Foundation Engineering
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Lecture – 17
Shallow Foundation – Settlement II

In this lecture 17, I will discuss about the Settlement calculation of Shallow Foundation. So, last class I have discuss immediate settlement, then the consolidation settlement.

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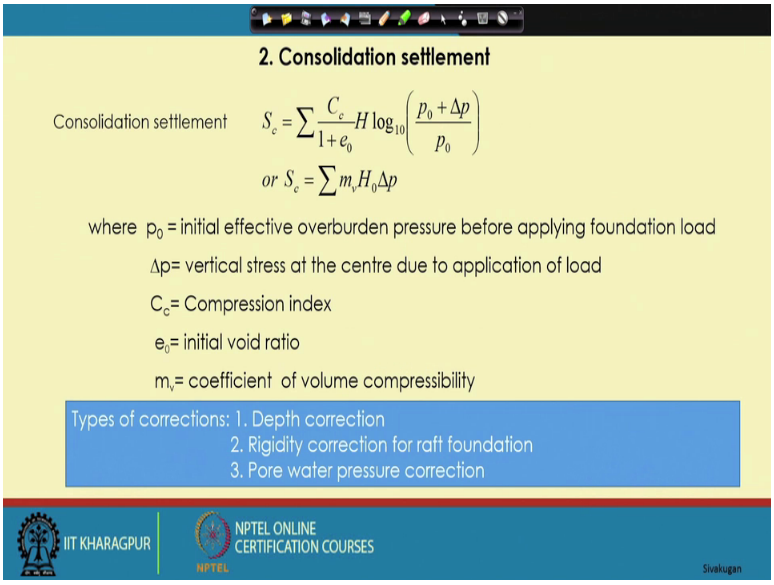

So, these are the consolidation immediate settlement I have discussed in the last class, then how to get the influence factor I f given the table also and, then what would be the probable ranges of elastic modulus of soil different soils, and how we will calculate the elastic modulus of soil and what are the possible ranges of Poisson ratio values, are also given in the last class lecture. So, in this class I have already discussed in the last class over the consolidation settlement. So, these are the two possible ways we can determine the consolidation settlement, depending upon the values or the parameters available.

So, these are the expressions we have to apply for different layers, so that in the immediate settlement if it is rigid foundations so and we have to apply two corrections rigidity corrections and the depth correction. And if it is flexible foundation, or the isolated footing then you have to apply for the depth correction. Or in the consolidation settlement you have to apply for three correction rigidity consolidation and the poor water pressure correction, because our consolidation equation that we are using it is 1 D consolidation equation, but the consolidation process is actually the 3 D process.

So, we have to apply a correction that you have to get that correction from correction factor from the chart, or the available values that I have given in the last class.

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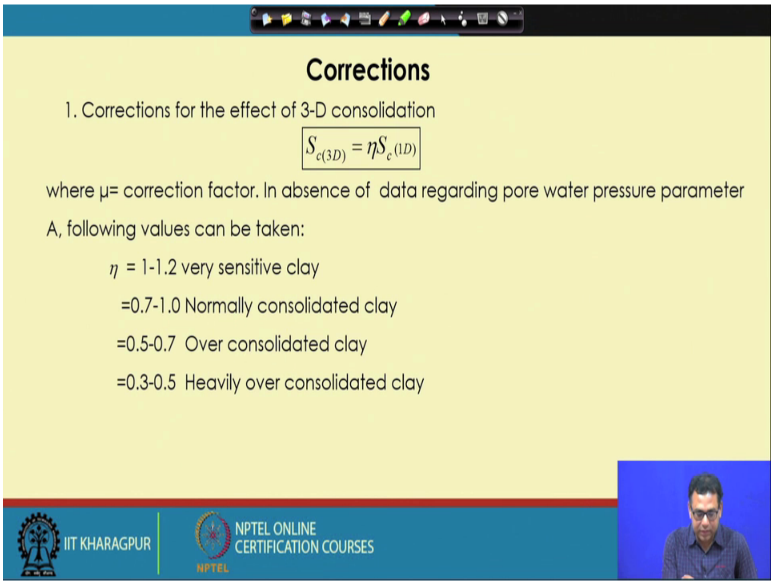

So, these are the available values for different soil of this correction factor.

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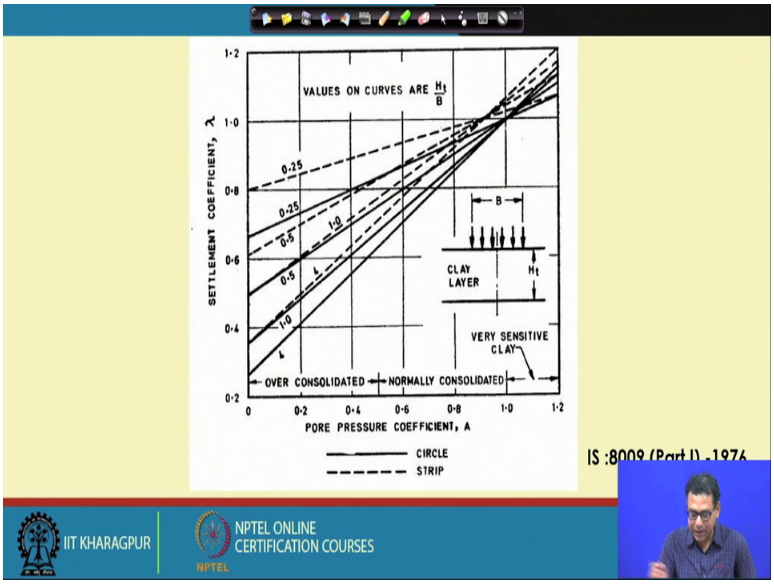

And if the parameter A is available when from this chart, also you can determine this correction factor. So, this things already been discuss so, this is as per the IS code.

