Foundation Engineering
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Lecture – 40
Pile Foundation – XIV

Last class I have discuss about the design of pile foundation considering both bearing capacity as well as the settlement. In this class I will discuss about the negative skin friction of pile.

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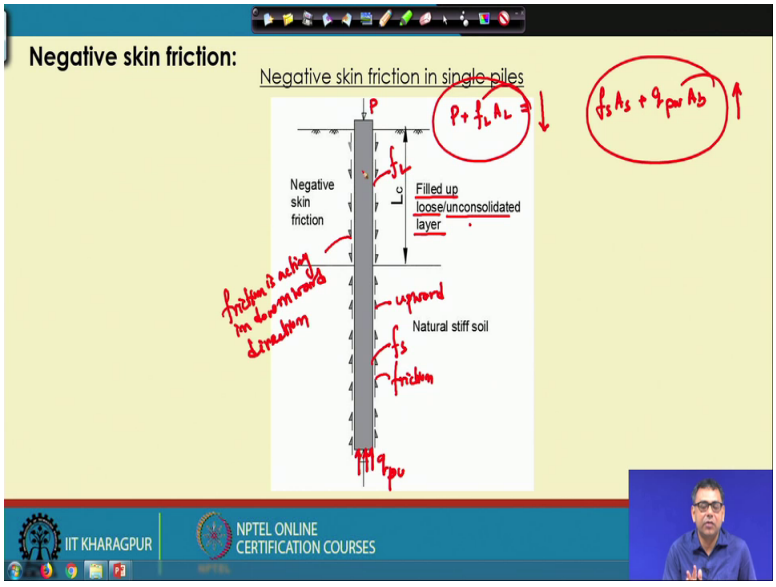

Now, what is negative skin friction ok? So, when we talk about pile load shearing mechanism where, if we apply the load on a pile the resistance will be given to the pile by keep resistance or bearing and then the friction. So, this is the tip resistance of the bearing and this is the friction.

So, now if I apply the load on a piles so, pile will deform in the downward direction. So, the relative deformation of the pile and the soil is such that that pile will deform more compare to the surrounding soil. So, what will happen? The pile will relatively deforming in downward direction. So, your friction will act in the upward direction. For example, this lower part of this figure where thus, pile is deforming downward direction compared to the surrounding soil. So, your friction is acting upward. So, this friction is acting upward.

Now, if any situation is occurred when the relative deformation of the pile is upward direction so, your friction will act in the down ward direction. When this thing will happen? So, these things will happen when that soil deformation is more than the pile deformation. So, when you are applying load on a pile now, the your pile will deform and if the surrounding soil also deform significant, by significant amount. Then what will happen? The relative deformation of the pile will be in the upward direction because, your soil is deforming more than the pile.

So, in that case your friction will act in the downward direction. So, it is upward this upper part of this figure. So, your friction is acting in downward direction. So, in that case it will not give you any the resistance. It will act as a negative effect on the pile load carrying capacity. Because, in such case you will get the resistance only from the lower part of this pile and, upper part of this pile because as the friction resistance friction is acting downward direction. So, if this is the P is the load which is acting on the pile. So, you can see that if this is f L and this is f s and this is q b q pu.

So, you can write that P plus f L into A L that will be that is acting in downward direction. And, f s into A s plus q pu into A b this is acting in the upward direction. So that means, we cannot utilize in such case that full length of the pile for the friction resistance calculation. Now, when this things will happen? Now, if your soil is a, this suppose this top portion of the soil which is filled up and which is very loose or it is a unconsolidated layer.

So, if the soil is very loose it is a filled of soil, then what will happen? This soil will deform significant by significant amount and thus deformation of the soil compare to the pile will be more. In another case if soil is unconsolidated soil so, this soil will consolidate. So, during the consolidation process this there will be a significant amount of deformation. So, your deformation of the soil will be more compared to the pile deformation.

So, in these cases this upper portion of the soil will deform significantly as compared to the to the pile deformation. So, here there will be a negative skin friction will develop. So, in that case we cannot consider this friction as my frictional resistance of the pile because, this will act as a negative effect in terms of bearing capacity of the pile. So, how we will can calculate this load carrying capacity of pile in such case.

