Soil Mechanics/Geotechnical Engineering I
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Lecture – 51
Earth Pressure (Contd.)

Well let me continue with some of that aspect of Earth Pressure, we have plant kinds coulombs, we have discussed vertical wall inclined wall vertical level backfill incline backfill all those thing, we have considered how to use them; that we have discussed and everywhere one thing we have considered so far is the granular back backfill and, it is known it is known that granular backfill is advantageous, because it is good drained properties and it has.

So, if there is a water it can drain quickly and pressure of the wall will be reduced in that way, but sometime may be backfill may be used with some soil, which may have some amount of cohesion. So, we need to see how this pressure that can be calculated when the soil processing c and phi both.

So, far our consideration was consideration restricted to granular soil only, now it is with some amount of cohesion; that means c phi soil.

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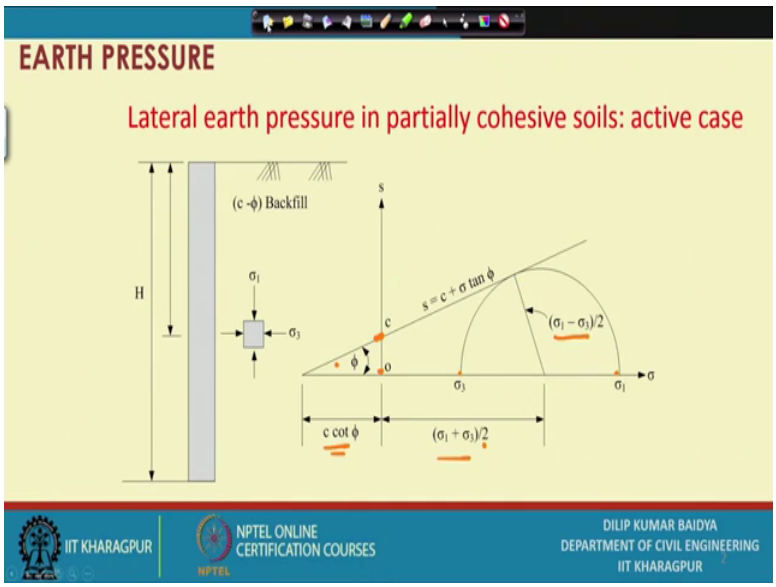

So, let me see that the first slide here, you can see this is the suppose backfill and this is the wall and we are considering the vertical wall for the time being and, you can see that at any point that sigma 1 and sigma 3. And, if it is c phi soil then off course your shear strength envelope will be the equation will be s is equal to c plus sigma tan phi and, this will be in shear strength axis it will act somewhere and intercept somewhere here and, the result tangents to the Mohr circles at failure.

So, Mohr circle this is the sigma 1 and suppose this is active case I am considering this is sigma 1 and at the fully active condition and, we are going to assume this is sigma 3. So, based on this Mohr circle is drawn this Mohr circle again is expected to the tangential to the failure envelope which is so, far whatever we have discussed the failure envelope partial through the origin or axis, but here actually it is not partial through it intersecting the shear strength axis. And now this angle; obviously, has to be filed and, if it is so, geometrically this portion will be c cot phi and, again this portion will be definitely sigma 1 plus sigma 3 by 3.

And this radius will be sigma 1 minus sigma 3 by 2. So, these are the things if it is known, then using the geometry again the way, we have done active case for phi soil. Similarly we use this triangle now, we will use this triangle and from the geometry you can see that relationship between sigma 1 and sigma 3.

