Foundation Engineering
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Lecture – 18
Shallow Foundation - Settlement III

So in the last class, I have discussed about the settlement calculation of clay soil and the granular soil. And then I discuss about the plate load test and how the, this test is conducted. Then how, what are the correlations of the plate and the real foundation in terms of settlement and the bearing capacity for granular soil as well as the clay soil.

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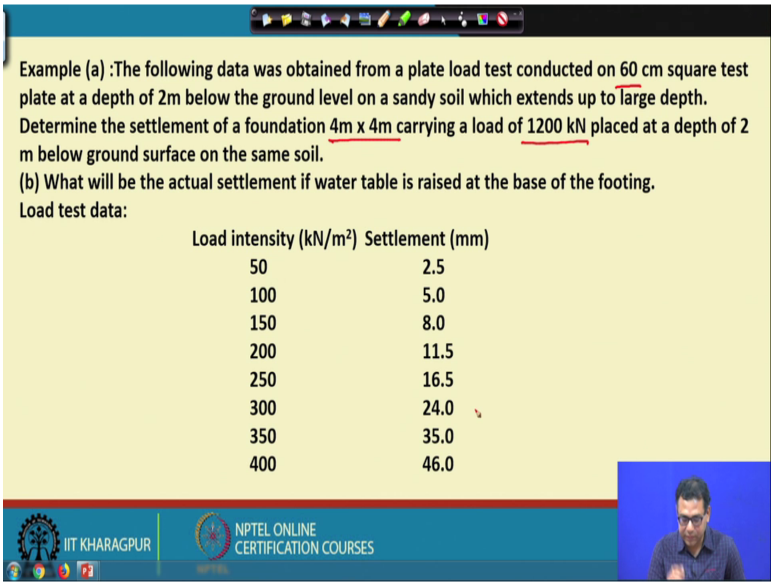

Now today, I will solve a problem on the plate load test. So, this is the example a the first example that I am talking about that, following data was obtained from a plate load test conducted on 60 centimeter square plate. So, the plate size which is 60 centimeter and the plate load test is conducted at a depth of 2 meter below the ground level on a sandy soil. So, which extend up to a large depth so that means, the homogeneous soil.

So, determine the settlement of a foundation of seek 4 cross 4. So, 4 meter cross 4 meter carrying a load of 1200 kilo Newton placed at a depth of 2 meter below the ground surface on the same soil so; that means, here the depth of foundation and depth of plate both are same. So, you do not need to apply any corrections. So now, what will be the actual settle settlement if water table is raised at the base of the footing? So, initially in the example a there is no water table effect, but in the example b, if the water table is raise at the base of the footing then, what would be the actual settlement? So; that means, the real foundation is 4 by 4 and the load is acting at 1200 kilo Newton.

So, what do the settlement of the foundation? So, this is the load intensity in terms of kilo Newton per meter square and this is the settlement. So, this is load is apply this settlement is measure at the end so; that means, here so for the each load increment. So, first one is 50, then the 100, then 150. So, this is the 50 increment for 200, 250, 300, 350 and 400. So, here maybe, so you are safe load that you have calculated is 250 kilo Newton. So, you are applying one fifth of that.

So, first one is the one fifth means the 50 kilo Newton. Second one is the two fifth; that means the 100 kilo Newton to like that. So, and this is up to the failure of the loading. So, or up to the, these up to the required settlement that I have discussed in the last class. So here, this is up to 400 kilo Newton per meter square so; that means, here the it is the incremental load is 50 kilo Newton per meter square and this is the corresponding settlement.

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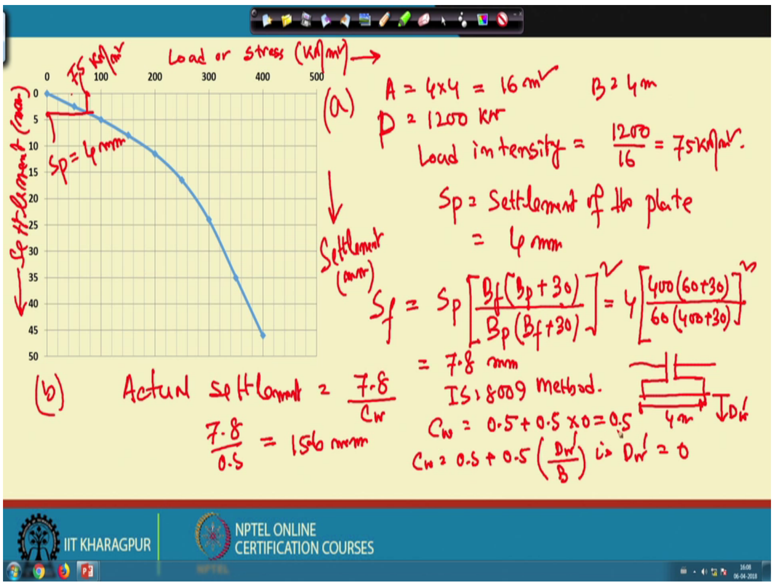

