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

Lecture – 44
Earth Pressure – IV

So, in this class I will discuss that what would be the Earth Pressure if the soil is c phi soil. So, last all the earth pressure problems I have discussed that soil is only phi soil and today I will discuss if the soil is the c phi soil ok.

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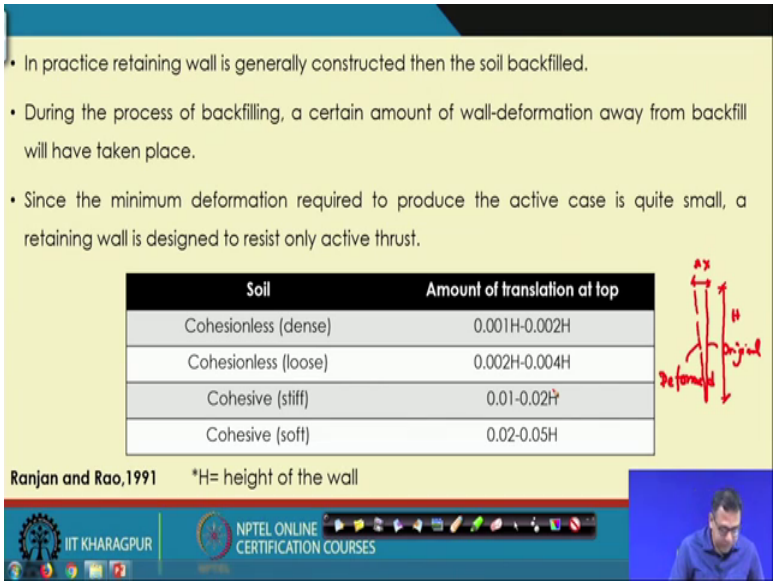

So, now so, in general that when we design retaining wall or earth retaining structure we design it against the active condition ok. Now, the question is why we will not design it against the at rest condition? Ok, so; that means, active condition the one reason is that if I design it under active condition then our earth pressure will be a less compared to the at rest condition.

So, our force that will come on to the on the wall will also be less and one thing that if why we want to design it for the active condition then you have to allow up certain amount of deformation of the wall. And that is acceptable because, we can allow a certain amount of information because, all the foundation design also we will allow certain amount of deformation on that is called permissible settlement.

So, you design our foundation under permissible settlement. So, here also we can design our foundation or retaining structure under active condition. Because, in generally in the practice retaining wall is generally constructed then the backfilled soil is placed ok.

So, during this process of backfilling the certain amount of while deformation away from backfield we will have taken place. So, since the deformation is very less to form a active condition. So, a retaining wall is always designed under active condition. So, you can see that for this active amount of translation at top. So, amount of translation at top means suppose this if wall so, that we on the active condition it will deform like this. This is the original and this is the deform ok.

So, this is the amount of deformation of the top or translation of the top and that this is say delta x. So, for the cohesion less soil dense this is if this is the height of the wall, then this delta x is 0.001 H; that means, it is only 0.1 percentage of H or 2.2 percentage of H. So, if we have that much of deformation then the active stage is occurred. So, that is why that much of deformation we can allow and we can design it under active condition.

So, for the cohesion less soil so, loose this is 0.2 percent to 0.4 percent and cohesive soil if it is stiff, it is 1 percent to 2 percent or 0.1 to 0.01 2.0 to H and for cohesive less cohesive soil sort it is 2 percent to 5 percent. So, it is very small amount of deformation to get active stage.

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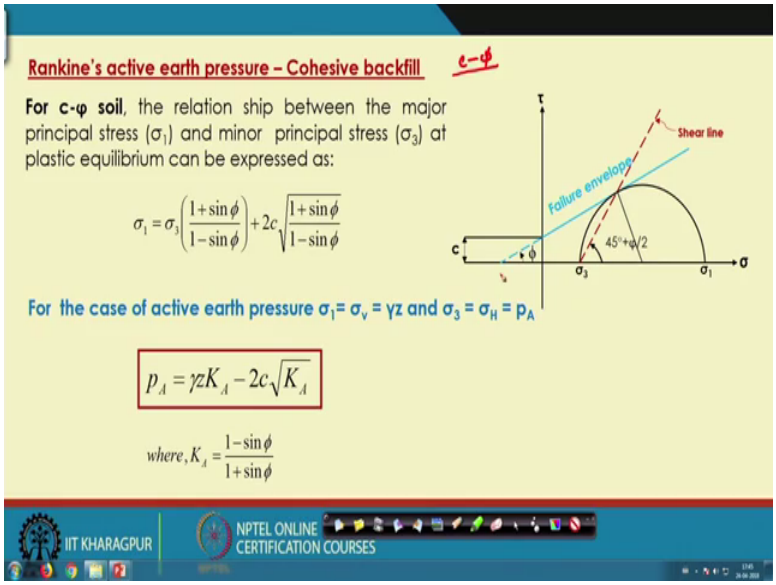