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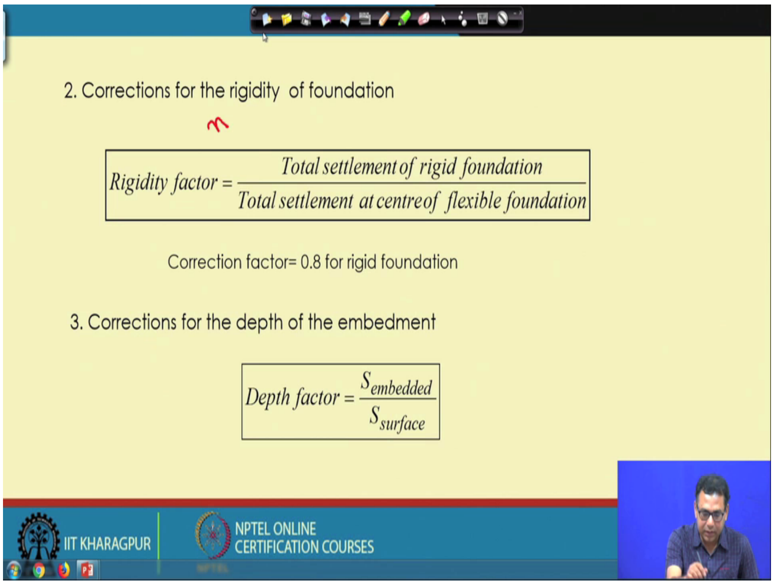

So, that is the correction factor for the poor water pressure. So now, we have the two more corrections: one is the rigidity correction of the foundation; another is the correction for the depth factor depth. And so, the rigidity correction factor we will get the total settlement of rigid foundation divided by the total settlement of centre, at the centre of flexible foundation.

So, generally the correction factor is taken as 0.8. So, when we calculate the influence factor in the towel, if you notice that towel, then you will find that the influence factor at the centre of the flexible foundation and influence factor are the rigid foundation, or the rare foundation. So, then we will find that the rigid foundation influence factor is around 0.8 times the influence factor of the centre of flexible foundation.

So, in the rigidity correction we take the 0.8 as a rigidity correction. So, we will calculate the settlement considering the footing as a flexible foundation and, you will use the flexible foundation values required values and, then we apply this rigidity correction 0.8 for the rigid foundation, because here the (Refer Time: 04:11) will be less as the foundation is a rigid 1 so, that rigidity effect we have to consider. And then the depth factor also you can get depth factor from this chart.

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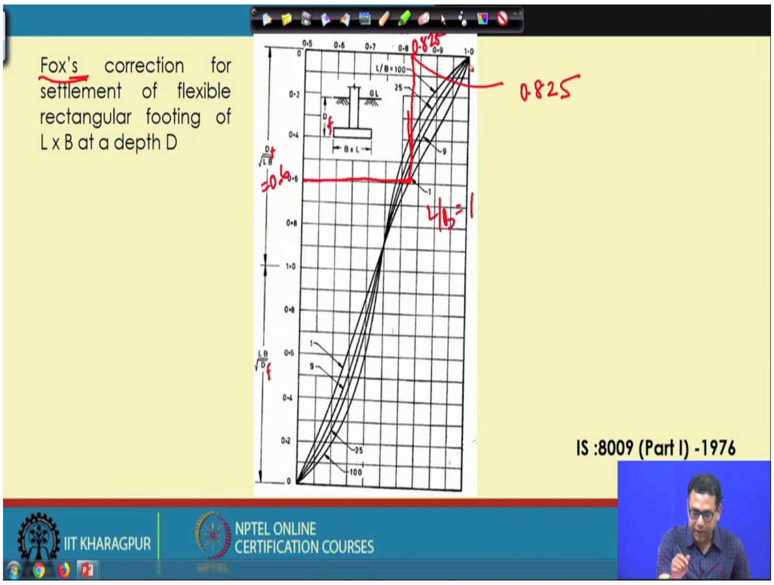

So, this chart is given in IS code IS 8009 part 1976. So, how we will use this chat, this chart, or these corrections is call the Fox's corrections for the settlement. For a flexible rectangular footing of L by B at a depth of D so, that also as we are mentioned that we are using all flexible foundation correction factors, but ultimately for the rigid foundation we have to apply the 0.8. So, for the rigid foundation also for depth correction you will use this chart.

Now, for this chart so, there is a term D so, this D is actually the D f depth of the foundation L is the length of the footing B is the width of the footing. And so, this is D f and these lines are developed for L by B this is for the 100 this is 25 this is 9 and this is 1 and this is the two part so, this is one is D f root over L by B another L by B root over D f. So, now, this chart this the lower portion of this chat and be used for the foundation which is which whose depth of foundation is high.

So relatively higher depth of foundation we can use for this lower chart and, for the for example, when you calculate the pile foundation settlement calculation, we may use this lower portion of the cha chart. So, this is for the relatively higher depth of foundation and, but most of the cases in shallow foundation, we will use the upper portion of the chart where this will be D f root over L by B. So, if I know root over L by B, if I know the L by B value, then from here suppose for the this D f root over L by B 0.6 if the L by

B value is 1. So, the correction value will be around 0.85 so, a point this is 0.85 so, this is this will be 0.825.

So, this will be the correction factor value. So, this is a 0.825 so, corresponding to D f if this is value is 0.6 and L by B is equal to 1 or the square footing, then you will get this correction factor as 0.825. So, is the depth correction factor.