So, what we are doing the first it is plotted. So, this is the x axis is the, this is the load x axis is the load or the stress that you are applying. So, it is in terms of kilo Newton per meter square. This is the x axis and the y axis is the settlement in millimeter. So, this is the y axis, so and this is the settlement and this total thing is plotted. So, this is the load settlement curve load verses settlement curve. So now, the load intensity the total area of the footing is 4 cross 4. So, that is the 16 meter square and the load is load P is 1200 kilo Newton. So, the load intensity is equal to 1200 divided by 16. So, this is 75 kilo Newton per meter square.

So, now the 75 kilo Newton per meter square so, this is each line is representing 20 kilo Newton per meter square. So, 75 will be this is 20, 40, 60. So, will be around here, so this is the 75, this is 75 kilo Newton meter square and this is the, this axis is basically the settlement axis in millimeter. So, corresponding settlement of the plate this is the Sp settlement of the plate is 4 millimeter. So, from the chart the corresponding into 75 kilo Newton per meter square the Sp settlement of the plate is equal to 4 millimeter from the curve.

So now, the settlement of the foundation that I want to calculate so, if I use this correlation Sp, Bp, Bf into Bp plus 30 divided by Bp Bf plus 30. So, this is whole square, so now if I put this values the Sp is 4, then Bf this is the width of the footing is 400 because, it is in centimeter. So, 400 width of the plate is 60 plus 30. So, divided by 60 400 plus 30. So, this is whole square. So, the settlement of the plate settlement of the foundation is coming out to be 7.8 millimeter. So, this is the answer for the part a so; that means, corresponding to 1200 kilo Newton; the settlement of the foundation will be 7.8 millimeter.

Now, this is the part a, now the part b. So, our actual settlement is equal to the settlement and the Cw, Cw is the correction factor. So, as the correction factor; that means, mention that we have 2 correction factor that we can use. Now, if I use the IS 8009 method then my Cw value will be 0.5 plus 0.5 into 0 because here, as per this IS code method. So, this is your Dw dash is measure form here because, this is the expression is 0.5 plus 0.5 into Dw dash divided by B.

So, here your value is equal to 4 meter. So, B value is 4 meter, but D a value is measure from the base and the water table is at the base. So, you have Df dash is 0 that is Dw dash Dw dash is equal to 0. So, Dw dash is equal to 0 means thus Cw is 0.5. So, for the IS code this is 7.8 divided by 0.5. So, that will be equal to 15.6 meter millimeter. So, this is 615.6 millimeter is the actual settlement you have Cw value is 0.5.

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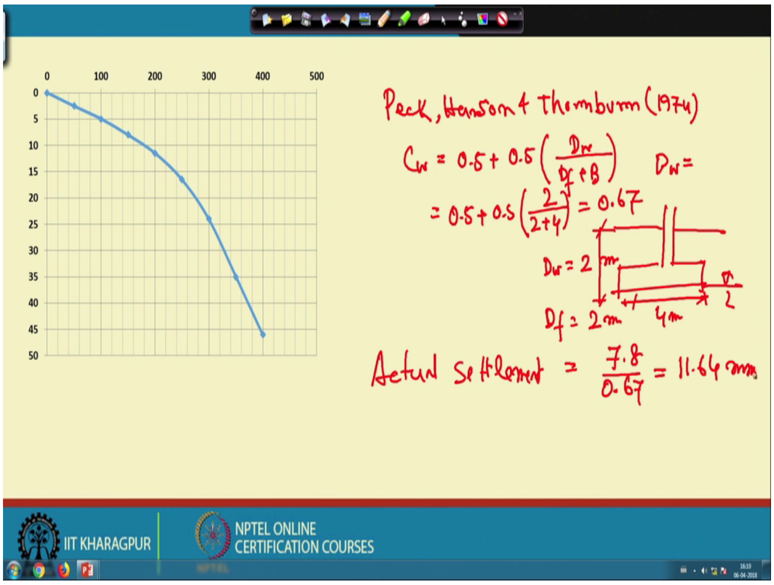

