Foundation Engineering
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Lecture - 21
Shallow Foundation – Design I

So, in this lecture I will discuss about how we can design various foundation Shallow Foundations like, isolated footing or raft foundation resting on clay, or the sand. So, but remember that when we are talking about design so, I will not discuss about the structural design of the foundations, I will not discuss about the reinforcement design, or the detailing of the foundation.

Here, design means that I will discuss only the geotechnical design of the consideration of the foundation design, means that I will discuss about the dimension of the footing and, where I will place that footing. That means, the depth of foundation and the dimension of the foundation so, that the load that is coming on this foundation the foundation can carry that load.

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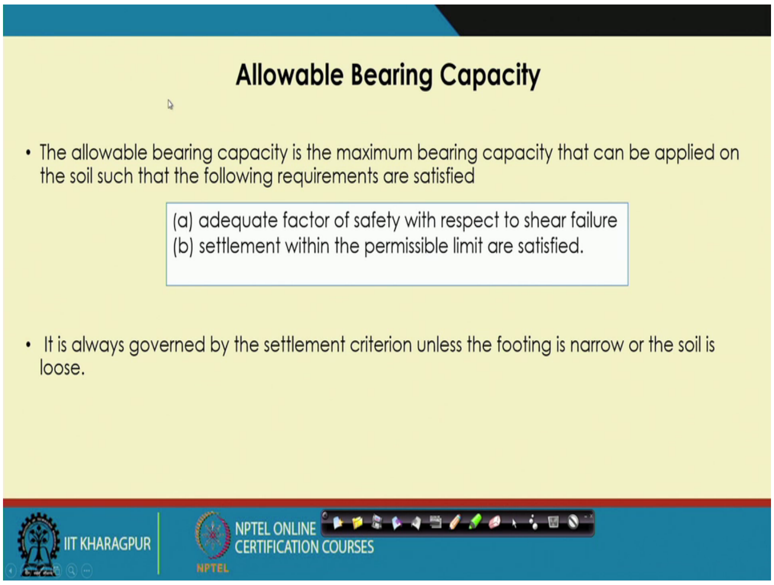

So, before I going for this design part so, till now I have discuss the bearing capacity calculation of foundation and the settlement calculation of foundation separately. So, as I mentioned that there is a term allowable bearing capacity of the foundation. So, this allowable bearing capacity of the foundation means that the maximum load, or the stress of footing can take in terms of bearing capacity criteria. And, the maximum load or stress of footing can take in terms of settlement criteria, then minimum of these stress, or load will be the allowable bearing capacity of the foundation.

So, we have to satisfy both the criteria's and based on that the minimum stress will be the allowable bearing capacity of the foundation, or bearing capacity that can be applied on the soil, such that following two criteria's are satisfy. As I mentioned this what are this type two criteria's, that adequate factor of safety with respect to the shearing failure and settlement within the permissible limit are satisfied.

So, it is most of the cases it is observed that the settlement criteria, always governed this allowable bearing capacity, always the footing is very narrow or the strip and or the soil is loose. Otherwise, most of the cases that will find the big settlement criteria will govern this allowable bearing capacity.

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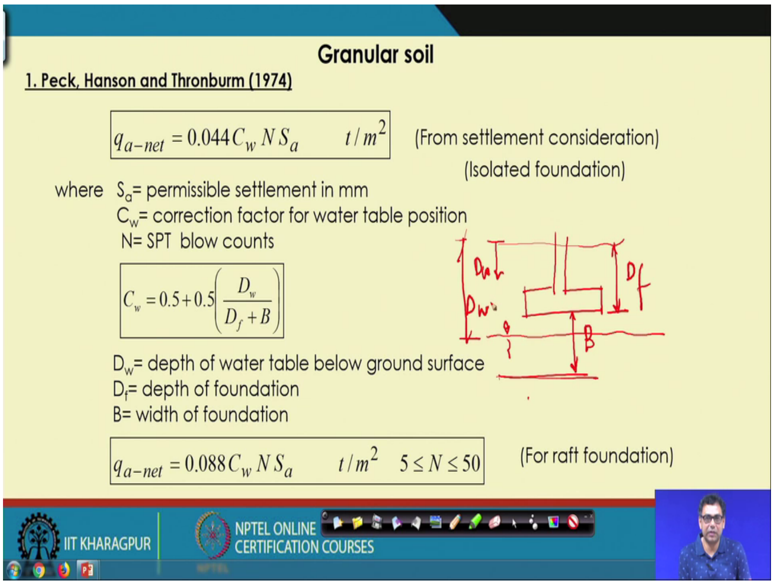

So, but the before I start the design part so, we will also that if we have we can also determine the net allowable bearing capacity based on the in situ test data. So that means, here we can see and these things are applicable for granular soil, as I mentioned that this in situ test are all useful for the granular soil. Because in the clay soil here this in situ test, because the clay behavior is long term, but this in situ test are short term test. So, there you may not get the proper behavior of the clay into this in situ test value in other way, in the clay we can collect the undisturbed soil sample.

