saturated is given as 18 if you look at the problem and gamma w we are considering 10 kN/m square meter cube and H 2 is 1.2 that is depth of stratum II plus water 10 gamma w is 10 and S 2 is 1.2. So, from this I can get 7.5 + 4.4 plus 12. So, total is coming 23.9 kN/m square.

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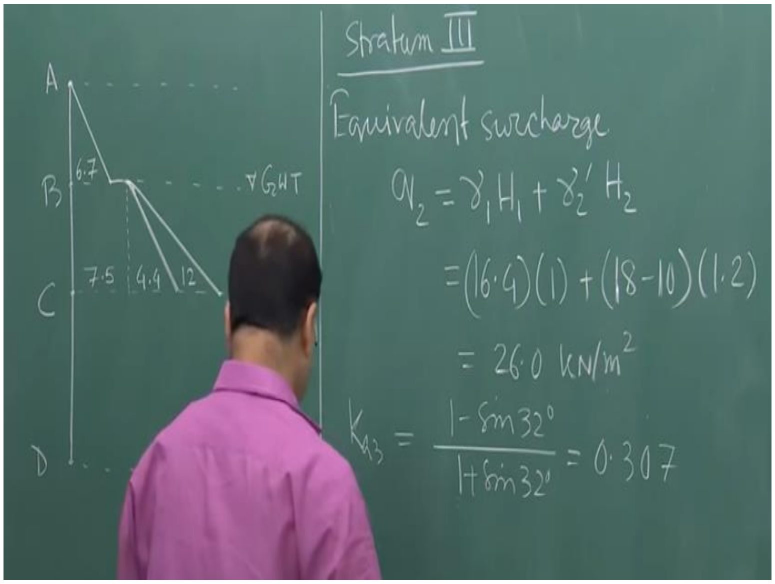

Now come back to the plot. So, at point B what you are getting when you are considering stratum II it is 7.5. So, say this is your point 7.5. So, you are getting some jump okay 7.5 and it is ending at 23.9 total is 23.9 at point C that means at this level you will be getting total as 23.9. Out of 23.9 7.5 is there 4.4 is coming from stratum II itself and 12 is coming from water. So, your plot will be so this is your 7.5, this is your 4.4, and this is your 12 okay. So, you have got the pressure distribution like this. Now what we can do?

We can find out the pressure distribution considering stratum III. Now if you consider stratum III so equivalent surcharge as before we can calculate surcharge due to stratum I and stratum II. Now when you are considering stratum III basically your equivalent surcharge that means on top of this stratum III what are the layers lying the stratum 2 and stratum 1 both are lying on top of your stratum III. So, that will be acting as the surcharge component. So, equivalent surcharge will be q 2 which can be calculated as gamma 1 H 1 plus gamma 2 prime H 2 where gamma 1 is the unit weight of stratum 1.

H 1 is the depth of stratum I and gamma 2 prime is the submerged unit weight of stratum II and H 2 is the depth of stratum II. So, that will be acting as the uniform surcharge on top of stratum III. So, I will be getting from this 16.4 into 1 + 18 - 10 will be your gamma 2 prime into 1.2 which comes as 26.0 kN/m square okay. Now I can calculate other components required components K a 3 which is nothing but 1 - sin 32 degree by 1 + sin 32 degree which comes as 0.307.

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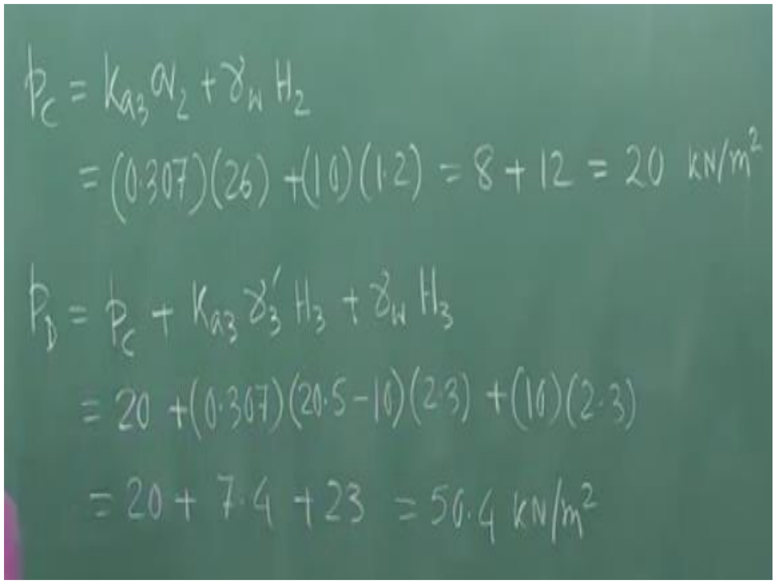

So, therefore p c again you will be getting p c so you will be getting the jump now. So, p c will be equal to what K a 3 q 2 + gamma w H 2 that will be coming due to the water because now water is there okay. So, K a 3 into q 2 that will be the lateral pressure due to the surcharge. They are uniform equivalent surcharge whatever you have calculated just now plus gamma w into H 2 will be nothing but the water pressure at that level okay so which will be equal to 0.307 into q 2 is 26 + gamma w is 10 and H 2 is 1.2 that comes as 8 + 12 which will be equal to 20 kN/m square okay. So, how we can plot this I will come back that thing later on. So, first we will calculate p D.