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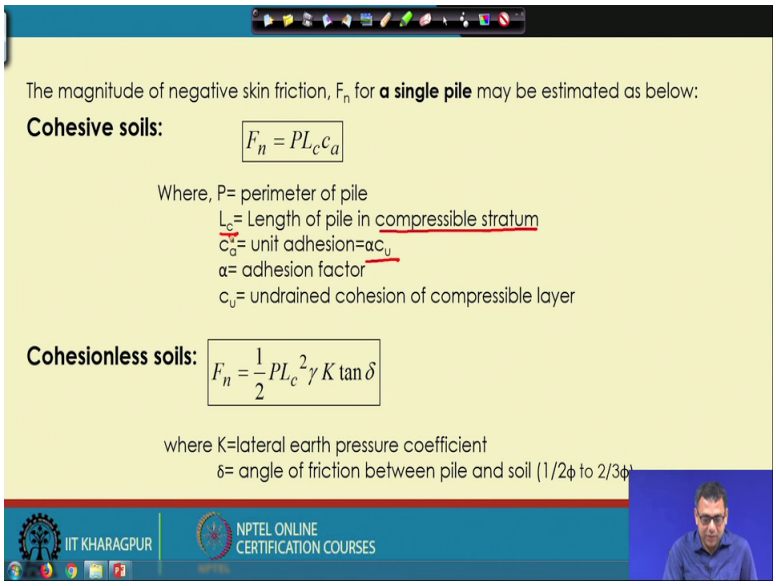

So, for the cohesive soil the similar way we can calculate this negative skin friction a similar way as we calculated the, we have calculated the skin friction of the pile. So, here the c a is the unit adhesion and that will be again alpha into c u and L c is the length of the pile incompressible strata; that means, up to which this there is a loose sand or the unconsolidated layer. So, only that portion length is L c. So, if I go back to the previous figure so, this will be the L c only the top portion or the uncommon, uncompressible layer.

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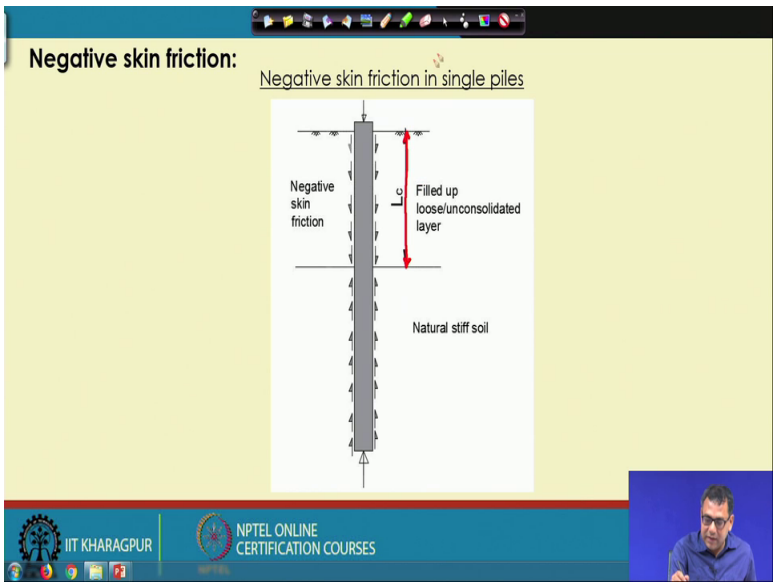

So, this is L c and then this is the perimeter of the pile and they see that mean this is the area of the top portion of the pile, where the negative skin friction is developed into alpha into c u. And, similarly for the cohesion less soil also we can calculate the similar way. This is the center portion of the top uncompressible layer, we have to calculate the lateral stress so, and into tan delta.

So that means, that we will be the gamma K tan delta into L c then the a perimeter or of that pile and into their length. So, that will give you the total negative skin friction. The similar way that we calculate the friction, skin friction of a pile in cohesion less soil. So, and here the alpha value is taken as half phi to two-third phi generally in this case. And, this case adhesion value, we will consider the same adhesion value as we have considered for the calculation of pile friction resistance in cohesive soil.

