Geotechnical Engineering II / Foundation Engineering

Prof. Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 44
Pile foundation (Contd.)

Good morning. Once again I welcome you to this lecture on Foundation Engineering and at we are at actually in the last lecture I was actually discussing about the capacity of the pile and then single pile and then also I have discussed about the use of group pile.

Use of piles in group and there also I have mentioned that when the pile will be used in a group then actually the capacity generally will be reduced not suppose if n number of piles are there then your final capacity will not be n times the individual capacity sometimes it maybe, but many situation it will be reduced.

And, what are the situation? It can be full will be there n times the come individual capacity where it not all those thing I have discussed and then when the pile is used in a group then because of the interaction between the pile there actually efficiency is reducing; so, that how to calculate that efficiency, that also I have discussed.

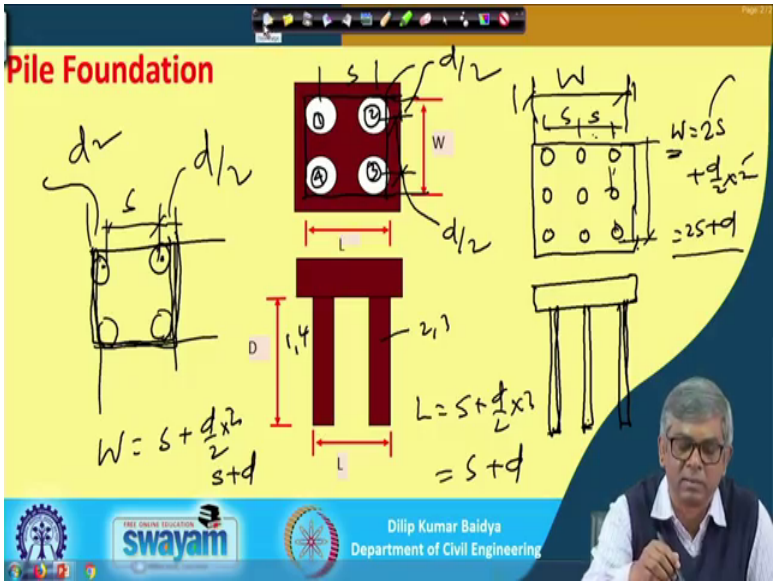
And, then in the finally, design of capacity of the group two different ways can be done. One is actually, suppose I will calculate the individual pile capacity and based on their spacing and diameter I can find out the efficiency. And, then if I assume that the piles are independently failed or if at all failed then independently pile will fail in that case I will calculate the capacity of group efficiency multiplied by the individual capacity multiplied by number of piles. So, that is one way of obtaining group capacity based on individual pile failure.

But, in as I have mentioned the previous lecture that if the piles are closely spaced then instead of pile failing individually they may fail at as a whole in the form of a block and that block actually what will be the dimension of block and then how to using that block how to find out the capacity of the group that block capacity of the group that perhaps I have not discussed; so that part I will take.

And, then finally, I will take a numerical problem and then a pile group with based on individual pile failure what could be the capacity; based on block failure what could be

the capacity and finally, what could be the recommended value of design value of the pile capacity that I will discuss.

(Refer Slide Time: 03:17)



So, first let me take the first slide that is actually giving you the how I can consider the group as you can see here the suppose the 4 piles are at group it can be any number. Suppose, if there is a in if there is a nine numbers of piles are there suppose like this is also another group.

So, suppose something like that pile cap will be there and if I draw the elevation we will use something like this we will see something like this and we will see something like this; so whatever maybe so, whether it is 4 or 6 or 8 anything. So, there may be square or rectangular pattern if it is placed. So, this is actually in the square pattern four piles are there pile number 1 suppose this is 1, this is suppose 2, this is suppose 3 and this is suppose 4. So, this is actually 2 and 3 and this is showing 1 and 4, ok.