So, p D is p c + K a 3 gamma 3 prime H 3 plus water pressure gamma w H 3. Please try to understand. So, p c will be always there right. So, whatever you have calculated just now this 20 will be there plus K a 3 into gamma 3 prime what is gamma 3 prime. That is the submerged unit weight of stratum III into H 3. H 3 is depth of stratum III plus the water pressure at that level right. So, D is the bottommost point of the wall. So, that gives me 20 + 0.307 into gamma 3 prime is equal to 20.5 - 10. What is H 3? 2.3 + 10 into 2.3 that comes as 20 + 7.4 + 23 is equal to 50.4 kN/m square.

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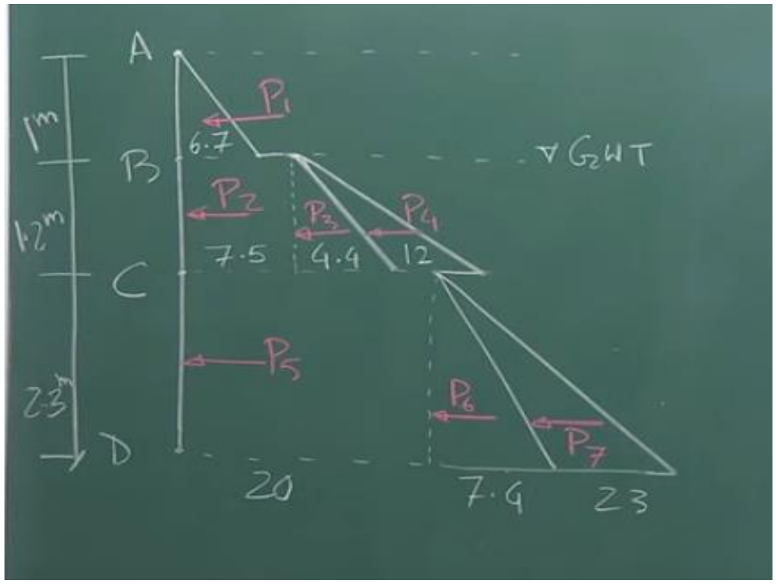

So, if I plot that thing here so what you are getting? Earlier your p c was when you considered stratum II at that time p c was 23.9, 7.5 + 4.4 + 12. Now when you are considering stratum III at that time what you are getting p c is equal to 20. That means you are getting some reduction. So, discontinuity obviously but all the times it will be increasing that is not necessary. So, here actually you have got the increase 6.7 it has got increased to 7.5 but it may not be true always.

So, whatever we are seeing now for stratum III actually okay when you are considering point C so coming back from stratum II to stratum III at that time at the interface you are getting 23.9 but you are when you are considering stratum III itself you are getting the pressure active earth pressure at point C is 20. So, you are getting some reduction. So, say this is point say 20. So, this is my 20 say okay. Now from there you are getting this and you are getting this.

So, this is your 7.4 and this is your 23 okay. So, this is the distribution this is the distribution of active earth pressure. So, please be careful when you are solving this type of problem okay. So, once you get the distribution now you can find out the different thrust for different say area and you can add them together to get the resultant thrust and finally you can find out the point of application. So, getting distribution, itself is a big deal.

So, once you once you have got this distribution then the other things will be very simple. Now basically this part we are calling the force is due to this triangular area top triangular area is say P 1. Then this rectangular area say P 2. Then this triangular area say P 3 and this triangular area say P 4. Then this rectangular area say P 5. This triangular area say P 6 and this triangular area say P 7. Now our job is to find out P 1 to P 7 okay. Now let us see how we can find out that. So, we can calculate all the forces now.

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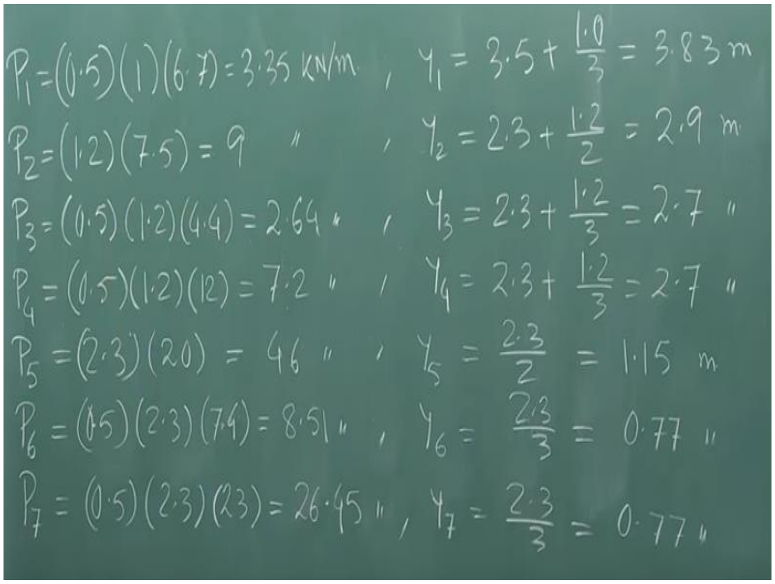

Say P 1 how we can calculate P 1? So, I can write down this is your 2.3 m this is your 1.2 m. This is your 1 m. So, P 1 is how much? P 1 is 0.5 that is the area of triangle 0.5 into 1 that is the height into 6.7 which comes as 3.35 kN/m run kilo newton per meter run of the wall because normal to board you are having infinite length of the wall. So, that is the plane strength problem or 2D problem anyway.

So, this is your P 1. I hope you have understood. So, 0.5 into 1 that is the height and 6.7 is the base. So, that gives me 3.35 kN/m run of the wall. So, that load or the thrust is P 1 okay and where it is acting from the base. If I say that is Y1 where it is acting? 2.3 + 1.2 + 1 by 3 okay. That means 2.3 + 1.2 is equal to 3.5 + 1 by 3 which comes as 3.83 m. Similarly, I can calculate P 2 which is nothing but the area of this rectangle okay, this rectangle. So, P 2 is nothing but 1.2 into 7.5 that comes as 9 kN/m run.