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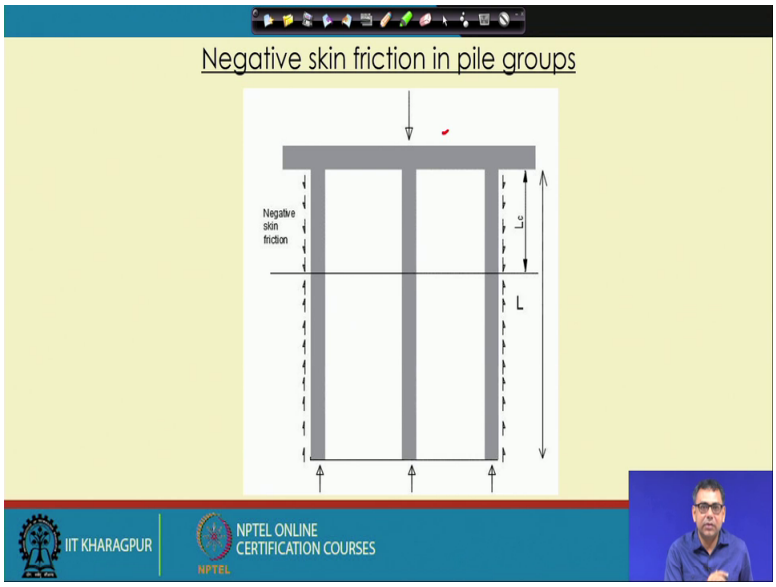

So, this is the previous calculation is for the single pile, now if it is the group pile in the clay the same way we can calculate. So, this is the group pile configuration.

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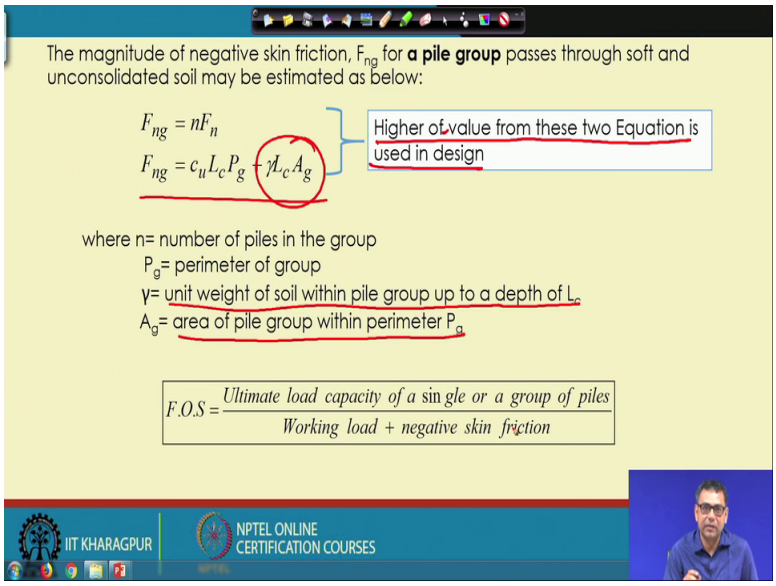

So the, we have to consider in both the way; that means, one for single pile a consideration another for the block failure consolidation consideration. So, single pile consideration you calculate the negative skin friction is developed for the single pile, then multiplied to the number of pile. And, if it is for the block then you have to consider the negative skin friction for that block surrounding to that block.

So, that is the perimeter of this group into the L c into c u, but here the alpha value will be 1 because, as it is between soil and soil. In addition to there is one thing that we have to consider the weight of that block we an calculating the negatives skin friction for the block. That weight is L c is the length and gamma is the unit weight of that block and A g is the area of that group. So that means, we have to consider the area of the pile group within the perimeter and the unit weight of the soil within the group pile group up to a depth of L c.

Because, this is one thing you have to add with the group bearing capacity or group skin negative skin friction calculation. And, remember that when you we consider the pile load carrying capacity you considered the minimum one as the pile load carrying capacity, but here it is the negative effect. So, among these two higher one we have to consider from these two as the our design negative skin friction. So, and the factor of safety you have to calculate the ultimate load carrying capacity of the pile single or group.

And, remember that when you calculate the ultimate load carrying capacity of the pile you will not consider the L c portion. We will consider the length if L is the length of the piles we will considered L minus L c length during the pile friction resistance calculation. So, ultimate load carrying capacity of singular group pile divided by the working load, the load that is acting on the pile plus the negative skin friction that is developed so, that will be the factor of safety and that should be greater than 2.5 to 3. So, we will solve one problem and then we will see that how we can incorporate the negative skin friction part in the pile load carrying capacity calculation. So, the problem that I have consider, so I have consider the layer soil.

