Geotechnical Engineering II / Foundation Engineering
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Lecture – 47
Sheet pile wall

Good morning. Once again, I welcome you to this lecture series on Foundation Engineering and we have already completed a number of topics. For example, trail investigation, shallow foundation, deep foundation, retaining wall and while discussing retaining wall I have mentioned about different types of wall and out of which we have only taken gravity retaining wall, cantilever retaining wall and to for some extent retaining wall just I have given a just taken introduced.

But, I have mentioned another type of wall that was Sheet pile wall and that was particular application and again in sheet pile wall also can be of different types. So, let me start with that sheet pile wall.

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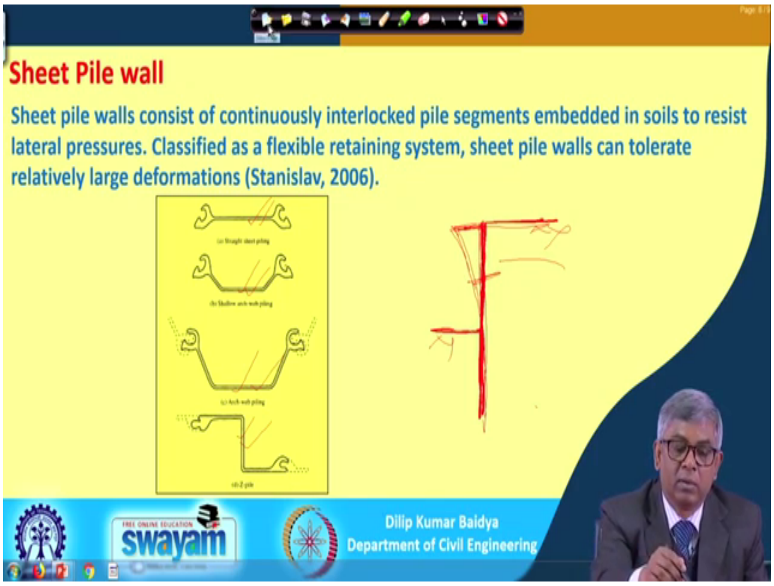

And you can see that sheet pile wall consist of continuously interlocked pile segments embedded in soils to resist lateral pressure and classified and it is classified as a flexible retaining wall and because it can resist a large amount of lateral deformation. So, if I typically if I show the elevation it will be something like this and it will be embedded here and it is our ground original ground mark.

So, if it is so, this is actually thin sheet like material thin sheet and the cross section of the sheet are can be like this, can be like this, can be like this or can be like this. So, these are the steel sheets and there is a interlocking. So, there is one another can be connected and one by one then laterally it can be extended and it has a dimension actually depending on requirement depth will be also will be cut accordingly. So, this is seen actually cross section and it is perpendicular to the pole will be the elevation.

So, this is actually length suppose required. So, this will be embedded, but typically if I cut here I may see this, I may see this, I may see this or I may see this. So, like that if this is the ground mark and this is again ground mark and if it is a thin sheet like this, then because of this pressure it will deflect something like this ok. So, that means, in normal retaining wall we do not allow that much deflection, but here it can undergo large lateral deformation.

So, that is the a difference with normal or regular retaining wall. So, this is the your sheet pile wall typically cross sectional things how it deforms.

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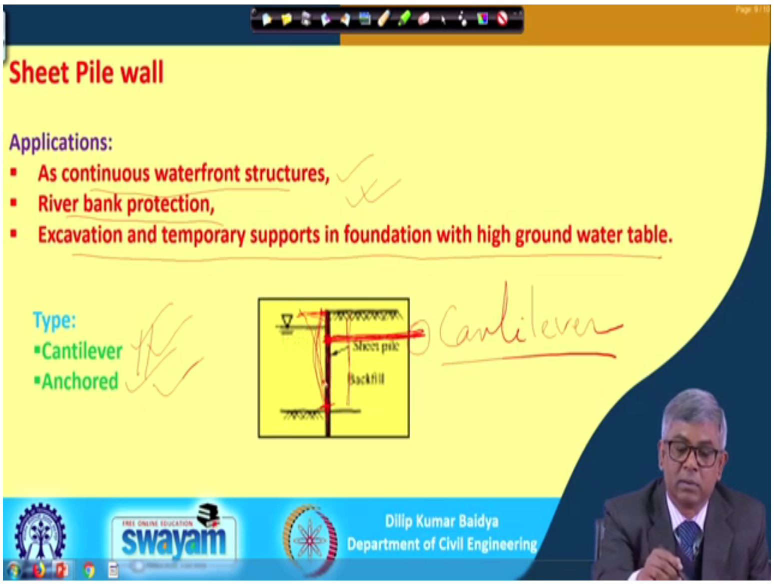