Where it is acting Y 2, 2.3 + 1.2 by 2 okay. 2.3 +s 1.2 by 2 that comes as 2.9 m. Now coming to P 3. P 3 again is a triangular distribution okay. So, 0.5 into height is 1.2 and base is 4.4. That gives me 2.64 kN/m run and where it is acting Y 3. Now look at this plot Y 3 will be 2.3 + 1.2 by 3 right? 2.3 + 1.2 by 3 that comes as 2.7 m. Similarly, I can calculate P 4. P 4 again that is due to the water.

Again, it is triangular distribution. So, I can write 0.5 into 1.2 into base is 12. So, that gives me 7.2 kN/m run and Y 4 is equal to same right. 2.3 + 1.2 by 3 is equal to 2.7 m. Now coming back to P 5. What is P 5? P 5 is the area under this rectangle entire rectangle right. So, P 5 is nothing but 2.3 multiplied by 20 that gives me 46 and what is Y 5? Y 5 will be simply 2.3 by 2. 2.3 by 2 which is equal to 1.15 m.

Then P 6 that is triangular distribution. So, that is nothing but 0.5 into 2.3 into 7.4 which is equal to 8.51 and Y 6 is equal to what? 2.3 by 3 which is equal to 0.77 m. Now coming to P 7. P 7 is this triangle last triangle okay due to the water. So, that is again 0.5 into 2.3 into what is the base 23 that gives me 26.45 26.45 kN/m run okay. Now what is Y 7? That is same 2.3 by 3 which is nothing but so you have calculated all the forces okay. So, now this is the exercise you have to do.

Once you have got the distribution unless until you got you get the distribution you will not be able to find out this thing okay or if you want to find out all those things you will be doing the mistake without plotting without getting the distribution do not go for this type of calculation because you will be getting I mean error or you will be getting mistake that is quite obvious because you will be forgetting to consider some force some thrust or something like that because unless until you get the distribution like this you will not be getting the proper discontinuity or the jump condition. So, you may do the mistake in calculation of the forces. It is always better to go for plot or the distribution and then you go for this type of calculation.

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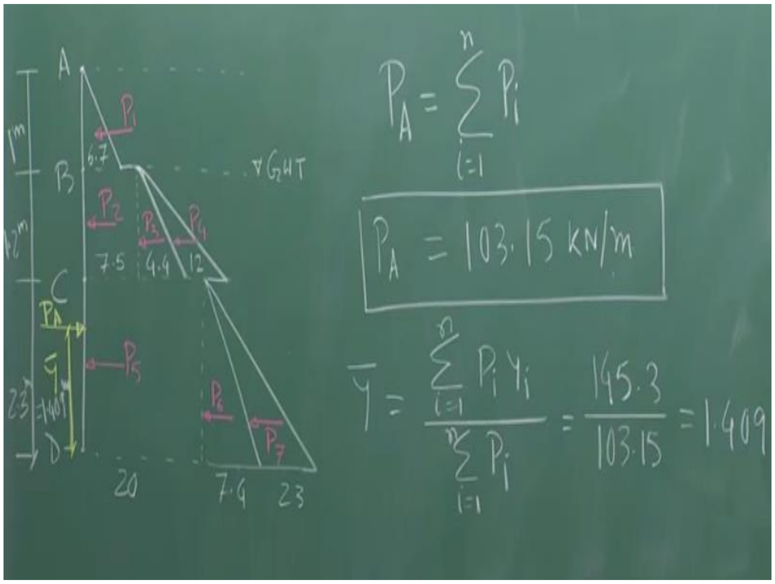

So, your total active thrust will be how much? Summation of i is equal to 1 to n P 1. So, P 1 is P 1 to P 7. So, that gives me if you add them 103.15 kN/m run. So, this is your P A. This is the resultant thrust. So, whenever you are asked to find out the resultant thrust you have to calculate like this okay. So, this is the total thrust active thrust on the wall. Now what is the point of application of this thrust.

So, point of application if I want to find out Y bar that means from the base. So, Y 1 to Y 7 everything is measured from the base of the wall. So, Y bar is also from the base of the wall. So, that means if I want to find out that P A. Say this is my P A and this is my Y bar okay. So, Y bar is equal to summation of P i Y i by summation of P i that gives me if you do this 145.3 I am not writing all the values you can check it which comes as 1.409 m. So, this is your 1.409 Y bar is equal to okay. So, you can write here actually that the total thrust is coming as 103.15.

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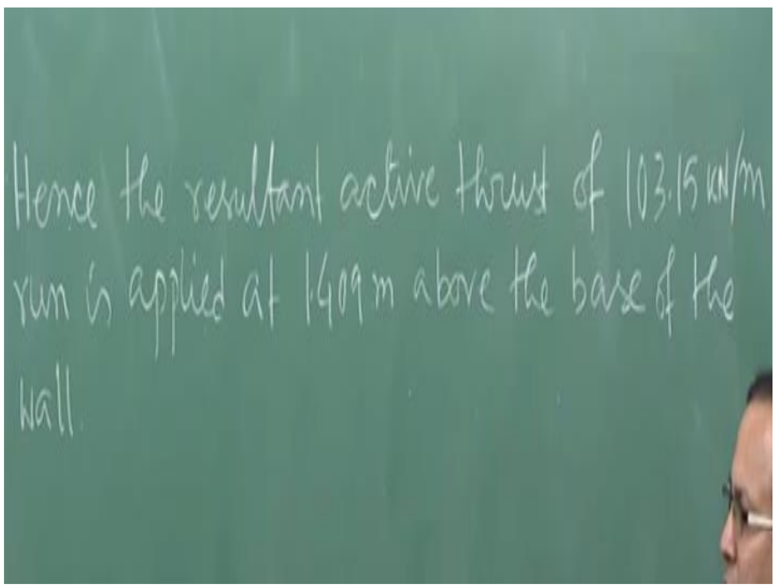

So, hence the resultant active thrust of 103.15 kN/m run is applied at 1.409 m above the base of the wall okay. So, this is the problem. So, you have solved very critical problem and you look at the distribution the distribution getting this distribution is not so easy okay. So, you have to understand the concept properly and based on that you calculate step by step to get the pressure at the interfaces and then you get the distribution okay. Now we will go to the next problem.