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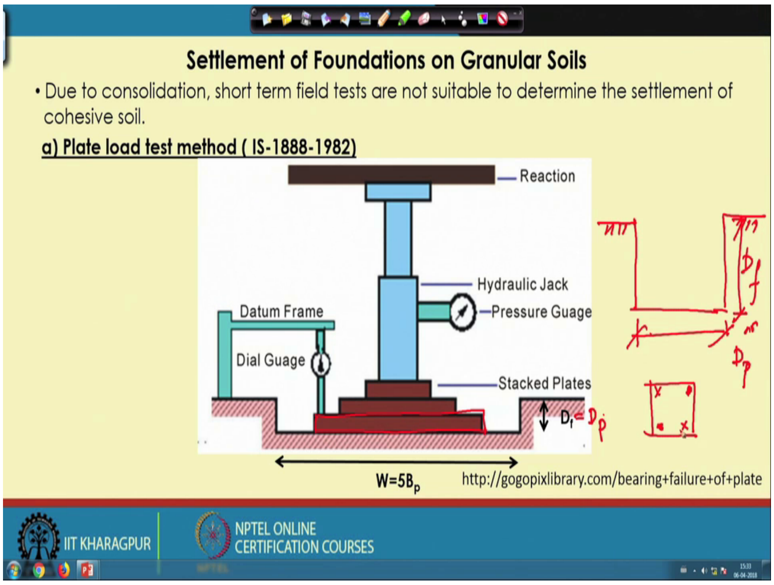

So, the settlement calculation that we have discuss, that this is for the immediate settlement and the consolidation settlement. So, these two methods are generally used for the clay soil because obviously consideration settlement will be used for the clay soil. And the immediate settlement that we have discussed that also, we used for the clay soil, because in the clay soil also, we will consider the immediate settlement though it will be less compared to the consolidation settlement.

But during the total settlement calculation, we will use we will calculate the immediate settlement as well as the consolidation settlement of the clay and then we will add. And another thing I want to mention that in this course, I will discuss only the consolidation settlement, further this primary consolidation settlement. The third one that is more useful or applicable for the organic clay. So, that we will not discuss here, we will discuss here mostly this is two immediate and the primary consolidation settlement.

Because these two are very common in this soil mechanics and so, we will use this two and our soil, or according to that we will choose that mean whether it is the inorganic type of clay, where this consolidation settlement and the immediate settlement are the two major factors and for the sand the immediate settlement is the major factor.

But when you are talking about the settlement of sand, or the granular material, then we have to use the field test data, rather than using the laboratory test data, because as I have already mentioned that the getting undisturbed soil sample is possible, or easy for the clay soil. So, in the clay soil we will get the undisturbed soil sample and, then we will test the soil sample in the lab and, then you will get the properties those property I will use for our settlement calculation purpose.

But in the sandy soil getting the undisturbed soil sample is difficult. So, that is why we rely on the field test for the consolidation for the settlement calculation. So, I will discuss that how what are the first method that, what are the methods that we are used to determine the settlement of a granular soil. The first method that you are talking about is the plate load test method. So, it is not only the settlement the bearing capacity also we can determine by using the plate load test.

So, this is a field test so, till now the methods that are discuss all are theoretical methods, where we have to use the soil parameters and, then we will get the ultimate bearing capacity, or the settlement of the foundation. But this is the plate load test here in the field itself by the field test data, we can determine the bearing capacity or the settlement of a foundation or so, that is the advantage of the plate load test. So, that we are testing it on the field where the foundation will be constructed and, from that data you are using for the foundation design. So, that is the advantage of the plate load test.

So, what is plate load test this is the plate load test instead of using the real foundation, we are using a plate on which we are applying the load and then we are measuring the settlement. So, this plate is a treated as a foundation and ideally the depth of the plate, where we are placing this plate the depth of the plate should be equal to the depth of the foundation.

But sometimes it may not be possible so, in that case when you use this data we have to take the proper precaution, or you have to apply the depth corrections. If your place of the placing depth of the plate and the depth of foundations they are not same, but ideally it should be same so here also we placed so that means, you have to construct pit. So, this is the pit and this is basically the depth of the plate, or that should be ideally depth of the foundation. So, this is the D f or D p depth of the plate.

So, this is the D f or you can say this is D f or D p depth of the plate, f means the foundation p means the plate. And this pit width should be at least five times the width of the plate. So, this is the plate so, these are this is the plate and the width of the plate should be five times the width of the width of the pit should be five times width of the pit.

So, now reaction frame is placed so, with the help of this reaction frame a load is applied through a hydraulic jack and, this pressure gauge or the dial gauge is used this pressure gauge, or the proving ring is use this to measure the load that is applied, on this dial gauge we will measure the settlement of the plate. So that means, we are applying load and we are measuring the settlement. So that means, this dial gauge is used to measure the settlement. And generally we apply two dial gauges, two opposite corners of the plate. So that means, if this is the plate so, we place two dial gauges one is here another is here, or here or here two and then we take the average of these two values as the settlement of the plate.

