Foundation Engineering
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Lecture – 24
Shallow Foundation – Design IV

So, in the last class I have discussed about the design of an isolated footing, resting on clay now in the in that problem.

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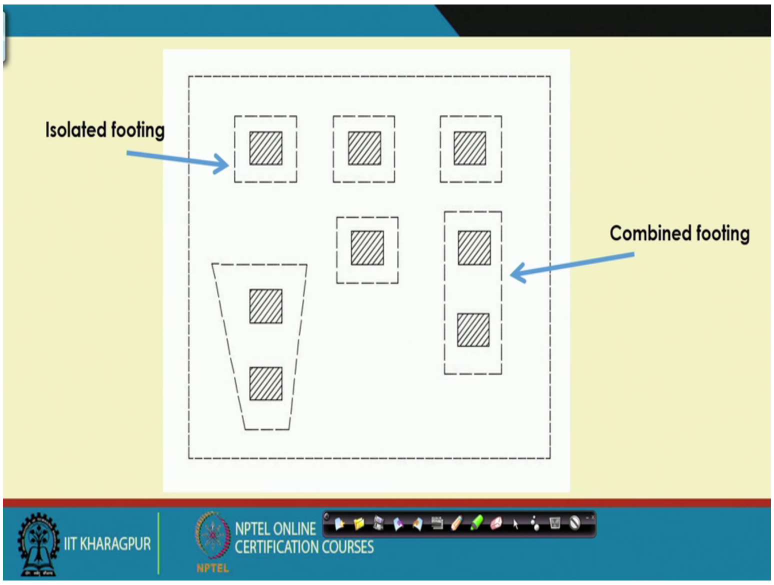

So, this is the isolated footing that I have designed in that problem if this foundation is the combined type of footing, then how we will design that. So, design procedure is same as this isolated footing. So, in that case, you have to convert this all the way that is coming for that foundation into that centroid of that foundation; and you choose the dimension according to that and then check the dimension on the, on the soil whether that dimension is safe against bearing capacity and settlement and or and then you decide that who which dimension we will choose.

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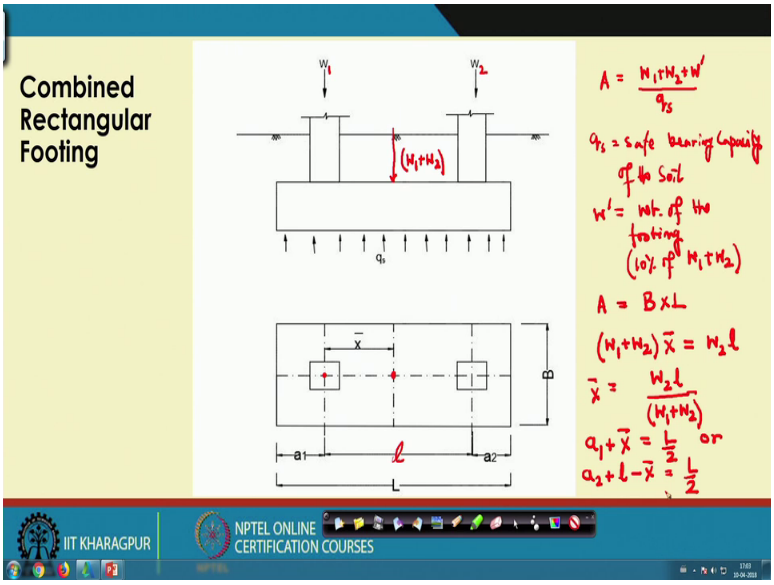

For example, suppose so this is the combined rectangular foundation. So, here that the 2 columns load are coming W and W this will be the one will be the W 1 another will be say W 2. So, to that loadings are coming and now we have to first, I will discuss how I will choose a dimension of this foundation. So, this is the l is the distance between the 2 columns x bar is the centroid distance from the centre of this right or left column.

And a 1 and a 2 are the distance from the centre of the column to the edge of the right and the left portion of the footing, B is the width of the footing L is the length of the footing.