Now, let me see this one actually this is the applications various applications actually you can see the as continuous water front structure. So, like jetty and all that places this sheet pile wall would be there river bank protection. So, there is a river bank to be protected then continuous sheet pile wall can be given then that will help to register erosion. Then excavation and temporary supports in foundation with high ground water table. So, when you want to go deep excavation particularly then you can have this kind of support and then either temporary or permanent.

And again these are the application different type of application of (Refer Time: 04:09) sheet pile wall and again this sheet pile wall again further can be classified in two ways either it is cantilever or it is anchored. So, you can see here that this is the typical example of cantilever retaining cantilever. Why it is called cantilever? Because it is see embedded portion and this is the elevated portion. So, this is this much depth of soil it is supporting by this wall and there is no this portion if I consider this is fixed and this will bend like a cantilever beam. So, that is why it is called cantilever sheet pile wall.

And if the deformation is because of this high excavation if the deformation is too large sometimes to reduce the deformation somewhere in between anchored it will be gone inside and by different ways this anchoring can be done. So, if it is this type of connection is given then that is called anchored sheet pile wall and this anchored sheet pile walls purpose is reduce the deformation.

So, here actually if it is free deformation can be so much and if you do that your deformation will be something like this. So, your top deformation will be reduced significantly, so, something like that will have deformation. So, this is a different means cantilever and then anchored. And so, this is the example of cantilever now I will go to next that is your anchored retaining wall.

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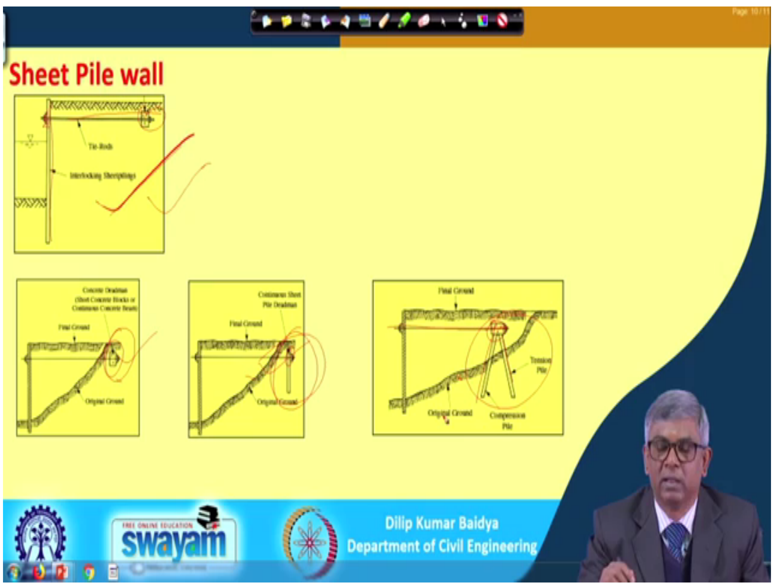

Anchored sheet pile wall, you can see this is the typically anchored sheet pile wall. This is the sheet pile wall and this is anchored and by some means an anchoring can be done different ways and you can see this one dead weight can be kept here or there can be continuous wall can be built where it will be tied or there can be some better pile and then there will be some connection. So, this is can be connected.

So, this is different ways of anchoring. This is three different types of anchoring. In general anchored means when that will from the ground level below the ground level at some level if it is connected to the sheet pile and it is anchored somewhere that is called anchored sheet pile wall. And what are the different ways of anchoring? This is one, this is the one by wall this is the wall sometime better pile connection here.

