Geotechnical Engineering II / Foundation Engineering

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Lecture - 18
Settlement of Foundation (Contd.)

Once again let me continue with Settlement of Foundation and that too I have mentioned that we the foundation settlement total settlement may consist of three core parts; one is immediate settlement, consolidation settlement and secondary compression and we are now discussing on immediate or elastic settlement. And for different shape of footing on different soil, if it is a infinitely homogeneous soil layer, then how to find out the settlement I have just mentioned and but the soil and that is comparatively easy single formula and only if you know the width of the footing and soils Young's modulus and Poisson ratio, then we will be able to find out the settlement.

But then the actual field condition may not be homogenous up to the infinite depth or up to large depth. In fact, below the footing quite often will have multiple layers. And when these multiple layers so footing raised on multiple layer of soil, then actually how to find out the settlement. So, we have discussed smart methods in the previous lecture and we have given two models; one is for actually strip footing and another model for square and circular footing. And using this two model, how to find out the settlement I have discussed also, but let me take one problem to explain the how this method can be used. And let me go to this problem.

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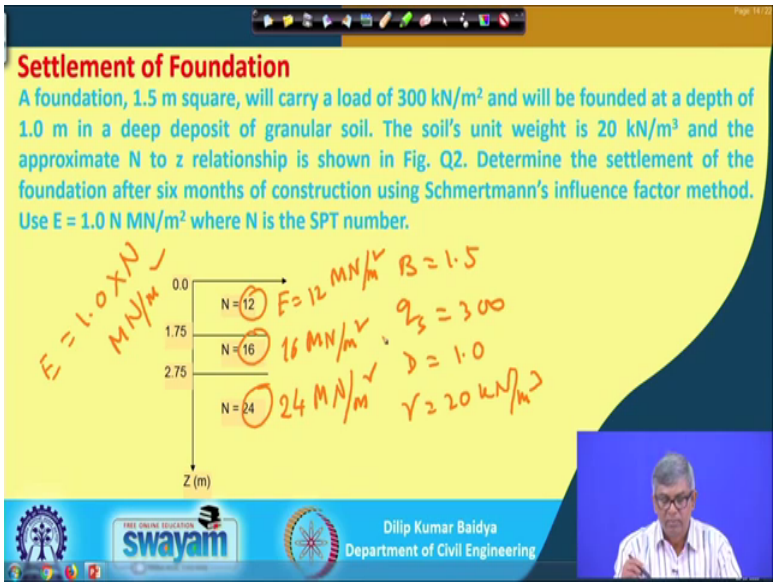

The problem is given here.

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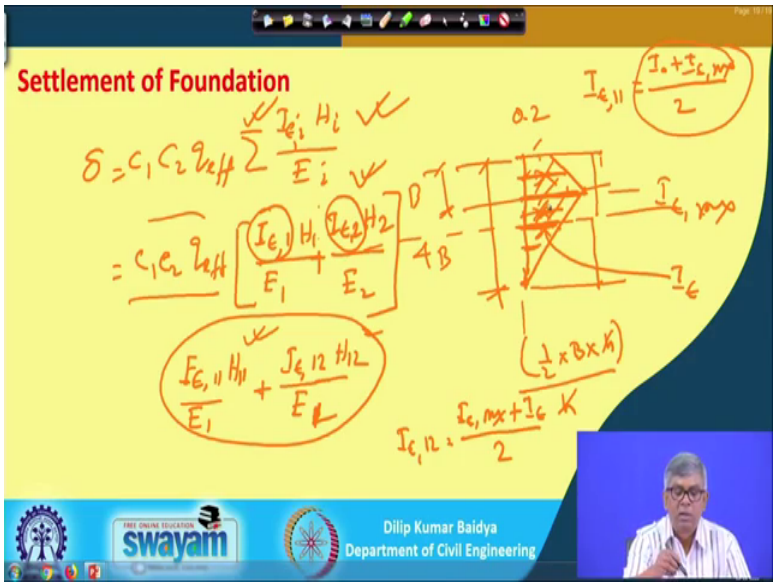

But before going to the problem, let me take you sometime to explain how to use this equation. The equation was the initially, the model was something like these. Suppose, so this is the model. This is either this depth. Suppose, if it is a strip it will be 4 B and similarly this will be B and this will be your 0.2 considering strip and this is actually I epsilon max.

