Geology and Soil Mechanics

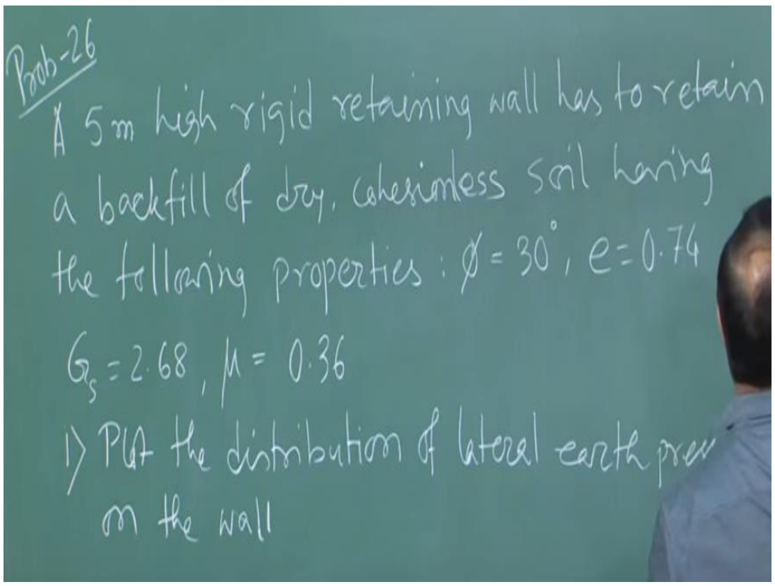
Prof. P. Ghosh
Department of Civil Engineering
Indian Institute of Technology Kanpur

Lecture - 63

Problems on Earth Pressure on Retaining Wall Edit Lesson

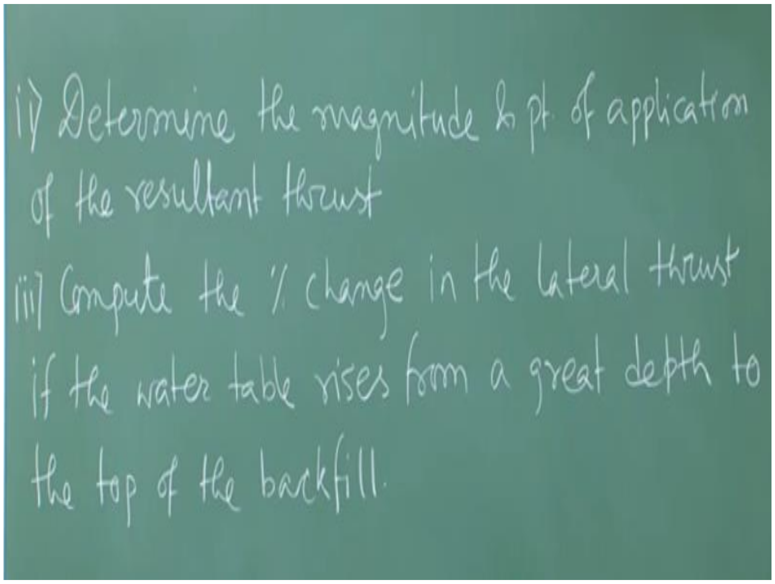
Welcome back. So, in the last lecture we solved a couple of problems on earth pressure theory. So, today we will be taking a few more problems on earth pressure theory okay.

(Refer Slide Time: 00:28)



So, the first problem is the problem says that a 5m high rigid retaining wall has to retain a backfill of dry cohesionless soil having the following properties such that phi is equal to 30 degree, void ratio is equal to 0.74, specific gravity is equal to 2.68, and Poisson’s ratio is equal to 0.36. So, first thing is plot the distribution of lateral earth pressure on the wall.

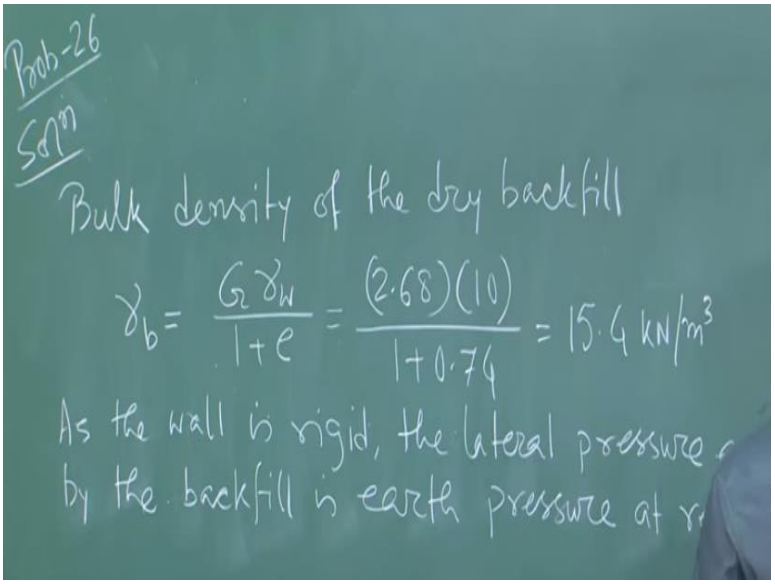
(Refer Slide Time: 02:47)



Second is determine the magnitude and point of application of the resultant thrust and third one is compute the percentage change in the lateral thrust if the water table rises from a great depth to the top of the backfill okay. So, this is the problem. So, problem says that a 5 m high rigid retaining wall has to retain a backfill of dry cohesionless soil having the following properties, phi is equal to 30 degree, e that is the void ratio equal to 0.74, specific gravity G s equal to 2.68, and the Poisson's ratio mu equal to 0.36.