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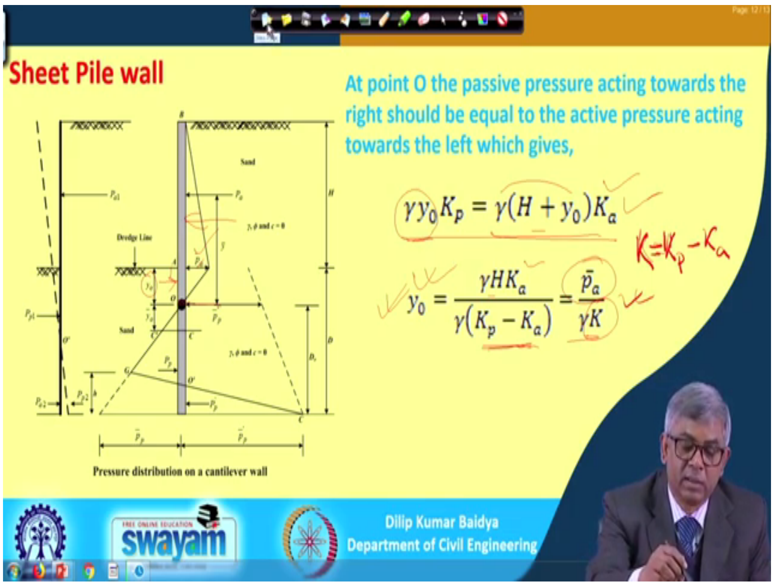

Next, actually now as I have shown before that your retaining wall flexible retaining wall and you can see deformation typical deformation when it will be ground mark is here and it is cantilever and this is embedded then the wall typically rotate like this. If it rotates like this then what happen this is this portion is active and this portion is passive and again this portion is active.

So, these are the three different zones are there and if you typically plot the pressure diagram then you can see the pressure will be it will be active pressure diagram here. And then when you go deeper then because of the addition of the passive pressure it will become 0, somewhere then it will become some value and again this side there will be some this side again passive value will be there. So, this will be this side is passive, this side active. So, here actually this side active and here in this zone this side actually your passive and this side active, this side shows similarly here also reversed.

So, this is the typical pressure diagram and you can see if the H is the cantilever portion then you need find out most important part in this cantilever retaining wall to determine the how much depth of embedment is required ok. So, to find out that, so, there are you can see here there are two part from where actually your pressure become 0 from there to the end of this actually if D naught if you say and if I from here to here if I say y naught, the depth required will be D naught plus y naught.

And this actually then we can that is one thing that you have to find of the depth of the embedment and similarly at the same time the sheet pile wall actually thin actually depending upon your the bending moment you have to choose a section. So, that is why that you have to find out also the bending moment.

So, that part I may not discuss in length mostly I will try to find out depth of the embedment that is the only part I will discuss in length. So, here you can see that D can be, so, D actually a total embedment depth and based on this pressure diagram I can show two parts that is D naught actually from 0 where the pressure become 0 to the end that is D naught and from the dredge level to the where pressure become 0 that distance is suppose y naught this two together actually your depth of the embedment required.

And once based on this calculation whatever depth of embedment we will get and to have the definite factor of safety we can increase by 20 to 40 percent actually that become the final depth of embedment.

So, we can see here again when you have the sheet pile cantilever sheet pile wall then from pile actually the embedded zone that is this is zone and this is the retaining zone. So, two zones are there. So, this type this zone generally it has to be cohesion less, the sandy soil and this portion if it is sand is good otherwise also it can be possible that it can be either sand or clay soil clayey soil.

So, that means, we can have again different combination sand continuously sand here, sand here, then one type of analysis then again sand here and cohesive soil here. Then there will be analysis will be another type of analysis and if it is both places cohesive here and cohesive here ok, that is also another type of analysis, but that is rarely used because this zone cohesive soil hardly will be used. So, we will not discuss in length only I am telling you the different combination; that means, only sand that is retained soil also sand, embedded soil also the soft sand. And retained soil is sand and embedment is done in cohesive soil then that will be another type of analysis.

So, this is the typical pressure diagram. So, one by one actually you have to find out different parameter y naught. So, different terms are shown here p p double dash, P p bar, P p dash bar and then these are the things we have to find out actually and then based on that we can find out D naught. So, before going to D naught let me find out the y naught where actually y naught will be there because your at this point actually 0; that means, at point O this is at point O the passive pressure acting towards the right passive pressure acting towards the right from here and active pressure right should be equal to the active pressure acting towards the left. So, this side actually active pressure this side actually passive pressure.