Now, but our expression for settlement is delta equal to C 1, C 2 q effective and then sigma I e epsilon i H i divided by E i. So, equation is like that. So, how to apply this equation? So, suppose I imagine the soil has a has two layers; one layer is this and another layer up to some depth, but I need not go up to that depth what I have to do, I have to find out settlement for this layer and settlement for this layer up to this depth.

So, how I can find out this? This equation can be written slightly different ways like you can see now. So, this is a area it is little two trapezium actually; this is one trapezium and this is another trapezium. This area coming under one soil, but your expression can be written something like this; C 1 C 2 q effective and I can write sorry I epsilon 1 H 1 divided by E 1 plus I epsilon sorry, I epsilon 2 H 2 divided by E 2 I can write the equation in this formula. So, n it is two layer, I can write equation like this. This is this summation removing this summation, I can write this.

Now, my I have to find out what I E 1 that mean influence factor for the layer 1 and I E 2, influence factor for layer 2 I have to find out. Now, we can see this is a area variation is there. So, there is not a one value that is a irregular shape and this is a triangular shape ok. So, there they have also different point different I value. So, how to find out this one? So that means, I may vary over depth, but it is varying linearly. So, because of that, I can take the average.

So, suppose this one, this is a triangular area. So, triangular area at the middle of the, so, I can take the half. What is the value at the base and at the 0? So, at the middle, it will be definitely half. So that means, how to what concept we are using concept actually using to find out the average influence factor, I can think of finding out the area divided by the depth. So, half multiplied by base multiplied by height, this is area and divided by height. So, it will become b by 2; that means, what about the value here? Half of that can be taken for I E for second layer, but for first layer how to find out the I E here actually since irregular, I can divide it again first layer into two parts. This is one part and this is this is one part and this is another part

So, I can write this first part. I can write sorry I E 1 1 by E 1 H 1 1 plus I E 1 2 divide multiplied by H 1 2 divided by E 2; that means, what I have done sorry this is again E 1 because same layer. So, what I will find out, I E 1 1 and I E 1 2; that means, I will find out average of the average I here and average I from here.

So, for that what I need this maximum value is known. So, I know this distance and, I know the layer position, then from the symmetric triangle, I can find out this value. I can from the symmetric triangle, I can find out this value. Once I know this value, I know this I know this I know this. So, now, what I will find out this is trapezoidal area, I 1 1, I E 1 1, I will find out this one. This is suppose this is suppose I 0, I say plus I E max divided by this plus this divided by 2. Then, it will be average is not. So, I, so half multiplied by this multiplied by height is the area and area divided by the depth, I will get the average.

So,, so, this is the value of I E 1. Similarly, I epsilon 1 2 will be I E max plus this value, suppose I E of I, I I epsilon which to be determined from the symmetric triangle divided by 2. So that means, since that I have this equation, now since two layers, I can write in two components, I E 1 and I E 2 and when in the zone 1, if the two different areas are their irregular, then again I can find out two areas are there. So, I can find out I E into two parts; I E 1 1, I E 1 2. So, that for that actually what I will do, I will find out this first and this all three are known. So, I will be doing I E 1 can be obtained this way. I E 1 2 can be obtained this way. Then finally, substitute here and I know what is the height here, what is the height here. So, multiplied by this and this then I will get the ultimately, component for first one and then second one.

So, like that, I will add and that multiplied by these, I will get the total settlement of the footing resting on these two layer soil. If it is any number of layer, suppose in between there are number of like, then you have to divide more number of pieces this triangular area and this area into more number of parts. So, that is the thing I will try to show by this problem. So, this is the one, this is a problem actually you can see now. It has a foundation 1.5 meter square; that means, square foundation will carry a load of 300 kilo Newton per meter square and will be so; that means, 300; that means you are sorry.