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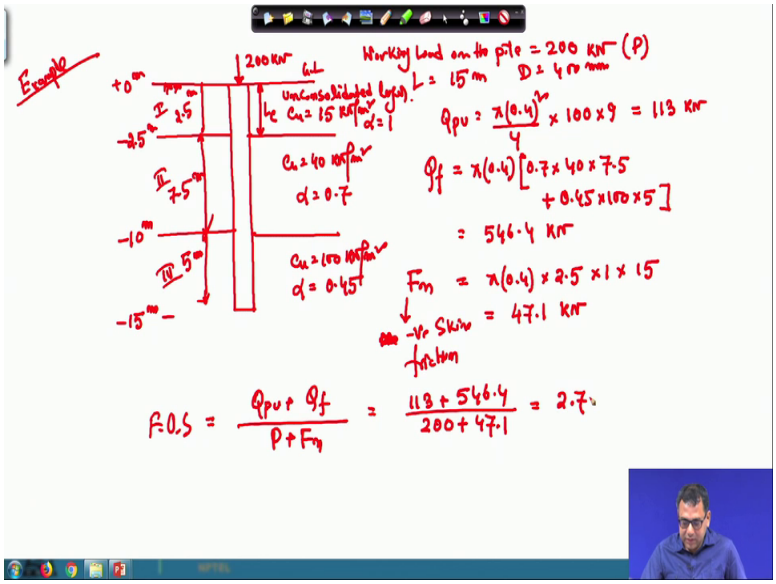

So, this is the ground surface. So, this is the layer soil. So, this is the ground layer and the load which is acting on a pile is 200 kilo Newton a single piles. So, working load on the pile is equal to 200 kilo Newton. And, as I mentioned so we will consider this weight including the weight of the pile. So, and that is 3 layer: layer I, layer II, and layer III. So, 3 layers. So, this is plus 0 meter, this is minus 2.5 meter, this is minus 10 meter and the total length of the pile is 15 meter.

So that means, this one will be also this is 2.5 then 10 meter. So, this is minus 15 meter because this is the total length of the pile. So, this top layer is the layer which is developing the skin, negative skin friction because, this is unconsolidated layer whose, this is layer is unconsolidated layer which c u value is 15 kilo Newton per meter square.

And, this layer II c u value is 40 kilo Newton per meter square and this c u value is 100 kilo Newton per meter square.

So, from the table that we are getting alpha value for the first layer is 1, alpha value is equal to 0.7 for the second layer and alpha value is equal to 0.45 for the third layer. So, we can use the same table or the graph that we have used for the skin friction calculation of pi. So, now the we can write that Q pu that will be single pile pi diameter of this pile is 400 millimeter. So, this is 0.4 square divided by 4 into c u, c u is 100 into 9 because, this tip resistance here it is in the third layer pile base and there the c u value is 100. So, this is 113 kilo Newton.

Now, we are calculating the frictional resistance, directly you are calculating the force. So, as I mention when you calculate the friction resistance we will consider only the second and the third layer. So, this is the L c that L c we will not consider. So, we can consider pi d now, for the second layer alpha is 0.7 c u is 40 and the length is 7.5 meter. Then for the third layer alpha is 0.45, c u is 100 and length is 5 meter because, this is 7.5 meter and this one is 5 meter and this one is 2.5 meter.

So, this Q f value is 546.4 kilo Newton. Now, we will calculate the negative skin friction that is the negative skin friction. So, this negative is skin friction consider the L c part. So, this will be pi 0.4 L c is 2.5 alpha is 1 and c u is 15 kilo Newton per meter square. So, this is 47.1 kilo Newton. So, the factor of safety will be equal to the load carrying capacity of the pile. So, Q pu plus Q f divided by working load of the pile, if that is P say P plus F n. So, this will be 113 plus 546.4 divided by P, P is 200 plus F n is 47.1.

So, this is 2.7 and is the factor safety. So, this way we can calculate the skin friction of a pile and here I have solve single pile a problem. So, similar way we can solve a group pile, problem group pile problem also. So, in this topic with this negative skin friction topic I have finished the pile foundation part. But, remember that I have discussed the pile foundation only under compressive load and perfectly particle pile. So, before I finish the, this total pile foundation part and go to the next chapter that is the lateral r pressure pile, add pressure then I want to discuss two things.