So, this passive pressure and this active pressure must be equal. So, that is what if we would we had done if this depth at your pressure become 0, if it is y naught then gamma times y naught multiplied by K p is the passive pressure from here and this side what is the active pressure? Active pressure will be up to this, so, H plus y naught H plus y naught multiplied by gamma into K a. So, that become active pressure from the right passive pressure from the left side left and this must be equal because I am getting at this point 0.

So, this if I equate then I am getting a y naught; y naught will be gamma HK a by gamma K p minus K a and gamma HK a actually gamma gamma get cancelled and HK a no sorry gamma HK a is given as p a bar that is the one p a bar gamma HK a and K p minus K a is written as K actually K p minus ka is here nothing, but K p minus K a ok. So, this; that means, if I can calculate what is the active pressure at this point what is the active pressure at this point divided by gamma times K p minus K a if I do then I will get y naught, that is, first parameter is obtained.

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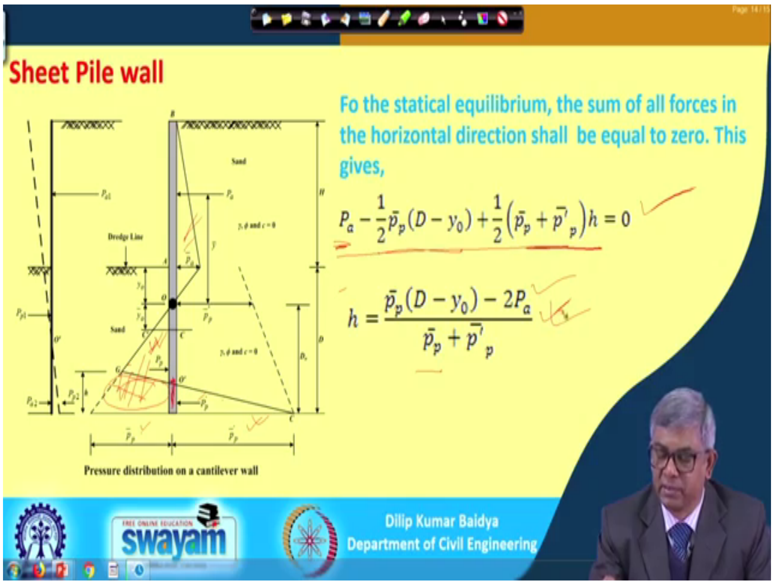

Next part will be you can see here next part for the static equilibrium; that means, if this is the pressure diagram and effective pressure diagram actually this one you can see this is the pressure diagram these are the final pressure diagram of this because of this bending the pressure will be this side and then pressure according to the bending shape of the wall actually pressure diagram will be like this.

So, we can say for static equilibrium that the sum of the all forces in horizontal direction from the left and right must be equal and if I want to do that then you can see that this entire thing is nothing, but P a this is P a minus half p p bar half p p bar this one half p p bar D minus y naught and total depth is D, D minus y naught. So, this portion I am taking this portion I am taking this portion plus half plus this become this is plus and this will be plus and this is minus. So, P a minus this plus half p p bar minus p p bar dash.

So, this is actually p p bar dash plus p p bar this one; so, this area actually ok, so; that means, I need to take this area, but I have taken this area because of that I am now taking this area so; that means, 2 I ones plus and minus. So, this will be ultimately eliminated. So, this is the way it is done. So, you can see I have taken I have to take this area I have to take this area minus this area plus this area. So, what I have done I have taken this area, I have subtracted this much area; that means, I have subtracted this much more.

So, what I have to do while adding this now if I add this and this then this is actually whatever subtracted this will be again added so, it will be balanced. So, this is the way the force equilibrium is done and if you simplify then your h become p p bar; that means, this one D minus y naught minus 2 P a; that means, this one area of this diagram and divided by p p bar plus p p bar dash; p p bar dash is this one.

So, this is the another expression of h we are getting and the h is shown here actually; that means, where actually this from the ground where actually this from active to passive it is happening that actually you have to find out. So, this is h we have calculated.