So now the area is equal to will be W 1 plus W 2 plus W dash divided by the q s or q safe q safe is the allowable bearing capacity against which I am designing it ok. And the q safe is the allowable or safe bearing capacity of the soil and W a dash is the weight of the footing which is generally taken as around 10 percent of W 1 plus W 2. So, this way I will get the area this is the area I can get and then, suppose my dimension I am get inform that area is B cross l ok.

And then I can if I take the moment of this loading from this point, then I can write that W 1 plus W 2 because now here the W 1 and W 2 is acting, because here now I am assuming that this is acting in centroid. So, this is W 1 plus W 2 because both the put load now he acting in the centroid of this footing. So, W 1 plus W 2 into x bar will be equal to W 2 into l, l is the length of this a distance between 2 column. So, my x bar will be equal to W 2 into l divided by W 1 plus W 2. Similarly, I can write that a 1 plus x bar will be equal to here l by 2, or a 2 plus l minus x bar because a 2 plus l minus x bar that is also l by 2.

So now we have we have unknowns a 1 a 2 l B these are the unknowns ok. So now, how I can determine these unknowns because now we have x one x bar I can calculate because l is known W 1 is known W 2 is known. So, I know the x bar. So, and I have this I can if I assume any B value L value if I assume l value or B value then if I know the area, then I can assume the B value if I assume the B value I can get the L value also, and then if I know the L value from here, I know if I know the L value I know the x bar; I can calculate a 1 and a 2, based on that I will take the dimension ok.

So now this dimension we have to now decide when we decide this dimension then we have to go for the checking whether it is safe against settlement and bearing or not, and then we will do the. So, do the design so same as the or the previous problem that I have solved. So, here the only thing is that you have to choose the proper dimension what will be the B L a 1 a 2. So, this will be the (Refer Time: 06:04) so that; your the total load should act as the centroid of the footing that is the case.

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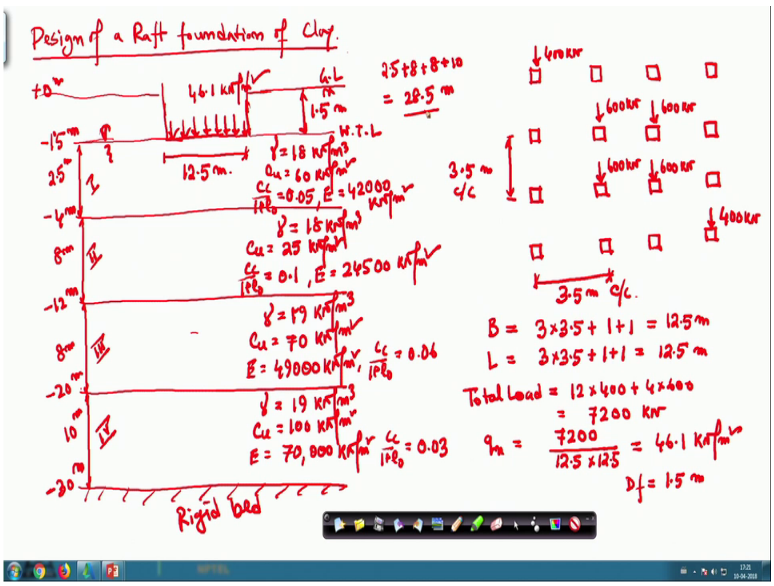

And next one that I will do so, this is the design of a raft foundation on clay. So, suppose we have a column arrangement is like this. So, this is the column arrangement of a building. And so, this is the 3 meter centre to centre each column as I say 3 meter centre to centre. So, 3 meter centre to centre this side, and this side also the each column is sorry 3.5 meter centre to centre this is also 3.5 meter centre to centre; this is also 3.5 meter centre to centre.

Now, for the this outer columns each column is carrying 400 kilo newton and the inner 4 columns they are carrying 600 kilo newton each ok. So, this outer columns are carrying 400 kilo newton each. So now, the so first thing I have to check it whether the isolated footing is sufficient or not. If we find the isolated footing is not sufficient and the all the footings are overlapping each other then in that case we will go for the come with go for this raft foundation, where all the foundation foot all the columns were taking under one foundation. And another thing that we are talking all in this case we are talking about the maximum settlement, but we have to also check if we are designing this isolated footing that for the differential settlement also because in different columns the loading is not same.