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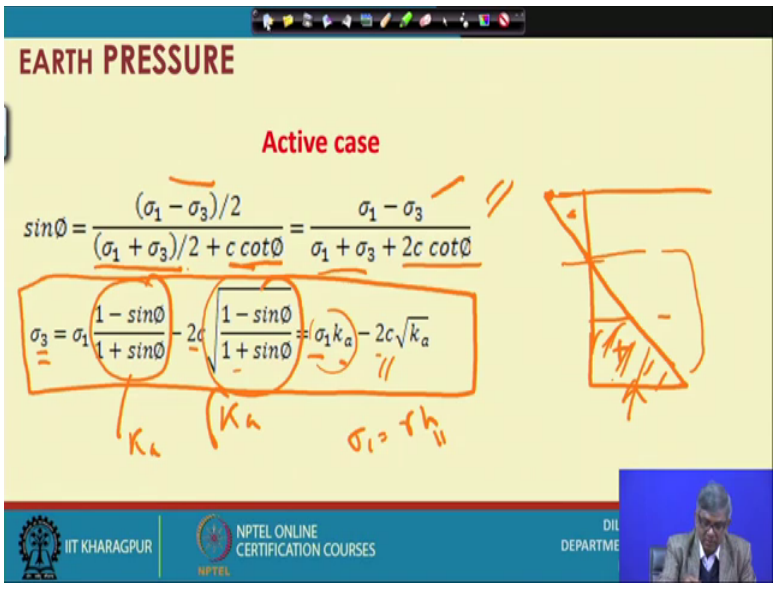

So, if I go that way. So, let me see the next slide you see that so, sin phi I have expressed in sin phi sin phi will be radius divided by this distance. So, this distance will be go back and go back sin phi will be sin phi will be nothing, but this by this, and this is actually radius and this is actually this plus this.

So, this is the thing is done there also this is the thing done there also you can see, you can see this is the radius first and this is the radius and this is the from the 0 to center of the circle and plus from the 0 origin to the vertex of that triangle c cot phi. So, this is the so if I little simplification, if I do it will be sigma 1 minus sigma 3 divided by sigma 1 plus sigma 3 plus 2 c cot phi. So, you are getting this expression and this is sin phi in terms of expression. So, I have to express sigma 3 in terms of other parameters like c phi and sigma 1.

So, if I this one is several stage, if I do and simplify it will reduced to this it will reduced to this form, the sigma 3 will be equal to sigma 1 into 1 minus sin phi 1 plus phi sin phi minus 2 c under root 1 minus sin phi 1 plus sin phi. So, you can see this is actually nothing, but as per Rankin K a and this is actually is this portion is nothing, but root K a. So, I can write sigma 1 k a minus 2 c root k a; that means, if I consider now ground surface here and, when your depth is 0 H equal to 0. So, sigma 1 will be equal to gamma times H and so, when gamma is 0 sorry when h is equal to 0 then you can see that sigma 1 will become 0; that means, this portion will be 0 that means, sigma 3 will have a negative value.

So, that value is suppose this negative value is there and, then with the increase of the it increase of the h the value will be again this plus and minus in this and equal they will become sometime 0 and, then this plus value become the that will become positive at some day. So, the pressure diagram for c earth pressure diagram for c phi soil this is minus and this will be like this.

So, this is the only difference the k a expression is same only because of the c, we can see that pressure diagram is changing and, where depth equal to 0 there is a negative pressure at this surface and, that negative pressure means what it creates ten circular soil and so, that is actually minus 2 c root k a and with the increase of h. The value become negative value decreases and some time it become 0 and then finally, it become positive

this is the value at the bottom of the suppose value. Now so, now you can find out the what is the thrust sometime we can this much minus this much minus get cancels.

So, this will be the only thrust this is the pressure only acting as thrust, sometime to make say for we ignore the minus part, only we consider the area of this and that too consider the thrust otherwise it can be done. So, this is 1 part I will just show next I will go to the passive case you can see passive case.