So, now so, we will discuss that what will happen Rankine if the what will happen to the Rankine's active earth pressure if the soil is cohesive soil or it is a c phi soil. So, here the soil is c phi soil. So, in that case this will be the Mohr circle because in the cohesive soil your Mohr circle there will be a c value and there will be a phi value. So, I can prove that how I am getting this expression, this is the final expression. So, let me prove that thing first then we will discuss the forces and the point or applications all these things.

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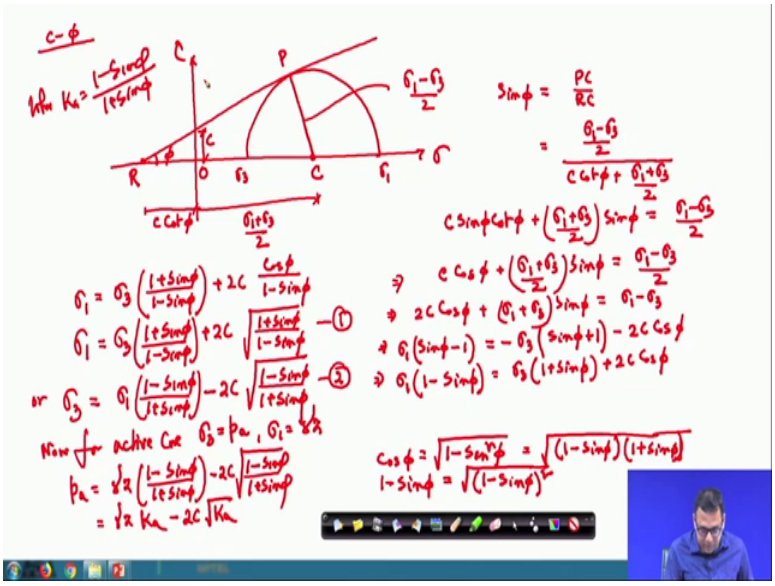

So, now if it is a c phi soil then I can write or I can draw this Mohr circle, but here it will not pass to the origin because it has a c value as well as the phi value. So, this is the phi value and this one is the c value cohesion. And this is the, your Mohr circle and this is again this is sigma 1, this is sigma 3, this is the center.

So, center will be sigma 1 plus sigma 3 divided by 2 plus there is a term this is c this is phi. So, these things I can write this is c cot phi. Because, this one is the c cohesion this is the phi so, I can write this amount is c cot phi. And so, if this is the origin O and this is tau and this is sigma and this is the center C and I can draw a line this is the P where this circle touches the failure envelope. And this point is say R and similarly the radius this radius will be, this radius sigma 1 minus sigma 3 divided by 2 this is the radius of the circle.

Now, I can write that sin phi is equal to again sin phi will be PC divided by RC or CR ok. Again the PC is here sigma 1 minus sigma 3 divided by 2 and RC is c cot phi plus sigma

1 plus sigma 3 divided by 2 ok. So, now, I can write here that c sin phi cot phi plus sigma 1 plus sigma 3 divided by 2 sin phi will be equal to sigma 1 minus sigma 3 divided by 2. So, now cot phi means the cos phi divided by sin phi so, sin phi sin phi will cancel out. So, I can write c cos phi plus sigma 1 plus sigma 3 divided by 2 sin phi that will be equal to sigma 1 minus sigma 3 divided by 2. So, I can further write that 2c cos phi plus sigma 1 plus sigma 3 sin phi will be equal to sigma 1 minus sigma 3.

Now, if I take all the sigma 3, sigma 1 this side. So, sigma 1 if I take common this will be sin phi and this will come this side so, sin phi minus 1. And if I take sigma 3 all in this side so, all in this side so, this will be sigma 3 minus sin phi this is also sigma minus so, plus 1 and again the minus 2c cos phi part. Now, if I take minus common and cancel from both the sides; so, this will be sigma 1 1 minus sin phi that will be sigma 3, 1 plus sin phi that will be plus 2c cos phi. So, I can write sigma 1 is equal to sigma 3 1 plus sin phi 1 minus sin phi and this will be plus 2c cos phi 1 minus sin phi and this cos phi I can write that cos phi is equal to root over 1 minus sine square phi.

