Foundation Engineering
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Lecture - 57
Sheet Piles – VI

So this class first I will solve one example problem to show you how I will design the anchor, I will fix the anchor position and then I will determine the anchor force and depth of the sheet pile anchored sheet pile in granular soil.

So, I will take the same problem that I have taken during the solution of cantilever sheet pile in granular soil.

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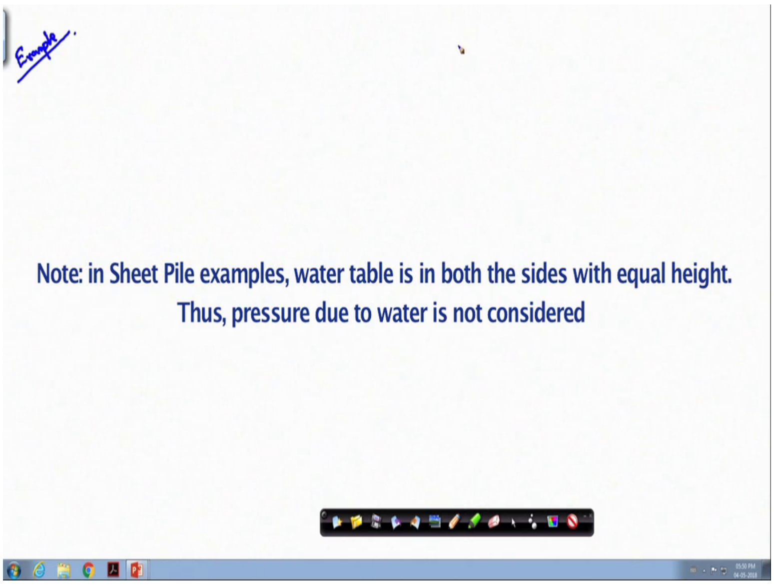

So, that the same problem I am taking here.

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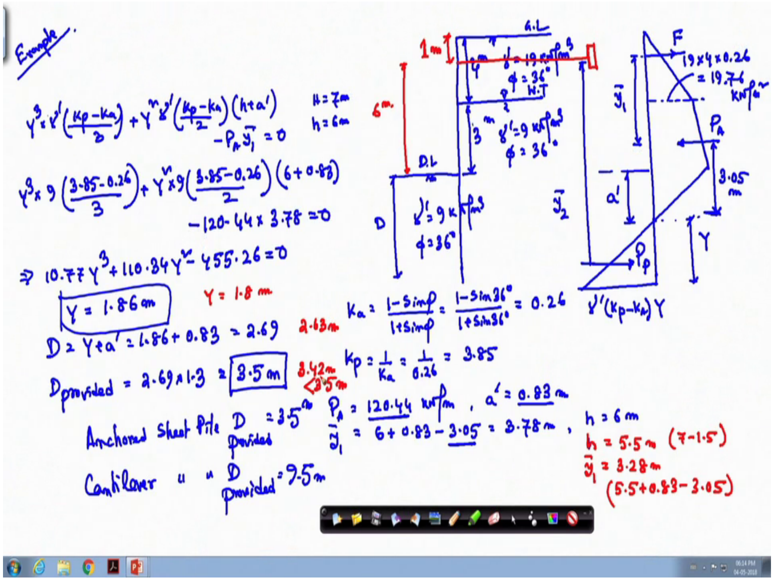

So, the problem that was chosen that this is the sheet pile sheet pile, this is the dredge level, this is the ground surface and there was water table is 4 meter below the ground level, this is ground level, this is dredge level and this dredge level; this is 7 meter ok.

So, this is the water table and unit weight was given 19 kilo Newton per meter cube above the water table, and 5 value was 36 degree. And below the water table unit weight was given 9 kilo Newton per meter cube and 5 value was same 36 degree ok. And below the, a dredge level also unit weight was 9 kilo Newton per meter cube and 5 value is 36.

