Foundation Engineering
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Lecture - 19
Shallow Foundation - Settlement IV

So, last class are solve problem of plate load test, and we I determine the value of allowable bearing pressure or allowable bearing capacity of foundation based on the plate load test data. So, you know this class I will discuss the others method by which we can determine the settlement of foundation resting on granular material.

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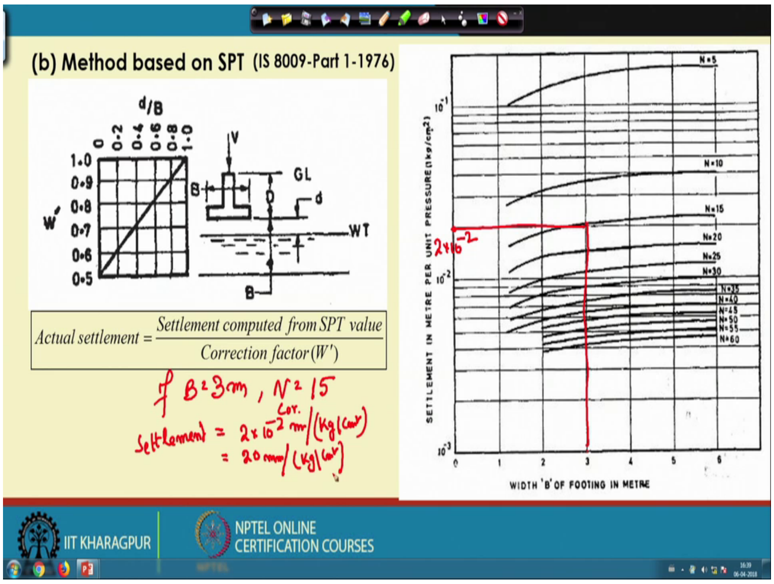

So, the next method by which we can determine the settlement is based on the SPT value or standard penetration test value. So, this is the IS code chart which we can use. So, this chart is from IS 8009 part 2 1976. So, here we can see that this is the N value, different N value starting from 5 to 60 and this is a width of the footing. So, x axis is a width of the footing this charts are for different N value and y axis is a settlement in meter per unit pressure in terms of k g per centimeter square

So, which means that; that if suppose we have a if we have a footing width if say footing width is 3 meter and N value is say 15 is the N value corrected N value this is N corrected. So, what will be the so this is the 3 this is the 15 N value chart. So, this is the 3 corresponding to this 1. So, this value is equal to 2 into 10 to the power minus 2 ok.

So, this is in the log scale the y axis is the log scale so this is in a semi log graph. So, in the so; that means, we can say that our settlement will be equal to 2 into 10 to the power minus 2 meter per k g per centimeter square ok. So, it is in terms of so if you multiply it is by 1000. So, it will be 20 millimeter per k g per centimeter. So, this per k g per centimeter is the load intensity.

So now if you have if your same loading intensity of the foundation is 1 k g per centimeter square or 100 kilo Newton per centimeter meter square, then your total settlement will be 20 millimeter if the your loading intensity suppose if the loading intensity is 2 k g per centimeter square or 200 kilo Newton per meter square then the settlement will be 20 into 2, 40 millimeter.

So, this is way we can use this chart; and other thing is that here also I can use the water table effect. So, you can use this chart remember that here this is W dash and again the actual settlement is settlement computed form SPT value divided by correction factor W dash. W dash is d by B, B is the width of the footing and d is measure from the base of the footing.

So, similar to again if it is d is 0, d is 0 then this is 0.5 if d is 0.5 that so; that means, this chart is similar to others IS code value; that means, if you are water table is at the base of the footing or above than the it is 0.5 and then it varies at B if it is at the distance B from the base of the footing there it is 1 so, it is in between 0.5 to 1. So, and this w dash we can calculate. So, even in the water table effect calculation also is the actual settlement to be the settlement that you are calculating from the SPT value and then divided by the correction factor. So, suppose if it is the base of the footing as per IS code this correction factor is 0.5.

So, if you are settlement that you are calculating from the SPT value is 20 millimeter, and the foot water table is are the base of the footing then it will be 20 divided by 0.5. So, it will be 40 millimeter because of the effect of the water table.

So, this is the water table effect, that also you can incorporated and this is we can use this chart to determine the settlement of the granular soil. So, next method that is the based on SCPT is standard cone penetration test.