Plot the distribution of lateral earth pressure on the wall okay. So, and the second is determine the magnitude and point of application of the resultant thrust and third one is compute the percentage change in the lateral thrust if the water table rises from a great depth to the top of the backfill okay. So, these 3 things we are supposed to find out from the problem given.

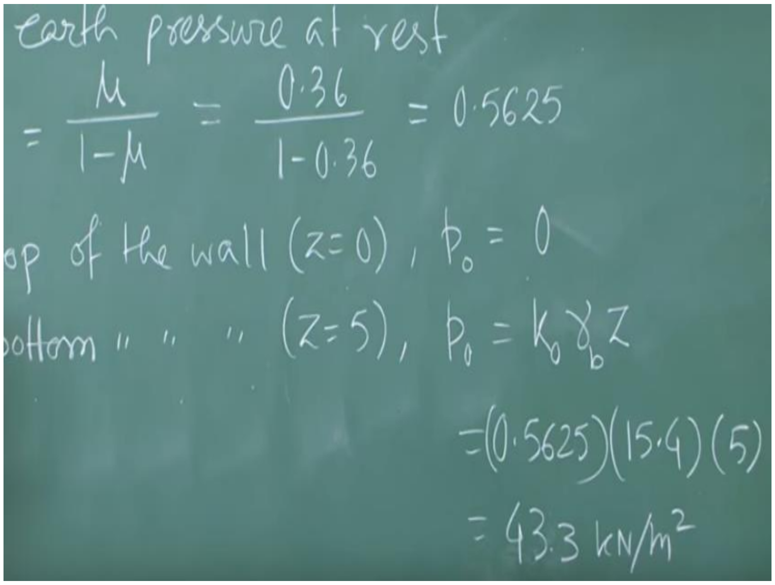
(Refer Slide Time: 05:29)



Now coming to the solution okay so first we need to find out the bulk density of the backfill right. We know the specific gravity, we know the void ratio, from there we can find out the bulk density of the backfill soil. So, bulk density of the dry backfill is equal to gamma b is equal to G into gamma w divided by 1 + e. So, this expression you know from the basic definition of your bulk density.

So, from this I can get bulk density is equal to 15.4 kN/m cube okay. Now as the wall rigid because if the wall is rigid that means there is no movement in the wall. So, if there is no movement then what kind of earth pressure you are expecting. So, earth pressure at rest condition. So, as the wall is rigid the lateral pressure exerted by the backfill is earth pressure at rest right. So, this is rigid retaining wall. So, that means there is no movement of the wall is happening. So, it is completely firm at the location where the wall is fixed okay.

(Refer Slide Time: 08:00)

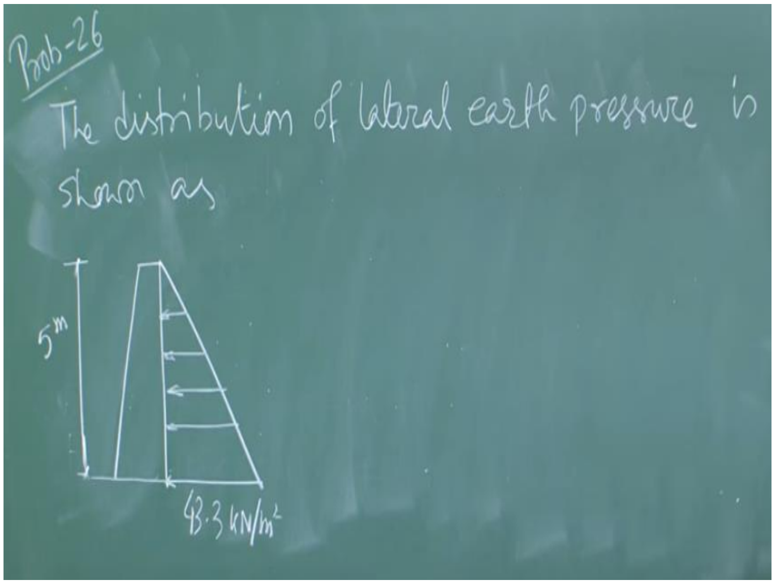


So, therefore coefficient of earth pressure at rest can be found out by K 0. So, what will be the expression for coefficient of earth pressure rest condition so K 0 is equal to mu by 1 - mu. That already we have seen in the lecture part right mu by 1 - mu and that is nothing but equal to 0.36 by 1 - 0.36 which comes around 0.5625 okay. So, at the top of the wall that means z equal to 0 P 0 is equal to 0 right.

We are considering earth pressure we are considering rigid wall so therefore whatever pressure you will be getting that is earth pressure at rest condition so at top of the wall what will be the pressure. That is P 0 is equal to K a into z sorry not K a K 0 basically that is nothing but earth pressure at rest condition. So, coefficient of earth pressure rest condition is K 0. So, the P 0 is equal to K 0 into z.