So, that was the problem the same problem that I took during the solution of cantilever sheet pile. But now here I am placing on anchor ok. So, this is the anchor and this is say 1 meter. Initially I am solving this problem placing the anchor 1 meter below the ground level.

So, later on I will show I will fix the actual position of the anchor so, but now I am solving it 1 meter below the ground level. So, this distance is 6 meter because this is a total sorry this one is 3 meter it is not 7 meter; this problem was this is 3 meter 4 meter plus 3 meter its total was 7 meter, the H was H value is 7 meter now the small h value is 6 meter; here this is the small h value and this is the D that we will solve this is the D.

And again if I draw the pressure distribution, then we will see that up to this water table, this is the pressure and that value was 19; 19 into and your k a value is 1 minus sin phi divided by 1 plus sin phi, that is 1 minus sin 36 degree 1 plus sin 36 degree that is equal to 0.26 and k p was 1 by k a. So, that is 1 by 0.26 that is equal to 3.85 fine.

So, that was done so; that means, here that ka value this stress was 19 into unit weight gamma is 19 height is 4 in to 0.26. So, that is this value was coming out to be 19.76 kilo Newton per meter square ok. Then it will continue like this then here the distribution will be something like this.

Because this is that anchored sheet pile and then here 1 F will act ok. So, this is the a dash and the P A value is the total portion this portion is P A and if you look at your previous problem then the P A value was coming out to be 120.44 kilo Newton per meter ok. The P A value is 124 kilo Newton per meter a dash was 0.83 meter.

Just you see the previous problem that I have solved for cantilever sheet pile in granular soil. So, I am using the same data. So, that is why the P A value of 120.44 kilo Newton per meter a dash is 0.83 and the y bar initially the y bar was from this point in case of cantilever now your y bar is from here ok. So, this is y 1 bar and you have a P p which is from here is y 2 bar and you know that y 2 bar is being replaced ok. So, this is P p

Now, this value is gamma you will use the, I will use the gamma dash because this is the y capital Y and capital Y is below water table. So, gamma dash k p minus ka into capital Y this is the value. So, now, here y dash will be this is total 1 is 6 meter plus a dash. So, initially when I solve the cantilever problem my y dash from this portion if you look at this problem. So, I determined that my, this value from this point to this one P A was 3.05 meter 3.05 meter.

So, now this case my y bar will be that the, from here this is 6 meter plus 0.83 minus 3.05. So, now, the y 1 this y 1 bar will be 6 meter plus the, a dash is 0.83 minus this 3.05 meter. So, this is equal to 3.78 meter and the small h is 6 meter.

So, I have determined the y bar P A distance from this point in the previous problem you can directly calculate or determine the y bar y 1 bar from this point also by taking the liberum with respect from the rod level you can determine directly the y 1 bar, but I am here doing in the other way that as I have already determined this position of P A from this point.

So, this is the. So, these things I am getting the previous example this one I am getting previous example, this one I am getting previous example, this one also I am getting previous. So, you see the previous example and then you will find how these values are coming ok; so, because I am using the same problem. So, this is h is 6.

So, now that I have the final expression that capital Y 3, then 9 because if you look at the final expression. So, this is the final expression.

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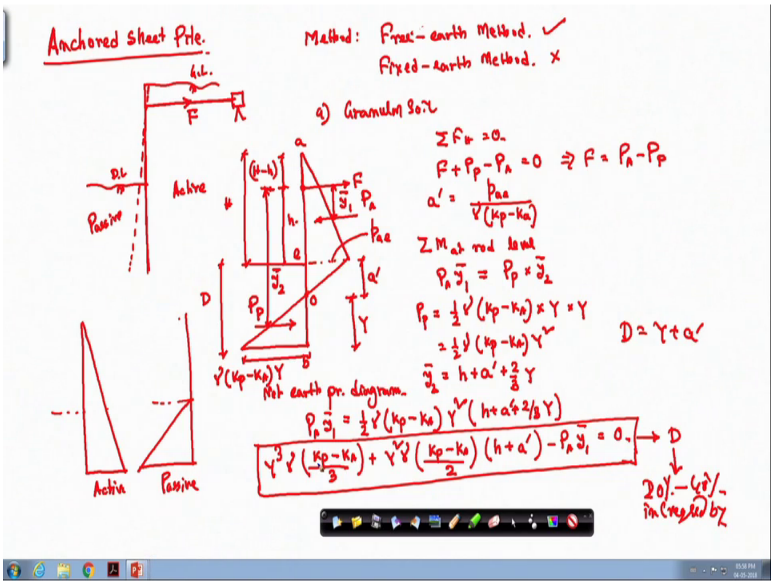