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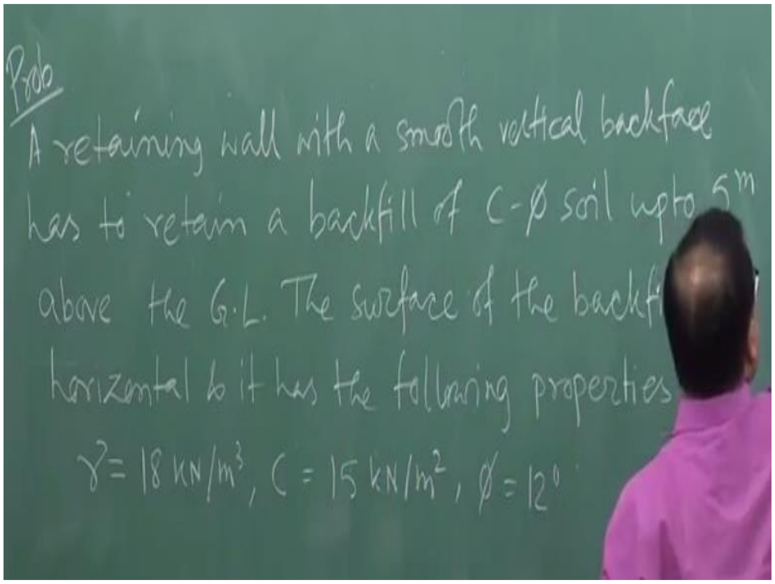

So, next problem says a retaining wall with a smooth vertical backface. So, when you are considering smooth vertical backface basically your Rankine's theory holds good. So, smooth vertical backface has to retain a backfill of c-phi soil up to 5 m above the ground level okay above G.L. The surface of the backfill is horizontal and it has the following properties such as gamma equal to 18 kN/m cube, c equal to 15 kN/m square, and phi equal to 12 degree.

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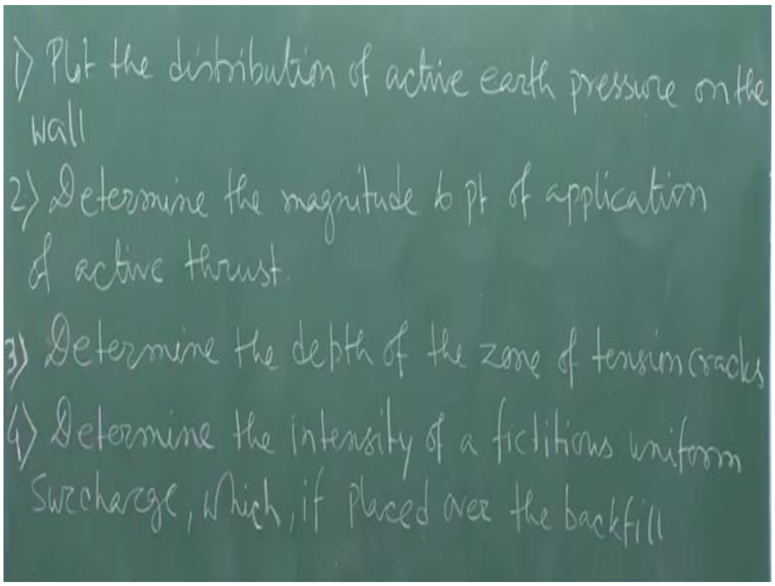

Then plot first one is plot the distribution of active earth pressure on the wall plot the distribution of active earth pressure on the wall. Second is determine the magnitude and point of application of active thrust. Third is determine the depth of the zone of tension cracks. Fourth one is determine the intensity of a fictitious uniform surcharge which if placed over the backfill can prevent the formation of tension cracks.

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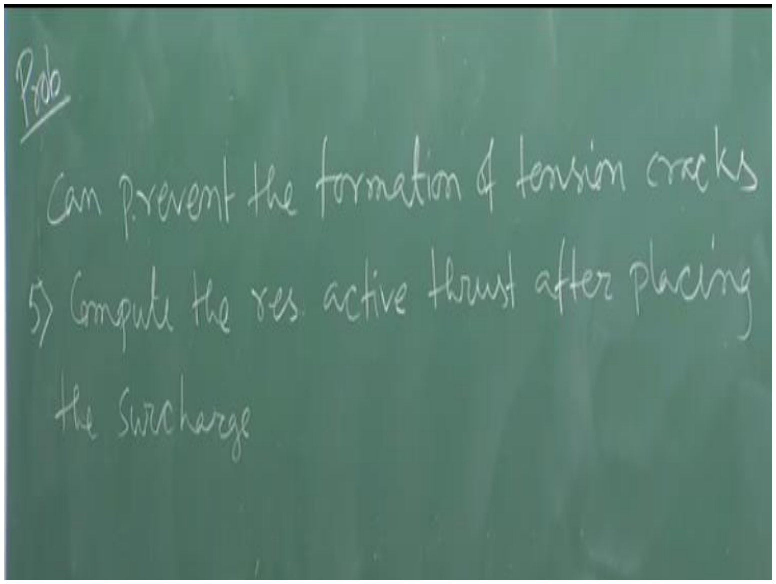

Can prevent the formation of tension cracks and number 5 is compute the resultant active thrust after placing the surcharge okay. So, this is your problem. So, now let us solve this problem.