So, in the sine square phi, I can write this will be 1 minus sin phi and 1 plus sin phi. And this 1 minus sin phi also I can write this is root over 1 minus sin phi square. So, this one I can write in 1 minus sin phi is nothing, but this is root over 1 minus sin phi square. So, now if I put this thing so; that means, here 1 minus sin phi and 1 minus sin phi 1 will cancel out and they will be root over 1 plus sin phi divided by 1 minus sin phi. So, this way I can write this is sigma 3 1 plus sin phi 1 minus sin phi plus 2c, then root over 1 plus sin phi 1 minus sin phi ok.

Because, here 1 minus sin phi 1 minus sin phi that 1 will cancel out. There will be root over 1 plus sin phi and this is 1 minus sin phi both are in within the root ok. So, final expression is this 1 or I can write or I can write that sigma 3 is equal to sigma 1 1 minus sin phi 1 plus sin phi minus 2c root over 1 minus sin phi 1 plus sin phi ok. So, we have 2 expressions this is sigma 1 so, we had expression number 1 or expression number 2.

So, expression number 1 is sigma 1 is equal to sigma 3 it is some value plus 2c and the same expression I have written in different form. Here sigma 3 is equal to sigma 1 into that expression into that 1 minus sin phi into divided by 1 plus sin phi minus 2c. If you take this thing this side so, it will be minus 2c. Now, for active case that your sigma 3 is equal to PA and sigma 1 is equal to gamma z ok. Because, these expressions I am

deriving is not for incline surface, it is for perfectly horizontal surface, phi value is equal to 0.

So, I can write this expression so, I can write for active case our pa is equal to gamma z 1 minus sin phi 1 plus sin phi minus 2c root over 1 minus sin phi 1 plus sin phi. Now, 1 minus sin phi 1 plus sin phi is nothing, but K A. So, I can write this is gamma z K A minus 2c root over K A, where K A is equal to 1 minus sin phi 1 plus sin phi. So, this is for the active case, now for the passive case. So, I have these expression sigma 1 equal to sigma 3 1 plus sin phi.

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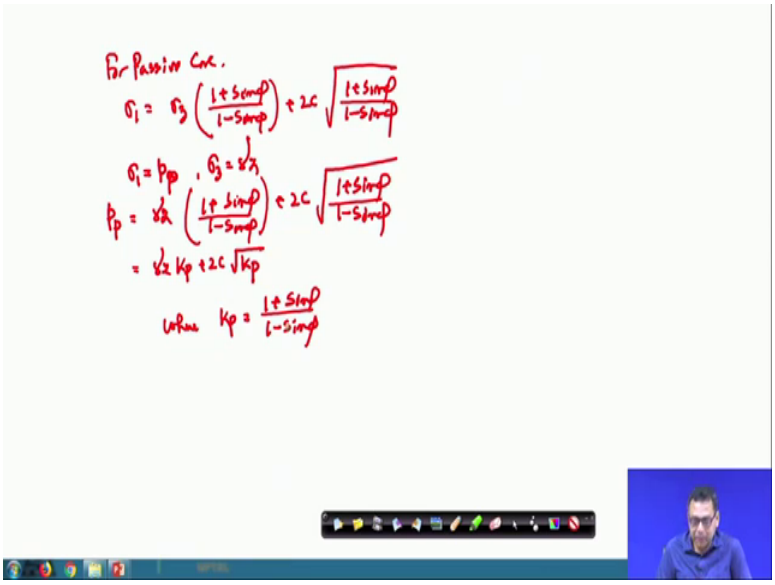

So, I have expression sigma 1 is equal to sigma 3 1 plus sin phi 1 minus sin phi plus 2c root over 1 plus sin phi 1 minus sin phi. And for the passive case your sigma 1 is equal to P A and sigma 3 is equal to gamma z. So, I can write sorry this is P P. So, I can write that P P is equal to gamma z 1 plus sin phi 1 minus sin phi plus 2c root over 1 plus sin phi 1 minus sin phi. And again gamma z into K P plus 2c root over K P where, K P is equal to 1 plus sin phi 1 minus sin phi ok.