Capital Y 3 gamma k p minus k a by 3 this is the final expression that expression I am putting these values into here I am use the gamma dash because capital Y is below the ground level. Then this is your the same expression I am writing the same expression gamma dash kp minus ka divided by 3 plus capital Y square again I will take gamma dash kp minus ka divided by 2 into h plus a dash, then minus P A y 1 bar is 0.

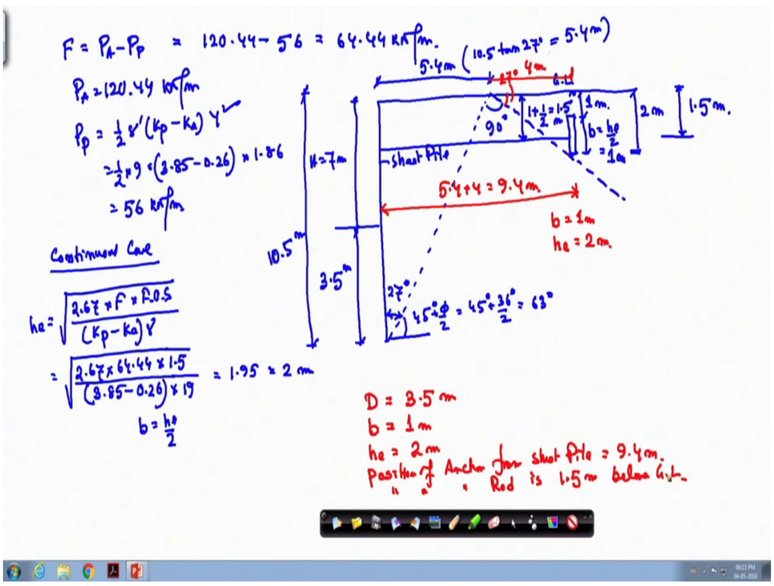
So, now capital Y 3 cube into 9 k p is 3.85 ka is 0.26 divided by 3 plus capital Y square, gamma is 9 k p is 3.85 0.26 divided by 2 h is 6 yeah h is 6 a dash is 0.83 then minus P A is 120.44, y 1 bar is y 1 bar is 3.78. So, that is equal to 0.

Now, finally, you solve this expression the final form that I am getting is 10.77 capital Y cube plus 110.34 capital Y square minus 455.26 is equal to 0 ok. So, after solving these you can solve it to calculator also you can solve it to trial and error also I am getting y is equal to 1.86 meter. So, your D is y plus a bar. So, this is 1.86 plus a bar is 0.83 and that is 2.69 and then D provided is equal to 2.69 I am giving 30 percent extra 1.3 that is around 3.5 meter ok.

So, you can see that in case of the same problem if I use the cantilever sheet pile wall then the required or the provided depth was 9.5 meter, but here, the provided depth is 3.5 meter. So, it is reduce by significant amount if I provide the encourage so; that means, the same problem. So, for the anchored sheet pile sheet pile, the D provided is 3.5 meter for the same problem cantilever sheet pile D provided was 9.5 meter.

So, you can see there is a significant amount of reduction of the required depth of the sheet pile if I provide the encourage. So, now, the we are provided a depth of 3.5 meter

Now, I will calculate the anchor design part. (Refer Slide Time: 13:05)



So, the anchor design part my f or anchor force is P A minus P P now P A you know that P A is 120.44 kilo Newton per meter and P P the expression was given. So, what was the P P P expression? The P P expression was this is the P P expression this is half gamma k p minus k a y square ok.