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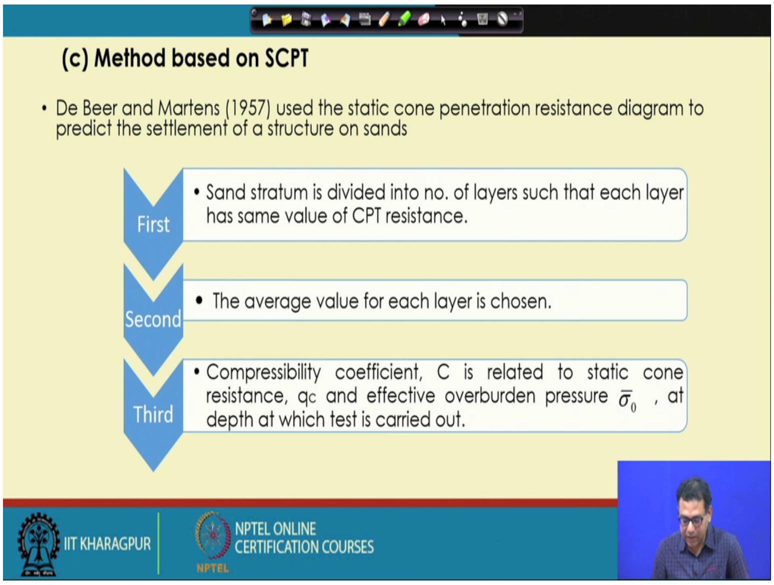

So, the method is a proposed by the de beer and martens 1957 first. So, where we can use this SCPT data to determine the settlement also, say here what you have to do you have to divide our total soil below the foundation in number of layers ok.

And then we, such that; the cone resistance of the SPT SCPT cone resistance is more less same on that layer and then we calculate the compressibility coefficient c at the middle of each layer and then we carried out. And the effective burden over pressure at that mean the cone resistance and the effective overburden pressure and the compressibility coefficient. So, compressibility coefficient cone resistance and the effective over in pressure we calculate as the middle of each layer.

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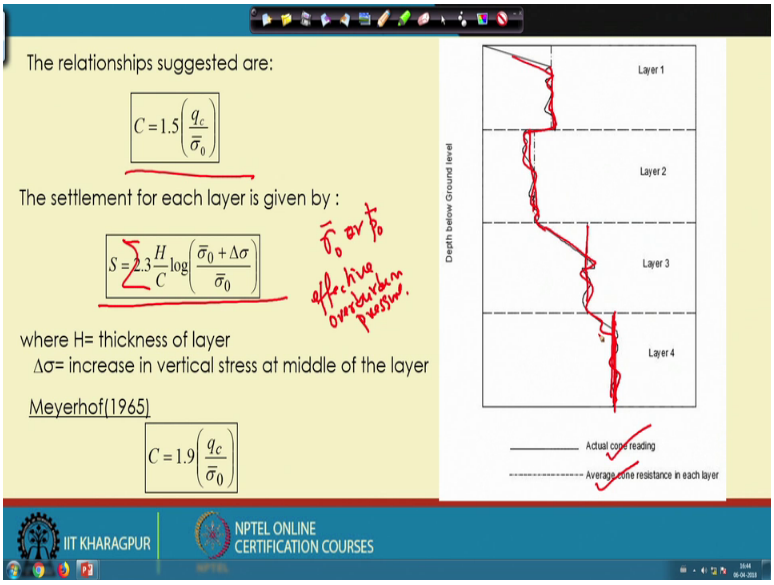

And then using this correlation or using this expression we can determine the S value, what is that? H is the thickness of each layer.

So, then this will be the summation, if I this is the number of layer this will be the summation. So, this is 2.3 H by C, C is this is the compressibility coefficient. And this C you can determine by using this correlation sigma b 0 is or the that is or the p 0 bar is the effective overburden pressure, effective over in pressure at the middle of each layer and sigma or delta sigma is the increment of the vertical stress at the middle of each layer due to the application of the external load.

So, this is sigma 0 bar is the effective overburden pressure and del sigma or the del p is the increment of stress due to the external load. So, and then q c is the cone resistance that will get from the SCPT value. And then if I use the Meyerhof suggestion then this compressibility coefficient C is 1.9 q c divided by sigma 0 bar in whereas, for previous method de beer or marten and marten is given 1.5. So, this is the other talking about this is lines or the q c radiation of a particular soil, and then we are divided it number of layer. So, that the average value is more or less same for all the layers we are taking the average value, where the variation is almost same.