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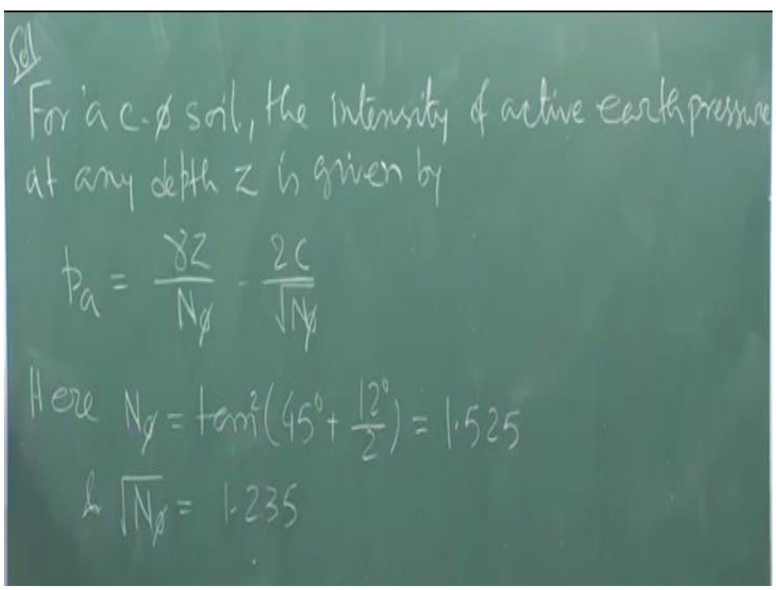

Now solution. For a c-phi soil the intensity of active earth pressure at any depth z is given by what? You know that right. Already we have discussed this thing in the lecture right. So, that active earth pressure is p a is equal to gamma z by N phi - 2c by root over N phi right. This is the active earth pressure intensity at any depth z in c-phi soil is it not? So, now here your N phi is nothing but tan square 45 degree + phi by 2 so which comes as 1.525 and we can calculate for our ready reference root over N phi is 1.235.

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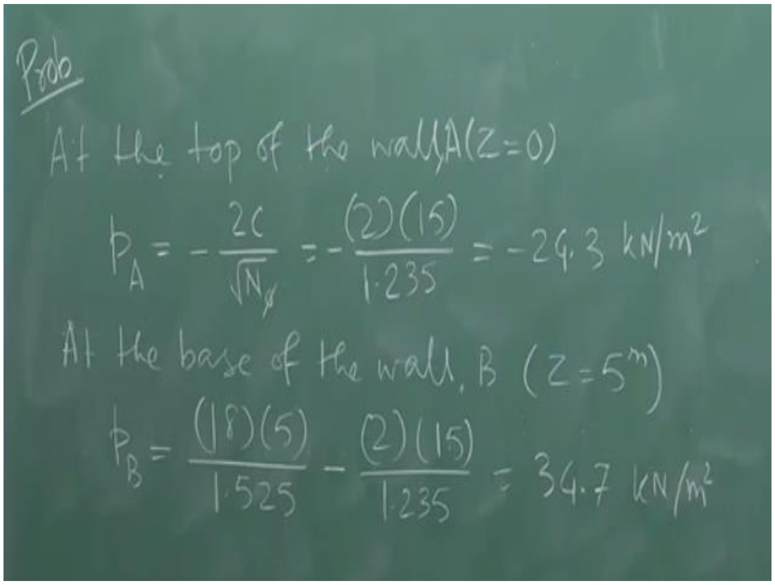

So, at the top of the wall that means z equal to 0. What is your active earth pressure? Say at that point we are defining as say point A at the top of the wall say A okay that means z equal to 0. That p A active earth pressure is given by because this part will be becoming 0 because z is 0 so gamma z by N phi will be 0 so remaining part will be - 2c by root over N phi. So, where I can write - 2 into 15 by 1.235 which gives me - 24.3 kN/m square.

Now at the base of the wall say point B that means z equal to 5 m at that time what will be your active earth pressure p B is equal to gamma z gamma z is now H right so gamma into 5 m is your z, so at the base of the wall. So, 18 into 5 divided by 1.525 - 2 into 15 divided by 1.235 equal to 34.7 kN/m square. That means we have got the active earth pressure at the top of the wall as well as the base of the wall. So, we know 2 coordinates.

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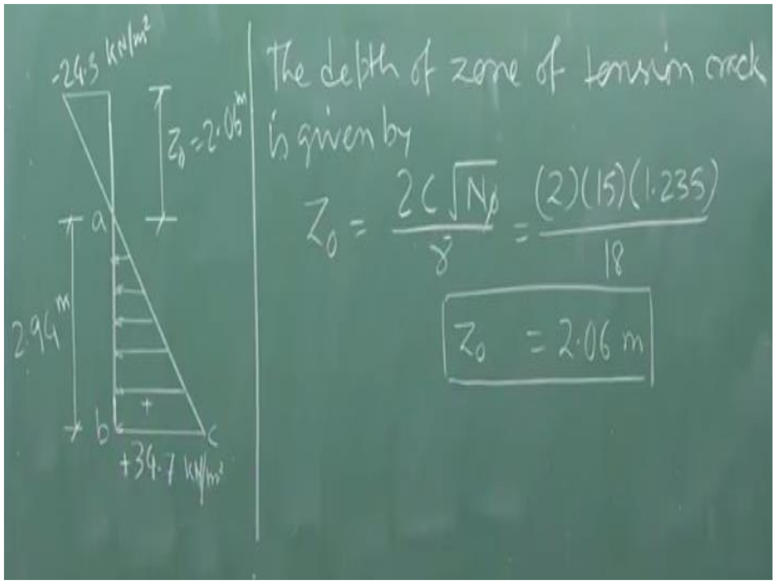