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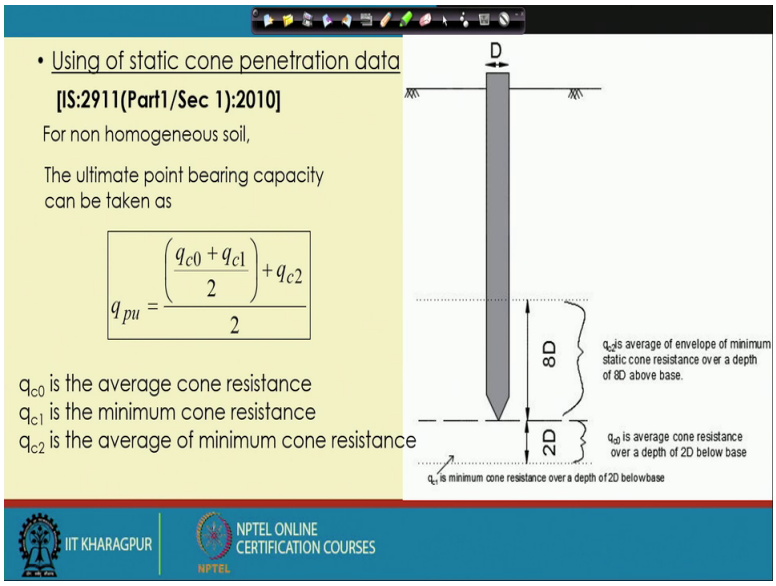

That I have discussed about the this cone static cone penetration data using this static cone penetration data to calculate the pile tip resistance and the frictional resistance. In that day I solve one problem with a particular cone resistance data along the depth.

Now, today I will show you couple of more variation of cone resistance and along with the depth. And, then we will see how we can take this average minimum part because, that is very important to understand. We can take the average and the average of minimum for different variation of q c with depth. So, the first variation that I am talking about is that this is your depth of the pile or along the depth of the soil layer and this side is the q c, the similar problem I have taken.

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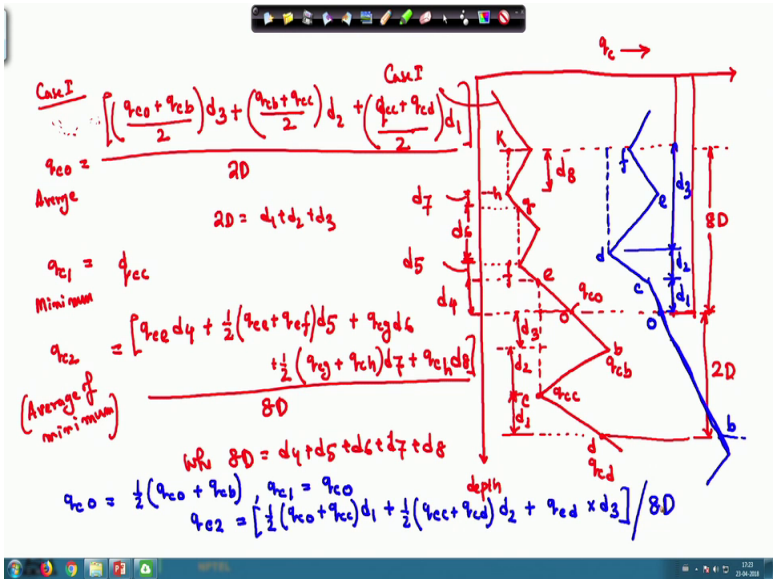

So, q c can be any unit can be is kilo Pascal, it can be in the mega Pascal. So, this is the depth. So, first variation that I am considering, say this is the variation of the q c versus depth and the pile is at here. So, pile depth piece at here, this is the position of the pile say. So, this is the position of the pile. So, we can say this is the o point and this is the b point, this is the c point. This is because, here as per the recommendation that we have to go 8D above the base and 2D below the base.