So, your settlement will also be different. So, you check the settlement for every columns and then check whether that differential settlement is within the limit or not. If no within not within the limit then we have to redesign, it redesign the dimension of the footing such that total settlement as well as the differential settlement should be also within the permissible limit ok, but here we assume after the checking we find the that this isolated footing is not sufficient. So, we are going for the raft foundation. So, we will take all the columns under a foundation single foundation and that is a raft foundation.

So what is the dimension for the first trial I am taking? So, for the first trail I am taking so the B value is we are taking. So, this is the centre to centre and then this is 1 2 3 into 3.5; so that will give you distance between from this column to this column centre of this column and then I am taking 1 meter this site additional plus 1 meter this site ok.

So, that is the first trial I am taking and because we have to provide some additional part from the each of the footing for the (Refer Time: 10:11) of the column for the foundation so this is equal to 12.5 meter. Similarly, L also I am taking this is 3 into 3.5 then I am taking the one meter in both the side additional from the centre of the columns. So, 1 meter plus 1 meter that is also 12.5 meter ok. So, this is the dimension now, what is the total load is coming on this foundation? So, total load is coming there are outer column is 1 2 3 4 5 6 7 8 9 10 11 12.

So, 12 columns they are taking 400 kilo newton load and 4 columns are taking 600 kilo newton load; so the total load is 7200 kilo newton ok. And the dimension is taken 12 cross 12.5 cross 12.5. And so, the net load or stress that is acting on the base of the foundation is 7200 divided by 12.5 into 12.5 so that is equal to 46.1 kilo newton per meter square ok. And we have assumed the depth of foundation is at 1.5 meter below the ground level. So, this is the assumption for the first trail, now come back to the soil properties ok.

So, this is the base of the foundation, where the net stress that is acting is 46.1 kilo newton per meter square and the width is taken as 12.5 meter. And this is this base of the foundation is at 1.5 meter below the ground level and ground level say here. So, this is GL the this distance is 1.5 meter and this is plus 0 meter and water table is also at a depth of 1.5 meter. So, this is the water table water table location. So, this is also water table location which is 1.5 meter below ground level.

So now the soil has 4 layers, this is the first layer second layer, third layer and the forth layer. After that is a rigid bed and as I mention for the rigid bed there will be no settlement. So, this is the rigid bed or the rock bed. So now, the dimension is given, so this layer is minus 4 meter this is minus 12 meter and this was minus 20 meter and this is minus 30 meter ok. So, the properties that are given this is layer number 1-layer number 2-layer number 3 and layer number 4 and.

The properties that is given for the for the first layer this is kilo newton per meter cube unit weight and cu is 60 kilo newton per meter square and cc 1 plus E 0 is equal to 0.05 and E value is equal to 42000 kilo newton per meter square. So, again if the E value is not given, for a normally consolidated soil, the reasonable 700 to 1000 in between or 750 and 700 cu will be a reasonable value so that, I have used in the previous problems.

So, again for the second layer unit weight is 18 kilo newton per meter cube and your cu value is 25 kilo newton meter square cc 1 plus E 0 is 0.1 and E is taken 24500 kilo newton per meter square. For the third layer unit weight is 19 kilo newton per meter cube and cu value is 70 kilo newton meter square and E value is given 49000 kilo newton per meter square and cc 1 plus E 0 is equal to 0.06.

And for the 4th layer unit weight is 19 kilo newton per meter cube, cu value is equal to 100 kilo newton per meter square and E value is 70000 kilo newton per meter square and cc 1 plus E 0 is 0.03 ok. So, these are the values are given and we have to now design the foundation. And remember that here if you find that for the bearing capacity calculation on influence zone is B, so and B is 12.5 so 12.5, this is 1.5 so and below here 12.5 will be somewhere here.

So that means, the most of the layer is influence is a second layer and the minimum lowest cu value and then equation is 25 and that is for the second layer. So, one thing that as the most of the layer is influenced by the second layer because your this is this layer thickness is say 2.5 meter. This layer thickness is 8 meter this layer also 8 meter this layer is 10 meter, but the influence zone because this is 12.5.