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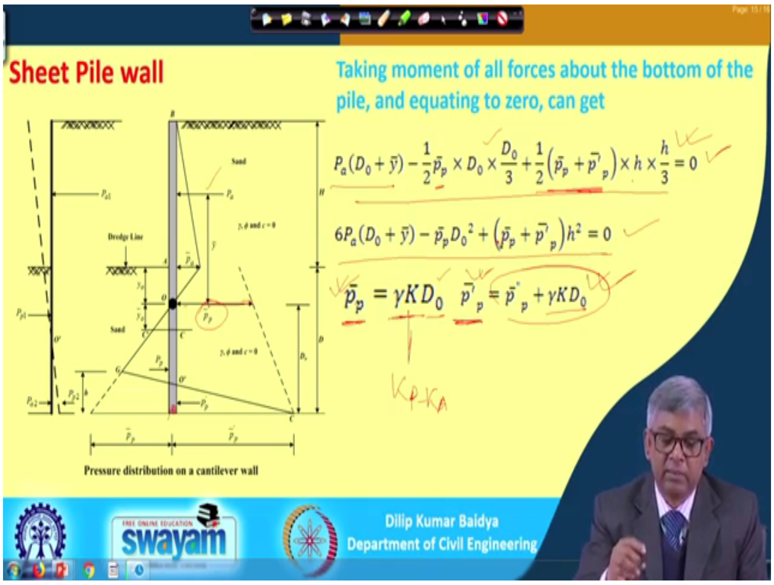

Next part will be next part actually you can take the moment with respect to the bottom of the pile. So, here actually if I take all forces if I take moment here and that must be also equal to 0 because there is no other external moment acting on it. So, you can see P a P a moment D naught plus y bar D naught P a actually if I take. So, this is D naught plus y bar. So, suppose this area is acting somewhere this resultant of this force is acting suppose somewhere here; so, P a multiplied by D naught plus y bar and then a half p p bar this one D naught multiplied by D naught by 3, so that one third distance plus this force multiplied by h.

So, this area and multiplied by H by 3. So, this is the moment taken from this and if I simplify then it become like this and 6 P a D naught plus y bar minus p p bar D naught square plus p p bar plus p p dash bar h square. And now p p bar if I can say gamma h gamma K D naught, if I say p p bar equal to gamma K D naught gamma K is here K a K

P minus K A K P minus K A and p p dash bar will be nothing, but p p double dash bar plus gamma h K naught. So, that means, p p double dash is this one you have to find out this one.

So, if I this if I express this one by this and this one by this and if I substitute all in this then further it will be simplified to a form.

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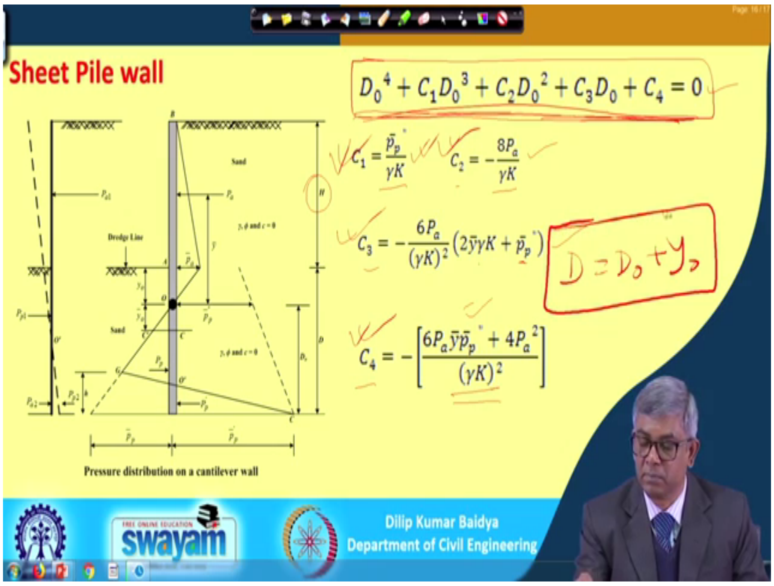

You can see it will be modified it will be reduced to actually you have to substitute those and then simplify and that can be again finally, retained in this simple equation form and where D is the function D naught is the function and C 1, C 2, C 3 and C 4 are four constants.