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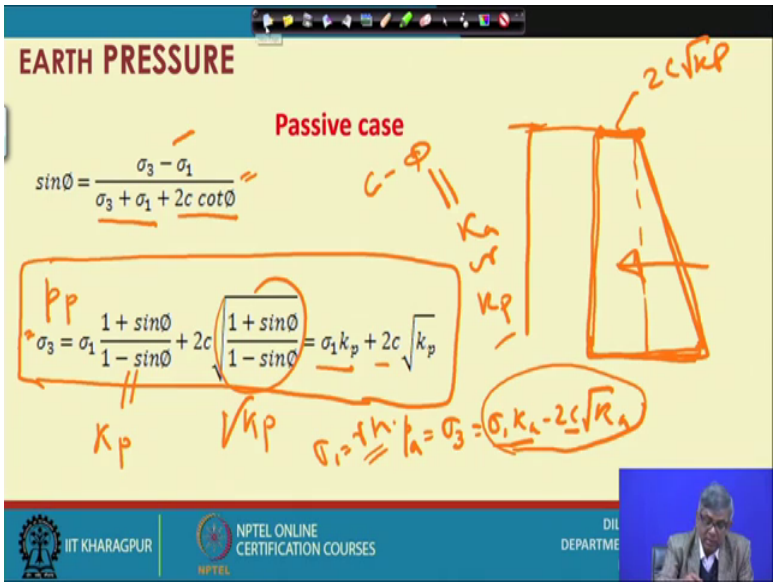

Passive case again it will be same sin phi and will change, let me go back once again. So, these become a actually these becomes sigma, when it is a passive case this is the original and then it is final ok. So, this is the only thing. So, otherwise everything change so, this becomes sigma 3 this becomes sigma 1 that is the only change. So, this change if I do accordingly if I ultimately this by this is sin phi. So, if I do that so, passive case your expression for sin phi will be sigma 1 minus sigma 3 by sigma 3 plus sigma 1 2 c cot phi sigma 3 is a bigger there actually.

So, this way if I write and now off course if I express sigma 3 in terms of sigma 1, then I get this expression I get this expression; that means, what sigma 3 equal to sigma 1 plus sin phi by 1 minus sin phi plus 2 c under root 1 plus sin phi by 1 minus sin phi this is nothing, but k p this is nothing, but root k p. So, I can write sigma 1 k p plus 2 c root k p. So, if there is a ground here ok, and see if I want to find out the pressure diagram.

So, sigma 1 is nothing, but gamma times h so, at when h is equal to 0 this component become 0, but this components it will be there. So, because of that there will be a positive value at this point which will be equal to 2 c root k p and, this is suppose this is the wall phase and this is the value. And from this value further when h is increasing.

So, this will be adding so; that means, from here it will be sloped, so, diagram will be something like this and it is a passive case, then earth pressure diagram will be some positive value at the surface and again some positive value at this top of the diagram and to find out the total thrust on the wall, or you can find out the area of this diagram to find out the area of this diagram I can make a triangle and a rectangle, or you can both the area of the trapezium based formula and centroid that also, you can be used otherwise these area of this diagram is the thrust which will be acting somewhere there.

So, this is actually some extension of rankines and coulombs theory, when there is a some amount of c is present to the soil. So, what is the active so, because of the presence of c your earth pressure coefficient either in active, or passive case is not changing soil processing both c and phi based on phi we find out k a or k p.

So, this same thing will be there. And now while finding out the this sigma 3 is nothing, but here actually it is nothing, but p p p passive pressure intensity and, so we are getting the p p in terms of these sigma 1 k p and c ok. So, this is the way you have to do and, similarly whatever we have got there active case we have got sigma 3 equal to sigma 1 k a minus 2 c root k a, there also you can see this sigma 3 is nothing, but p a active pressure intensity, which is respect to vertical pressure intensity cohesion and active earth pressure coefficient. So, this 3 thing the 2 things also I have a just may be highlighted in addition to the granular soil.