So, 10.5 and 2 meter, this layer the third layer is influenced by only up to 2 meter. So, the third layer is influenced by up to 2 meter then the first layer is influenced by 2.5 meter. So, and then second layer is influenced by 8 meter. So, that is the maximum so one-way that you can take the lowest value of cu and you can do the calculation because that will give you the I mean the safest design ok.

So, because you are taking the lowest cu value, but I would prefer to take the weighted average, but if you want you can take the 25 also because that is the lowest value and the most than that influence zone is covered by the second layer only most of the influence zone is covered by second layer and that is giving the lowest value. So, you can take that value as you design cu, but I will prefer to take the weighted average. So, that is why I will take the weighted average of cu.

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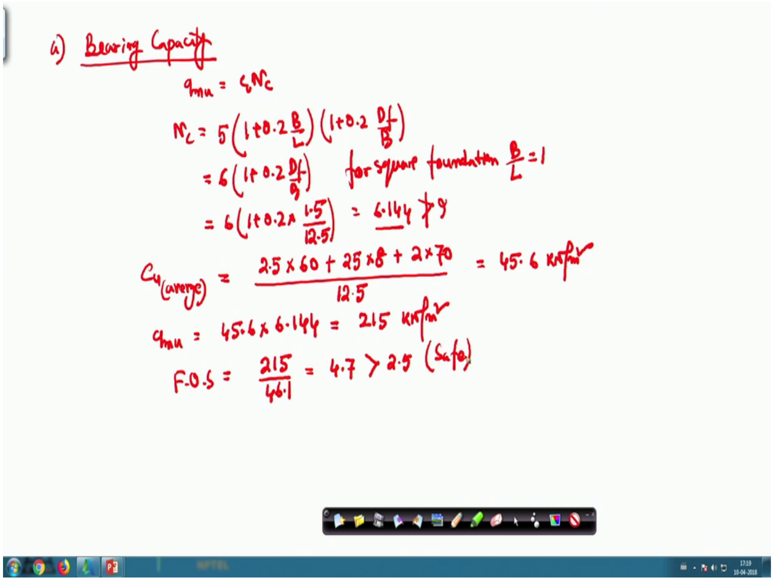

So, yeah so; that means, now the first checking is the bearing capacity. And again this is for the for the c soil only cu soil only. So, I will take net ultimate is c cu N c and I will take the Skempton expression that I have used for the isolated footing also. So, N c value in general way for the rectangle footing is 5 1 plus 0.2 B by L into 1 plus 0.2 Df by B. And for the square footing this will be 6 1 plus 0.2 Df by B that is for square foundation as B by L is equal to 1. And so, this value is coming out to be 6 1 plus 0.2 Df is taken 1.5-meter B is 12.5 meter. So, this is 6.14 and this is not greater than equal to 9.

So, I can take 6.14 as a value because it cannot be should cannot be greater than 9 also that is for the Skempton recommendation. So, I am taking the cu average is equal to so for the first layer the 2.5 meter is influence zone and that is cu value is 60 because in the first layer cu value is 60 and 2.5, second layer 50 is the cu value influence zone is 88 meter and the third layer influence zone is again 2 meter and cu value is 70.

So, then plus 25 into 8 plus 2 into 70 divided by 12.5 meter and that is equal to 45.6 kilo newton per meter square. So, q net ultimate is 45.6 into 6.14 or 6.144 that is equal to 215 kilo newton per meter square ok. So, my factor of safety is equal to 2.5 divided by net stress that is acting which is 46.1 because net stress is 46.1 is the net stress and then that is equal to 4.7, which is greater than 2.5 and safe. So, it is very much safe I can say because 2.5 is requirement 2.5 to 3 it is 4.7 close to 5 so, but let us see whether how much it is safe against settlement, then we will decide whether we will redesign it or not ok.