That means if this is wall total depth of the wall okay. So, I know this this is my 24.3 minus and this I know this is 34.7 plus kN/m square. This is also kilo newton per meter square okay. Now I can join this two. Now you can do this graphically as well as I mean analytically. Graphically means you plot this thing graphically so all those things all those coordinates will be plotted graphically and you join these 2 lines and then you find out what is the depth where this active earth pressure is becoming zero or else you can find out that thing from your previous knowledge that is z 0 right.

So, the depth of zone of tension crack is given by so we are not going for graphically. So, we are just calculating this thing is given by what. Z 0 is how much do you remember? Z 0 is 2c root over N phi by gamma 2 c root over N phi by gamma. So, what is z 0? Z 0 is this depth right. So, that is coming as, if you put all the values, 2 into 15 into 1.235 by say gamma 18 it comes as 2.06 m. So, this is your 2.06 m and remaining part will be 2.94 m okay. So, lets us this point as say small a, b, and c. So, this is the positive pressure that means compressive thrust or the push okay and top part will be under tension okay.

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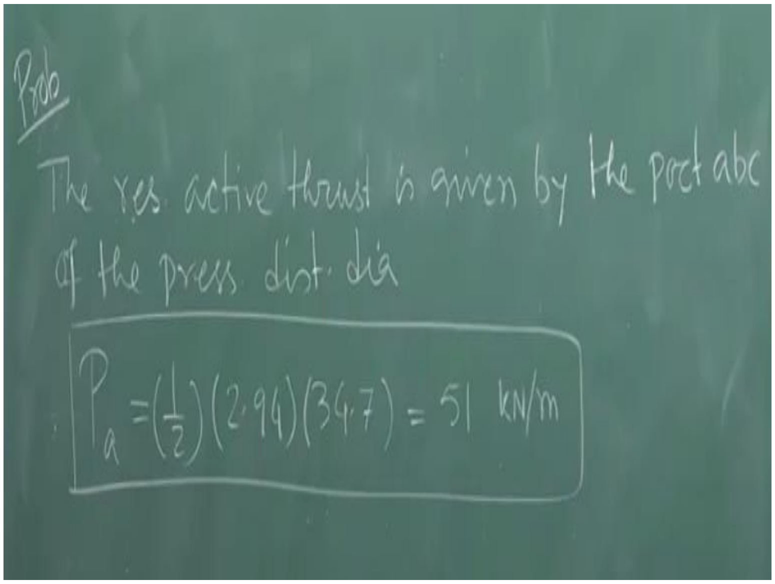

So, once we have got z 0 we can calculate the resultant active thrust. The resultant active thrust is given by the resultant active thrust is given by the part abc of the pressure distribution diagram is it not. So, that is the total resultant active thrust. Already we considered that thing that we will not that this is the total resultant active thrust which is acting on the wall. So, if we have the tension crack then this part will be completely ignored right. So, once this part is ignored then this whole area will be the will be acting as the total thrust on the wall. So, that is coming as P a is half into 2.94 into 34.7 is equal to 51 kN/m run okay.

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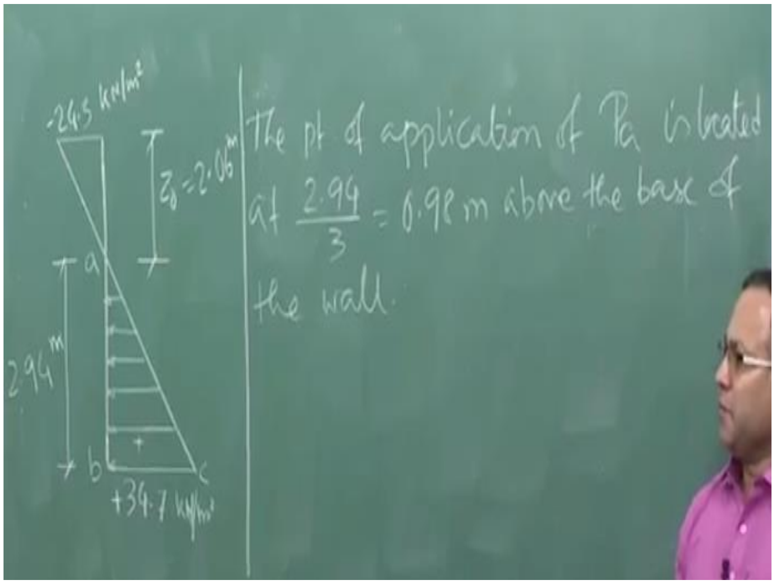

And the point of application the point of application of P a is located at 2.94 by 3 that is 0.98 m above the base of the wall okay. So, this things will cover the first 3 part of the problem okay. So, this things will cover first 3 part of the problem.