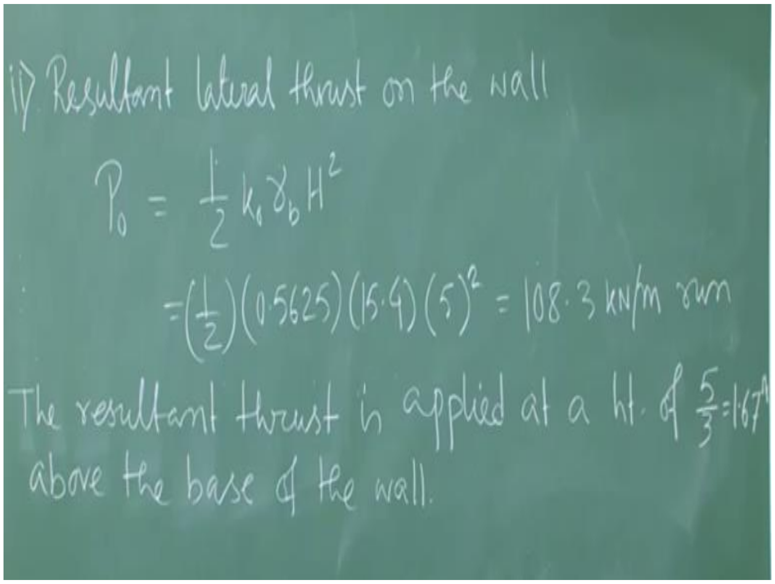
So, at z equal to 0 that pressure earth pressure at rest condition or the lateral pressure is simply zero okay. So, at the bottom of the wall that means z equal to 5 your earth pressure is equal to K 0 gamma into z. So, which gives me 0.5625 into 15.4 into 5 which comes around 53.3 kN/m square.

(Refer Slide Time: 10:32)



So, the distribution of lateral earth pressure is shown as so this is the wall okay the total height of the wall is say 5 m and your lateral earth pressure is shown here so that is 43.3 kN/m square at the base okay 43.3 kN/m square per meter run of the wall okay. So, therefore the first part is over the first part you have to find out the distribution of lateral earth pressure on the retaining wall. So, that already we have got it. Now the second part.

(Refer Slide Time: 11:54)

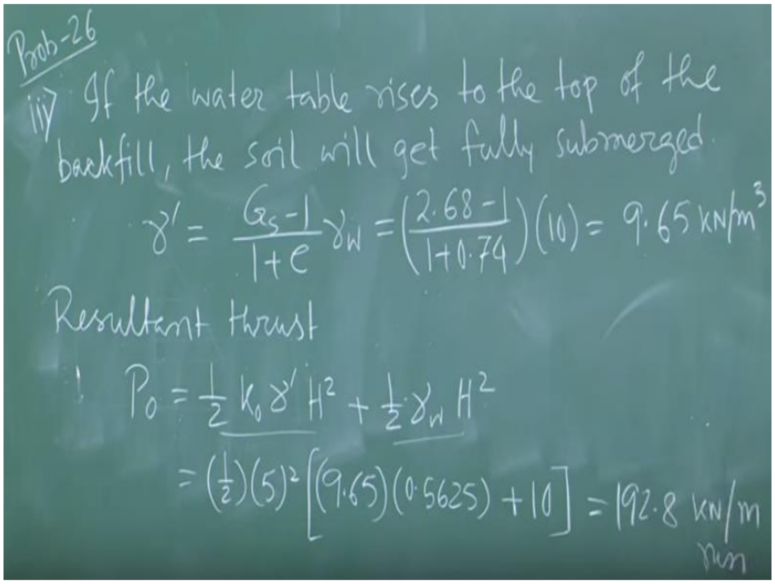


In the second part resultant lateral thrust on the wall considering the unit width okay so because in one direction that is normal to the board your wall is having the I mean infinite length so per unit width okay considering per unit width resultant lateral thrust on the wall will be coming as P 0 that is the total thrust is equal to half K 0 gamma b H square. So, by putting the values K 0 is

0.5625 that comes around 108.3 kN/m run of the wall okay. So, we have got the total thrust. Now this total thrust is acting at which point?

If I want to find out the point of application of this total thrust this total thrust will be acting if this is your total thrust say and this is your point of application so this depth is nothing but H by 3 right from the base of the wall. So, I can write the resultant thrust is applied at a height of 5 by 3 is equal to 1.67 m above the base of the wall. So, we have got the resultant force that means capital P 0 as 108.3 kN/m run and we have got the point of application of this resultant thrust. Now coming to the third part.

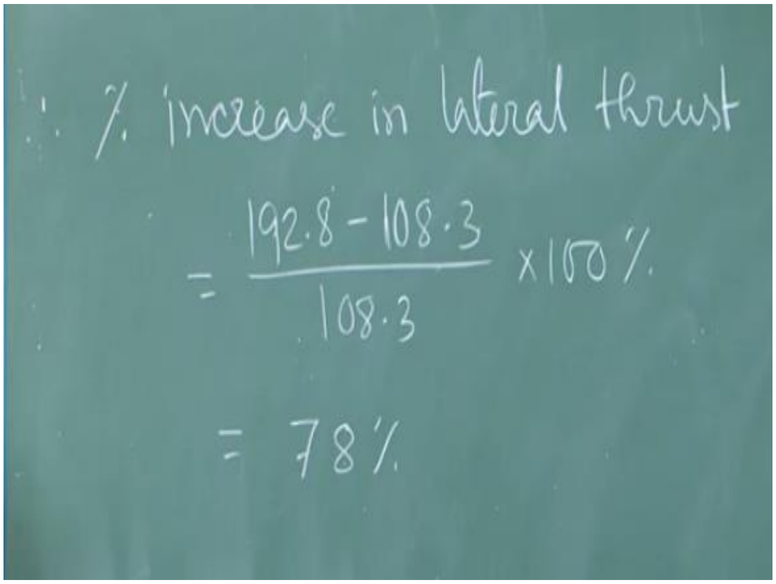
(Refer Slide Time: 14:49)



In the third part if the water table rises to the top of the backfill the soil will get fully submerged right. That means at some depth your water table was there now water table is rising at the top of the backfill. So, the whole backfill soil will be under submerged condition. So, let calculate the submerged unit weight because that will be required to find out the lateral pressure. So, that is nothing but G s - 1 by 1 + e into gamma w okay. So, if I put the values so I will get gamma prime equal to right 9.65 kN/m cube.