So, 2D below the base is say here, this is the 2D, I remember that this is not as per the scale. So, this drawing is not as per the scale. So, an 8D is here from the base. So, this part this point you say this is d. Similarly, now the expression is given as is q pu q c 0 plus q c 1 divided by 2 plus q c 2; q c 0 is the average cone resistance, q c 1 is the minimum cone resistant and q c 2 is the average of minimum cone resistance. So, I will talk about this q c 0 q c 1 and q c 2. So, first case that this is the case I, this red one this is the distribution for case I. So, this case I so, I can write that q c 0; q c 0 is the average of the cone penetration resistance below the soil of the pile or the below the pile soil up to twice D.

So, this is below the, this is the pile base and below that up to twice D. So, q c 0 this average we can write so, if this depth this depth is say d 3, this depth is d 2 and this depth is d 1. This is the depth d 1 d 2 d 3, these are the depth. Now, I can see here the q c value is q c 0, here q cb, here q cc, here q cd, this way I am just naming this point. So, q c 0

will be q c 0 plus q cb divided by 2; that mean average of this point into the depth d 3. Then plus I will take the average of this portion, that will be q cb plus q cc divided by 2 into the depth d 2.

Plus I will take this portion that is q cc plus q cd divided by 2 into d 1. Then the total you have to divide by twice D or basically or you can write that twice D is equal to d 1 plus d 2 plus d 3. That will give you q c 0, average of registration, average of cone penetration q c up to the twice D from the base of the pile. And here the minimum value that is the q c 1 minimum value is what, how much? So, minimum value this is the this way it is increasing. So, minimum value is this one, this is the minimum value. So, the q c 1 will be q cc that is the minimum values. So, because here this is the minimum value so, this is the lowest value or the minimum value.

Now, I will take the weighted average part, this average part minimum average. So, this is the only average, this is the minimum value and then the q c 2 is the average of minimum. So, this one how we will calculate that? First this is the lowest value, you draw a vertical line so, this will intersect here. So, you are I am giving the name of this point is e, then this minimum value is this one. So, this is f then this is the minimum value is this one. So, after that this portion is increasing. So, again you draw a vertical line. So, this is the minimum value I am giving the name is g, then it is this one it is the minimum. So, this is say h and then again the minimum one you go up to this. So, that is a is k because, we are finishing here because this is the up to the this zone you have to consider 8D clear.

Now, here the depth we are talking about that from here to here o to e this is say d 4. Then e to f this is e this is f this is e d 5. Then from f to g this is d 6, f to g is d 6. Then g to h is d 7 and h to k is d 8 clear. So, I am giving the distance between all the points from o to e it is d 4, then there is a change e to f it is d 5, f to g it is d 6, d g to h it is d 7 and then h to k it is d 8.

So, the q c 2 will be so, d 4 here from now, I will start from this point. This point to this point it is uniform and that minimum value is corresponding to q c or q e. So, I think I am writing this is q ce, this is the e or you can write q cc because both are same. So, I am writing q ce then it is uniform. So, this will be d 4 plus it is, now it is not uniform it is

there is a variation. So, we will take the average; average of q ce plus q cf and the depth is d 5.

Then from the f it is again uniform because that is the minimum one, again uniform. So, I will take this is q cg into the depth is d 6, then again it is changing there is a variation. Then I will take the average, whenever there is a variation take the average. When there is state line is uniform take the only that value is a average is q cg plus q ch divided by 2 and the depth is d 7, then it is again uniform. So, I can write q ck q ck or equal right q ch also or you can write q ch that will be good. Because, so this will be q c h into the depth is d 8.

Then the total one you have to take divide the total one by 8D, where 8D is equal to d 4 plus d 5 plus d 6 plus d 7 plus d 8. So, this is the one variation that I was talking about. Now, I am taking another one more variation. So, I am take in one more variation which is straightly simpler. So, one more variation I am taking. So, this is the variation I am taking, this is the green one is the another variation. So, this is the depth. So, now I am marking this point, this is as usual this is the blue one is there another variation. This is o, this one is c, this one is d, this point e f and this point is b.

So, the blue one I am just writing here because, it will not take much area. So, the q c 0 which is the average and here up to this twice b from the base of the pile there is only one variation. So, I will take the average of these two point. So, the average value will be half into q c 0 plus q cb which I am not multiplying it with depth because, you have to multiplying with depth and again you have to divide with that depth. So, like these two will cancel out. So, this will be the average. Now, the q c 1 the minimum value so, here you can see here up to this twice D it is increasing. So, the minimum value will be this one at this zone.