So, this is the expression of a and K K P for c phi soil and this is the expression of P A and P P for the c phi soil. Now, so, this is the same expression that sigma 1 equal to sigma 3 1 plus sin phi. So, that and the sigma 3 expression I have already derived. So, from here I can write P A is equal to gamma z K A minus 2c root over K A. And this is

the Mohr circle and again the Mohr this failure plane will make an angle 45 degree plus phi by 2 for the active case.

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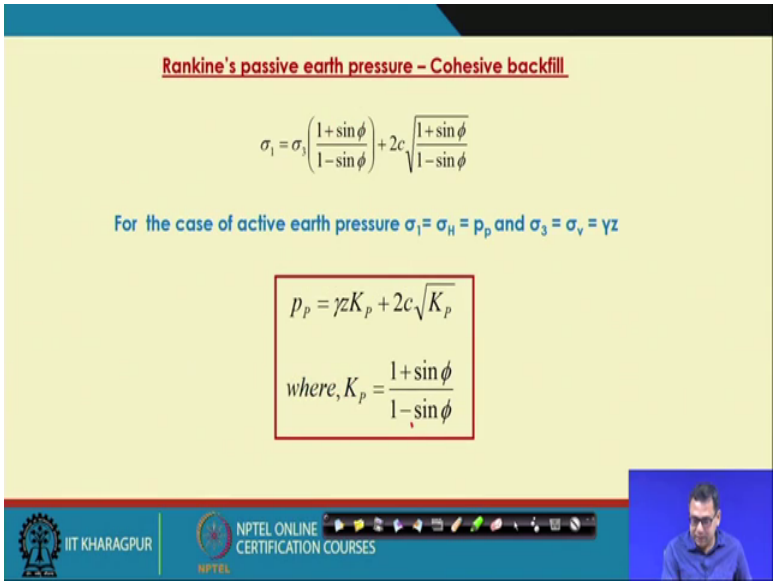

And similarly for the for the passive case yeah similarly for the passive case this is the same expression K P this will be plus 2c root K P. So, I have derived this expression so, K P is 1 plus sin phi 1 minus sin phi, this is for the passive case. But and we have few more cases. So, this is the a Mohr circle for a general case ok.

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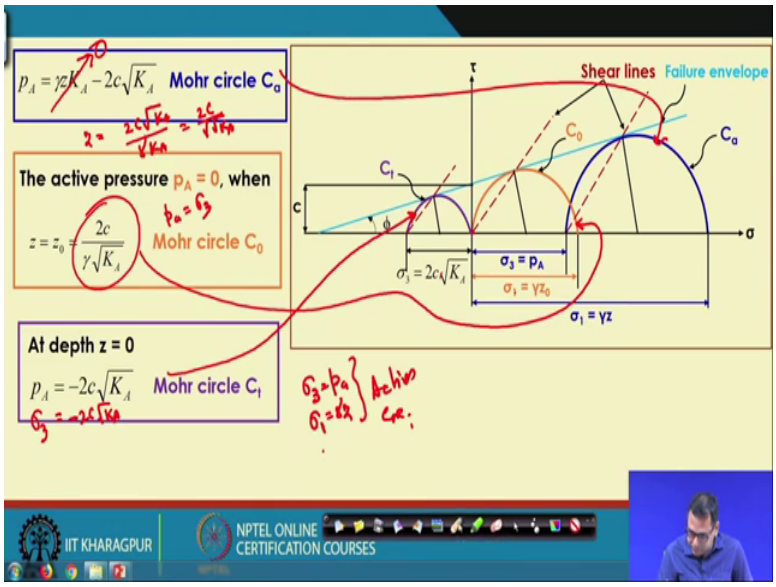

Now, we have this is the expression of pa this is the expression of P A and this C a is the circle corresponding to this expression. This is the circle corresponding to this expression. Now, if P A is equal to 0 this P A is equal to 0 then we can get z value. It pa is equal to 0 then from here z value will be 2c K A by gamma K A and this is K A. So, I can write 2c gamma root K A. So, this is the value 2c gamma root K A. So, here your P A value is 0 and you know that P A is nothing, but sigma 3. So, your sigma 3 value will also 0.

So, remember that, in that case your Mohr circle will pass through the origin. Because, your sigma 3 is values equal to 0 because, your P A is equal to sigma 3 and P A value is 0. So; that means, this is the this circle. So, now, if I put at z equal to 0 at z equal to 0 means this is your sigma a gamma z into K A that part is 0. So, you know that your sigma 3 is equal to P A and sigma 1 is equal to gamma zero, this is for active case.