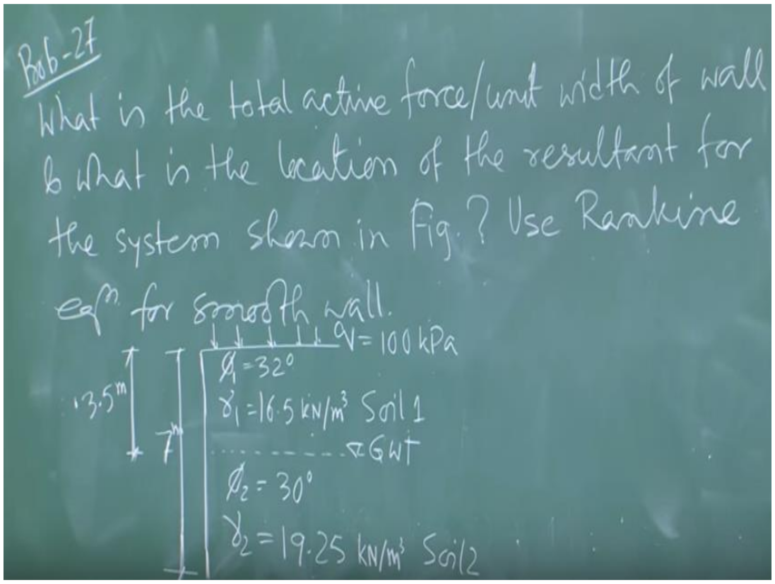
So, therefore resultant thrust capital P 0 is equal to half into K 0 gamma prime H square so that is due to the soil because the submerged backfill is there so that is due to the soil plus your water will give some pressure now hydrostatic pressure right so that will be half gamma w H square okay. So, this part is coming from the soil and this part is coming from the water. So, that is the total thrust now acting on the wall. So, if I put the values so half H square into gamma prime multiplied by K 0 + gamma w is equal to 192.8 kN/m run.

(Refer Slide Time: 17:52)



So, therefore percentage increase in lateral thrust is equal to 192.8 - 108.3 by 108.3 into 100 percent so that comes around 78%. So, you are getting 78% increase okay on the lateral thrust once the water table is rising up to the top of the backfill.

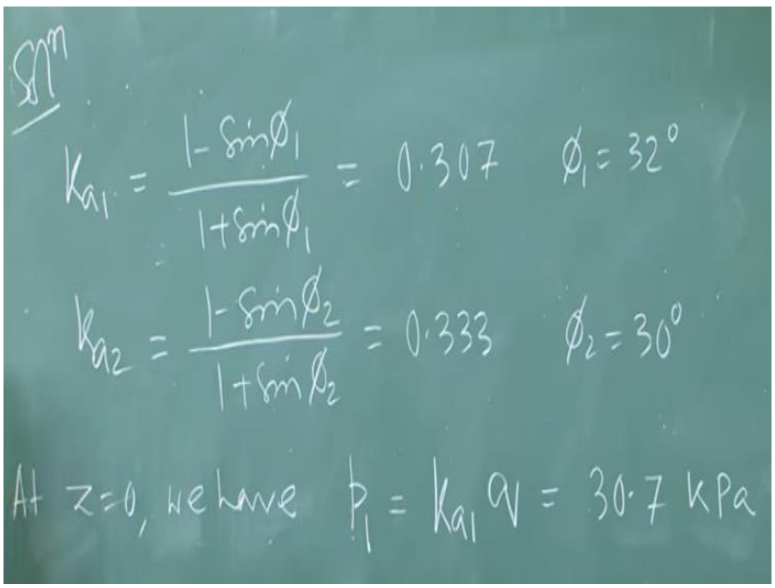
(Refer Slide Time: 18:46)



And the second problem says problem say 27. What is the total active force per unit width of wall and what is the location of the resultant for the system shown in figure? Use Rankine equation for smooth wall okay. The total depth of the wall is 7 m. Now the backfill is having 2 layers. The top layer which is having the depth of 3.5 m which is having the property of phi 1 equal to 32 degree and gamma 1 equal to 16.5 kN/m cube okay. You have the surcharge q which is equal to 100 kPa okay.

So, this is your soil 1 and you have the water table which is at this level okay at the mid depth of the wall. This is your ground water table and the soil 2 which is having the property phi 2 equal to 30 degree and gamma 2 equal to 19.25 kN/m cube. This is your soil 2 okay. So, this is the problem. So, for this type of retaining wall you need to calculate the total active force that means active thrust okay per unit width of the wall and the point of application of that active thrust okay for this type of problem. Let us let us see how we can solve this problem.