Now, I have to calculate the block capacity of the pile and to find out the block capacity of the pile I have to find out the dimension of the block. So, how to find out the dimension of the block? You can see that if the piles are you can see here the outer this is the diameter D and this is the spacing actually from here to here it is a spacing centre to centre and this side actually it will be how much it will be d by 2 and this side will be again this side it will be again d by 2.

So, ultimately if I draw a line tangential to the external surface of the pile and then what ever if it is a square pattern or rectangular pattern either you will get a square or rectangle suppose, I will do this once again draw here separately suppose like this and like this and like this. So, I will draw the tangent from here, I draw the tangent from here, I will draw the tangent from here, I will draw the tangent from here.

So, that means, this is the block I am getting the dimension of the block or top dimension I am getting. So, what should be the dimension? So, if it is the centre to centre distance is S and then it will be d by 2 and here also d by 2. So, this total distance W will be equal to S plus d by 2. Actually d by 2 multiplied by 2; that mean S plus d, ok.

So, suppose here actually you can see here there are S S; so, that means, here dimension W will be equal to twice S plus d by 2 multiplied by 2 is equal to twice S plus d. So, that means, if in a particular row if there are three or four or whatever maybe the number how many in between spacing is there, you can see one or two. So, twice the spacing multiplied plus d will be the width.

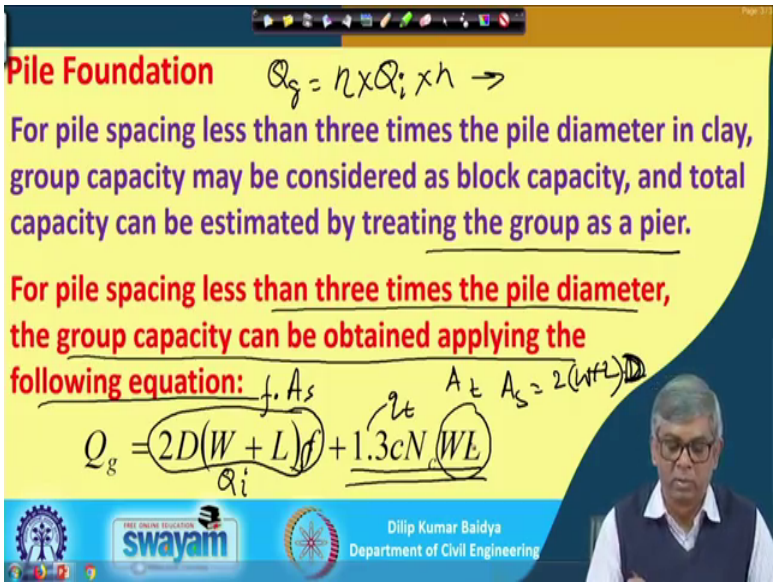
So, here actually similarly I have shown that how we have got w we have shown here because tangentially if I draw the line that give you the W and L now how to find out W and L that is the way it is shown the when it here actually W, if this is W sorry, if this is W width W is this then actually you can see S plus S plus d by 2 plus d by 2. So, that is why I have writ10 twice S plus d by 2 multiplied by 2; so twice S plus d ultimately.

Similarly, this direction also this direction also will have same thing this direction also will have same thing that is equal spacing in directional also. So, there also it will get will be twice S plus d and here also since single spacing only two piles are there; so only one S. So, S so, that is S plus d by 2 multiplied by 2. So, S plus d this side also same thing if the spacing is same L also will be equal to S plus d by 2 multiplied by 2; that means, S plus d.

And, this is actually dimension that will plan view of the block and what is the elevation? That is elevation actually embedded length of the pile will be your length of the block. So, that means, you are getting the block dimension equal to W, L and d. And, so, then when you will get a block and then if it is you can find out what is the base resistance or the fictional resistance based on that I can find out the capacity.

So, let me go to that part.