Now, if I use the another method that that is the Peck Hanson and Thornburn 1974. In their case Cw is equal to 0.5 plus 0.5 Dw Df plus B. So, here Dw will be the base of the footing and the Dw basically this is here the base of the footing means here the Dw is measure from the surface. So, and this is the position of the water table. So, Dw is equal to 2 meter and Df value is also 2 meter and d value is 4 meter. So, in that case Cw value is 0.5 point 0.5 Dw is 2 divided by 2 plus 3 sorry 4. So because, it is B value is 4 meter. So, it is 4, so that been see a this is value is 0.67. So, actual settlement will be 7.8 divided by 0.67. So, it is 11 0.64 millimeter.

So, if I use the IS code, IS code the always give higher settlement if I use apply the water table correction. Because here, from the base to the surface always it is 0.5, but in other methods will give you slightly lower settlement value. Similarly, IS code will give you lower safe bearing capacity and the other method will giving slightly higher lower safe bearing capacity value. So, this is the 2 method that I have discuss for this problem.

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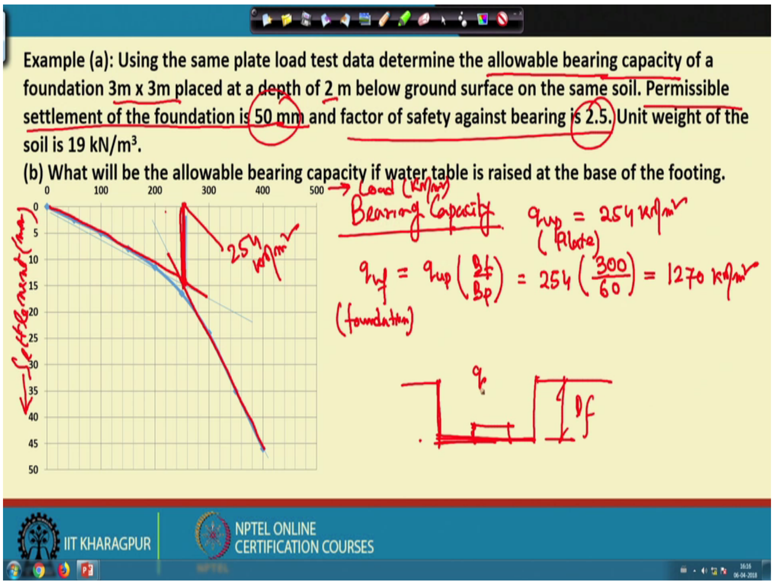

So now, the next problem the next problem if. So, if I use the same plate load test data and determine the allowable bearing capacity of a foundation. So, remember that here I want to determine the allowable bearing capacity ok. So, what is the allowable bearing capacity? Allowable bearing capacity definition as given the maximum load it can take in terms of bearing capacity or safe bearing capacity or and the maximum load. It can take in terms of settlement criteria and minimum of these 2 will give you allowable bearing capacity.

So, previous problem where there is a particular load on a foundation, now corresponding to that load. What would be the settlement? And then if the water table effect is there, then what would be a settlement? But here, the problem is that that we have foundation the say that the foundation weight is square footing again 3 cross 3 and depth of foundation is 2 meter and the settlement and there is a permissible settlement of the foundation is 50 millimeter. And factor of safety against bearing capacity is 2.5. Unit weight of the soil is 19 kilo Newton per meter square.

So here, now we have to calculate the allowable bearing capacity. So, as there is 2 criteria first criteria will check the bearing capacity and second criteria will check the settlement. So, one is bearing capacity criteria and one is settlement criteria. So, we have permissible settlement. So, base we are using both 2 criteria is and then, will fine what would be the allowable bearing capacity? Ok.

So first, till let me do the first criteria is the bearing capacity or the bearing. So, we are talking the bearing capacity criteria, another mention in the bearing capacity. You have to apply the factor of safety and that is 2.5 in case of settlement we have the factor safety we apply, but there is permissible settlement and that is 50 millimeter; that means, you have, you have to design you have foundation such that the settle settlement should not be more than this permissible settlement, here this 50 millimeter.