So, the minimum value will be q c o. So, this is o and this is 0 remember that. So, do not be confused this is o, this is 0 and then I can write that q c 0. So, q c 2 so, from here I will start. So, here it is increasing then decreasing. So, the minimum value is this one. So, you take a line take a line and so, I am writing this depth. So, this is the say depth d 1 then again it is changing, this is the depth d 2 and then from here to here it is uniform. So, there is no changing of the qc value. So, this will be the d 3.

So, my q c 2 will be here it is changing. So, it will be half into q c o plus q cc, then this we have to multiply with d 1 plus this is again changing. So, half q cc plus q cd, the depth is d 2 then plus it is uniform. So, this will be q cd into d 3 then the total one divided by 8 D. So, after these two more variation hopefully this is now clear to you, that how we can determine this, these minimum average and average these things. Now, if you go back to the problem that I have solved then you can see I have done exactly the same thing with some numerical values.

So, before I finish this part I want to give you a small information that we are talking about that in when we are talking about the driving pre cast pile. So, we mentioned I have mentioned that we have to use some minimum or the additional steel or reinforcement for handling and transportation of those pre cast pile. So, now we can so, we can put this handling equipment or the equally handling arrangement we can do in such a way that the minimum amount of moment will be developed within the pile during the transportation and the handling. So, I am giving just that information that how we can plan that handling and transportation for a pre cast pile so that there will be minimum amount of moment will develop.

So, minimum amount of stress will generate and minimum amount of strain enforcement you have to provide because, that is the advantage that you have to disadvantage, that is the disadvantage that you have to provide. Additional steel for pre cast pile due to the handling and transportation. So, that is the information and then for the pre cast pile so, if the additional due to handling and transposition because, these piles are constructed in the construction here that from the here you have to transport them to the site.

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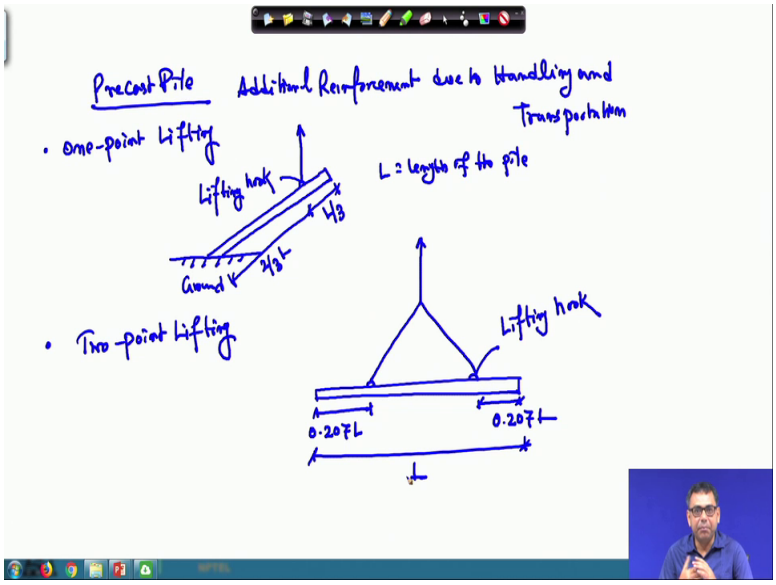

So, what will happen if there is a one point lifting; lifting means during the transportation you have to lift that pile. So, if there is one point lifting then where you which portion you of the pile you will lift to get the minimum bending moment. Also, the lifting if it is one point then this is the ground surface. So, one part one end of the pile will be at ground surface and another end you will lift and this lifting hook you will provide in such that. So, this is the lifting hook such that this is L by 3 and this one is twice L by 3, where L is the length of the pile.

Now, this lifting hook you have to provide during the construction of the pile for the lifting purpose. Now, if it is a two-point lifting suppose, then the pile whole total pile will be in the air. And, this is the lifting hook and lifting is done this way. This is the lifting point and this is the lifting hook. So, this point is 0.207 L and this point is also 0.207 L and the total one is the length. So, if you do you are lifting arrangement in this way then you have to provide the minimum amount of reinforcement due to the handling and transportation.

So, with this I am just finishing this chapter. So, in the next class I will start the next chapter with is which is lateral earth pressure.

Thank you.