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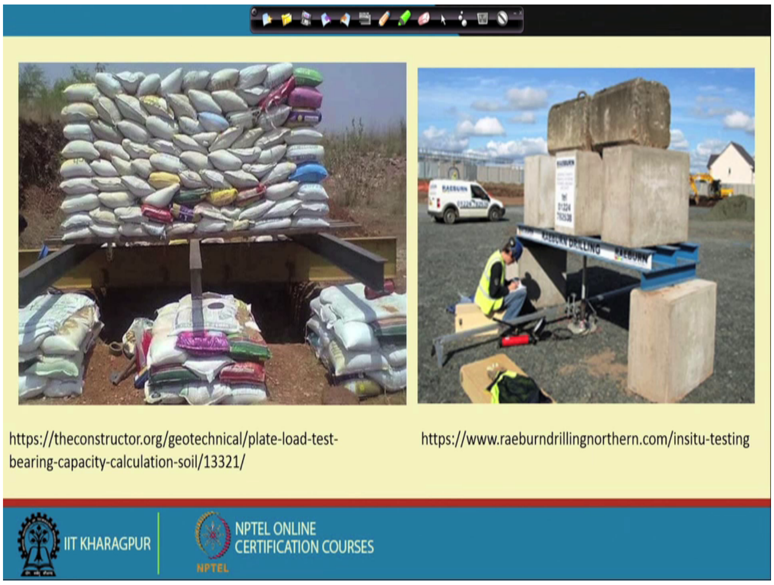

And, then if I see this is the photographs or the plate load test. So, this is the plate, where it is tested and this is again this is a trange, or the pit where the plate is placed and these are the reaction frame, these are the sand bags where this load is applied, because these hydraulic jack is giving a pressure on this frame.

So, that is giving the reactions so, we should have a sufficient weight over this over this I mean over this over this reaction frame. So that means, here we have to apply the load and these are the dial gauges. So, the dial gauges are used to measure the settlement and sometimes this proving rings are also used to measure the um load that is applied and, here load cell can also be used to measure the load, I sometime in place of dial gauge LVDT can also be used to measure the settlement. So, ultimately we in a plate we are applying a load and we are measuring the settlement and this is done in the field.

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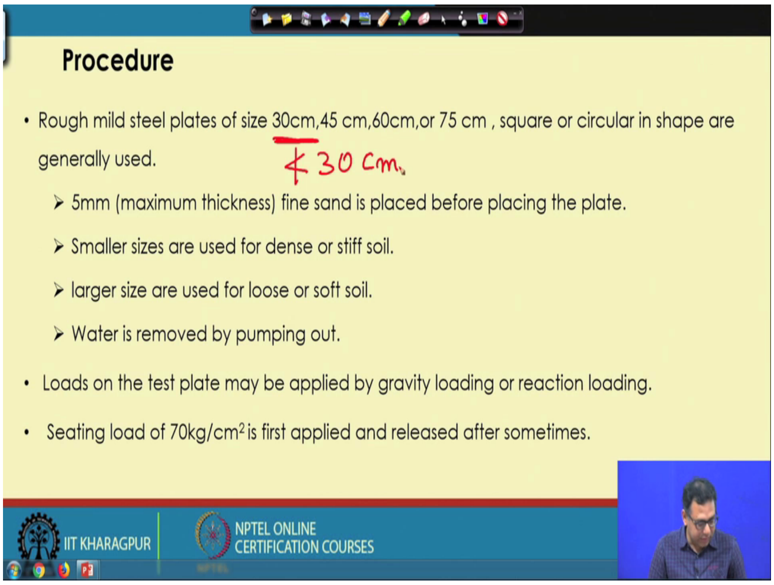

So, this is the total procedure of this plate load test. So, rough mild steel plate so, generally keep in mind, that the minimum plate size should be used 30 centimetre, we cannot use a plate size which is less than 30 centimetre, because that is this is not recommended less than 30 is not recommended. Then we will not get the appropriate result.

And the other plate size are 40 centimetre 60 centimetre and up to 70 centimetre that is square or circular in shape. So, when you place the plate on the ground of 500 5 millimetre fine sand is placed on the ground on the on the pit and, then we place the plate. So, this will give you a smooth contact between the between the soil and the plate.

The generally smaller sizes of plated plates are used for dense, or stiff soil and largest size of are used for the loose and the soft soil.

Now, water is removed by pumping out if in the trange there is water. So, you we have to remove the water to conduct the test so; that means, the loads can be the loads on the test plate may be applied by gravity loading, or the reaction frame that already discussed so, through the reaction frame we apply the load. And before we apply the actual load a seating load of 70 kg per centimetre square is first applied and, they are released after some time. So, this seating load we will help this plate to make a smooth make a contact, or perfect contact with the soil and the plate that is why this seating load is applied.

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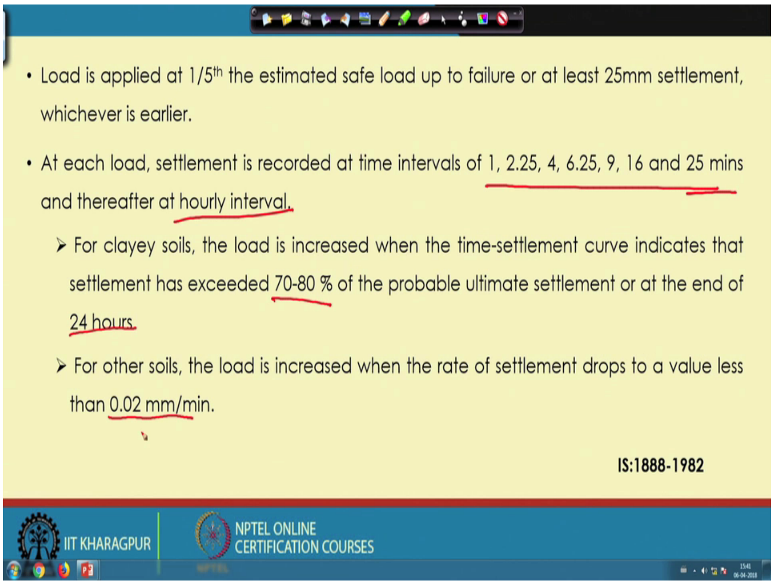

Then load is applied at once fifth of estimated safe load, or up to the failure or at least 20 millimetre settlement whichever is earlier. So, this it means that that before we do the plate load test. So, you have to know the properties of the soil of that site and based on that property by using the available theories for bearing capacity you have to determine the safe load capacity of that plate on that soil.