So, first bearing capacity calculation, so this is the chart so now, if I draw because there is no particular peak through this is the curve. So, again this is the settlement, which is millimeter and this is the load in kilo Newton per meter square or stress this X axis. So now, if I draw able can end. So, this is the initial straight portion of the curve, this is the final straight portion of the curve. So, this is the intersection point. So, corresponding value is coming out to be this is 254 kilo Newton per meter square. So, this is 240 this is 254.

So, from the chart so that means, the q u p q u p ultimate load is 254 kilo Newton per meter square. So, this is the granular soil on the sand. So now, the q u f q u f is the ultimate load for the foundation. This is for the foundation; this is for the plate. So, that will be q u p into Bf divided by Bp. So, 254, so footing is 3 meter divided by or 300 and divided by 60 is 3 meter and this is 60 millimeter. So, 300 millimeter by 60 so, this value is 1270 kilo Newton per meter square.

So remember that, this is the ultimate load of the foundation and one thing that I want to explain that, you can take the this load and then divided by the factor safety. Then you will get the safe node that is, that can act on the foundation in terms of bearing capacity, but one thing that here the plate load test is conducted at the base of the foundation.

So, this is the Df when we these portion of soil is remove. So, we are not getting the is the resistance or we are not getting the effect of this portion of soil, but when the construction will be their. So, after placing the foundation you will also fill this portion of soil. So, really in the real field you will get the, you will get the resistance.

So, more capacity for this portion of the soil and this portion of the soil is nothing. But the surcharge q so; that means, you have a 3 effect one is the due to the coefficient first term, second term is due to the surcharge and third term is due to the weight of the soil or the friction ok.

So, this surcharge terms second term effect we will not getting from the plate load test data value, but in the real field you will get the resistance for the second term of the surcharge also also. So, that mean indirectly I can calculate that value also. So, how I can calculate that value?

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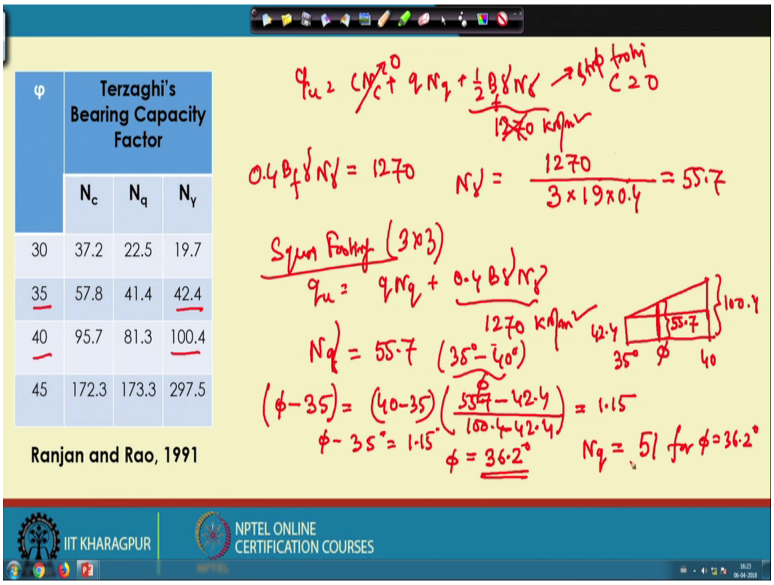

So, how can calculate the value? So, if I use the Terzaghi's bearing capacity expression. So, I know that Terzaghi's bearing capacity expression is your q u. Q u is CNc plus q qNq plus half B gamma N gamma. Now here, this part is 0 because you are C value is 0 it is it is granular soil. So now, the contribution that I am getting is for this one this 1270 kilo Newton per meter square is this one this is the 1270 kilo Newton per meter square because, I am not getting this contribution that I want to add. Now here; that means, half B of the foundation this is B of the foundation gamma N gamma is equal to 1270.

So, I can get the N gamma value from here 1270 into 2 divided by Bf. Bf is 3 into gamma is 19 and this is the square footing. So, instead of half so, you will use point 4. So, as it is the square footing this is for the plane strain this is for the strip footing. So, as this for the square footing are my q u is q N q plus point 4 B gamma N gamma. So, this is the actually 1200 and 70 kilo Newton per meter square. Because, this is for the square footing because this is the 3 meter cross 3 meter plate so, but this expression is applicable for the basic expression which is applicable for the strip footing. So, actually this is not the 1200 and 70 the 1200 and 70 is this one.