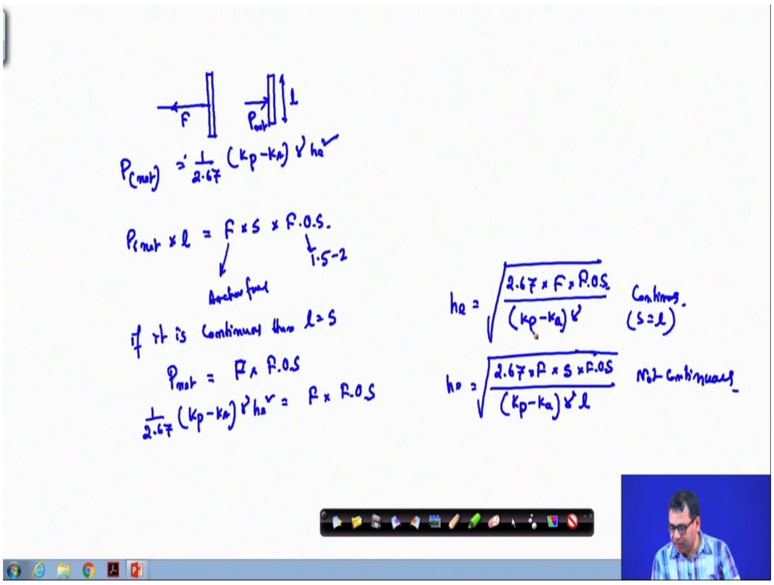
So, here the gamma will be the 9 because y is below water table. So, half gamma dash k p minus k a into capital Y square. So, half into 9 into 3.85 minus 0.26 and capital Y is 1.86 capital Y we are getting 1.86 that is the capital Y. So, 1.86 or this value is your 56 kilo Newton per meter. So, your P P is 56 kilo Newton per meter. So, your f will be

120.44 minus 56 this is 64.44 kilo Newton per meter. So, this is 644 kilo Newton per meter

So, now I will design the anchor position. So, I i have provided the anchor depth is 3.5 meter I have a H is 7 meter. So, as I mention this is the, this is the ground surface or ground level and this will be the 45 degree this value is 45 degree plus phi by 2. So, this is 45 degree plus 5 is 36 degree divided by 2. So, this is 63 degree.

So, this height total height is 10.5 meter. So, this is the total height is this total one is 10.5 meter this total one and this angle is 63 degree means this angle is 27 degree 90 minus 63. So, I know this height I know this angle. So, I can determine this distance. So, this distance is coming out to be 5.4 meter. So, how we will get this distance? This one divided by this one is 10 40. So, this is tan 27. So, this 1 will be 10.5 into tan 27 degree ok. So, that is equal to 5.4 meter.

So, now I draw a perpendicular line here. So, this is your 90 degree. Now let us start the, determine the he because I have to fix the anchor from the sheet pile because this is the sheet pile. So, let us let us determine the he value first ok. So, if I case the continuous case, if I consider the continuous case continuous case my he value is equal to 2.67 into F into the factor of safety divided by k p minus k a into gamma ok. (Refer Slide Time: 17:17)



So, this is the, your expression for the continuous case 2.67 into F into factor of safety divided by k p minus ka into gamma and so, that is our case.

So, now if I put the value 2.67 F value is F is 64.44 and factor of safety I am taking 1.5. So, I am taking 1.5 as a factor of safety again k p is 3.85 minus 0.26 and here I will take the unit weight as 19 because this portion is above the grounds water table because water table is 4 meter below the ground surface and this region I have consider 1 meter, but so; that means, it is above the water table.

So, this value is coming out to be around 1.95. So, I am providing 2 meter ok. So, he value is 2 meter. So, he is here suppose this is the 2 meter 2 meter. So, this is the position of the he say. So, this is say position of the he as I mention the he value and h should be above this line. So, I am placing the h is here. So, this is the he and this equation is derived considering b is equal to he by 2. So, h is 2 meter. So, this is your b. So, this will be b is equal to he by 2 so; that means, this will be 1 meter. So, this is 1 meter so; that means, this 1 is also 1 meter.