So, and we have already discuss the available theory. So, based on that if we know the sea and 5, or the stain properties or the unit weight of the soil, then we can determine what would be the safe load and, then we have to apply the one-fifth of that estimated safe load up to the failure or at least 25 millimetre settlement. Suppose that suppose if the safe load is 100 kilo Newton per metre square, then we have to first load increment that you have to apply is twenty kilo Newton per metre square, or the if the total load is 20 kilo Newton, then the first increment of load will be 20 total load is 100 kilo Newton, then first increment of load will be 20 kilo Newton, then next one will be the 40 kilo Newton, then next one will be the 60 kilo Newton like that.

So that means, one-fifth of the safe load of that plate. So, that how will get the safe load by using the available bearing capacity theories. So, we have to get the soil properties for that. Now, for the each load when you apply the each increment of the each load the settlement is recorded, in the time intervals of 1 minute 2.25 minute 6 4 6.25, 9, 16 and 25 minutes interval and there after every hourly we have to take the load reading.

So that means, we have first applied say for firstly application say twenty kilo Newton we applied. And then we record it for 1 minute 2.25 and 4 like this interval and then up to 25 minutes, then every 1 hour we take the reading of the settlement, we are taking reading means we are the taking the reading of the dial gauge or the LVDT to get the settlement you are measuring the settlement. So, and then for the clay soil this load is increased when the next increment is applied, when the time settlement curves indicate the settlement had exceed 70 to 80 percent of probable ultimate settlement, or at the end of 24 hours.

So, what does it mean it means that if the soil is sandy soil or granular soil so, that means, they are all the settlements are immediate settlement. So, you will get the settlement immediately so, after say few hours you will find out that there is I mean no further increment of the settlement, or no further significant increment of the settlement. So, they are depending upon soil, or depending upon the site condition may takes a say few minutes to few hours.

But if it is granular soil, because the range is 0.205 millimetre per minute so, if your settlement range reaches this limit, or if it is less than that; that means, there is a change in settlement is 0.02 minute millimetre per minute, then we will stop. So, for the sand we will get this thing very early, because it because of most of the things are immediate settlement, but as I mentioned this test is also suitable for the granular soil, but for the clay also we can use this we can do this test also in the clay, but as the clay the most of the settlement, or the consolidation settlement and this type of test is a short term test.

So, for the long term settlement it is very it is not I mean it is not very useful to use these things for the long term settlement, because we will not get the long term settlement, because we are doing this test for the short term. And for, but clay has the long term settlement so, we in case of clay so, first for a particular load and if we apply on the plate. So, for that particular load what would be the probable settlement that you have to calculate, you have to calculate by using the previous expressions, that I have given that immediate settlement and for that load what will be the consolation settlement, then you will get the pro maximum probable ultimate settlement for that particular load.

So, if your test reaches more than 70 to 80 percent of that probable ultimate settlement, or after 24 hours. So, whichever is earlier you have to apply the next increment of load. And again for the next increment of load what would be the probable maximum settlement, you have to calculate and then you have to use you have to see whether it is exceed 70 percent or 80 percent of that, if exceed that then you apply the next increment, this is for the clay.

And for the sand generally you follow that if the settlement a rate is less than 0.02 millimetre per minute, then we apply the next increment of load and in the clay either 24 hours, or if it exceeds the 70 to 80 percent of the probable ultimate settlement. So, probable ultimate settlement, you will calculate by available the theoretical expressions for immediate and the consolidation settlement.

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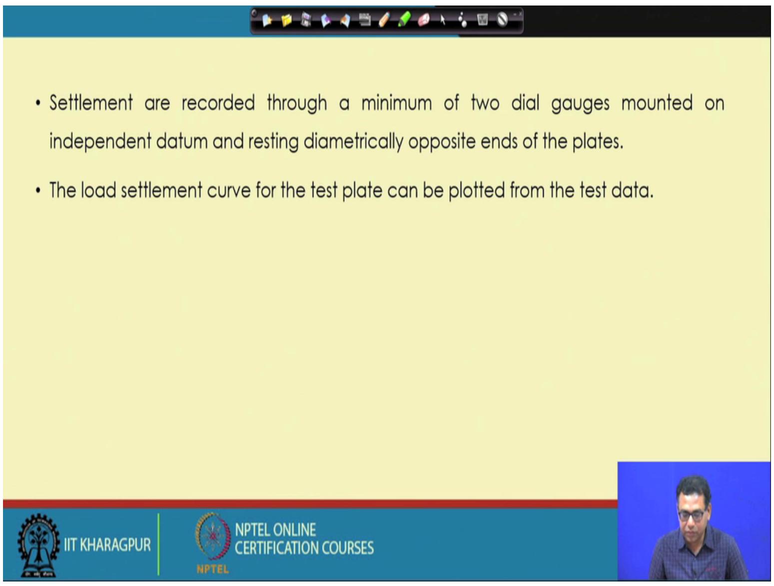

So, next one the settlement are recorded, through a minimum of two dial gauge and, it is placed diagonally opposite to the plate and load settlement curve for the test plate can be plotted from the plate load test data. So, ultimately the end product of this test that we will get a load versus settlement plot; so, we will apply the load we will measure the settlement and, then that we will plot that and from that plot, we will you for that plot, we will use for our design purpose.