So, now, if gamma z is or z is 0; that means, sigma 1 will be 0. So, in that case also your Mohr circle will pass to the origin. But in that case your sigma 3; that means, sigma 3 value is minus 2c root K A. Because, if you put this is 0 this is 0 this will be the minus 2c root K A. So, your Mohr circle will shift to this origin this side of the origin ok. So, now, this is the case for this Mohr circle. So, this is very important these 3 circles so, it is a very common questions that if your P A is 0 what would be the Mohr circle ? If your z is equal to 0 what would be the Mohr circle?

Then you have to draw a Mohr circle in this way and remember that in that case sigma 3 will be 2c root K A. And here the sigma 3 is equal to P A for the blue and here sigma for the second circle sigma 3 is equal to 0 and sigma 1 is equal to gamma into z 0. So, you just remember these things.

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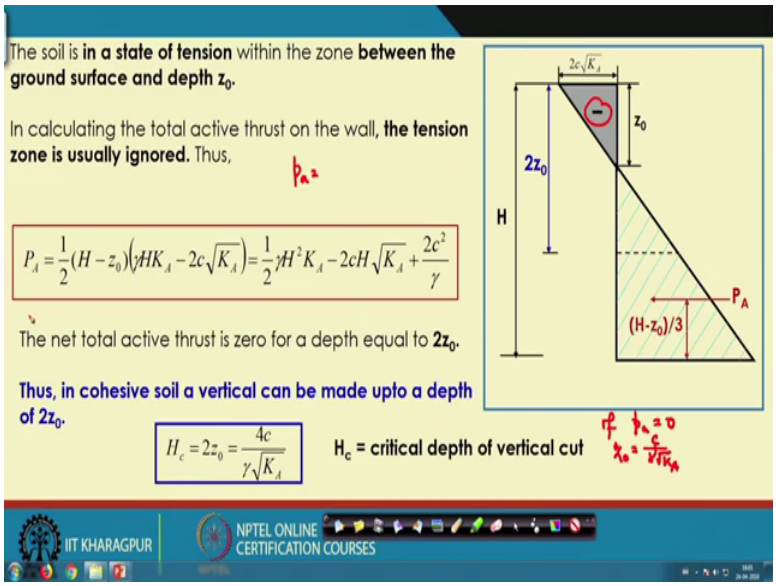

Then another important thing that I have already mentioned that if your P A is equal to 0 then your z 0 is equal to c gamma root K A. So, does it mean that act z z 0 point your stress is 0, lateral earth pressure, active lateral earth pressure at z 0 is equal to 0. So, and above this z 0 your earth pressure is negative because, we have minus c term. So, this is negative actual expression is your P A is equal to you can see this expression that P A is equal to this is the expression P A is equal to gamma z into K A minus 2c root K A.

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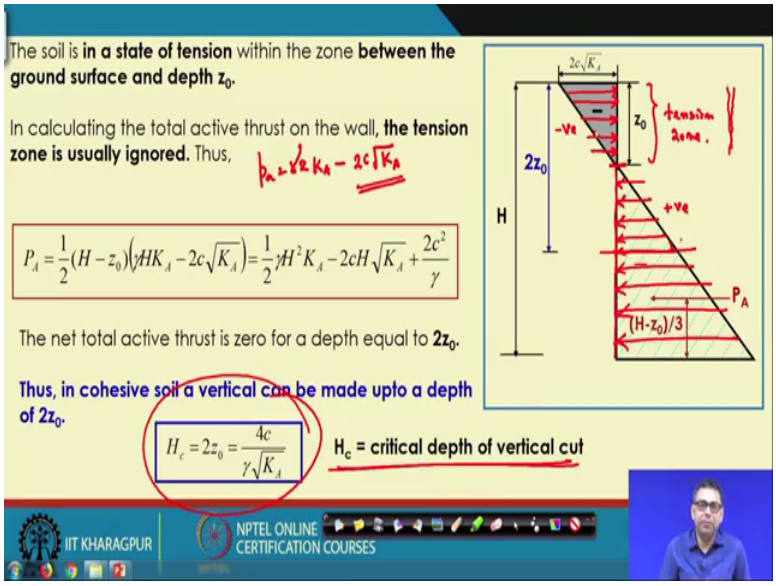

So, I can write that P A is equal to gamma z K A minus 2c root K A equal rights small a or capital A. So; that means, here if your up to the z 0 this is negative part is more compared to the positive part. After that it will into positive part will increase. So, up to this point there will be a negative earth pressure; that means, here attention will. So, this is the negative means if the tension. So, this is the tension zone so, ok.