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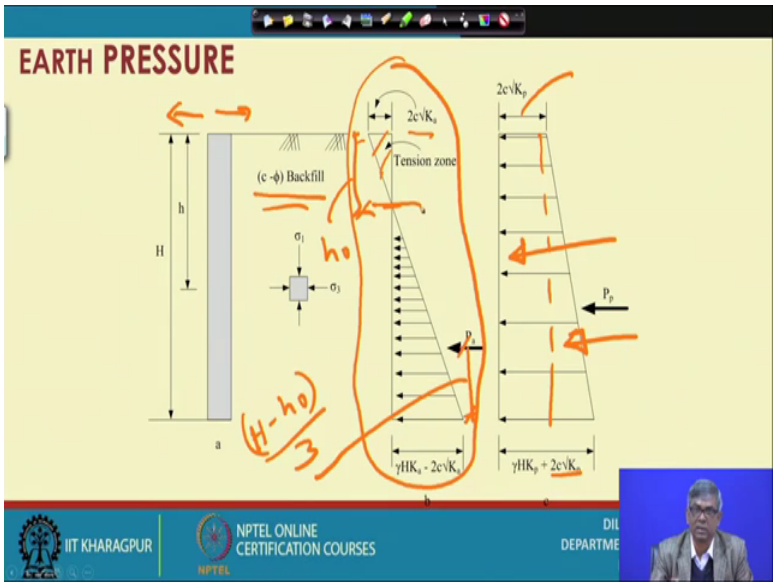

Next let us see the once again together active and passive how is the pressure diagram I will show again. So, you can see here the soil cohesive backfill and with having c and phi and sigma 1 and sigma 3 like this, because of the wall movement in this direction or these direction. So, moves these direction this is the active case and your pressure diagram will be something like this, at this point 2 c root k a at this point gamma is k minus 2 c root k a.

And when it is wall moves this direction then your pressure diagram wall will be 2 c root k p and at this point will be gamma h k p plus 2 c root k p. So, this 2 things to be remembered and to find out the thrust, you can ignore this portion take this triangular area find out the area diagram and at 1 third of this p naught in terms of height of the wall, you have to find out where it is 0 from there.

So, if it is h naught at a height it is becoming 0 h naught. So, this will be this will be H minus h naught will be the height this is the height divided by 3 the point of application where as for these the point of application you have to find out you can divide into 2 part rectangular part will be at the midpoint, triangular point will be at H by 3 time, then resultant at resultant point of application can be obtained by taking moment ok.

So, this is the diagram you have to understand, sometime without calculation also if you do not know the value of c phi or anything, but if it is asked to find out the active

pressure diagram passive pressure diagram for a c phi soil, this is the diagram you have to show in terms of this parameter no need to have values.

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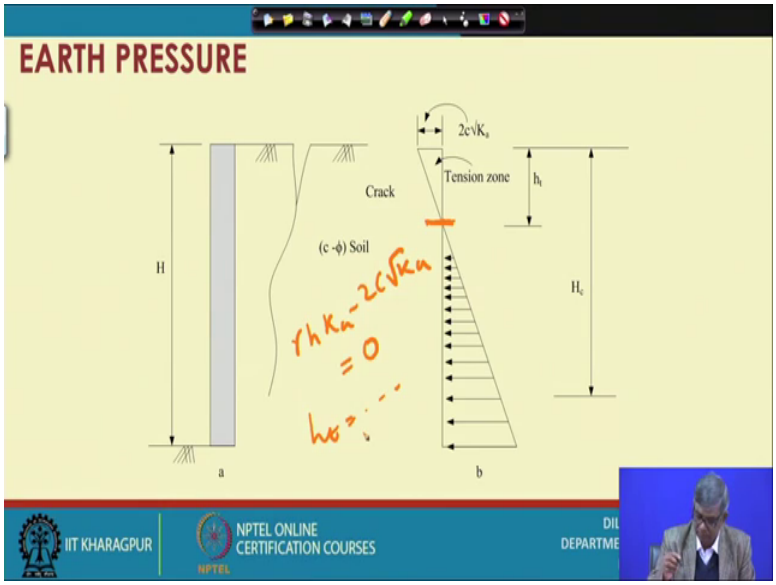

Now, you can see as I have mentioned that when it is active case, you have you will have negative pressure negative lateral pressure negative lateral pressure means, what it is tension when there is a tension means while actually will have cracks. So, this is the way it can crack actually for c phi soil. So, we can find out what is the depth at which tension will create.

So, what is the bases actually you considered; that means, the crack will reach up to a point where, your pressure is 0, neither plus nor minus. So, you have the expression gamma h k a minus 2 c root k a this is the expression so, at this point if I equal to zero; that means, how to find out this depth of tension crack, we assume that at a depth where tension crack will reach, or it will not go beyond that that is the point where actually pressure is 0.