So, that means, your square footing b become 1.5 and your q s become 300 and you will be found it at a depth of 1 meter. So, D equal to 1 and the soils unit weight is gamma equal to 20 kilo Newton per meter cube and the approximate n to z relationship is shown in figure with the, I will talk about that. Actually, instead of given instead of giving E value, E value can be correlated with n value that the SPT number which we will discuss later on. So, n is the SPT blow count for this layer it was 12, for this layer it was 16, for this layer it was 24. A relationship with E, relationship with n to E is given here E equal

to 1 multiplied by n in mega Newton per meter square. That is ultimately that first layer E will be equal to 12 mega Newton per meter square, second layer it is 16 mega Newton per meter square and third layer it is 24 mega Newton per meter square. So, this is the situation given. So, for this, I have to find out the settlement ok. So, for that, let me see 1 by 1.

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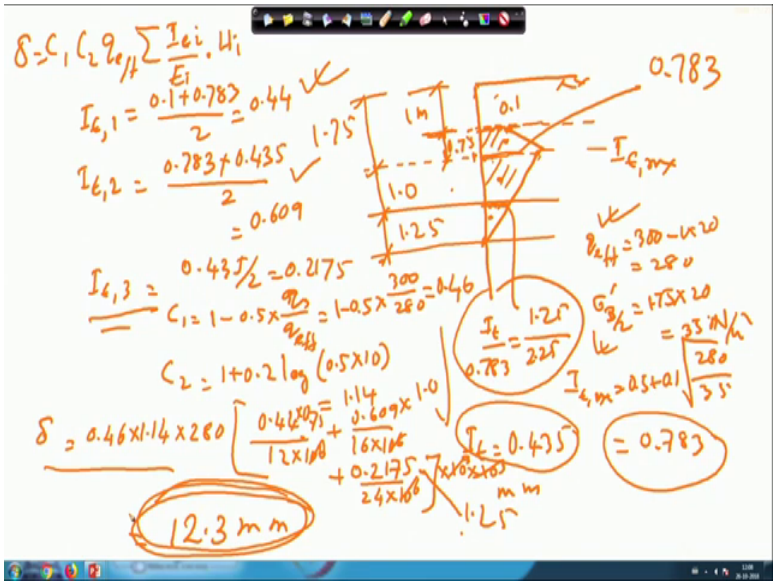

Suppose, your ground surface is somewhere here and your footing is at one meter depth, suppose footing is at this depth. So that means, your diagram will start from here and since it is a square footing the value here actually 0.1 and since it is a square footing, it will be b by 2 maximum will be at b by 2 and. So, that will be somewhere these and maximum will be at 2 b depth. So, this, so, diagram will be something like this and this is 1 meter, first layer is 1 meter and second layer will be, now first layer will be this is depth of foundation. Your first layer actually up to 1.75 meter and since it is b by 2, b is 1.5. This is also 1.75. So, because of that, it is coinciding.

So, first layer and I E max that is I E max at the same level and then, second layer is at 1 meter below. This is again 1 meter and this is actually again that will become 1.25, ok. So, this layer is extended beyond that, but I will take settlement up to this. So, this is the diagram now. So, you will have q effective, q effective will be 300 minus 1 multiplied 20. So, it will be 280 and you will be having sigma B dash it is sigma B by 2 dash actually sigma B by 2 dash. That will be equal to will be 1.75 multiplied by 20. So, that

will be equal to 35 kilo Newton per meter square and I E max I epsilon max will be equal to 0.5 plus 0.1 under root q effective is here 280 and sigma b by 2 dash that is 35. So, that gives you 0.783.

So, this value is 78, 0.783. And if I know the distance, so I can find out, I E suppose this layer. So, this I E I can find out from the symmetric triangle. So, I epsilon divided by 0.783, this is 0.783, these value is 0.783. So, I 0.783 will be equal to 1.25. So, this side is 1.25 divided by the entire height that is 2.25. So, from there I will get I epsilon will be equal to 0.435.