So, now if I place this rod at the center so; that means, the rod position will be 1 plus half of that; so, 1 divided by 2. So, this distance is 1.5 meter. So, this distance is that the rod distance is will be 1.5 meter, but during my analysis I consider this is 1 meter.

Now, again you check it whether now actual position is 1.5 meter below the ground level ok. So, now, check it whether that this position if I change the 1.5 instead of 1 it will change or not. So, y it will be the changes; if I change this 1. So, the changes will be. So, I am if I use the different color the changes will be that your this is initially this is h value will change nah smallest initially is 6 meter, now the h will be if I take this one your h will be equal to this will be 5.5 meter nah. So, this h will be 5.5 meter and another change will be y 1 bar.

So, y 1 bar will be now, here this will be y 1 bar will be 3.28. So, this will be 2 changes only other things will remain same because only changes will be your h will be now instead of 6 meter it will be 5.5 and now y bar 1 will be 3.28.

Now, if I put these values here this in this equation plus a a dash k p gamma ka all will remain same. So, if I change these things, if I put these values in this equation now your next trial y value will come out to be instead of 1.86 it is coming 1.8 meter. So, the d provided will come ok. So, 1.8, but here I have provided 1.86 which is which is greater than 1.8. Actual now after revision, your required y is 1.8 meter, but I have provided 1.86

meter. So, I have provided extra length. So, that; that means, we are in I am in the safe side.

So, that is why in the actual position your anchor position will be in the 1.5 meter below the ground level, but if I revise this analysis I am in the safe side. So, there will no need to change this design so, but one thing is remain that that the this portion this position you have to calculate because again how I will calculate that if this is 27 this is 90 this angle will be again 27 degree

So, now I know this is 2 meters this is 2 meter; this is 27 degree this height is 2 meter this is 2 meter yeah this is 2 meter this is 27 degree. So, I can I determining the distance. So, this distance is this is 4 meter. So, the total one your position of the anchor from the sheet pipe will be 5.4 plus 4 9.4 meter ok. So, final recommendation your anchor length will be this anchor rod will be at 1.5 meter from the ground level and position of this anchor should be 9.4 meter from the sheet pile, and your b value is 1 meter and he is 2 meter this is the final recommendation

So, an again if I show that how I am getting this he; he is I am getting this is 7 minus 1.5 this is 5.5 and y bar I am getting this is 5.5 then 0.83 minus 3.05 y bar and so, this is y is 1.8 meter. So, d D required will be in that case is 2.63 meter and D provided will be 3.42 meter D which is greater than 3.5 meter. So, my analysis or design is fine.

So, the final design recommendation that D is 3.5 meter b this is the anchor design is 1 meter he anchor design is 2 meter and the position of anchor from sheet pile is equal to 9.4 meter ok; and anchor rob from the sheet pile this is the horizontally and vertically the position of anchor rod is 1.5 meter below gl ok. So, this is the final recommendation.

So, now I have solve the same problem with and without anchor and you have noticed that if I use the anchor or required depth and significantly reduce, but again have to design this anchor also.

So, now the next thing that I will start is that your anchored sheet pile in cohesive soil.