(Refer Slide Time: 08:05)



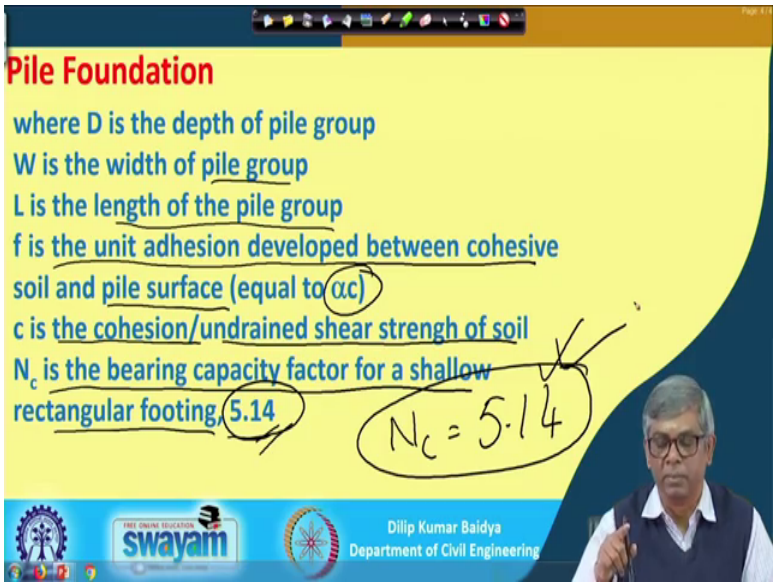
Next you can hear that it is written here for pile spacing less than three times the pile diameter in clay group capacity may be considered as a block capacity. See individual pile; that means, whatever I have done that is Q group equal to efficiency multiplied by Q i multiplied by n that is the way that is individual pile failure there all the piles are independent.

Now, when the pile they are close; that means, less than three times the diameter then it may also play there is a chance of failing as a block. So, you have to find out the block capacity and compare with this and see which one is smaller. So, that is what may be consider as a block capacity and total capacity can be estimated by treating the group as a pier. As I have told the what is the dimension of the pier? Dimension of the pier is actually W, L and d and what is W, L and d that I have shown.

For piles spacing less than three times the pile diameter the group capacity can be obtained applying the following equation. So, you can see here we know that this is the pic this is actually Q i or Q S. So, Q S actually what f multiplied by A S. So, as actually nothing, but A S is nothing, but a perimeter is a twice W plus L and multiplied by L or L or D here.

So, this becomes the perimeter here. So, that is what it is a 2D W plus L multiplied by f this is actually nothing, but nothing that is nothing, but f into A S and since it is A square so, it is bearing capacity equation you can re collect that 1.3 c N c and this is nothing, but A t ; that means, base area. So, 1.3 c N c is the that is q t multiplied by A t. So, the 1.3 c N c is the q t and A t is the W multiplied by L. So, this is the way actually one can find out the block capacity.

(Refer Slide Time: 10:27)



And, whatever terms I have used those are explained here D is the depth of the pile, W is the width of the pile, L is the length of the width of the pile group and L is the length of the pile group, f is the unit adhesion development between cohesive soil and the pile surface and which will be equal to alpha times c; same principal whatever we have used for capacity calculation for single pile same thing when it is a block also it should be alpha times c.