So, now I have to find out the total settlement and for a total settlement I need; that means, I have to find out for this layer, I have to find out for this layer, I have to find out for this layer. So, three parts, there will be three parts. So, I epsilon 1 will be how much. So, I know 0.1 here at 0.783. So, it will be 0.1 plus 0.783 divided by 2 that will be equal to your 0.44 and I epsilon 2 will be equal to you can see this plus this by 2. So, this will be 0.783 plus this 1 is 0.435, 0.435 divided by 2 that will be equal to actually your 0.609 and I epsilon 3 will become the half of this; that means, 0.435 divided by 2 and that is be 0.2175.

So, we have got this. Now, you have to find out C 1. C 1 actually your C 1 equal to 1 minus 0.5 multiplied by q s by q effective. The q s by q effective; that means, in 1 minus 0.5 multiplied by 300 divided by 280 and that gives you 0.46 and C 2. Actually, it is mentioned after 6 months. So, it will be 1 plus 0.2 log 0.5 multiplied by 10. If I do this, then you will get 0.14.

Then, your delta becomes 0.46 multiplied by 1.14 multiplied by 280 that is outside of the expression and this will be three component. So, I E 1 it will be 0.44 divided by it is 12 multiplied by 10 to the power 6 and plus second 1 is 0.609 divided by the it was 16 multiplied by 10 to the power 6 plus, the last one is 0.2175 divided by 24 multiplied by 10 to the power 6 and this is 10 to the power 6 Newton per meter square. This was it kilo Newton. So, for that, I can multiplied by 10 q and then I can multiply for to express in millimeter another 10 cube. So, these, these will get canceled. So, it will be expressed in millimeter and if I simplify this entire thing then finally, we will get settlement equal to total settlement will be equal to 12.3 millimeter ok

So, this is the one. So, everything I have shown here very clearly. I hope you can see that the footing is placed at 1 meter. So, this is the ground mark, but this is the footing level and first layer is up to 1.75 meter and since it is a square footing, then is influence factor will become maximum at b by 2 from the base of the footing. So, base of the footing is these and b by 2 is 0.75. So, these depth become 0.75. So that means, that total depth from the surface that I max become at 1.75 meter depth and this is the depth of first layer also; that means, depth of first layer and the I max is coinciding.

So, beyond that, I will not consider, but from here I will be considering. Then, then I E max actually there is the expression. For that actually, we have the I E max actually 0.5 plus 0.1 under root q effective by sigma b by 2 dash. So, for that q effective I have calculated sigma b by 2 effective I calculated and use this expression I have got the I maximum. Once I have got I maximum, so, I have put here and then I know that for square footing and circular footing, the strain becomes 0 at a depth to be depth. So, to be from base means how much it will be? It will be 3 meter. So, you can see this is 0.75, this is 1. So, 1.75 and then, this will be 1.25.

And so, from the first layer, a second layer thickness is 1 meter. So, 1.75 to 2.75 is the first layer and the third layer is extending beyond, but I will be considering from 2.75 to 3 meter depth. So, this is the thing, 3 meter from the base of the footing. So, this is taken. So, once I know this value, this value and this value, then what I have to find out I have to find out now. I influence factor of this layer, influence factor of this layer and influence factor of this layer.

So, so to find out the influence factor of this layer what I need to find out, I need to find out this value. How to find out this value? I can consider this triangle and this triangle from this symmetric triangle, I can express this and from there I can find out I E that is 0.435 ok. So, this is this once this is known. Now once I know this one, then what is the average value of I of this layer, half of that that is shown here and then: what is the average value of I for this layer. This will be just summation of half of sum of summation of this and this multiplied by 0.5. So, that is the thing is done and what is the average value of this that is half of this summation, half of summation of these and this. So, that is done here.