If I say t equal to 0 from there will get h equal to h t which I will show the next a slide. So, h t will be there will be some expression will get finally ok.

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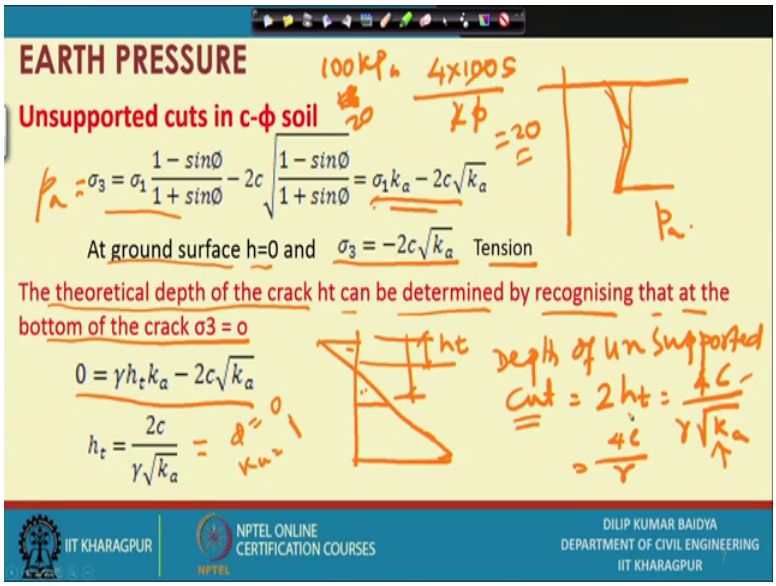

Then you can see now unsupported cut that is what our ultimate aim upto what that tension crack will go in some area, it is useful some calculation it will useful, but in many time many a time what we do is escalation, suppose there is a soil you have to escalate it a quite deep and these escalation; obviously, if you know the soil is sandy, then we cannot do without any support any escalation because, now as soon as you cut soil will flow and come to the escalated portion, but if the soil is processing some amount of phi, generally it can vertically you can cut up to some depth ok.

So, that some depth is what that you have to find out. So, for that you can see that we have already expressed sigma 3 or it is actually you can say p a equal to sigma 1, 1 is the expression you have got at a ground surface h equal to 0 sigma 3 becomes this and tension, that negative pressure is started from surface and this negative pressure will go up to some depth also. The theoretical depth of the crack at h t can be determined by recognize that and the bottom of the crack sigma 3 is 0, suppose that crack is formed something like this way crack is formed.

So, at this point at least your sigma 3 is 0 or sigma 3 or p a intensity of active pressure is 0. So, if I assume that then I can write this expression 0 equal to gamma h t k a minus 2 c k a. So, if I simplify this then your h t become 2 c by gamma root k a, but this is not the actual unsupported cut depth, since your pressure diagram is something like this, already I have mentioned is something like this.

So, this is negative pressure and; that means, to balance this negative pressure another similar depth actually you can go for ultimately infect, twice of this h t this is this is h t twice of h t you can discover it without any support so; that means, depth of the unsupported cut depth of unsupported cut will be equal to twice h t equal to four c by gamma root k a ok.

And if it is purely cohesive soil if the purely cohesive soil, then this unsupported cut will be 4 c by gamma and you can see now, if it is a c value of a soil is 100 k p a c value of soil is 100 k p a and, then 4 c by 4 into 100 divided by gamma suppose 18 kilo meter per meter cube, or suppose I take for the simplicity I take 20, if I take 20, then this gives you 5 and it 20 meter; that means, if a soil a soil is having only c which is having 100 value k p a low soil that soil theoretically actually almost 20 meter you can vertically cut without any support ok.

So, this is the 1 similarly we have got the expression for p a and p p, if all purely you can say granular soil and c phi soil, but if you have only if you have only c soil, then what will be the value of earth pressure that also you can find out when phi equal to 0 phi equal to 0 k a equal to what 1 is it not. So, so this value directly gamma into h will be there minus 2 c.