So, what is C 1 actually? C 1 is actually p p double dash bar by gamma K, C 2 is minus 8 p a by gamma K, C 3 is minus 6 P a gamma K square 2 y bar gamma K plus p p double dash bar C 4 equal to minus 6 P a y bar p p double dash bar plus 4 P a square by gamma. So, everything what is what it is shown in this diagram accordingly you can calculate and then; that means, you can calculate coefficient C 1 by this, coefficient C 2 by this, coefficient C 3 by this, coefficient C 4 by this and then put these in these equation and then this equation will be f equation of D naught of 4rth order equation of D naught.

Then this equation actually can be solved different ways in the exam or for solving depth of the foundation depth of the embedment here, we can solve this one by trial and error method. But, trial and error method how you will start actually? If this is the H then first of at the beginning you can start with embedment depth equal to the same depth and see the result of this and accordingly seeing the value of net value plus or minus we can decrease or increase. And finally, you will get a value where actually for a particular D naught it gives you close to 0 and that will be your depth of not depth of embedment D naught and if you with D naught if you add y naught you will get the depth of embedment.

So, this is the way; that means, I we have explained in this diagram what is what here and then based on that you calculate coefficient 1 C 1, coefficient 2 C 2, coefficient 3 C 3 and coefficient 4 C 4 and then this equation can be used D naught to the power 4 plus C 1 D naught cube plus C 2 D naught plus square plus C 4 equal to 0 and by this we given a we are getting this 4th order equation by trial and error method we can solve it to find out the D naught once you get the D naught then D become D naught plus y naught. So, this is the way one can find depth of embedment. And now I will go to a next slide.

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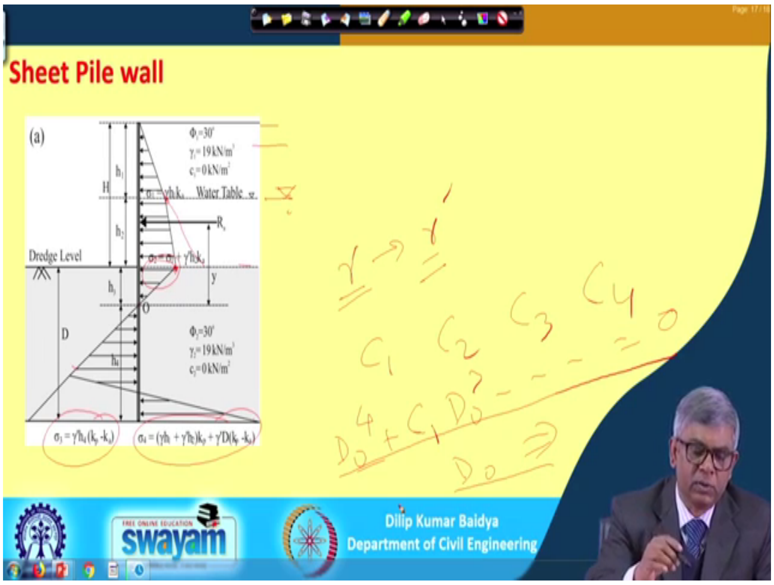

You can see here what I have shown here with this typically this type of retaining wall always there will be water table actually; water table will be somewhere here or it may close to the surface in your at least at your dredge level water will be there. So, because of that if there is water level table present, then how will be the analysis? What is the difference?

The everything will be same actually we can see only the pressure diagram will be change and how it will be change? Wherever there is water table below water table wherever there is a gamma will be replaced by gamma submerge. So, accordingly it was something like this, now it is reduced here.

So, similarly everywhere wherever there is gamma you can replace by gamma submerged accordingly this coordinate will get here everywhere it will get coordinate and that will be your final pressure diagram. And after getting that pressure diagram you can again whatever notation I have given here, whatever notation I have given here all can be kept unchanged and again using those notation again we can find out C 1, C 2, C 3 and C 4 and then finally, you can find out D naught to D 1 plus C 1 D naught cube to this equation equal to 0, then you can find out again D naught.