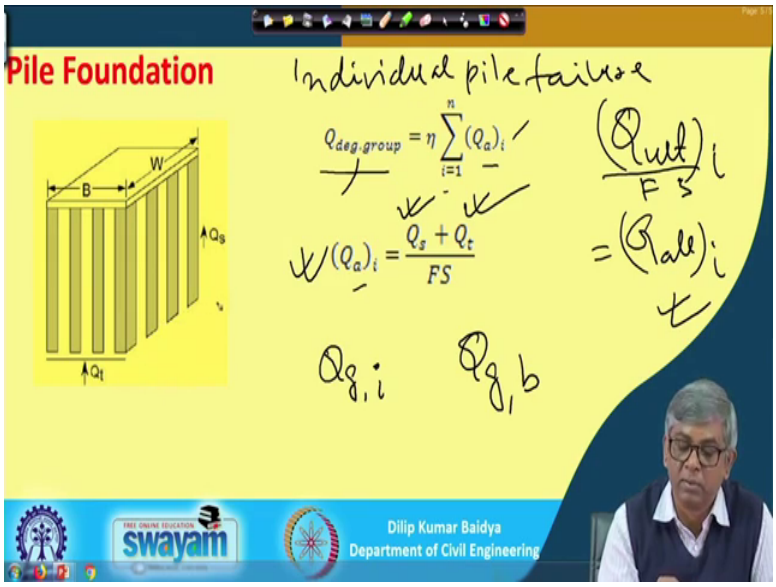
And, c is the cohesion or un drained shear strength of the soil, N c is the bearing capacity factor for a shallow foundation rectangular footing and which is actually while calculating the capacity of the single pile we have mentioned that since the deep foundation c N c will be increased. and that N c in non regular shallow foundation you have seen that is a 5.14, but for a single pile you have used that as a 9.

But, when the piles in a group at that time when you are considering the as a block and that blocks dimension is quite weak and because of that with respect to depth actually we

can conserve shallow foundation if you are not increasing the this value. So, here actually when you calculate the block capacity that time your N c value will be 5.14 as it was used in the shallow foundation.

When the pile assumed as a block that time when you are calculate the capacity then N c value to be taken as 5.14; whereas, if you want to find out the capacity of the single pile that time N c to be taken as 9. So, this difference can be should be remembered.

(Refer Slide Time: 12:19)



Now, you can see here as I have told you that you have to in the design in the design finally, what happens happen you will be getting number of piles in a group and then suppose their spacing everything is known, you can find out the individual capacity and you can find out the group capacity.

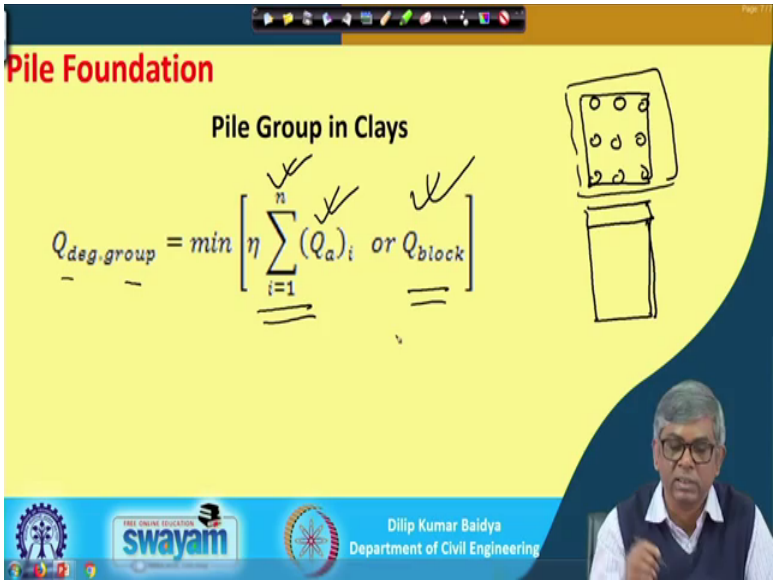
So, now, two group capacity calculation we have got now in the two ways we can find out one way is actually efficiency calculation then multiplied by individual pile capacity multiplied by number of piles; that means, one that is actually based on individual pile failure and then another way actually to consider as a block and that is actually block capacity.

So, group capacity can be either individual; that means, Q g you can say Q g based on individual pile failure and Q g based on block failure, this two ways it can be estimated. So, here actually there is a pile group and you can see the B and W is shown. So, from

here Q design and group will be efficiency times I want to find Q a i. So, Q a i means actually what? You will get Q ultimate i and Q allowable i; that means, that means what is the difference in this that way we have to divide by factor of safety then I will get this one.