(Refer Slide Time: 22:28)



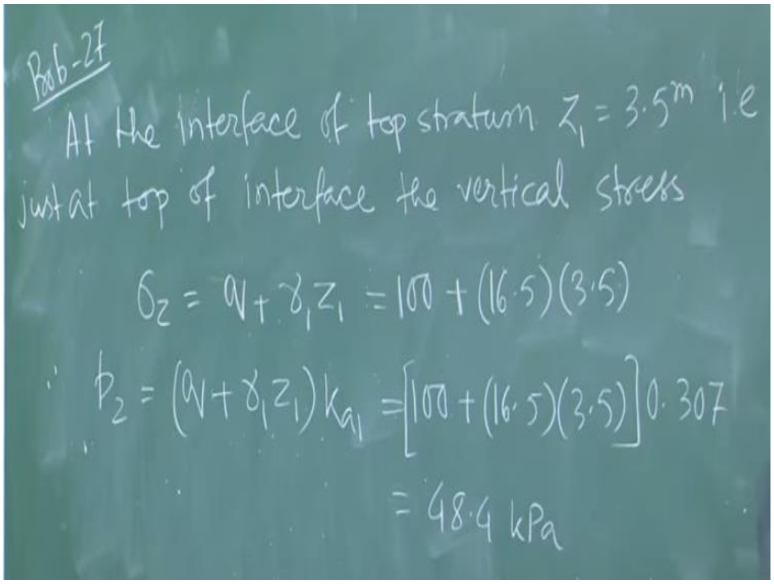
Now solution first you need to calculate the active earth pressure coefficient for both the layers because now you will be getting different earth pressure coefficient active earth pressure coefficient for different layers because soil 1 is having phi is equal to 32 degree whereas soil 2 is having phi is equal to 30 degree so you will be getting different active earth pressure coefficient at different soil layer. So, your K a 1 is equal to 1 - sin phi 1 by 1 + sin phi 1.

So, which is coming so phi 1 is equal to 32 degree as given in the problem okay. Similarly, K a 2 is equal to 1 - sin phi 2 by 1 + sin phi 2 which comes as 0.333 where phi 2 is equal to 30-degree okay. Now at z equal to 0 that means top of the wall at z equal to 0 means top of the wall if I consider we have p 1 that is the what is p 1? P 1 is the active earth pressure at the top of the wall. At that level what is the active earth pressure acting.

So, what should be the magnitude for of p 1 any guess? So, p 1 is nothing but the that will be completely contributed due to the surcharge of the soil. So, because the soil is I mean at z equal to 0 your active pressure from the soil is not coming into the picture right. At top of the wall you see you do not have any kind of active pressure because it is purely cohesionless soil.

It is not the cohesive soil so you will not be getting any pressure exerted by the backfill soil at the top of the wall. So, what will be only remaining so the remaining part will be the surcharge due to that you will be getting some active earth pressure at the top of the wall. What is that magnitude? K a 1 into q okay. So, K a 1 you know 0.307 and q you know 100 so you will be getting 30.7 kPa okay.

(Refer Slide Time: 25:24)



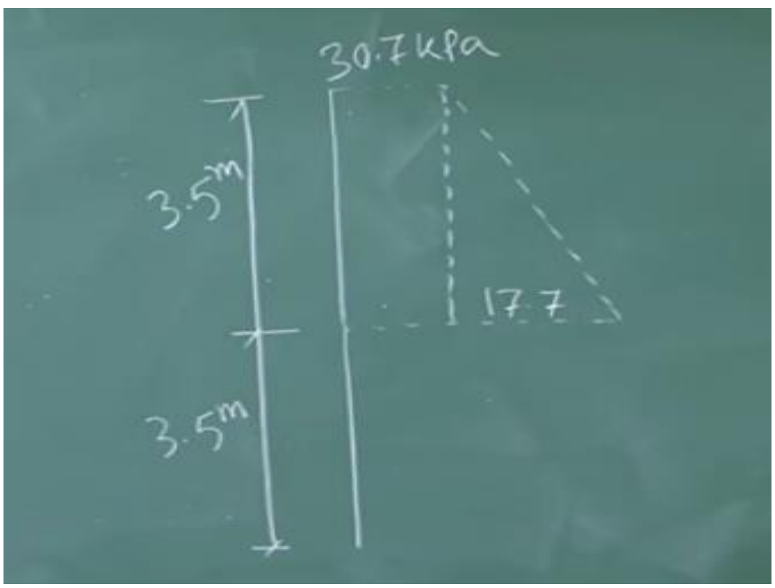
Now at the interface of top strata z 1 equal to 3.5 m that is just at top of just at top of interface the vertical stress just top of interface means so interface is happening at the depth of 3.5 m. Interface between 2 layers okay. So, soil layer is extending from z equal to 0 to z equal to 3.5 m and soil 2 is extending from z equal to 3.5 to z equal to 7 m right. So, at the interface we are considering what is happening at the interface let us see first.

So, at the interface of top stratum that z is equal to 3.5 m so interface is happening at 3.5 m depth below the ground surface that is just at top of interface what is happening we are going to find out and then we will be finding out just below the interface what is happening and then basically if there is some change at the interface abrupt change that means just on the top you will be getting something just at the base or at the below of the interface you will be getting something okay.

Just below the interface you will be getting something. So, anyway so just at top of interface the vertical stress is nothing but sigma z is equal to q + gamma 1 z 1 okay. So, what is your gamma 1? Gamma 1 is 16.5 kN/m cube that is given in the problem and z 1 is equal to 3.5 okay. So, q plus q of course that is there that is the surcharge that will be there for the whole deposit right. That will be constant. That is constant surcharge + gamma 1 into z 1.