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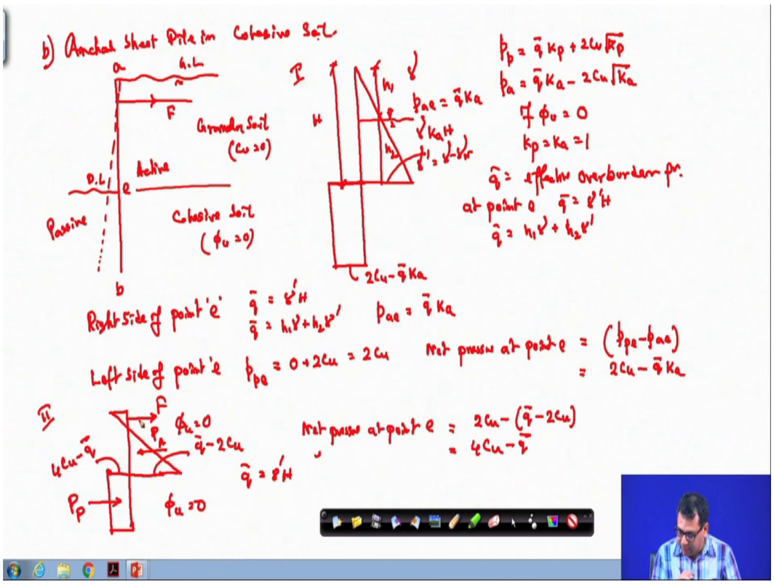

So, next one the anchored sheet pile in cohesive soil ok. So, this is the last part in the anchor. So, again I will discuss about the free earth method this is the dredge line, this is the ground level this is the anchor position or F and it will rotate with this is free earth method. So, this is active and this is passive.

So, now the problem are considered that this portion is granular soil and this portion is cohesive soil. So, that mean here C u is equal to 0 here phi u equal to 0 ok. So, the earth pressure distribution diagram will be again for the granular soil it will like this ok. So, and here if this is H then this value will be gamma into ka into H and that you can write this is pae; pae is equal to gamma ka into H.

So, again I can write that your P p is equal to q bar ka k p plus 2 C u root k p and P A is equal to gamma bar ka minus 2 C u root ka ok. Now if phi 0 5 u is 0 then kp will be ka will be 1 and again q bar is the effective overburden pressure.

Now, at point e if this is the e point this is the again b point this is the a point; at point e e your q bar is gamma dash into h depending upon the water table condition.

Now, if suppose if there is a water table here suppose this is h 1 this is h 2. So, you this is gamma this is gamma dash. So, in that case your q bar will be h 1 gamma plus h 2 gamma dash gamma dash is nothing, but gamma minus gamma w.

So, if the both the gamma above the water table and the saturated are same. So, this is the q bar. So, now, I can write that this is the pe and a granular soil this is the q bar now if your. So, this is I can write that this is pae. So, at the pressure the left hand side of the right hand side of the point e point e; that means, right hand side of the point e, your q bar is equal to gamma dash or gamma dash into H depending upon the water table position and I can write or here that is your q bar is h 1 gamma plus h 2 gamma dash.

So, I can write that the, this is the right hand side of the e. So, here I can write that my pae is equal to your q dash into ka ok. So, q bar into ka and for the left hand side of the left side of point e your ppe that will be equal to your q is equal to 0 here because the passive pressure your q is 0, then plus 2 C u ok. So, this will be 2 C u.

So, the net pressure at point e will be equal to p pe minus p ae. So, this is equal to your 2 C u minus q bar into ka if it is granular soil where C u is equal to 0. So, and I can write this is the value and here so; that means, here this will shift from this side to here. So, this is the net pressure diagram, now it is the it will shift side and again I have shown that for any distance below the z it will not change and here this side is again passive. So, it will continue up to here. So, this is the diagram.

Now, if that you have a soil like this that, this is the total phi soil then your diagram will be like this ok. This is for the this is also your phi u is equal to 0 here also phi u is equal to 0. In this case your the here your this value will be 2 C u minus q bar into ka because this is granular soil this is cohesive soil in this case this will be your here also k is equal to 0, here also k ka is equal to 1, here also ka is equal to 1, here also kp is equal to 1.

So, it will be 4 C u minus q bar because here another C u term will come here instead of it is gamma. So, this means here it will be q bar into k a. So, here it will be q bar minus 2 C u and q bar is equal to gamma into h.