So, once I get I E 1, I E 2, I E 3 and then total expression of settlement that is your delta equal to C 1, C 2 q effective multiplied by sigma I epsilon I divided by E I multiplied by H I. So, oh sorry, I have not multiplied by H here respective H. So, it will be here, here multiplied by 0.75. Here, it will be multiplied by 1 and here it will be multiplied by 1.25 that will be also there. So, I missed that one.

So, and if you multiplied by that the value may come little different that has to be checked. So, I think I do not have calculator now. So, this will be multiplied by 0.75, this will be multiplied by 1 and this will be multiplied by 10.25. The value by enlarge will come same because it is 0.75, it is close; this is 1 will be unchanged and this is 10.25 this and this will be balanced. So, value will come close to this, but I missed this one it has to be multiplied by thickness. So, I am not done that, here also multiplied by thickness, here also it will be multiplied by thickness. So, if I do all those things, then I will get a value something close to that 12.3.

So, this is these are the steps actually, finally, to be used for calculation of elastic settlement using smart man method. So, as I have told that circular footing, different shape of footing and we know, that circular footing q B 1 minus mu square by E delta multiplied by I and I equal to 1 for circular footing maximum.

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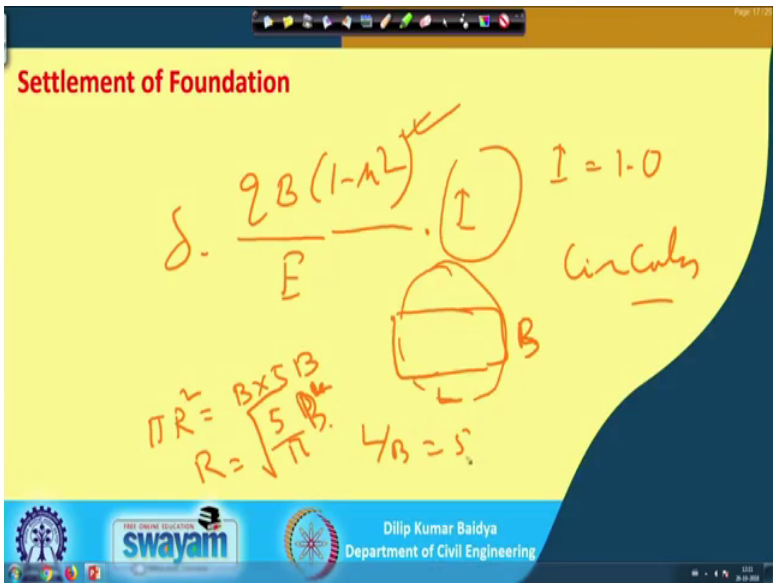

So, when that is so, instead of remembering different number, different I value, what I can do some time? Actually if there is footings is rectangular or something else, suppose

rectangular footing a rectangular footing L and sorry, L and this is B and L by B equal to suppose 5. So, this footing actually can be converted to an equivalent footing. Suppose, suppose the I can consider as pi R square equal to it will equal to B multiplied by 5 B. So, your R become R become 5 B square by under root under root pi by. So, R actually, so this equal this rectangular area can be imagine by an equivalent circle circular area, how actually R can be expressed under root 5 by pi multiplied by B.

So, this is the way if I R is expressed and then simply use this equation and then; that means, circular only one equation can be remember and for that what is the I value, if I remember and any shape like rectangle with different aspect ratio like this L by B equal to 5, then I can express pi R square equal to B in to 5 B. And then, R become this. So, if I use this R here, instead of R, instead of R is to B, so I can put here and only use equivalent circle equation. So, circular foundation equation and the result will be by enlarge similar only maybe 5 percent error.

So, some time, whatever table I have shown for different shape of footing and different aspect ratio, the different I value to be remember; instead of that, I can remember the value of circular footing and when if it is a noncircular footing, I can convert into equivalent circle and the use the equation of circular footing settlement. So, that is sometime quickly one can do it without remembering the detail table. So, with this I will close here.

Thank you.