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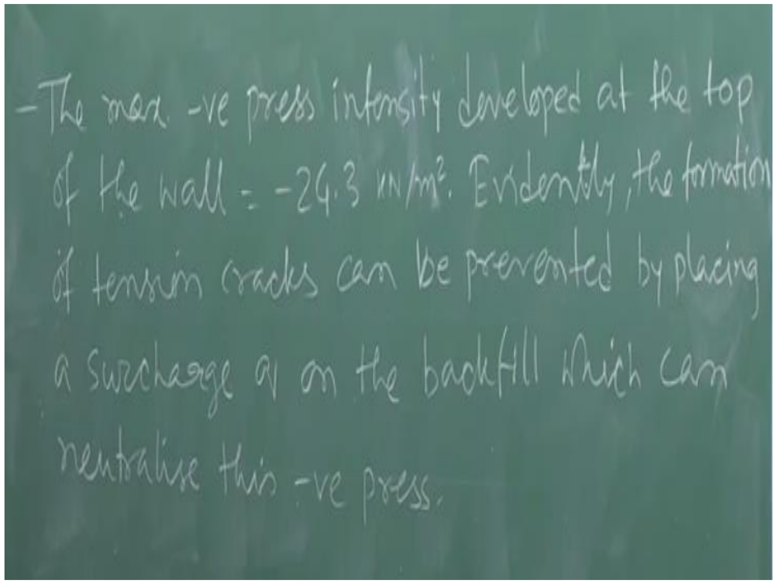

So, the first 3 parts of the problem we have covered just now. So, the maximum negative pressure intensity developed at the top developed at the top of the wall equal to - 24.3 kN/m square. Already we have seen that already we have calculated and we have seen that. Evidently, the formation of tension cracks can be prevented by placing a surcharge q on the backfill which can neutralize this negative pressure. So, what does it mean?

The maximum negative pressure intensity developed at the top of the wall is coming as - 24.3 kN/m square that already we have got it. Now the formation of the tension cracks can be prevented I mean see how you will prevent the formation of the tension cracks? That means if you do not have any tension at the top from the at the top of the wall then you will not be getting any tension crack.

Because of tension only you are not getting the tension cracks. Now somehow if you manage to get that 0-negative pressure then you will not be getting any tension crack so that says the formation of tension cracks can be prevented by placing a surcharge q on the backfill which can neutralize this negative pressure. So, if you apply some predetermined or prefixed some surcharge on top of the backfill then basically that will neutralize this negative pressure and ultimately you will be getting 0 pressure at the top of the wall and it will be increasing.

So, if that situation happens due to the application of this kind of fictitious surcharge then we can get rid of or we can avoid this kind of negative pressure generation at the top of the wall right.

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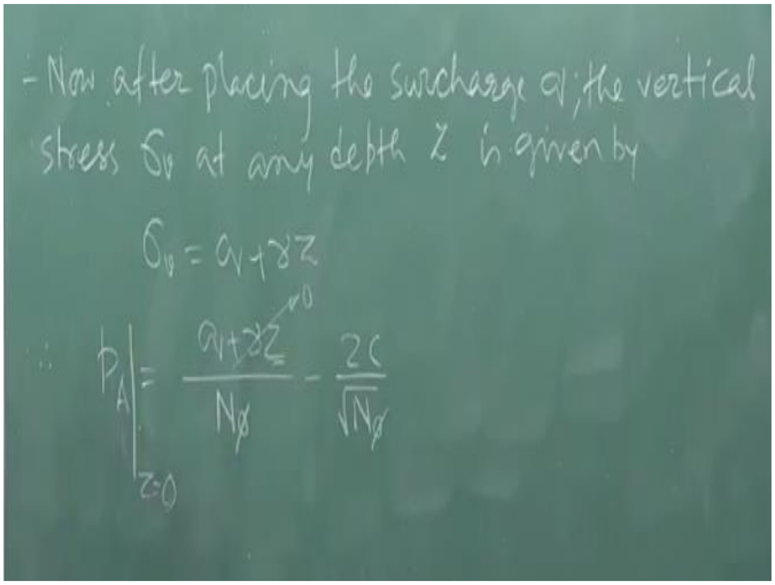

So, now after placing the surcharge q the vertical stress sigma v at any depth z is given by sigma v equal to q + gamma into z agreed? Q is the surcharge I do not know what is the value of q, I need to find out that q which can neutralize this negative pressure generation okay. So, q + gamma z is nothing but the vertical stress at any depth z. So, therefore the active earth pressure at point A that is at the top of the wall is nothing but q + gamma z N phi - 2c root over N phi. Am I right? So, instead of gamma z now you are having q. This term is coming as additional term. So, at point A point A means at z equal to 0 at that time this term will be going to be 0 so you will be remaining part will be.

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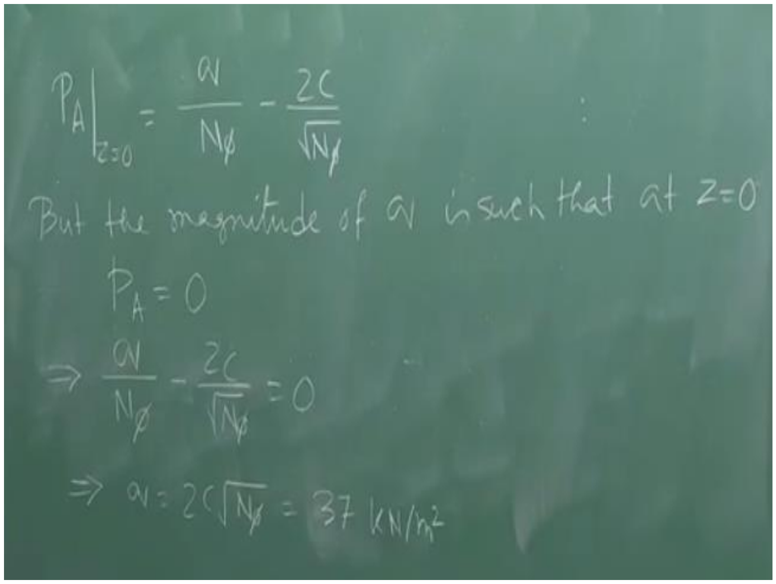

So, your P A at z equal to 0 will be what? q by N phi - 2c by root over N phi. Now why you are putting q why or what is the purpose of putting this q? To get rid of this negative pressure generation or development of negative pressure. That means how you will get rid of negative pressure? That means there is no negative pressure at the top of the wall. That means from top of the wall to some depth z 0 basically we are getting the negative pressure.