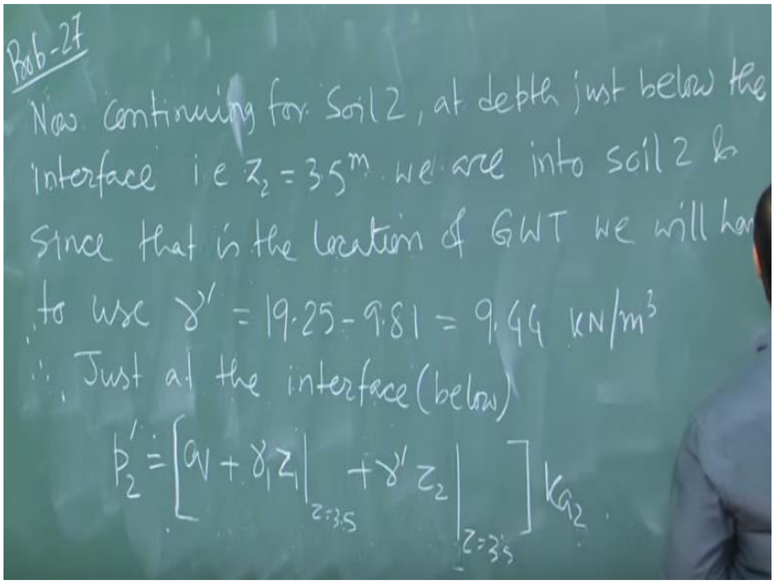
So, if I put this so 100 + 16.5 into 3.5 okay. This is your sigma z at the top of the interface please remember that is just at the top of the interface. So, therefore p 2 at that level what is your active earth pressure at that level means just at the top of interface what is the active earth pressure. So, p 2 is equal to q + gamma 1 z 1 into k a 1 right vertical pressure into earth pressure active earth pressure coefficient. So, that gives me 100 + 16.5 multiplied by 3.5 into 0.307 that comes as 48.4 kPa.

(Refer Slide Time: 29:27)



So, basically say 3.5 m 3.5 m okay. So, this is your 30.7 kPa okay and you have got p 2 equal to 48.4 kPa. Where it is acting? Just at the top of the interface. So, this is your 30.7. The total is 48.4. So, therefore this remaining is 17.7. I am not writing kPa everywhere so this is quite understood that everywhere it will be kPa. That is the pressure diagram okay. So, this is the pressure diagram at the top of the interface okay. So, at the top of the wall you have the pressure at 30.7 kPa which is due to the surcharge exclusively for surcharge and then at the base at the just at the top of the interface you are getting 48.4 just we have calculated. So, 30.7 + 17.7. So, that is the total pressure acting at just at top of the interface okay.

(Refer Slide Time: 31:03)

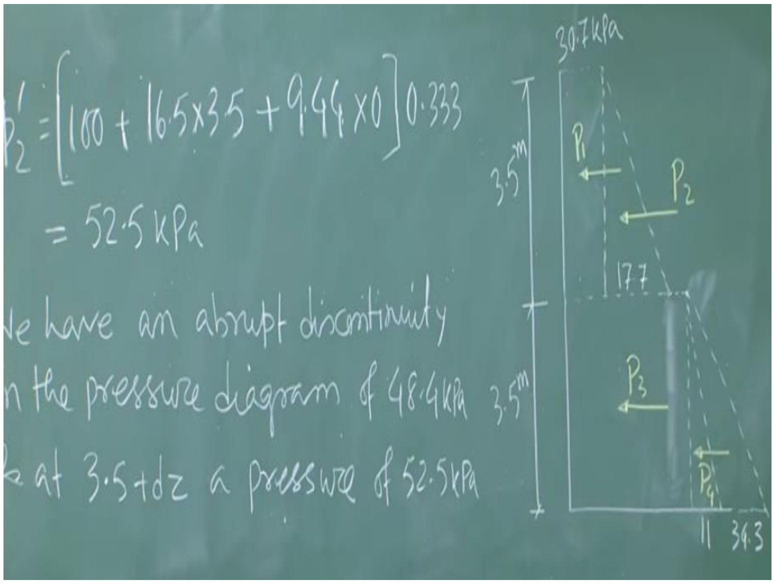


So, now continuing for soil 2 for soil 2 at depth just below the interface that is z 2 equal to 3.5 m right 3.5 m. We are into soil 2 and since that is the location of the ground water table we will have to use gamma prime which is nothing but 19.25 and here I am using gamma w equal to 9.81 which is nothing but 9.44 kN/m cube. So, basically interface is the problem. So, just top of that the top of the interface you are in soil 1 region.

Just below the interface you are in soil 2 right. So, just above or just at the top of the interface already we have calculated the pressure and that pressure diagram looks like this okay. Just below the interface basically you are entering soil 2 but still you are at the interface so physically z equal to 3.5 m right. So, just top and just below the interface we are considering. So, just below the interface your you still have z equal to 3.5 m and that is the location because the interface is the location of the ground water table and ground water table is should be considered just below the interface because just at the top of the interface there is no effect of water right.

So, just below the interface you are getting the effect of water okay. So, therefore the soil should be the soil 2 should be considered as submerged condition okay. So, just therefore just at the interface that means interface below the interface your p 2 prime will be equal to q + gamma 1 z 1 up to z where equal to 3.5. So, that is that contribution is coming from soil 1 + gamma z z 2 where z equal to 3.5 into k a 2 okay. So, z 1 means z 1 is the z which is varying within the soil 1 and z 2 which is z which is varying from in the soil 2 okay.