So, that also you can modify or there is a no where no friction is there in the soil purely cohesive soil then also got that how to find out pressure only k a become 1, k p become 1 and correspondingly this expression will remain unchanged, only thing k a k p value will be 1. And this is the generalized expression for unsupported depth of cut equal to 4 c by gamma root k a and if the soil is purely cohesive without any friction, then the equation modified to 4 c by gamma because, root k a means k a actually become 1 when phi becomes 0.

So, 4 c by gamma and taking 100 as the your as a cohesion value. And then you can see that at a site where only purely cohesive soil is present with a c value of 100, then we can have an escalation upto 20 meter without any support.

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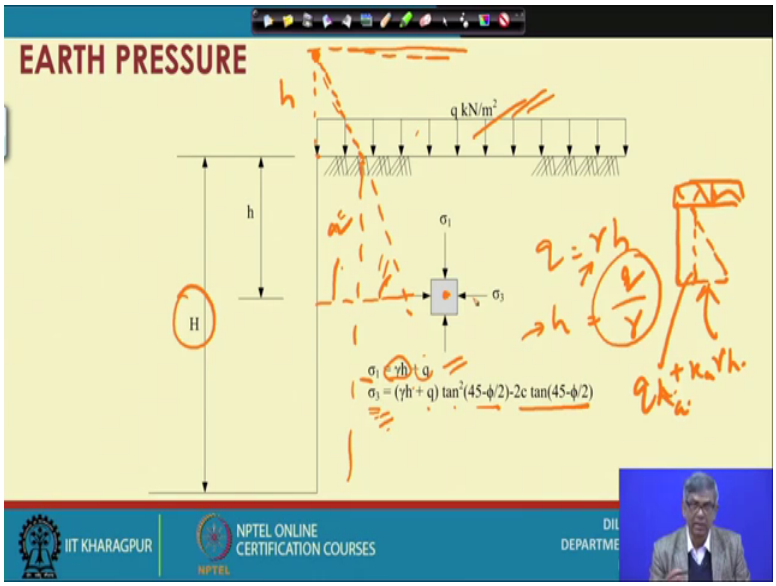

Next you can see now there is one more part I have only considered so, far the only the backfill, sometime on the backfill also over the backfill there may be priorities of equipment may be there, for some work, or some other reason some loading may be there. So, if there is a cost and loading over the surcharge in the form of surcharge is there, how to find out the pressure diagram.

So, these pressure diagram we can assume, this key surcharge can imagine as suppose, we can take q equal to suppose gamma h, assume gamma equal to soil gamma, then h equal to h equal to h equal to q by gamma, we can imagine here the wall is not here is wall is somewhere here and is a h is there, this actual height of the wall is here.

But another wall above that is there small h, which is equal to q by gamma and, if I draw the pressure diagram from here, it will be reaching to this value. This is the this is the way you can 1 can visualize, then if I consider the wall is started from here, then because of this rate of the soil at this point what is the pressure this is the pressure. So, that pressure will be constant and, because of this soil again there will be additional pressure, that is the way actually you have to do this is the philosophy see, if I consider this way.

Then you can see at any point any point you will have sigma 1 will be gamma h plus q will there, I I can consider this is the pressure and, then because of the soil again pressure is increasing like this. So, in that case what will happen this pressure is there that is q

plus this. So, that is gamma h plus q so, this is gamma h this 1 plus q. And similarly if it is c phi soil, then it is gamma h plus q tan square 45 minus q plus 2 c tan this one.

So, sigma 1 this one and sigma 3 this one, this way you can this is off course in general generalize c phi soil is considered and, based on that both the expression is given so; that means, if there is a if there is not c phi soil also, if there is a surcharge is there. So, what you have to do, if there is a wall here and surcharge is there sorry surcharge is there, then pressure diagram will be will have a because of these surcharge.