So, that is why N q value instead of point half we have to right point 0.4. So, 0.4 Bf gamma N gamma so; that means, this will be cancel out this will be divided by this will be 0.4. So, this is N q will be 1200 and 70 divided by 0.4 19 and this is 3 the width of footing. So, this is N q is coming out to be these value 55.7. So, form here my N q value sorry, N we are talking N gamma value is 55.7, but so I do not no what is the 5 value, 5 value is not given. So, form here using this chart, if I calculate the 5 value in the rivers way generally this charts are developed corresponding to the 5.

So, if I no the 5 you can develop this N q N gamma N c, but here when I know N gamma I N nah N gamma and I want to determine the 5 value. So, this is the N gamma is here N gamma is 55.7. So, it is in between 35 to 40 degree. So, you are 5 value is in between 35 to 40 degree. So, this is the range of the fine. Now, if you are values in between that, so you have to linearly interpolate this value. So, how you can linearly interpolate this is phi minus 35 that will be equal to 40 minus 35 into 55.7 minus 42.4 divided by 100.4 minus 40 minus 42.4.

So, this 5 this value is coming out to be this is 1.15. So, phi minus 35 degree is 1.15 degree. So, phi value is equal to 36.2 degree 36.15 36.2 degree because, we have just doing in the linear interpolation. Because, this is you are the form 35 degree phi the N q N gamma value is 42 point 4 because for the 35 42 point 4 for 40 100 point 4. So, for 40 this value is 100 point 4. So, you are doing just linear interpolation and our N q value it is it is 42 point 4. So, this value is somewhere here

So, this is my N q N gamma value that is 55.7 and this is the 5 the I want to determine. So from here, this 5 value is coming out to be 36.2. So, if I do the linear interpolation even in the other way also. If you have a phi in between that that mean 35 to 40 then N c N q N gamma you have to determine by linear interpolation.

So, once I get the phi value 36.2 so now, corresponding N q value from the chart is again. So, this is 36.2 from the chart by linear interpolation I will get. So, that N q value that I am getting is 51 from the chart. So, corresponding to for phi is equal to 36.2 and we are doing the linear interpolation same way that I have done for the previous case. So, N q value is 51.

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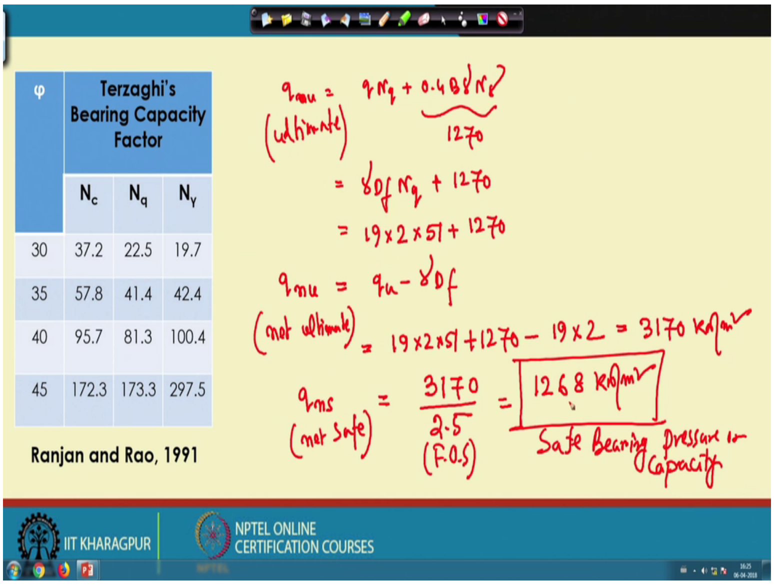

So now N q value is 51, so that our q N u ultimate. So, that will be q N q plus 0.4 B gamma N gamma. So, this is nothing but 1270 and. So, and then N q I will get the unit weight into Df into N q plus 1270 and unit weight is 19 Df is 2 because, you are depth of foundation is 2-meter N q I got 51 and plus 1270. And if I get the this is ultimate, if I get net ultimate then this is the N u ultimate and if I get the net ultimate then this will be the ultimate minus gamma Df.