So, here your tension crack will develop because soil cannot take tension, soil is weak in tension so, and your stress is negative. So, here; that means, your we a tension crack will develop in this zone ok. There will be a crack will developed in this zone up to z 0 ok. And another very important thing that now this did it this way the stress is acting in this direction because, in the see negative and this side your stress is acting in this direction.

Now, there will be at equal amount of z z 0. So, this stress will cancel this stress so, this positive stress will cancel this amount of the negative stress because, if I draw this triangle this triangle is same as this triangle. So, if I do not provide any support up to that twice z 0 from the top of this ground level, then there will be no issue you know while because there is no stress, this stress is equal to this stress. So, no support is required up to twice the z 0 depth from the top. After that you have to provide support because again this stress will be the additional stress. So, that twice z 0 is called the critical depth of a vertical cut.

So, up to the critical depth you do not need to provide any lateral support ok. So, suppose if you remove the soil up to twice z 0 or H c the soil will stand without any support. Because, this there the a positive stress is cancelled by the negative stress clear. But, if you excavate further H c then the support will be required. So, that depends upon the amount of shear strength parameters c or phi of the soil and the unit weight of the soil.

So, this is the very important concept, this critical depth concept is very useful and very important. And now there is 2 cases, one case you will find that that you have to draw the earth pressure. This is very common question that you draw the earth pressure before the tension crack appear and the after tension crack occurred. So, what will be the earth pressure? What will be the force before tension crack occurred and after tension crack occur. So, before tension crack occurred means you have to consider this negative pressure also. So, if you consider the negative earth pressure part then how we can determine that?

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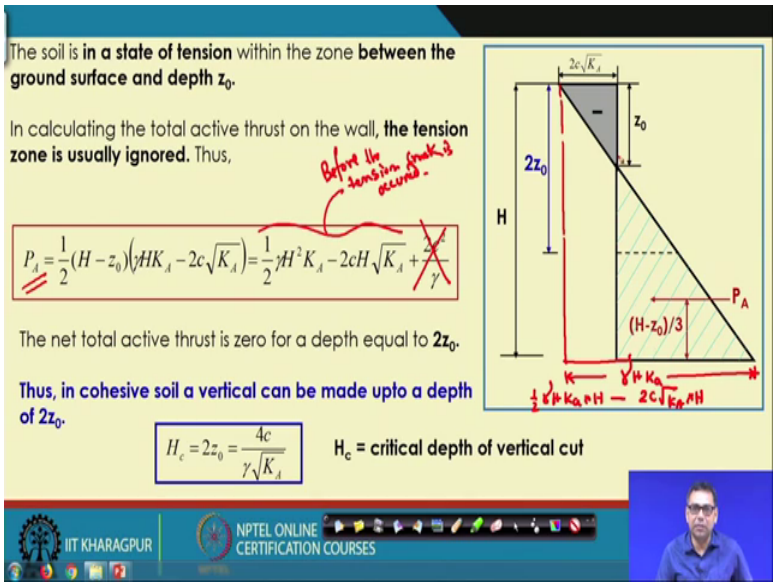

So, if I consider this negative part also then I can write this expression. So, this is the rectangle I am talk taking and here this part your this total soil is nothing, but this is your H and this is the this total one is nothing, but gamma into H into K A. Ok, and this one 2c minus K A. So, now, I if I consider this portion also then I have to write this gamma this triangle half gamma H square into K A this triangle half gamma. So, this mean this triangle is half gamma H into K A into H this is this triangle minus this rectangle this rectangle is 2c root K A into H.

So, if I take the rectangle so, this portion will cancel out and this is the mind we are taking once this one within this triangle we are taking this portion with the rectangle also. So, both will cancel out so, only this one minus this one. So, this is the so; that means, here this will be canceled out. If this is the earth pressure before the tension crack is occurred ok. So, this is earth pressure half gamma H square K A minus 2c 2c H into K A.

So; that means, before the tension crack is crack is occurred you have to consider the positive as well as the negative earth pressure during the total force calculation. Remember that, if tension crack is not occurred then we have to consider positive as well as negative earth pressure during the calculation of P A.