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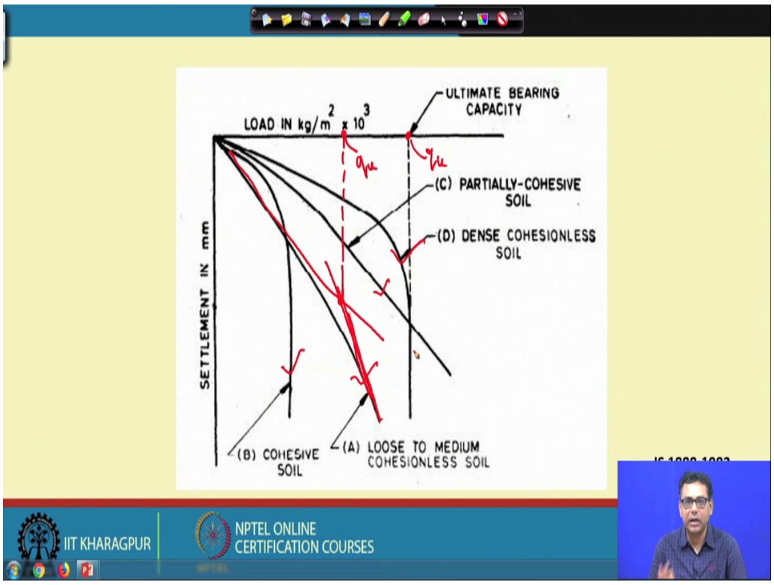

Now, after that we will get the end of the test we will get this type of plot. So, we will find so, cohesive soil we will get this is the plot for the cohesive soil, this is the plat for the loose to medium cohesion less soil, this is for the dense cohension less soil and this is partially cohesive soil. So, this chart is taken from the IS code.

But one thing that I want to mention that that here if you find these different plots so, here we will not get we are not getting any peck. So, then to get the ultimate load I have discuss in the previous class also, either you have to use for the double tangent method, or the single tangent method here, this load is parallel this settlement load settlement curve is parallel to the settlement axis.

So, we it is almost parallel to the settlement axis. So, we draw the tangent in the last state potion of the curve and, this we will give us the q ultimate ok, but for this type of curve where this it is not parallel to the settlement axis, then the initial state potion of the curve and the sorry initial state potion of the curve and the final state potion of the curve. So, if

I extend that then the inter section point, this is the inter section point. So, corresponding load or the stress we will give the ultimate load, or the stress.

So, this is the double tangent method this is the single tangent method by which by using this methods, we can determine what would the ultimate load from the load settlement plot.

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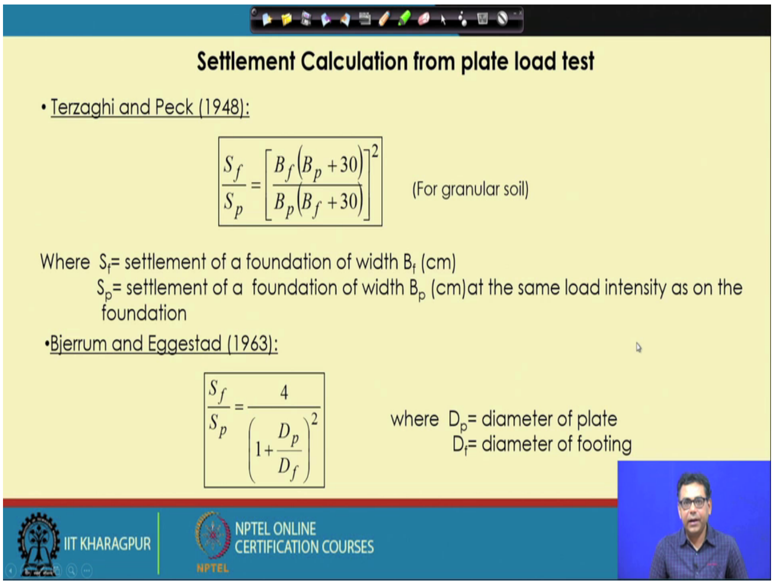

Then from this plate ultimately you have to calculate the settlement of the foundation, or load carrying capacity of the foundation. So, ultimately from this test data so, there are few correlations are given between the plate settlement and the foundation settlement. So, this is the correlation first proposed by Terzaghi and Peck; so b which if I use this correlation we can correlate the plate settlement with the foundation real foundation settlement.

So, S f mean the settlement of the foundation S p is the settlement of the plate. So, this is the correlation for granular soil remember that this is for the granular soil and, if you are using this correlation then B p and B f width of the plate and width of the footing should be in centimetre. So, remember that this should be in centimetre.

And this is applicable for granular soil and for the putting. So, you can use this correlation to correlate the plate settlement and the foundation settlement, or determination of the foundation settlement.

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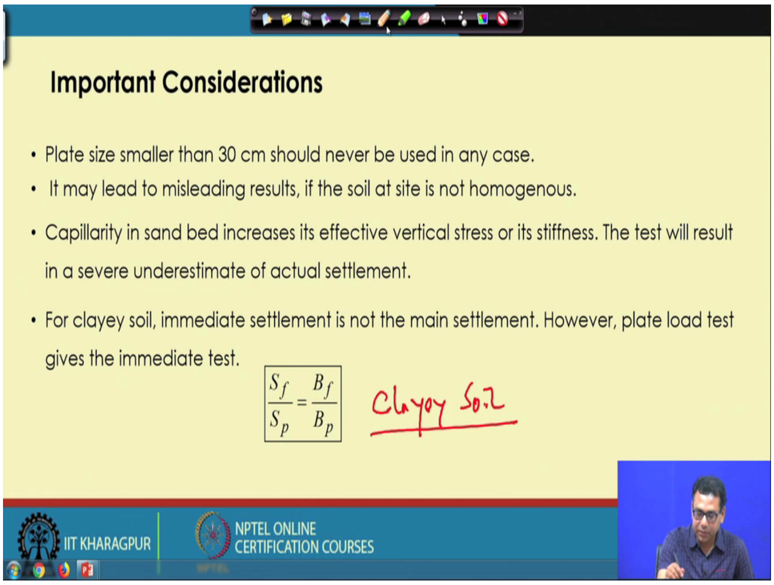

So, next one is for the important consideration. So, as I mention that we cannot use the plate size less than 30 centimetre. So, I mean then we will not get the appropriate, or proper results another very important thing that this test is suitable for the homogeneous soil for the layer soil. Then this test we will not give the appropriate result, because in if it is the homogeneous soil then influence of the real foundation and influence of the plate will be on the same soil. Because the size of the plate is the 30 centimetre, or then the real foundation size say 2 metre. So, e as I mention for the settlement we will go the influence zone up to twice B.