So, that will get the this is the net ultimate into 2 into 51 plus 1270 minus gamma is 19 into 2 Df is 2 metre. So, ultimately this value is 3170 kilo Newton per meter square. So, my the q net safe this is the q net safe load is or the safe load or safe bearing capacity or safe bearing pressure is 71, 3170 divided by 2.5. So, this is the factor of safety 2.5. So, the load is 1268 kilo Newton per meter square.

So, in terms of bearing, if I apply the bearing capacity criteria my safe load or the safe bearing pressure; this is the safe bearing pressure or capacity is 1268 kilo Newton per meter square. So, it is in terms of bearing criteria. Now, you have to apply the settlement criteria now if I apply the settlement criteria.

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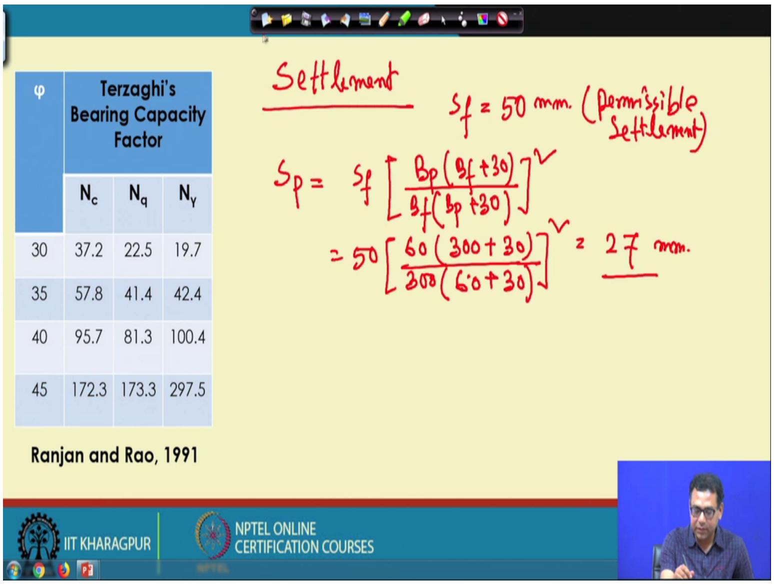

So, my permissible settlement for the foundation is 50 millimeter. So, this is the permissible settlement this is the. So, I am designing my foundation for 50 millimeter settlement. Now, I what would be the plate settlement corresponding to Sp is equal to 50. So, this is the Sf then this will be Bp then Bf plus 30 divided by Bf Bp plus 30. So, that is whole square, so if I foot 50 then, Bp is the width of the plate then width of the foundation.

This is 60 plus 30 whole square is equal to 27 millimeter. So, we are getting 27 millimeter is the settlement of the plate corresponding to the permissible settlement 50 for the footing.

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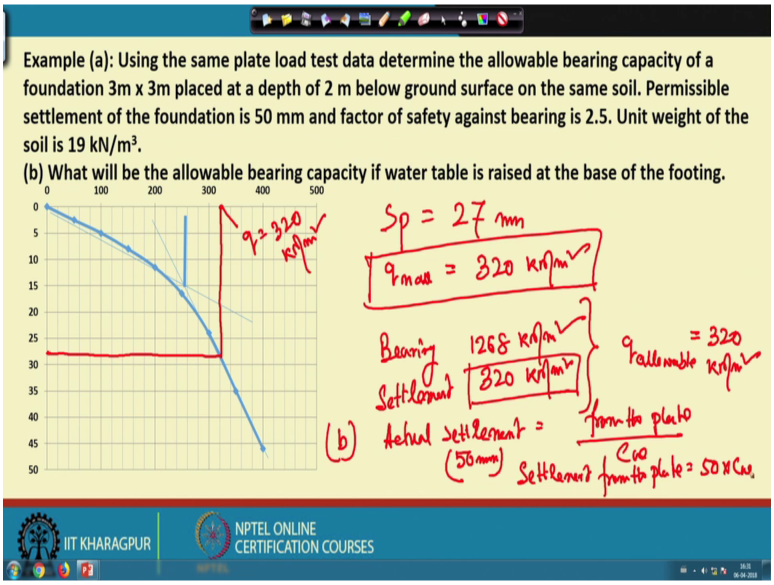

Now, if I go back to that if I go back to the load settlement curve so my, the s sorry Sp is 27 millimeter. Now the, this is the 27 millimeter around, so corresponding q is 320 kilo Newton per meter square. So, the q net ultimate net allowable is equal to 320 kilo Newton per meter square. So, this is in terms of settlement criteria on previous shown in terms of bearing capacity criteria. So, the total if I write this for the bearing it is coming out to be this value is coming out to be 1268 kilo Newton per meter square, and for settlement it is 320 kilo Newton per meter square.