So, I have taken actually without water table what if there is water table anywhere what is the change only change in gamma will replaced by gamma submerged below the water table. Rest of the calculations are the same calculation of C 1, C 2, C 3, C 4 all are same then finally, I expressed the equation forth order equation and then solve for D naught that is all. So, if there is water table it is it will become complicated definitely. So, because of that I have I have not doing in terms of water table I have considered in terms of without water table ok. So, if there is water table this is the only change you have to take.

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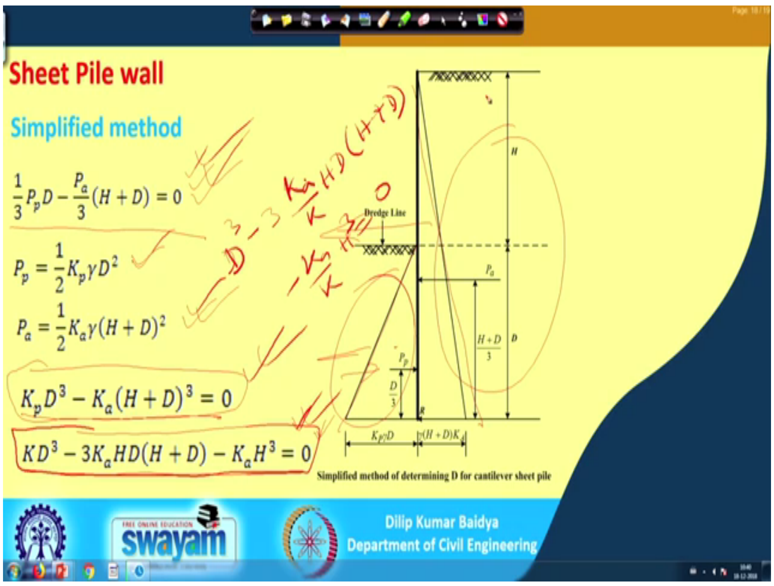

Now, next slide if you have if; you have; if you have suppose this is the one what I have done actually approximate real regression analysis we have done based on the bending of the retaining wall where it is becoming active, where it is becoming passive accordingly in the pressure diagram I have changed and I have taken all the effect of all. But there is a another method which actually simplified with and where actually we will not take all those complication I will consider since the wall this side wall is retained I will consider the wall this tendency to have move this side. So, this side I will consider that active and since the wall, this side wall is pushing this side and consider this side is passive, entire passive this is entire active. This is the way if I take then their calculation will be very very simple.

So, based on this you can see here it is done; that means, if I do simplified method; that means, this pressure and this pressure equal to. So, if you do that then you can get this equation and then P a is this and P p is this and P a is this. So, this if I substitute in the this equation then I will get this equation. I am getting this equation and this equation further if I expand then I will get equation or cubic equation I will get. This is the cubic equation and from this cubic equation you can see KD cube 3 K a H or I can further simplify simplification can be done D cube minus 3 K a, sorry K a over K HD H plus D minus K a over K H cube this is the way also can be expressed otherwise this is also ok.

So, that means, what I have done sheet pile wall this is the sheet pile wall the entire wall assumed this is the moving this side. So, entire this side is active and since wall is moving the entire this side is passive. So, this passive force and this passive force and this passive force must be equal, that is the thing I have written here. Then express the P p express P a substitute this equation and then simplify you will get this and further expanding and expressed in terms of D cube then you can get this is the equation.

This is again the equation of cubic equation. You can solve it by trial and error for D and that D if you compare with regression analysis will see that there will not be very close there will be some difference obviously, we can use a factor of safety compensate that. So, this analysis sometime particularly for class examination this is the this method is more applicable for you. In fact, your regression analysis I have shown that in the exam you can expect only the simplified method that is this is the method.

So, if the wall height is given H how to find out how to find out the D I showed depth embedded D then you can find out K active pressure on a wall height equal to H plus D and passive pressure on a wall height of D and then equate active pressure and passive pressure, simplify it and then express the equation in terms of D and then solve for D that is the way and that is actually important for exam regression analysis is only for showing you I have done, but this is very difficult to do in the exam. So, may not be important, but this is the one you can practice more.