So, for all the layer and taking the average value, so this is the actual cone resistance and then average cone resistance that we are taking for each layer. So, this is and then we use these methods.

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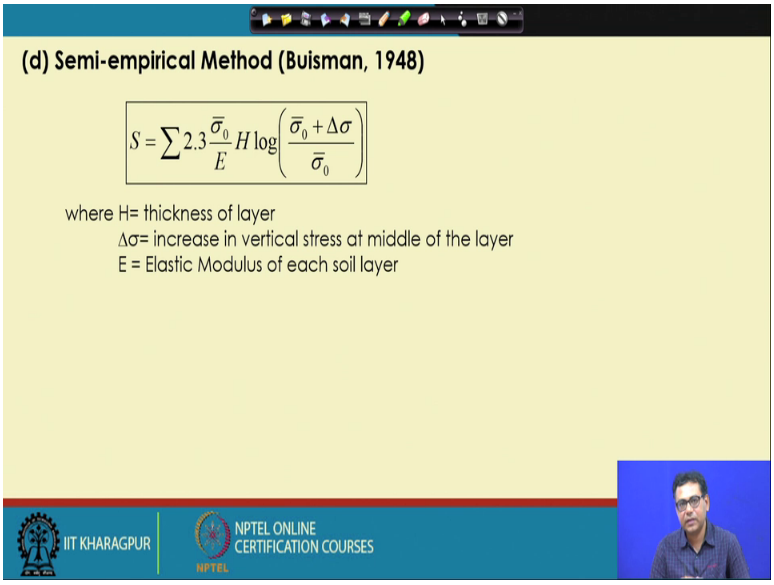

And then the next one is the semi empirical method this is provided by bushman 1948, where which is similar to the previous method SCTP. So, differences the here, here it is sigma 0 divided by E. So, initially it was C so this is the H is the thickness of each layer and again sigma delta sigma is the increasing vertical stress at the middle of each layer due to the application of the external load and el E is the elastic modulus of the each layer, and sigma 0 bar as usual the initial effective overburden pressure.

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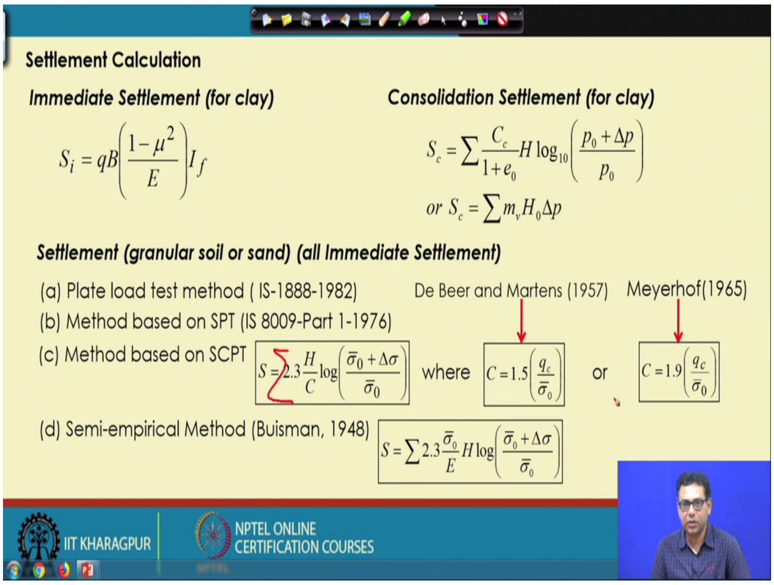

So now if I summarize all the settlement calculations method the till now we are discuss; that if I categorize it for the clay and for the sand. So, immediate settlement I can calculate for the clay by using this expression that; immediate settlement calculation. And the consolidation settlement I can use this expression or this expression, depending upon the ability of the parameter this is for the clay, but for the settlement calculation, but granular soil or the sandy soil where all the settlement or immediate settlement we can use this 4 method depending upon the availability of the value.

So, we can use the plate load test, we can use the SPT chart, we can use the SCPT value we can use the semi empirical method. So, this is the expression for the semi empirical method. Here also this is the summation and this is for C value calculation another we can use the de beer and Martens approach or we can use the Meyerhof approach. So, depend. So, either these 2 we can approach, this is 2 approach we can use. So, these are the total summary of this method.