If that negative pressure has to be avoided then what to do? That q or that P A that means the pressure active earth pressure at z equal to 0 must be 0 and then it should increase monotonously with the linear variation. So, in that way we can avoid the development of negative pressure. So, but the magnitude of q is such that at z equal to 0 active earth pressure is 0 right. This is the condition for applying q.

After application of q I will be getting the pressure, active earth pressure at point A that is at top of the wall is 0. So, if that is true I can write down q by N phi - 2c root over N phi is 0 which gives me q equal to 2c root over N phi. By putting all these values I will be getting q equal to 37 kN/m square.

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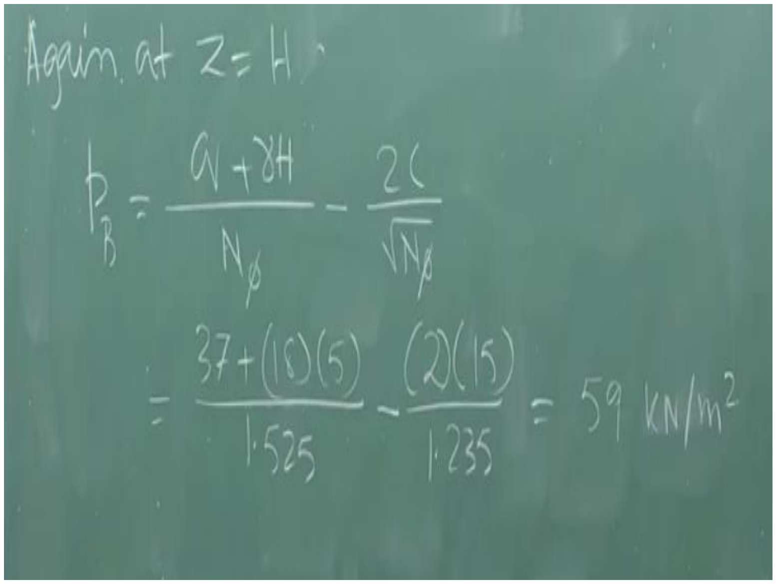

So, again at z equal to H your p B that means at the base of the wall p B is nothing but q + gamma H divided by N phi - 2c root over N phi. By putting all the values 37 + 18 into 5 divided by 1.525 - 2 into 15 by 1.235 which gives me 59 kN/m square.

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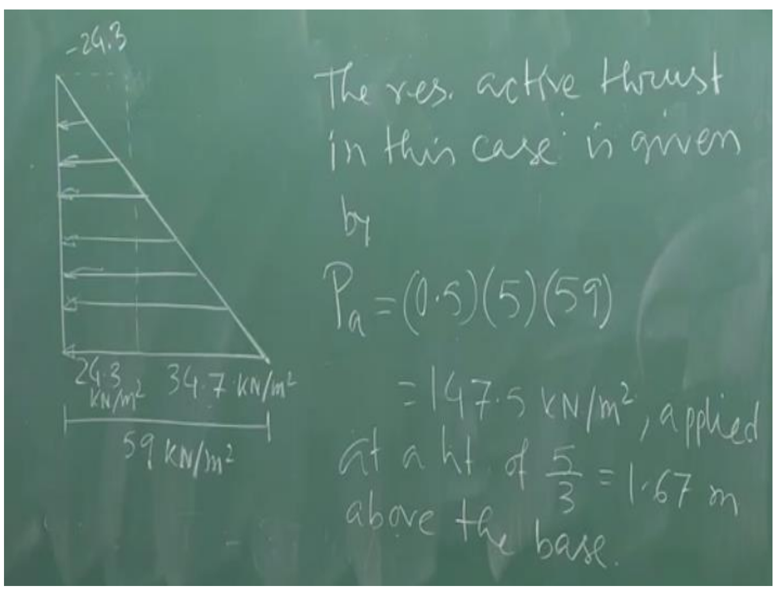

So, therefore the pressure distribution will look like say this is my total depth of the wall. So, this was negative 24.3 okay. So, earlier it was like that right. Now after putting the surcharge I will be getting this is my pressure distribution. This is your 24.3 which is getting neutralized by this surcharge and this is 34.7 and total is coming 59 understood.

So, this negative part we are able to avoid by putting this fictitious surcharge or that whatever uniform surcharge we are putting so we are if we put 37 kN/m square on top of the backfill we will not be getting any tension crack. So, tension crack can be avoided by putting this kind of surcharge. So, the resultant active thrust in this case is given by P a is equal to 0.5 into 5 m into 59 because now you do not have any kind of tension the complete compression complete thrust because this is the pressure distribution now okay. So, that gives me 147.5 kN/m square applied at a height of 5 by 3 that is nothing but 1.67 m above the base okay.

I hope you have understood this problem. This problem was very interesting problem. How to get rid of tension cracks right by putting the surcharge you can get rid of tension because you are neutralizing the tension whatever is getting developed at the top of the wall okay. So, I will stop here today. So, in the next lecture we will be taking few more numerical problems okay. Thank you very much.