Now, if the tension crack is occurred then there is a separation of the soil and the wall. So, will not consider the negative one will consider only the positive one. So, if we

consider the only the positive one then this will be your portion of the stress that mean how what is the portion of the stress?

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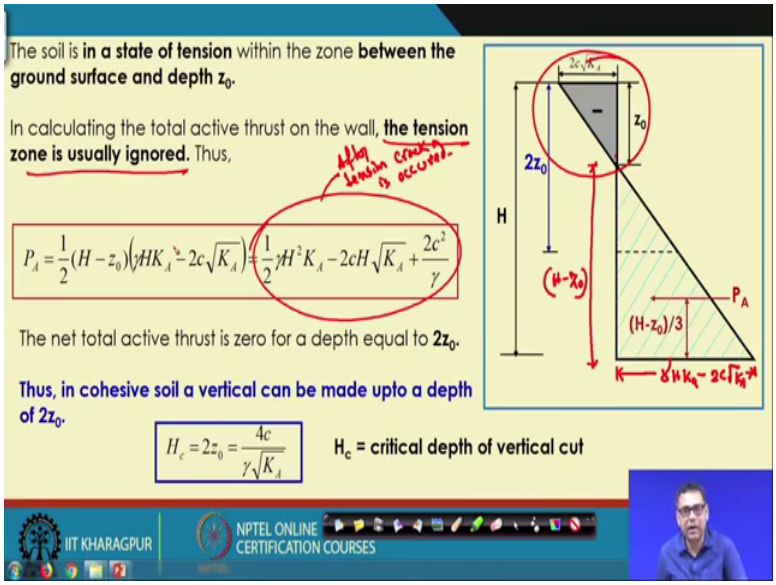

This one this value is nothing, but this is gamma into H into K minus 2c root K A this is this portion and this value is H minus z 0 ok. So, this triangle is half H minus H 0 into this one gamma H K minus 2c root K A. So, if you see simplify this thing this will be the form. So, these things that after tension crack is occurred ok. So, these are the 2 different cases. But, during the design or calculation of active earth pressure we generally do not consider this negative part.

So, if it is mentioned specifically that before the tension crack is occurred you calculate the force then only you consider this negative one. Otherwise if nothing is mentioned that we generally do not consider this negative part we consider only the positive part during that calculation of the earth pressure ok, remember that.

So, that is why we will generally this tension zone usually ignored. But, if it is specifically mentioned that you calculate the earth pressure before the tension crack is developed then only we have to consider. Otherwise do not consider generally it is been ignored we consider only the positive one.

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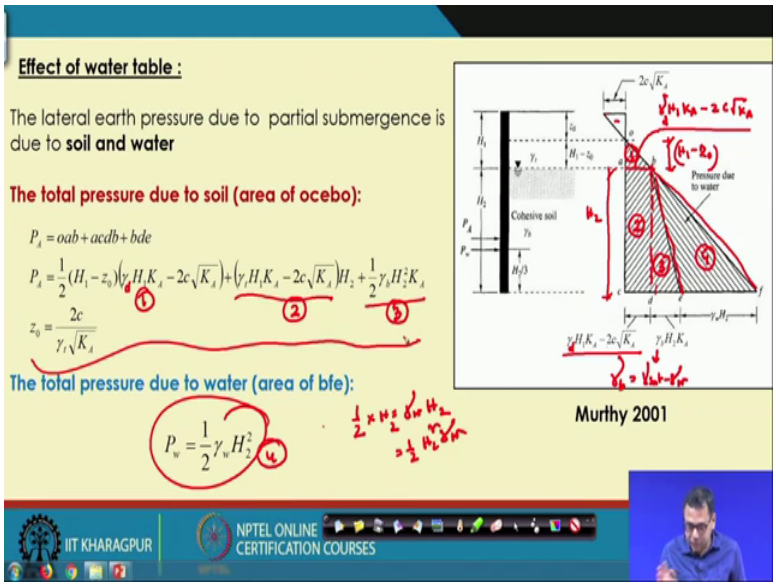

And then next one is that if there is water table in this c phi soil also, if there is a water table then what would be the earth pressure distribution? So, I have already discussed in case of c phi soil it is also similar that if you have a water table up to this H 1 then H 2 is the below water table. So; that means, if this z 0 is within this H 1 then this will be the distribution up to this point. And then this one will act as a surcharge here then this portion is for the additional stress of the lower part then this one is the water table part.