So now first I will solve the problem, where I will calculate the settlement immediate and the consolidation settlement of a foundation of a raft foundation resting on a on a clay. So, the problem definition is that the example problem.

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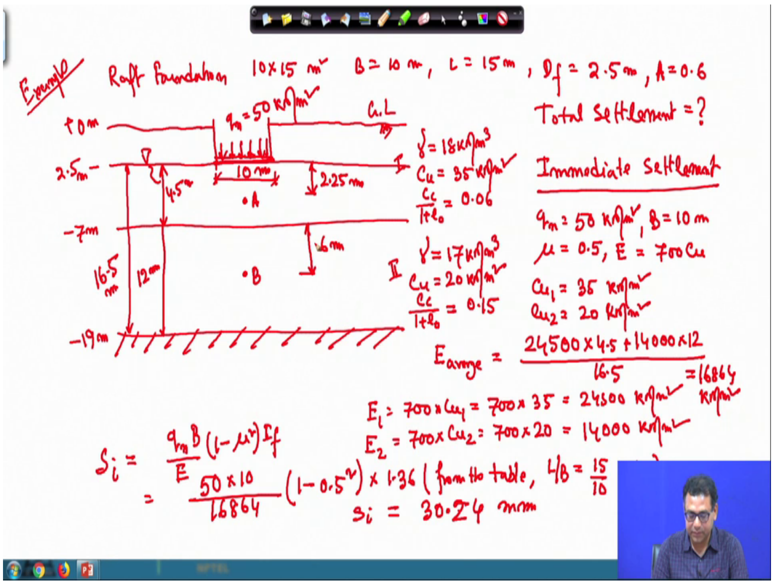

Is that that we have a raft foundation or dimension is 10 cross 15 meter square. So, that mean the 10-meter B is the 10 meter and L is equal to 15 meter ok.

So now this is the our ground surface, this is the GL or the ground level and it has the 2 soil layers' system that we are considering, this is my layer 1 this is the layer 2 and the thick this is the minus 19 meter and this layer is this is minus 7 meter and this is the 0 meter ok.

Now, the water table is at 2.5 meter below the ground surface. So, this is the water table which is minus 2.5 meter below the ground surface. Now properties that are given that unit weight of the soil is 18 kilo Newton per meter cube, and C u undrianed coefficient is 35 kilo Newton per meter square and c by 1 plus e 0 because this term will be required for settlement calculation is 0.06. So, c c and e 0 that will be determine by the consolidation test and so; that means, here we will get the c c compression index e 0.

And this layer to this unit weight is 17 kilo Newton per meter cube C u undrain coefficient is 20 kilo Newton per meter square and c c 1 plus e 0 is equal to 0.15. And the depth of foundation D f is also 2.5 meter. So, the depth of foundation is here so this is the raft. So, this is the raft where we are applying these stress and this is 10 meter. And the intensity of loading that q net q net about net stress is applied is 50 kilo Newton per meter square.

Now calculate; what is the total settlement of the foundation so that we have to calculate. Now the first I will calculate the immediate settlement and the second I will calculate the consolidation settlement, the first one is the immediate settlement ok. So now, the q net in is 50 kilo Newton meter square B is equal to 10 meter and we need the values at Poisson ratio in the clay the Poisson ratio is if it is the undrain condition, the Poisson ratio the range are given in the table. So, that load from here I am taking the k value Poisson ratio value is 0.5. In the problem that will be given in the assignment and the exam this Poisson ratio value will be given.

So, Poisson ratio and the elastic modulus is taken as 700 C u. So, in the normally consolidated range this value is around 750 to 1200 C u the table that have given. So, here I am taking 700 C u if nothing is mentioned you can take from that range or most of the cases I will mention this e value whether it is 700 or 750 c. Here it is mention 700 C u, and then the another thing is also mention the value that pore water parameter is also mention is 0.6, because this pore water parameter will be required a for the correction of poor water pressure.

So, this is the value now this C now this C u 1 first layer is 35 kilo Newton per meter square C u 2 is 20 kilo Newton per meter square ok. So, it is a layer soil and I have mention for the settlement calculation my influence zone that I will take the twice the width of the footing ok.