There is a diagram which will be equal to q times k a and then because of the soil this will be also k a times gamma into h this 2 together will be the pressure. So that means, you have to find out pressure will be at this point will be q plus weight of this soil and that has to be multiplied by the coefficient of earth pressure. Similarly if it is a passive pressure then k p will be multiplied.

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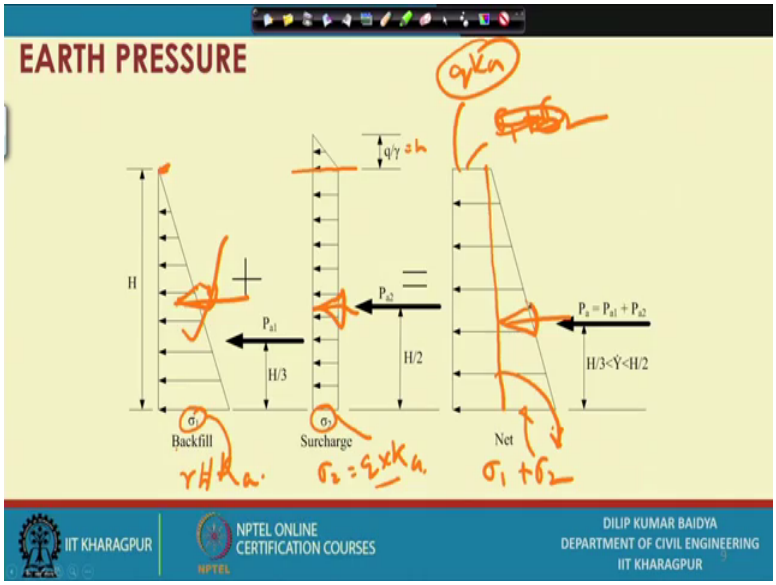

So, if you take this except this philosophy, then I can so in the next slide you can see corresponding to this you can see because of the soil pressure from here this is the diagram, sigma 1 which is actually you can say gamma into h into k a. And this is the diagram as I have assumed that height, this is actually height because of this height it will become pressure this much. So, if this is the pressure is constantly acting. So, this sigma 2 suppose q was acting so, sigma 2 will be q into k a and then, your total diagram will be sigma 1 plus sigma 2 here sigma 1 plus sigma 2 and here also will be sorry sigma

1 plus sigma 2 will be here it is sigma 1 I have written sigma 1 plus sigma 2 and, here also whatever value will be there these 0 will be there and, here it will be q into k a, this will be q into k a, this will be q into k a will be this value and here actually sigma 1 and sigma 2 that under that sigma 2 is this one.

And sigma 1 is this one so; that means, if there is a surcharge also you have to you can you can just forget about the surcharge, whatever the normal loading is there you find out the pressure diagram, additionally because of the surcharge if there is a q intensity of the load on the surcharge backfill is there, then simply a multiply by k a or k p depending upon whether it is active or passive and, that pressure is keep constant throughout the depth.

And then, find out the any diagram area of the diagram all the diagram and that will be the total active thrust total passive thrust and, to find out the point of application; obviously, you have to find out individual point of application here individual point of application here and, then resultant point of application here. So, that might taking the moment considering the moment equilibrium you can do this.

So, I actually by this, I have all most completed various aspect of the earth pressure calculation which is required undergraduate level. Only thing is I need to now take problem I have mentioned you can calculate this way that way. The ultimate relation do, what are the difficulties will not understand. So, I will take a number of problem may be in 6 7 problems I will take may be more than hour of 1 and half an hour I will spend, on solving problem, different types of problem, level backfill, incline backfill, layered backfill, then c phi soil all those combination and only granular backfill and c phi backfill together all combination with surcharge without surcharge.

All those combination I will take some problem and try to show the solution procedure solution here, is what you have to find out active pressure diagram or passive pressure diagram finally, active thrust which is nothing, but the area of the diagram. And then find out the point of application on the thrust. So, those things I will take in several 2 3 session, I will take a quite a good number of problem to show the application of whatever you have discussed in last 5 - 6 sessions.

Thank you.