And, how to find out Q a i? Q a i will you have to find out individual piles skin friction, individual pile tip resistance then apply factor of safety then based on that we will get Q a i. So, that is actually design value of group based on individual pile failure individual pile failure. So, this is one group will get.

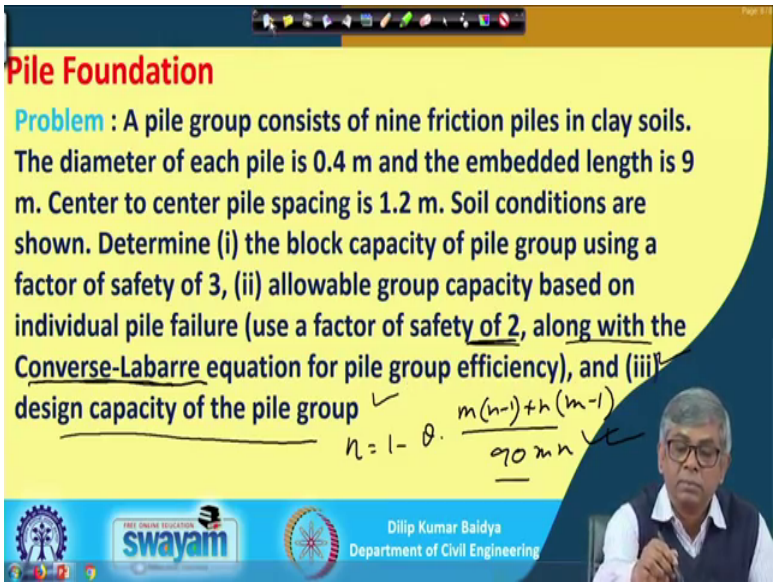
(Refer Slide Time: 14:31)



Next and for the and you can see and then we have shown also group capacity that is another I have shown. And, group capacity Q block you have to suppose if there is a this is the block we have convey pile cap may be somewhere here, but this is a block this is the block we have considered. So, Q block you will so; that means, I have now this is the one based on individual failure, this is block failure. So, I will calculate both and finally, I will compare and the smaller one to be recommended.

So, that minimum of Q designed group will be either will be equal to this based on individual failure what is the group capacity and based on block capacity what is the group capacity based on block failure what is the group capacity. This two to be calculated and then compared to find out the designed value.

(Refer Slide Time: 15:41)



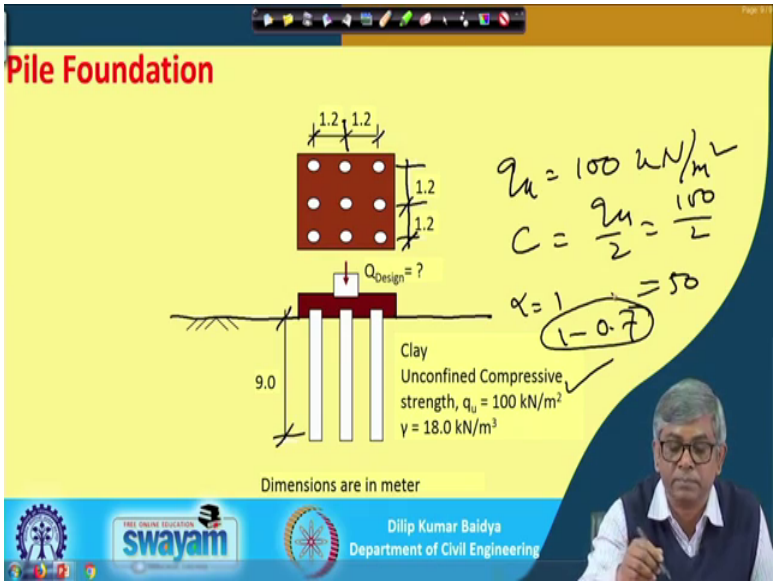
So, based on these now I will take a problem now suppose the problem is given like this a pile group consists of nine friction piles in clay soil; the diameter each pile is 0.4 meter and the embedded length is 9 meter and centre to centre pile spacing is 1.2 meter. Soil condition are shown actually I will show the figure and determine the block capacity of the pile group using fact using a factor of safety of 3, and allowable group capacity block capacity using factor of safety 3 allowable group capacity based on individual pile failure use a factor of safety 2, along with the covers level Converse-Labarre equation for pile group efficiency.