Now, here the net pressure in this case the net pressure will be net pressure at point e in the second case this case will be your p pe will be 2 C u minus q bar minus 2 C u. So, this will be 2 C u Cu 4 C u minus q bar. So, this is the 2 cases this is the case 2 case 1 in the case 1 the above the dredge level soil is granular below the dredge level cohesive, but in the case 2 both the soils are cohesive ok. So, this is the net pressure distribution diagram

So now, how I will calculate the forces? So, here the, what are the forces the same one if I consider this one. So, this will be your P A and there will be a anchor force F and there will be a active passive force P P P P A is only the positive portion and F.

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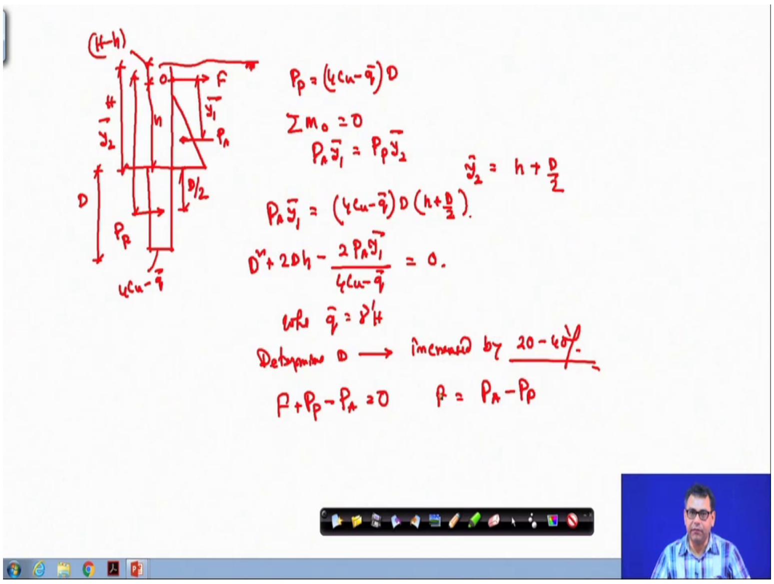

So, now finally, if I draw the diagram.

So, you can consider the any diagram. So, here I am considering the second one. So, this is the diagram. So, this is my P A this is F this is P P and P A is only the positive one. So, now, if I take and this is the D now your P P will be equal to 4 C u minus q bar in to the D that is a rectangle this is 4 C u minus q bar and this 1 is P P will get from this diagram. So, finally, if I take the moment at the anchor position or moment at o is 0 then I can write if this is y 1 bar, and this is y 2 bar. So, I can write that P A into y 1 bar will be P P into y 2 bar

So, y 2 bar is nothing, but that this is the small h; this is capital H and this portion is capital H minus small h this is the ground surface. So, small h is from the anchor rod to the dredge level y 2 bar will be small h plus this 1 is D by 2 ok. So, this will be D by 2. So, I can write finally, that P A into y 1 bar is equal to 4 C u minus q bar into D into h plus D by 2. So, final expression will be D square plus 2 D h minus 2 P A y 1 bar divided by 4 C u minus q bar that is equal to 0 where here q bar is gamma dash into h.

Now, if it is granular soil and c soil then you have to use this diagram, but I have use this one. So, you can use this one also. So, here also you determine D then increases it by 20 to 30 or 40 percent ok. So, that will be this D you have to provided

So, this is the expression of D for the cantilever sheet anchored sheet pile, in cohesive soil now once you get the D now from this expression that you will get the, your anchor force. So, yeah anchor force expression is not given ok. So, finally, the anchor force expression similar to the granular soil F plus P P minus P A is equal to 0. So, your f is equal to P A minus P P ok.

So, this is the expression once you get the D, you put this value here you will get the P p you can get determine the P A also you will get the F once you get the f then again at the same way you have to design the anchor for cohesive soil ok. You consider the active one side passive another side and you know in that case your diagram will be different, but you use the same concept to determine the or to design the anchor dimension position of the anchor in terms of horizontal as well as the vertical and determine the b value or the width of the anchor.

So, with this I am finishing this sheet pile part in the next class I will start the braced excavation and then I will start the next topic that is the underground conduit.

Thank you.