So now my influence zone because here it is the bedrock or the rigid. So, this is the rigid so they are. So, this sign indicates this bedrock indicates they are will be no settlement for the soil, this material or the settlement will be only for this soil which is from 0 to 19 meter. So, the influence zone is it twice B, B is the 10 meter. So, influence zone will be 20 meter below the base 4 the footing so, but the in these base of the footing these distance is 19 this is really 16.5 meter only because so that means, we have to restrict this zone within 16.5 meter, because this is the bedrock which is within the influence zone, and we are assuming that is bedrock this material will not deform. And so, the deformation will be for the clay only.

So, remember that if there is any bedrock the rigid material within this clay layer, then you have to take the influence zone up to that bedrock or the rigid layer only ok. Even if it is less than 2 B because here the 16.5 which is less than 2 b with still as it is bedrock we have to consider up to 16.5 so; that means, here 16.5. So, my you are E value, E average as I mention you have to take the average weighted average.

So, here we are doing the C u weighted average. So, in the other way we are we are doing the E weighted average weighted average that we are doing that for the E 1 it is 700 into C u 1. So, that is equal to 700 into 35. So, that is 24500 kilo Newton per meter square, and E 2 is equal to 700 into C u 2 that is 700 into 20 because you are C value is 20. So, this is 14000 kilo Newton per meter square.

So, weighted E average is 245000 into that one is this thickness of this layer is 4.5, 4.5 meter and this thickness is 12 meter yes. So, this will be 4.5 plus 14000 into 12; so divided by total 16.5 so this value is equal to 16864 kilo Newton per meter square so this is your E average.

So now my in immediate settlement, so that is equal to this q m into B divided by E 1 minus mu square into I f ok. So the, I f value for L by B, so here q N is 50 then B is 10 weighted average that we are taking is 16864 mu is taken 1 minus 0.5 square and I f value is 1.3 6 this is from the table, where L by B is equal to 15 by 10 into 1.5.

So, from the table corresponding to L by B that I have table are given. So, corresponding to L by B 1.5 I am taking I f value of the center of flexible footing remember that. So, I am designing is a raft foundation it is the rigid, but I f value am taking of for corresponding to L by B, 1.5 I f value at the center of flexible foundation because later on will apply the rigidity correction. So, the final value of this settlement or the Si will be equal to 30.24 millimeter.

So, this is the immediate settlement without any corrections. Now as I mentioned in the immediate settlement you have to apply 2 corrections. So, here it is the rigid footing. So, have to apply rigidity correction and the depth corrections.

So, the next one that we will apply these corrections.

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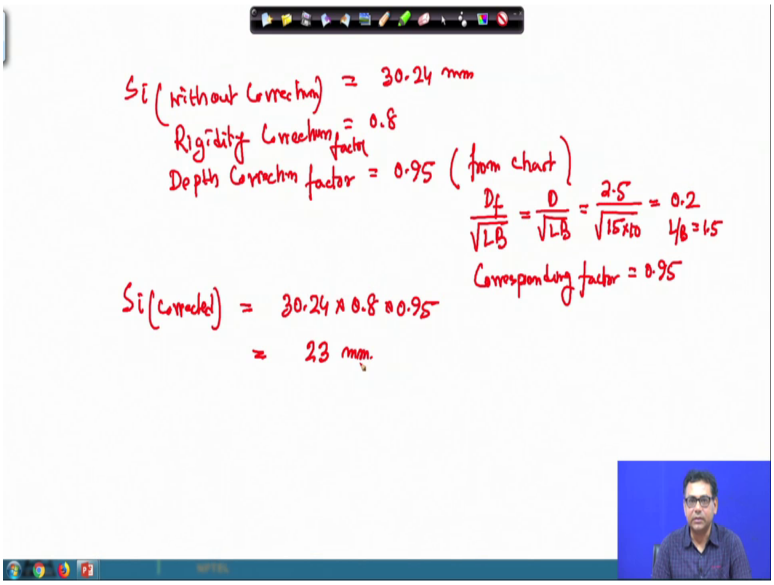

And so, our Si without correction is equal to 30.24 millimeter. So, we will get the rigidity correction, which is 0.8, and the depth correction this is rigidity correction factor and depth correction factor is equal to 0.95. So, how I am getting this is also from the chart. So, I have giving in the chart in the Fox correction charge. So, that from that chart I am getting this value our getting this values.

So, there is the need of d by D f or D by root L B so this is are D by root L B. So, D value is 2.5, L is 15 and B is ten. So, this is equal to 0.2 so corresponding factor is equal to 0.95 and then L by B is equal to 1.5. So, corresponding factor is 0.9 you are getting from the chart. So, that you gets look at the chart this from I am getting this value.