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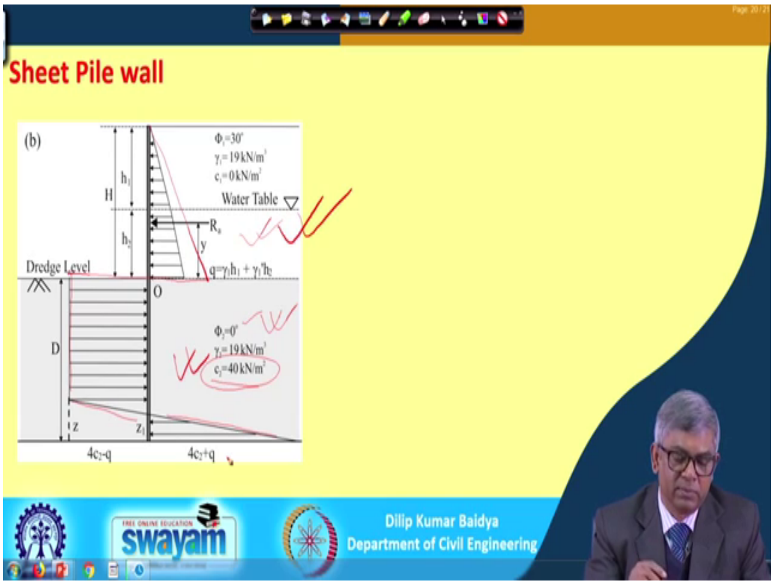

Next, actually I will show you that whatever I have told at the beginning that sheet pile wall can be of different combination; that means, above dredge level it is sand above dredge level sand and below this level this is actually cohesive you can see phi 0 and it is having a value of c. So, in that case your pressure diagram will be if it is no water table it will be like this, then it will go like this then this is again best of regression analysis.

If I want to do simple analysis similar to that simple diagram can be obtained that your this side active and this side passive and then equate and then find out the depth of the embedment that also can be done. But based on regression analysis if the cohesion soil above this level and cohesive soil below dredge level this is the diagram typical diagram. And again we can the way I have done for sand same thing actually first of all we can consider force equilibrium and then moment equilibrium and then based on that we can again arrive at another equation and again solve for equation to further depth of embedment.

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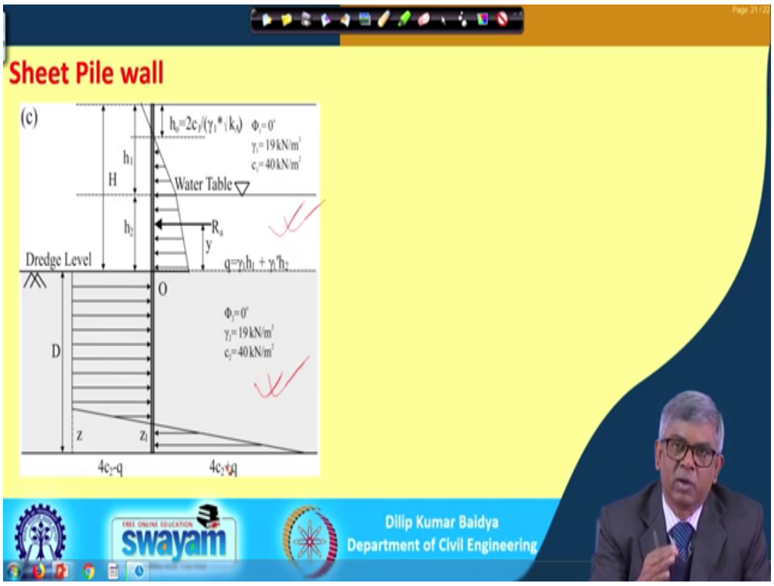

So, this is one and next one is again I will show this is another one actually you can see that this is above dredge level also sea soil below dredge level also sea soil. So, the typical pressure diagram will be something like this. Again, similar way the way I have done before the pressure equilibrium or force equilibrium, then momentum equilibrium, then formulate equation and solve for D, so, that also can be done.

So, I am not going in detail of these two part only sand that case only I have discussed, both simplified and modified and that may be enough for undergraduate. So, you can practice those. So, these are only thing I have shown that there can be other combination which is possible in the practice. With this I will stop here.

Thank you.