So, for the say real foundation the influence zone is up to 4 metre below the base of the footing, but in the real plate the influence zone is only 16 to 2 so, that we will be 120 centimetre. So, if it is the homogeneous soil then it is fine, because both the cases this influence zone is the same soil, but if it is in layer soil, then it may be a possibility that for the plate you are influence zone in is only on the top layer, but in the actual foundation influence zone may be in the other layers also.

Those in see effect of those layers are not incorporated are in the plate load test. So, those affect you are not getting into your plate load test result, because your plate load a plate loading in influence zone is not reached up to those layers. So, that is why you will you may not get the proper result and, then the capillary in sand bed increases its effective vertical stress or stiffness. So, the test will result in a reverse severe under estimate the actual settlement. So, if there is the capillary lies then you have to keep in mind this things that your result in a severe underestimate the actual settlement so, you have to take care in that case.

So, these are the thing so, these are the so it has some advantages we will get the data from the field itself, but it has other some limitations also these are some limitations. Another one then the clay soil we know the consolidation settlement, or the time dependent settlement, or the long term settlement are the major thing, but here we are getting the immediate settlement. But so, if I use this settlement so, then we have to use this expression. So, this is for this expression is valids for the clay soil.

So this is the settlement of the footing this is settlement of the plate and this is the width of the footing width of the plate. So, this is applicable for the clay soil though it will give you the immediate settlement.

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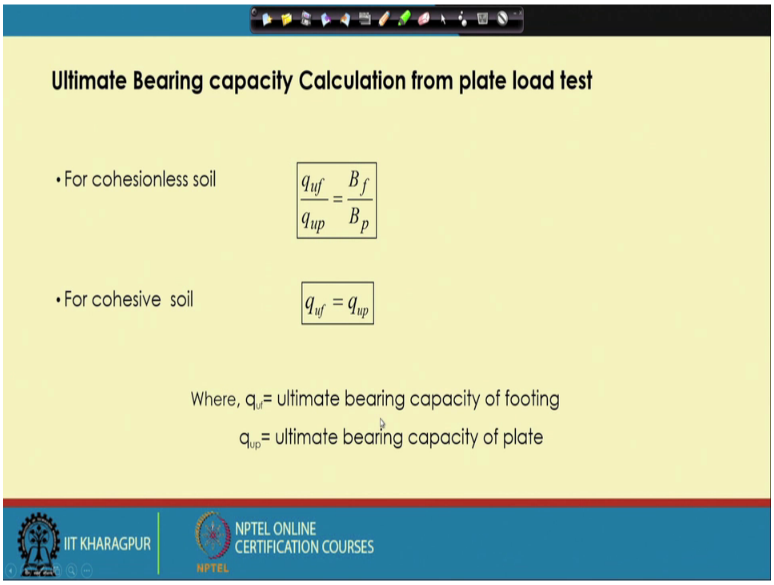

So, next one is in terms of ultimate bearing capacity calculation from the plate load test. So, for the cohesion less soil so, the ultimate load carrying capacity of the foundation, and the ultimate load carrying capacity of the plate can be correlated with the width of the plate and the width of the foundation. So, this is the correlation for cohesion less soil, but for the cohesive soil as I have already mentioned that the cohesive soil, your net ultimate, ultimate load or the net ultimate is not function of width even your ultimate load is the function of depth only, but it is not function of width.

So, none of the cases whether it is the ultimate load or net ultimate. So, your bearing capacity for clay soil is independent to the width of the footing. So, that is why here this width effect width is not given any effect. So, that is why you have a ultimate load carrying capacity of the plate is equal to the ultimate load carrying capacity of the foundation, remember that your soil should be homogeneous. So, these are the correlations in terms of bearing capacity

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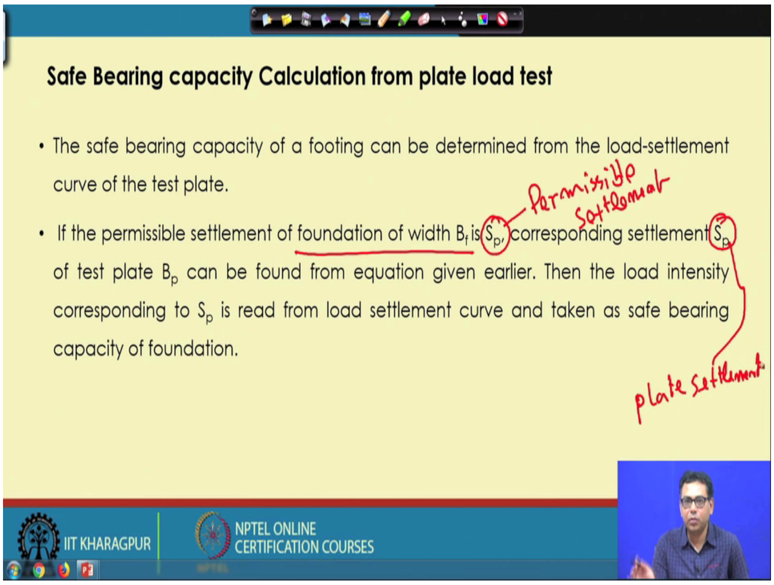

Now, the how I will calculate the safe bearing capacity form a plate load test. The safe bearing capacity of a footing can be determined from the load settlement curve of the taste plate. So, if you have a load settlement curve from that load settlement curve, we can determine what would be the safe bearing capacity from the plate load test data. Now, how we will do that so, if we have the permissible settlement of a footing real foundation is say S p, S p is the foundation of a permissible settlement of foundation of width is the S p ok. So, this is not the plate so, this is the permissible settlement ok.