So, this is the 3 different parts similar to the your phi soil also, but only there will be a negative zone. So, this is the negative zone and why they generally as I mentioned during the first calculation we considered this shaded portion only which is the positive part only. So, that in the final calculation is we are considering that this is the half into H 1 minus z 0 this is H 1 minus h 0. So, this is half into this value is gamma into H 1 into K A minus 2c root K A, this is this value ok.

So, that is and here the gamma will be gamma P or gamma bulk or gamma dry gamma bulk or gamma dry. So; that means, here it is written gamma T. So, you can write gamma D gamma D H 1 K minus 2c in root over K. Then next part you have to consider this portion this portion this value is again nothing, but the same value. This one and this one the same so, this is the gamma D.

So, this will be the rectangle and that is the rectangle. So, this is the rectangle we are talking about so, this is this value into H 2. So, this is the H 2. So, we are talking this

value into H 2 plus this triangle. This triangle is this is the gamma set minus gamma W this is gamma bulk. So, gamma bulk into H 2 into K A and plus gamma W H 2. So; that means, here you add these 2 and then this will give you this is the force for this triangle half into gamma B H 2 square into K and the for the water one this the third triangle whose height is H. So, this how it is coming this is the half into H into gamma W into H 2 ok.

So, this will give you half into H 2 square gamma W; so, this is the first part. So, first part is this one, this is the second part, second part is this one. This one is the third part, third part is this one, this is the fourth part, this is the fourth part ok. So, these are 4 parts you divide it into 4 parts and you can calculate this portion is due to the water and this portion is due to the soil ok. So, this way we can calculate the forces if the water table is also existing in the c phi soil.

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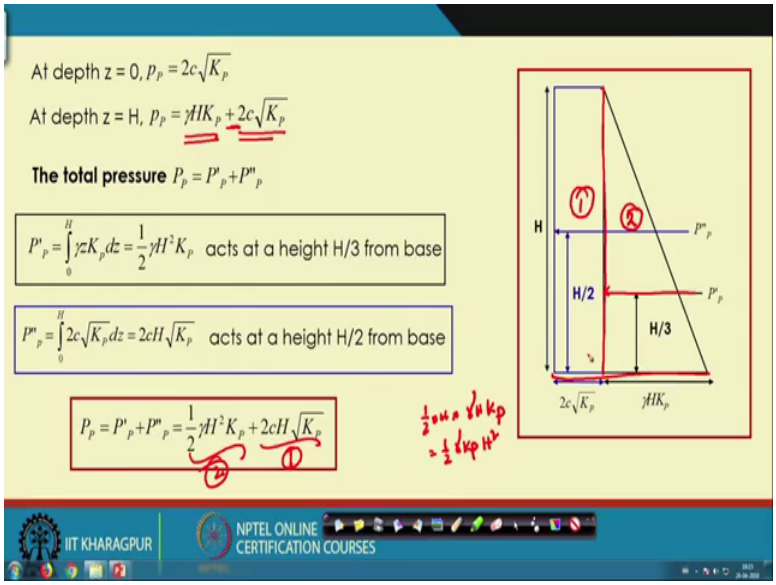

So, this is the passive earth pressure case I have already discussed, but the earth pressure distribution here we are there will be no negative pressure will develop because, here the value is this is gamma H K P plus c. So, this is plus c so, no negative pressure will develop. So, first gamma into h into K P, this is the rectangle this is the rectangle for the 2c root K P. So, this is the rectangle for 2c root K P and then this is the triangle for gamma H K P. So, this is the earth pressure distribution.

So, now we have 2 cases this is first and this is second. So, your first case this is the for the first case and this is for the second case or second distribution of the earth pressure. So, first case this is 2c root K P into H this is the rectangle. And this is half into gamma into H square into K P for the triangle ok because, for the triangle this will be the half into H into gamma H K P. This will be half gamma K P H square. So, this way we can determine the forces, but remember that here it will act at the height of H by 3 from the base. Here for the resistive rectangle it will act the height of H by 2 from the base. So, this way we can determine the forces of passive case also.

So, in the next class I will solve few examples to show you how we can calculate the active earth pressure and the passive earth pressure if it is a homogeneous soil, dry condition and sub match condition with or without surcharge. And if it is the layer soil also layered c phi soil or layered c phi soil ok. And then we will calculate the forces and point or application of that forces also.

Thank you.