(Refer Slide Time: 35:07)

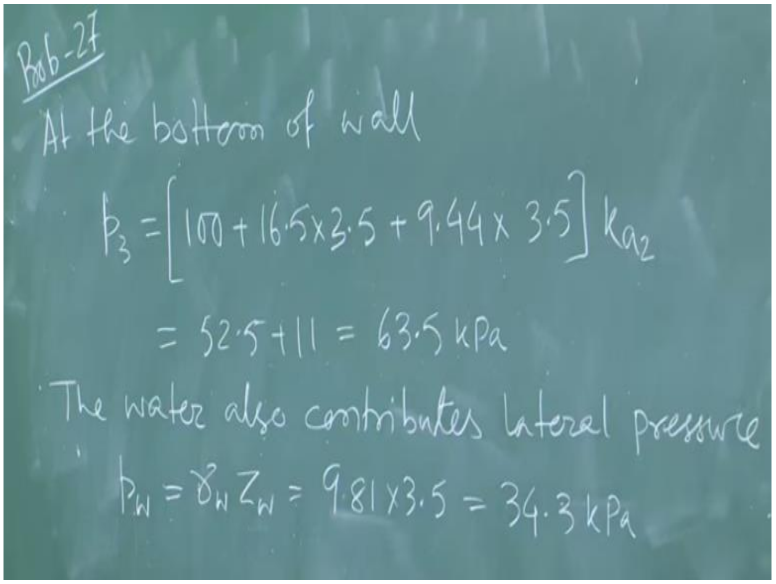


So, now in this expression you can find out p 2 prime is equal to just below the interface your p 2 prime will be equal to q that is 100 + 16.5 into 3.5 that is coming from that is the contribution that is the vertical pressure at the interface due to the soil 1 okay plus what is the vertical this gamma prime z 2 at the interface because z 2 is 0 at the interface because we have not yet entered soil 2 properly just below the interface we are there okay. So, your z 2 is 0 so 9.44 that is gamma submerged into 0 into K a 2, understood the concept.

I mean if you understand the concept then it is very simple okay. So, at the interface you have got 2 different condition so just above the interface just below the interface okay. So, from this I can get p 2 prime is equal to 52.5 kPa. Now what does it mean? So, you have got p 2 which is equal to 30.7 + 17.7 right when you considered from top to the interface up to the interface. Now you are considering just below the interface and you are getting p 2 prime. So, you are getting basically a sudden jump in the lateral earth pressure okay.

So, we can write down that. We have an abrupt discontinuity in the pressure diagram of 48.4 kPa and at 3.5 + dz that means you are in soil 2 but you are at interface okay a pressure of 52.5 kPa okay. So, that means you are getting some abrupt discontinuity abrupt change okay some 48.4 to 52.5. So, this up to this point is 48.4. The say 52.5 is happening here say for example say this is the point where you are getting 52.5 okay. At the interface both the things are happening due to the abrupt discontinuity okay.

(Refer Slide Time: 38:35)



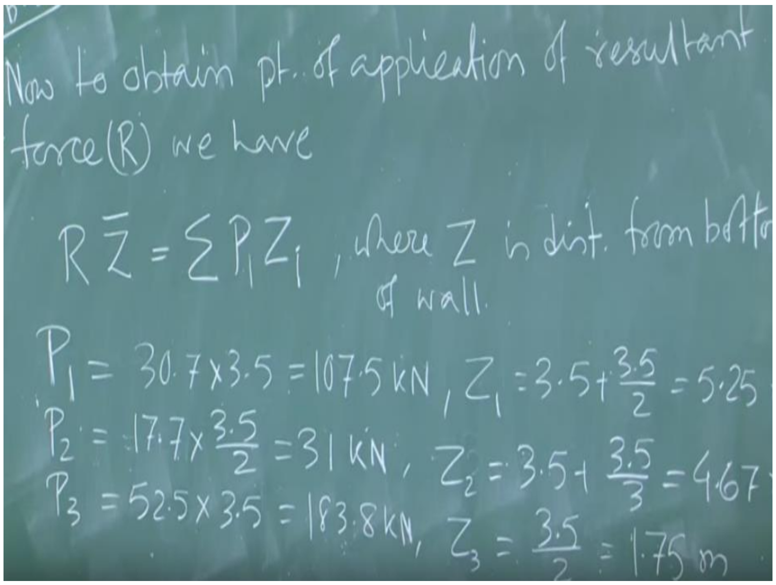
Now at the bottom of the wall what is the pressure? At the bottom of wall your p 3 that is pressure is equal to 100 plus the vertical so first the within this bracket whatever we are writing that is nothing but your vertical pressure plus the vertical pressure due to your soil 1 plus the vertical pressure due to your submerged soil 2 into K a 2 that is nothing but your p 3 which is acting at the base of the wall.

So, if you put the values you will be getting p 3 is equal to 52.5 + 11 is equal to 63.5 kPa. So, basically this is your 11 okay. So, you are getting the pressure at the base of the wall as 63.5. So, 52.5 + 11 is nothing but 63.5. So, this additional part will be 11 kPa okay as I wrote there okay. So, the water also contributes lateral pressure okay. So, therefore p w is equal to gamma w into z w.

So, what is your gamma w 9.81 and what is the total depth of water that is 3.5 m is equal to 34.3 kPa. So, the water pressure I mean pressure due to the water will be 0 at z equal to 3.5 m that means where the ground water table is getting started and you will be getting water pressure is equal to 34.3 kPa at z equal to 7 that means at the base of the wall. So, from there I can get the pressure distribution for water. So, this is your 34.3.

So, I will be getting the thrust say this is your P 1 this is your say P 2 this is your say P 3 this is your say P 4 okay. So, now if I calculate P 1, P 2, P 3, and P 4 so P 1 is nothing but the area under this rectangle. P 2 is the area under this triangle. P 3 is the area under this rectangle and P 4 is the area under this whole triangle okay. So, if I find out P 1, P 2, P 3, and P 4 from this diagram from the area of this diagram then the summation of P 1, P 2, P 3, and P 4 will be the total thrust acting on the wall and if I want to find out the point of application of the resultant force then we have to get the individual point of application of those forces right. So, next what we will do?