So, this is the permissible settlement of a real foundation width of B f. Now, the what will be the settlement this is the settlement of the plate this is the because here, both the cases S p is used so, that is why so, from the this permissible settlement what would be the settlement of the plate, that we corresponding to this permissible settlement, then we can determine this things by using the correlations that we does just discuses.

So, now from this correlation you will get what will the settlement of the plate corresponding to the permissible settlement of the footing, then from the load settlement curve, with respect to that settlement of the plate we will get the intensity of load and that intensity of load, we will give us the safe bearing capacity of the foundation or the safe bearing capacity from that load settlement curve. So, this will so that is why the load settlement curve can be used to determine the safe bearing capacity of the soil, as well as the it will it can use the settlement of the foundation also. So, ultimately we can use this test data for our design purpose.

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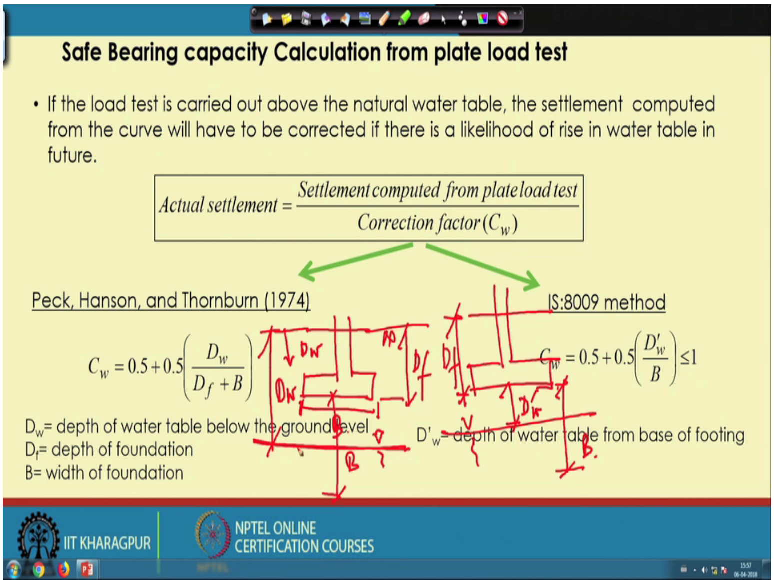

So, next one that in the safe bearing capacity calculation from the plate load test, we have to apply the corrections factory because till now we have consider that there is no water. So, water effect we have not consider, but if we think that there is the possibility of water table raise, then we have to consider the water table effect also so, that mean how we will consider the water table effect.

Now, for the actual settlement of a foundation that will be the settlement that we are getting from the plate load test divided the correction factor, remember that there is one thing is that when we are applying the correction factor for the bearing capacity, we are multiplying that correction factor with the bearing capacity, because water we will also always create a negative effect. So, if we if the water table increase height water table height increases, or the position of the water table increases, then what will happen that your bearing capacity value will decrease. So, that is why you have to multiply the bearing this correction factor and this correction factors are always less than 1. So, maximum it varies maximum value is 1.

So, it is always less than 1 or 1, depending upon the position of the water table. So, in case of bearing capacity as the water table reduces the bearing capacity so, you have to apply the correction factor you have to multiply the correction factor with the bearing capacity value, but in case of settlement here also it will create the negative effect. So, here you have to divided it so, that your amount of settlement will increase due to the effect of water table.

So, that is why in case of bearing capacity you have to multiply the correction factor in case of settlement, you have to divide the correction factor. So, that is the case here it is the settlement so, we have to give the correction factor you have to multiple divide it by the correction factor. And this correction factor we can get by two methods one is Peck Hanson and Thornburn 1974 and where D f is the depth of water table below the ground level. So, remember that the difference between this two methods, that if this is your foundation this is the ground level.

So, your here D f is D w is this one, this is the D f D is the depth of foundation B is width of foundation. So, any position of the water from the ground surface is called as D w, but as the per the I S method if you look at these method, then if this is the depth of the foundation D f, then your D w dash is measured from the base of the foundation D w dash is base of the foundation, suppose this is the position of the water table here, this is the position of the water table.

So, remember that here this is D w dash means it is measure from the base of the foundation and, D w means it is measure from the top of the or the from the ground surface. So, sometimes D w is limited to the base of the foundation also, but here in this case so; that means, the influence zone is up to D f plus B. So, that I have already explained. So, this is up to B here also influence zone is up to B beyond the B, or depth from the base of the foundation we do not consider the water table effect.

So, here if say water table is at the base so, D w dash is 0 then C w will be the 0.5. So, and here we can have a different value. So, in I S code according to the IS code, if your water table is at the base level, or above the base level, then the correction factor is always 0.5. So, base level from or above the base level it is 0.5 and at the B from the base of the footing is 1 and in between base to the B depth, we can use this expression ok.

So with this, I am finishing this today's lecture. In the next class I will solve problem by using a plate load test data, then I will show how we can use this plate load test data to determine the safe bearing capacity, or the settlement and how we can incorporate the water table effect.

Thank you.