That means, whatever equation I have shown that efficiency equal to 1 minus theta multiplied by m into n minus 1 plus m into n minus 1 divide by 19 mn that is by the name of Converse-Labarre that equation was named. So, that means, while calculating allowable group capacity based on individual pile failure that time you have to single pile you have to take a factor safety of two and efficiency to be calculated there are different method I have already mentioned. So, we have to use particular method that is Converse-Labarre method; that means, this is the equation.

And, so, block capacity we will find out based on group capacity based on individual failure also we will have to find out and then final third one actually design capacity to the pile group we have to take find out from the design capacity. How to find out the design capacity, I have already explained that you have to compare the two values the

smaller one or lower one to be taken as a recommended design value for the group capacity, ok.

(Refer Slide Time: 17:43)



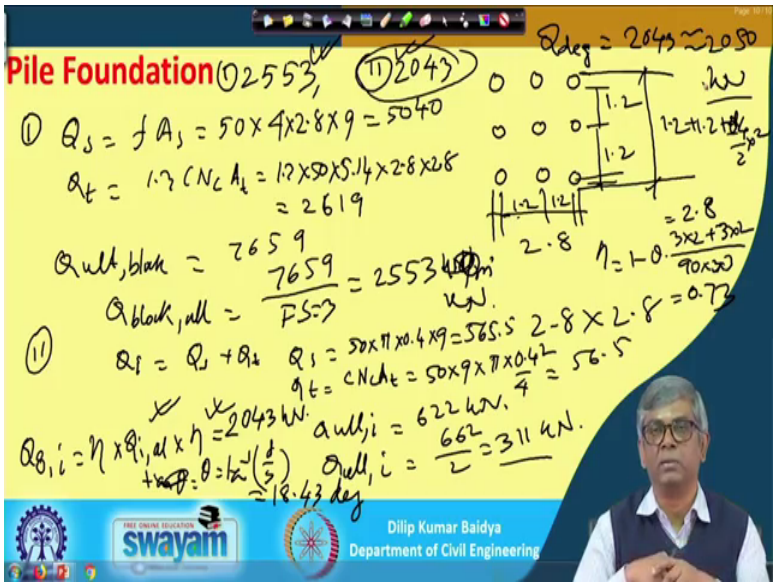
So, with this so, I have in this problem actually it is mentioned soil condition shown in the figure. So, let me go to the figure you can see the figure actually here the 9 piles are shown here and this is actually. So, 1.2 meter, 1.2 meter spacing both side and the depth is 9 meter actually you can see and this is the ground mark and, so, this is the problem and clay soil.

So, unconfined compression state is q u is given hundred and kilo Newton per metre square. So, from here I will get C equal to q u by 2; that means, 100 by 2; that means, 50 and gamma may not be used in the calculation, but it is given as a routine soil information here actually one thing is not given that is actually assumption factor.

So, when assumption factor is not given it is your choice sometimes you can assume as alpha equal to 1 or you can take any value between 1 to between 1 to 0.7 to 1 between any value can be assumed, ok; so these are the things. So, now, based on this information we can try to see the problem solution of the problem. So, first thing is asked actually group capacity like block capacity of the pile.

So, let me let me go to the next page.

(Refer Slide Time: 19:27)



So, let me block capacity. So, it is like this,. So, this is actually 1.2 this is 1.2. So; that means, this dimension suppose sorry, this will be 1.2 plus 1.2 plus d by 2; that means, 0.4 by 2 multiplied by 2. So, that means, it will be 2.4 plus 0.4 so, it will be 2.8. Similarly, this side it will be 1.2, 1.2 and this side d by 2, this side d by 2; so, it will be again 2.8. So, dimension of the block is 2.8 by 2.8.