So, Si corrected will be equal to 30.24 into 0.8 into 0.95 so that is equal to 23 millimeter. So, my immediate settlement is 23 millimeter after the correction ok.

So, next one will be the consolidation settlement, that will get this is the consolidation settlement ok.

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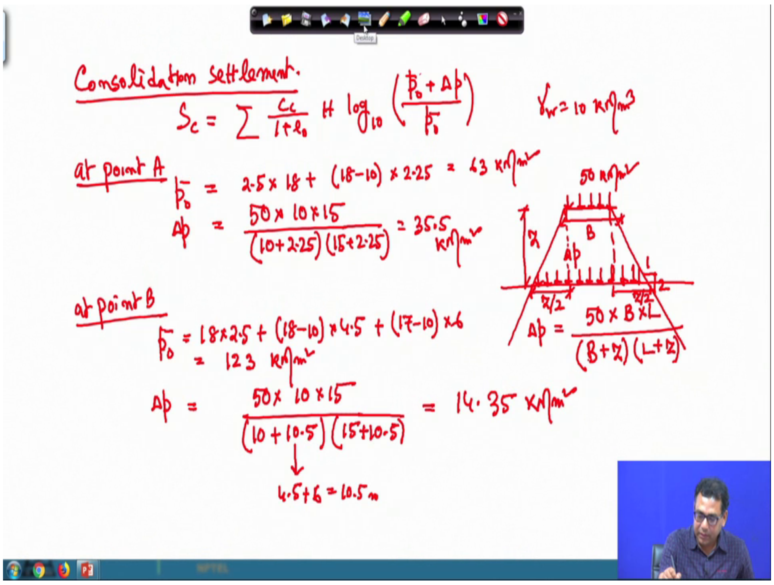

Now this expression Sc is summation of c c 1 plus e 0 H log 10 del p or I should first write p 0 bar or sigma 0 bar this is p 0 bar plus del p divided by p 0 bar ok.

Now, where I will use this thing so first if you look at this figure again; so there is 2 layers one is 4.5 meter another this 12 meter. So, I will take a point the middle of each layer. So, this is the point A this is the point B middle of each layer and the A point will be the 2.25 meter from the base and B point is 6 meter from the base. So, this is 2.2 meter and this is 6 meter from not 6 meter from the base 6 meter from the base of the first layer ok.

So now what I will do, I will calculate at point B sorry point A, my p 0 bar effective overburden safe pressure. And remember that her only one-unit weight is given so that unit weight will use as a saturated, I mean below the water table as well as the above the water table.

So, that will if it some cases will fine 2-unit weight may be given, one is for the saturated is the soil above the water table. So, here one is given. So, that is why I will use both the cases the same water unit weight. So, that is why the p 0 bar effective overburden pressure at point A so above water table is 2.5 into 18, but below water table is submerge.

So, 18 minus 10, 10 you are taking unit weight of the water as 10. So, you are taking gamma w as 10 kilo Newton per meter cube. So, I am that is 2.25 from the base of the foundation. So, this will be 63 kilo Newton per meter square. Next one del p, how I calculate del p? Here del p and calculating suppose this is the width of the foundation B and where the 50 kilo Newton is applied.

Now, here I am assuming the load is distributing like this, and that distribution is this is 1 is to 2 ok. So now, for at a any height say z. So, what will be the stress at that point? Because here it is 1 is to 2 distributions. So, stress at that point this is the del p additional stress will be; so del p will be equal to 50 into B into L divided by B plus z divided by L plus z ok.

So, this is the distribution here it will fine this is 0 by 2. So, this one is nothing but if this is 1 z so this is this is 2 this is 1. So, if 2 to is z this is this will be z by 2. Similarly, this will be also z by 2. So that means, here total stress will be 50 into B into L divided by B plus z into L plus z. Similarly, for the length direction same thing will happen.

Now, if I use this things then our del p will be 50 into 10 into 15 divided by it is 2.25 meter below the base. So, this will be 10 into 2.25 divided by 15 plus 2.25. So, this value is 35.5 kilo Newton per meter square.

Similarly, at point B, at point B p 0 bar again will be 18 into 2.5 then now it is 4.5 is the thickness of this layer. So, 18 divided by 10 into 4.5 then it is 6 meter, then 17 is the unit weight 17 divided by 10 into 6. So, this will be 123 kilo Newton per meter square and del p value will be again 50 into 10 into 15 divided by 10 plus because it is from the base the distance is 4.5 plus 6; that means, it will be 10.5. So, this is 10.5.