So, the minimum of this will be the q allowable or net allowable this q allowable is be 320 kilo Newton per meter square. So, q allowable will be the 320 kilo Newton per meter square if that is the minimum. So, in terms of settlement that we are getting, so here the settlement is you the giving the lower. So, that is basically the most of the cases we fine the settlement terms will give you the lower bearing capacity bearing.

So, that is the lower bearing capacity or the q allowable this is the bearing in terms of net safe or the safe load carrying capacity in terms of bearing then in terms of settlement is 320 kilo Newton per meter square. So, lower of this 2 or the smaller of this 2, it will give you the allowable bearing capacity. So, it is that was the term a now for the term b, if the water table effect is they are. So, definitely the water table effect is there. So, two-way you can do it. So, one-way you can take because you are ultimate settlement is 50 millimeter.

So now, you if you apply you apply the that is the actual settlement. So, your one way this is you are actual settlement is ment is equal to the settlement that you are getting from the plate. So, that is from the plate divided by Cw. So, actually settlement is 50 millimeter. So, that means, we multiply the Cw with actual settlement. So, you get the settlement from the t will be 50 into Cw. So, an if as for the IS code so, that is why you are settlement is so.

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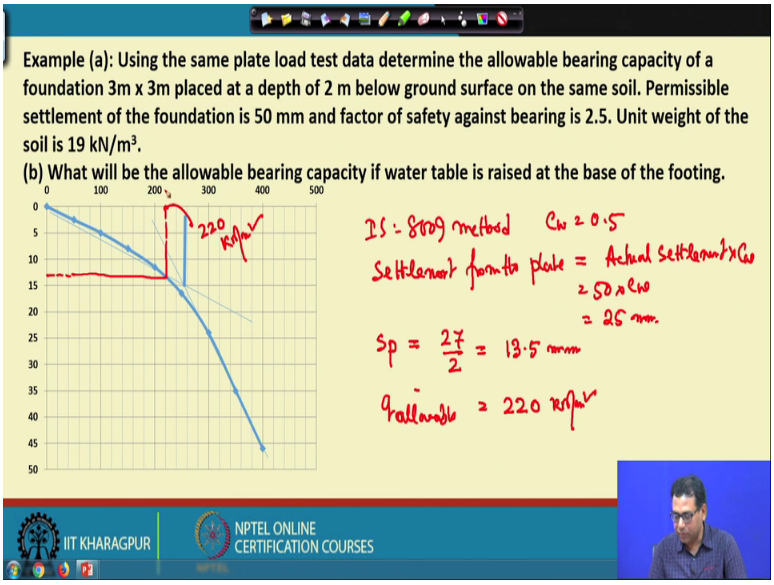

So, you are as for IS code IS 8009 method the same thing it is base of the foundation through your Cw is equal to 0.5 if you use the other one you will you will get the value. So, for the IS code is 0.5. So, you are actual settlement from the plate from the plate will be your actual settlement into Cw. So, actual settlement is 50 into Cw. So, this will be 25 millimeter. So, you calculate the settlement corresponding to the 25 millimeter and it is definitely for the if it is 50 is 27 them for the Sp, corresponding to 25 millimeter it will be 27 divided by 2 13.5 millimeter

So, corresponding to 13.5 millimeter, what would be the so corresponding to your 13.5 millimeter? What would be the value? So, this value is 220, so this will be. So, q allowable will be 220 kilo Newton per meter square. So, that is 13 point. So, this is 220 kilo Newton per meter square. So, this will be the 13.5 so, corresponding 220 kilo Newton per meter square.

So, this way because, I am I have applied the water table effect in the settlement only because, settlement is giving the lower value that is why I have applied the settlement. In similarly, you can apply it for the bearing also, but bearing definitely will give you the more value. So, that is why I am not have not applied it in the bearing water table effect. So, I have applied in the settlement.

So, you reduce the settlement and then corresponding bearing pressure you can calculate. So, this way we can determine the q allowable with the help of the plate load test data. So, and you have also introduce the water table effect and then we will see will be the reduction in the q allowable value. So, in the next class, I will discuss the others methods by which, we can determine the settlement of a granular material or the foundation on the granular material.

Thank you.