So, I can find out Q ultimate oh no, not Q ultimate I will show I will find out suppose Q s Q s will be f time A s. So, f actually alpha C and C I have got 50 and alpha if I take as 1. So, it will be actually 50 multiplied A S will be how much. The since it is a square 4 times 2.8 is the perimeter multiplied by length actually 9, ok.

So, this value will be there actually this is this value if you calculate we will get 5040 and Q t will be equal to 1.3 C N c multiplied by A t. So, it will be 1.3 multiplied by 50 multiplied by 5.14 and multiplied by multiplied by A t is actually 2.8 multiplied by 2.8. So, this will give you a value equal to 2619. So, Q ultimate block will be equal to this plus this equal to; that means, 7659. So, Q block allowable will be equal to 7659 divide by factor of safety equal to 3. So, if I do that then you will get 2553 kilo Newton per sorry 2.53 kilo Newton; so that means, block capacity become this.

Now, if we want to find out this is the first question asked; second question asked actually based on individual pile failure, ok. So, based on individual pile failure we have again Q i will be equal to Q s plus Q t and Q s will be equal to Q s will be equal to your

50; that means, C multiplied by A s will be equal to how much pi multiplied by 0.4 multiplied by 9. So, this is actually your. So, this will be coming 565.5.

And, your Q t will be equal to your it will be C N c A t. So, C is 50 N c actually individual pile so, it will be 9 and A t equal to pi multiplied by 0.4 square divide by 4 and that if you calculate it comes around 56.5. So, your Q ultimate individual it comes this two together around 622 kilo Newton and Q allowable I that will be 622 divide by 2; that means 311 kilo Newton.

Now, your Q group based on individual failure it will be eta multiplied by Q i allowable multiplied by n. So, this is already known, this is known 9, and eta; eta to be calculated if I put the eta value you can say your tan theta will be tan inverse sorry theta you will be equal to tan inverse d by S, ok. if I do that then you will get a theta equal to 18.43 degrees.

And, then if you put that equation eta equal to 1 minus theta multiplied by 3 multiplied by 2 plus 3 multiplied by 2 divided by 90 multiplied by 3 into multiplied by 3; so if you calculate it comes around 0.73. So, if I put this 0.73 value here and then Q i value then you will get a capacity equal to 2043; 2043 kilo Newton,.

So, this is actually; that means, second problems part second; from first I have getting the value actually equal to 2553, 2553 and from second I am getting the value equal to 2043, 2043,. So, this two values I have got. This is based on block failure, this is based on individual fail failure. So, two values I have got.

Now, I have to recommend for the design. So, what value I should recommend? As I have mentioned that minimum of this two. So, minimum of this should this is a minimum; that means, based on individual failure whatever capacity I will get that could be recommended value. So, Q design ultimately you can recommend Q design will be equal to 2043. So, approximately you can say 2050 also can be 2050 or 2000 itself can be given 2000 kilo Newton will be the capacity of this group.

So, this is a problem actually for calculation of group capacity of the piles when they are n number of piles in a group and particularly in the square group; most of the time it will be square group. It may not be of course, there in that case you have to do differently. But, when it is in square group then how to find out the block capacity how to find out

the group capacity based on individual failure. This two to be checked and based on that what will the slope must be lower value to be recommended as the group capacity of the design of the pile group.

So, this is the another application actually; that means, I have discussed about the pile capacity single pile, driven in clay, driven in sand and then group capacity again pile failure individually or as a block failure; so two different ways. So, these are the things are there and of course, this type of problem whatever I have taken this is generally when it is in the clay, but when it is in the sand the efficiency generally will be taken as a 100. So, it will be there is no issue to find out the group capacity ok.

So, with this I can stop this.

Thank you.