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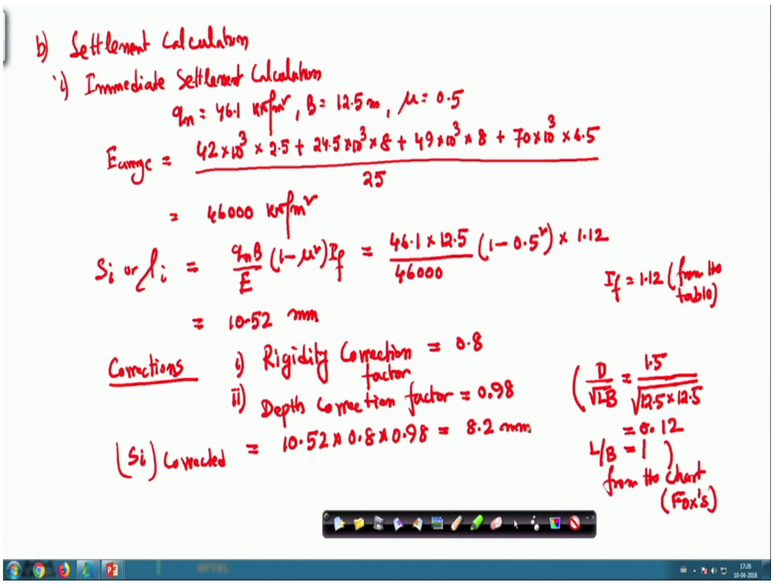

So, the next one we will do the settlement calculation and for the B is the settlement calculation. And first we will do the immediate settlement calculation. So, our q net is equal to 46.1 kilo newton per meter square B is equal to 12.5 meter and mu value (Refer Time: 22:50) will take 0.5 and the again E average or weighted average I am taking. So, here now the influence zone is 2.5 in 12.5 into 2; that means 25 meter is the influence zone, but my thickness of the layer before it is before the rigid bed is 2.5 plus 8 plus 8 plus 10.

So, it is it will be your 16 so that the total thickness will be 2.5 plus 8 plus 8 then plus 10 so; that means, it is equal to your 20 8.5 meter ok. So, this is 28.5 meter, but my influence zone is 25 meter. So, the total forth layer is not within the influence zone, but some part of the forth layer is within the influence zone. So now, this is 2805, but actually influence zone is 25 meter ok.

So now the E average I am taking is this is 42000 into 10 to the power 3 that is for the first layer. So, first layer thickness is 2.5 meter and this is 42000. So, first layer 42000 and 2.5 meter, for the second layer it is 24.5 into 10 to the power 3 kilo newton per meter square. So, that 24500 so and thickness is 8 meter.

So, I can write this is 24.5 into 10 to the power 3 and thickness is 8 meter similarly for the third layer it is 49000 into 3 and the thickness is 8 meter, but for the forth layer the thickness will be only 6.5 meter it is not the total one. So, for the next layer is 70000 is the E value kilo newton per meter square. So, it will be 6.5 meter. So, the total thickness 8 8 16 and 18.5 plus 6.5 so it will be 25 meter ok, because that is the influence zone.

So, my E value is 46000 kilo newton per meter square. So, the S c or the row c; that means, the row I is the immediate settlement and that is q n B by E into 1 minus mu square into I f. So, that is equal to 46.1 into 12.5 divided the E value is 46000 and 1 minus 0.5 square and again it is asquare foundation. So, at the centre is 1.12 is the, I f value from the table. So, I f is 1.12 from the, I remember that here I f, I am taking the flexible foundation centre for the square footing and later on we will apply the rigidity correction because it is rigid foundation.

So, that is why we can take the flexible foundation I f value at the centre that is taken here. So, this value is 10.52 millimeter. Now the corrections, the first correction is the rigidity correction which is equal to 0.8 because it is a rigid foundation raft foundation and second correction or correction factor this is the depth correction factor, factor your the value is D by root over LB. So, the d is 1.5 meter then root over 12.5 meter then cross 12.5 meter.

So, this value is 0.12 and corresponding L by B is equal to 1. And this value is factor is equal to 0.98, from the, this is from the chart or Foxs chart ok. So, from the Foxs chart i am getting the rigidity correction depth correction is 0.98. So, S I corrected will be equal to 10.52 into 0.8 into 0.98. So, that is equal to 8.2 meter ok. So, the immediate settlement that I have calculated is 8.2 millimeter and now I have to calculate the consolidation settlement then we will see whether the dimension that I have chosen is within the permissible limit or not. So, in the next class I will calculate the consolidation settlement then you will finish this problem.

Thank you.