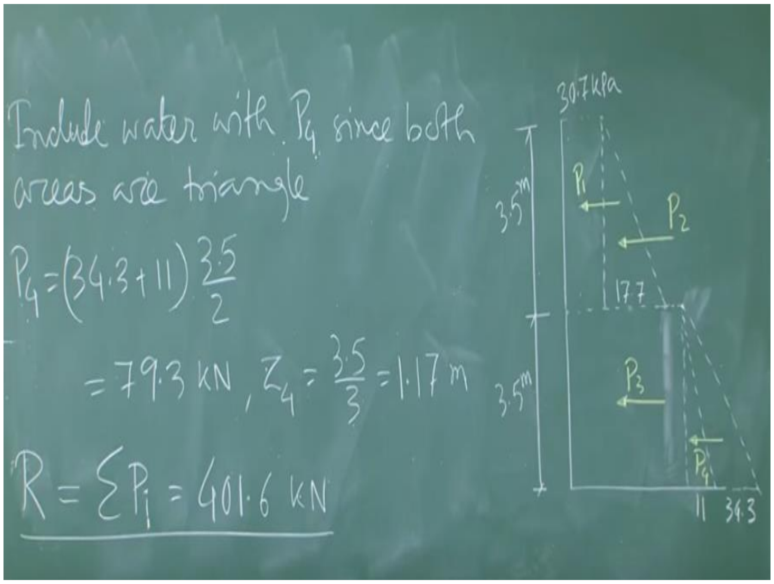
(Refer Slide Time: 43:14)



Now to obtain point of application of resultant force R we have R into capital Z bar is equal to summation of P 1 into capital Z i where capital Z is distance from bottom of wall okay. So, now let us calculate all the forces individually. P 1 what is P 1? P 1 is the area under that rectangle the top rectangle. So, P 1 is nothing but 30.7 into 3.5 which comes as 107.5 kN right. Now where it is acting? It is acting at the mid depth of this rectangular part. So, from the base what will be the distance? 3.5 + 3.5 by 2. So, your Z 1 so your capital Z 1 is equal to 3.5 + 3.5 by 2 which comes as 5.25 m.

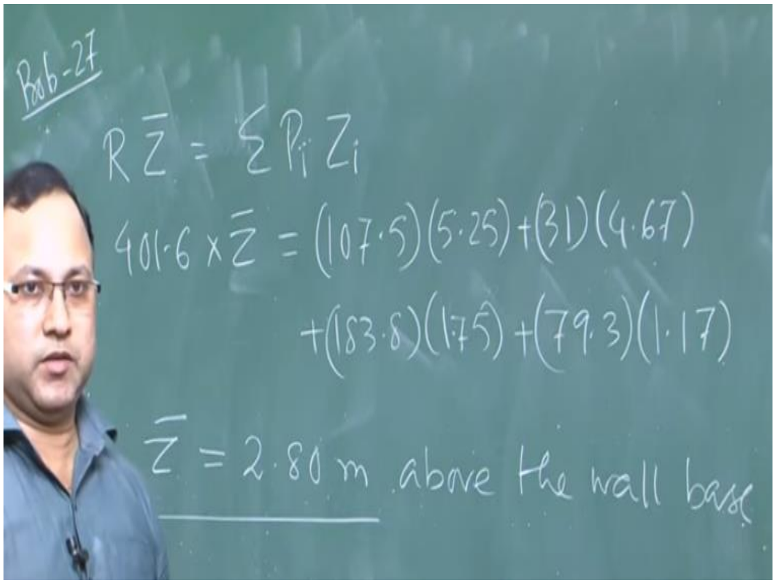
Similarly, I can find out P 2 which is nothing but 17.7 into 3.5 by 2 that is the area under this triangle 17.7 into 3.5 by 2. So, that comes as 31 kN and what will be Z 2? Z 2 is the capital Z 2 is the distance from the base of the wall to the point of application of P 2. So, that is nothing but 3.5 + 3.5 by 3. So, that comes as 4.67 m. Similarly, I can find out P 3. P 3 is 52.5 into 3.5 which comes around 183.8 kilo newton and your Z 3 is equal to simply 3.5 by 2. What is P 3? P 3 is the this area okay, area under this rectangle. So, 3.5 by 2 which is nothing but 1.75 m.

(Refer Slide Time: 46:55)



So, now include water with P 4 since both are both areas are triangle. So, we are considering this triangle and this triangle. So, there is a this is the whole triangle which will give me P 4. So, P 4 is equal to 34.3 + 11 into 3.5 by 2 agreed? So, that is the area of the whole triangle. So, that comes around 79.3 kN and z 4 is equal to 3.5 by 3 which is equal to 1.17 m. So, the resultant force resultant thrust R is equal to summation of P i which is equal to so P 1 + P 2 + P 3 + P4 if you do that you will be getting 401.6 kN. So, that is one of the answer okay have you got it. So, this is the total thrust acting on the wall due to this layered backfill and the point of application of this R is, how we will get it?

(Refer Slide Time: 48:51)



So, point of application of this R is R into Z bar capital Z bar is equal to summation of P i into Z i as I have written earlier right. So, R you know so from this I can write 401.6 into Z bar is equal to summation of so 107.5 into 5.25 + 31 into 4.67 + 183.8 1.75 + 79.3 into 1.17. So, from this I will be getting Z bar equal to 2.80 m above the wall base okay. So, this is your resultant force R and this is your point of application of the resultant force that is 2.8 m above the wall base okay. So, I will stop here today. So, in the next class we will take a few more problems on the earth pressure theory and then of course we will be solving some problems on the stress distribution and so on. Thank you very much.