So, this things is coming 4.5 plus 6 that is 10.5 meter. So, and similarly L direction it will be 15 plus 10.5. So, this value will be 14.35 kilo Newton per meter square.

So, once I get this value then I will get the Sc.

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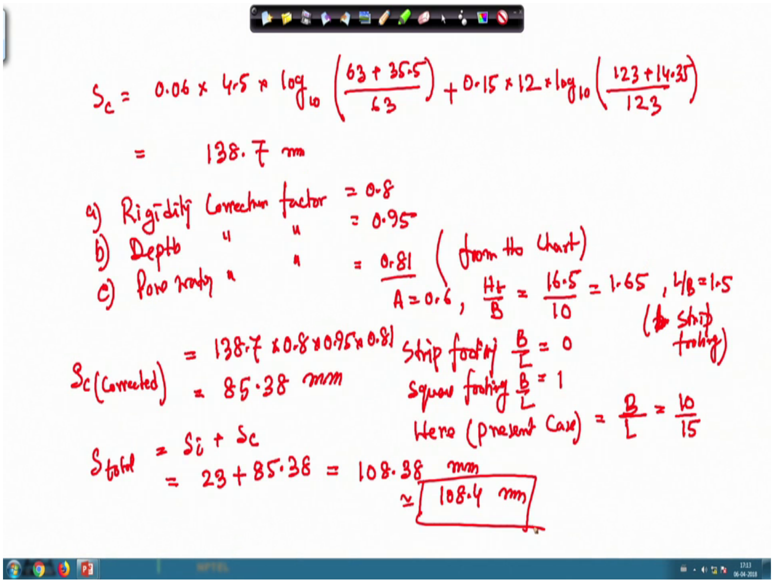

Which is the summation so c c plus 1 plus e 0 for first layer, first layer thickness is 4.5 then into log 10 p 0 bar is 60. I you are this is this value is 63 is p 0 bar and 35.5. So, this is 63 plus 35.5 divided by 63 then plus for the second layer is 0.15 into 12 is the thickness of the layer into log 10 123 plus 14.35 divided by 123. So, this value is given 138.7 millimeter ok

Now, the corrections again the rigidity correction factor, factor is 0.8 then b is the depth correction factor, correction factor which is 0.95 and then is the pore water correction factor, which we are getting 0.81. How we are getting? That is also from the chart and from the chart we have a is equal to 0.6 and there is a term Ht divided by B. Ht is the soil below the influence zone of the soil, below the base of the foundation here Ht value is total soil thickness below the foundation the soil zone is 16.5 and B is 10 meter. So, it is 1.65 and as in that chart you will find there is a for circular footing or square footing and for strip footing.

So, here the value here you are L by B is equal to 1.5 which is neither circular nor square nor the strip. So, here I have use the strip footing this is this is for the strip footing expressions strip footing value that is giving 0.81, but if you want you can you can take the strip footing value, and the square footing value then you can linearly interpolate this value for 1.5, because for the strip footing you are B by L is equal to 0 and for square footing is equal to B by L is equal to 1, but here present case it is L by sorry b by L is 10 divided by 15.

So, what you will can get you corresponding to this value you can you take the strip footing and the square footing that really linearly interpolate these value in between them. So, that way also you can calculate, but here I am directly using the strip footing value calculation because that will give you more are less the close value.

So now the corrected Sc corrected Sc is 138.7 into 0.8 into 0.95 into 0.81 so that is equal to 85.3 millimeter ok. So, the so total settlement is immediate plus consolidation settlement. So, immediate is 23 plus consolidation settlement is 85.38 so total one is 108.38 millimeter or it is close to 108.4 millimeter. So, that is the total settlement is calculated for this raft foundation resting on the clay.

So, in the next class I will solve problem, where I will determine the settlement of foundation which is resting on a granular soil ok. Because, here it is on the clay and you have discuss these 2 methodologies for the immediate settlement and the consolidation settlement.

Next class I will discuss the settlement calculation of foundation on resting on sand. And then, I will discuss the based on the available parameters or sand properties which method, because you have discussed there are 4 methods available based on the for the granular soil, plate load test, based on the SPT value, based on the SCPT value and some semi empirical expression. So, out of these four which one will use, so will decide depending upon the available soil properties.

Thank you.