So, in the clay it is easy to collect the undisturbed soil sample. So, we can collect the undisturbed soil sample you bring it into lab test it get the properties. So, those properties we can use for the in the theory so, which is available to calculate the bearing capacities in terms of bearing capacity, or allowable bearing capacity in terms of settlement as well as the bearing. But in case of sand because of collection of undisturbed soil sample is difficult. So, that is why we can go for this in situ test data, which is we where we can directly use these in situ test data and get the net allowable bearing capacity.

The first expression that I am giving it is the net allowable bearing capacity is given by these equation ok. So, this equation is 0.44 C w is the correction factor due to water table into S a, S a is the permissible settlement. And remember that, if you use these expression these will be turn per meter square. So, it is generally used for the isolated foundation for the raft foundation, we will use these expression which is 0.088 C w N S a, if your N value is within this limit.

And what is C w, C w is the water table correction. So, if D w is the so; that means, here again I am writing that if it is the ground surface. So, this is the foundation. So, your water table position is up to D after that there is no effect of water table. So, this is D f depth of foundation so, your D w is calculated from here. So, if the water table is somehow here then depth of pound water table will be the D w ok. So, these corrections we can apply here. So, these two the water table correction and S a is the permissible settlement so, what is the permissible settlement based on that you have to determine the net allowable bearing capacity.

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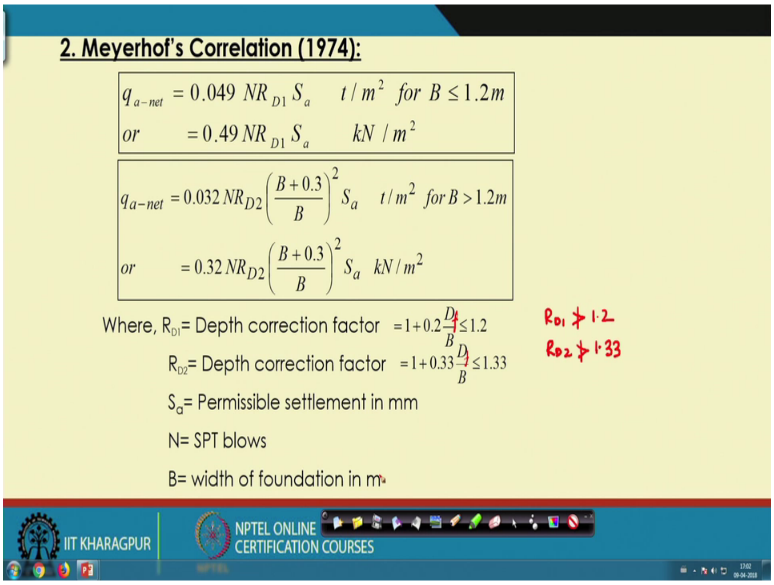

So, in the next one these Meyerhof corrections, the previous corrections were given by peck Hanson and Thornburg in 1974. And the next correlations is given by Meyerhof 1974. So, there also this is this 0.049 N R D into S a and these correlations all are empirical correlations. So, based on the observations they are proposed these correlations. So, that is why these are called the empirical correlations so; that means, here also turn per meter square in terms of kilo Newton this will be the correlations, if it is your B width of the foundation is less than 1.2 meter. If it is greater than 1.2 meter, then we have to use these correlations.

And these are the all factor which is the in this correlations already this depth factor water table factors are included and, this is for the depth factors and so, depth factor is given if D means the depth of foundation. So, you can write this is D f depth of foundation is less than 1 plus D f by B. So, less than equal to 1.2 and this is 1 plus D f by B less than equal to 1.33, but does it what does it mean it means that if this value is coming greater than 1.2. So, we cannot take greater than 1.2 the maximum limit of this R D 1 depth factor correction is 1.2 and the maximum limit of R D 2 is 1.33.

So, remember that that R D 2 R D 1 cannot be greater than 1.2 and R D 2 cannot be greater than 1.33, where this is the limit. So, if the depth is very high so, that you have to restrict this value is 1.2 and 1.33. So, that is the limit it is given and here also permissible settlement in millimeter N is the SPT blows and B is the width of foundation in meter, remember that as these correlation which has in the Meyerhof or the peck Hanson and Thornburg. So, all this correlations are empirical correlations. So, the unit that is mentioned here you have to specifically follow this unit, all like as otherwise you cannot use this correlation. So, remember that when you use this correlation this unit you have to specifically follow, when you are putting these value.

And then there is term S a is the permissible settlement and N is the SPT blows and so, the N is the SPT blows and remember that these SPT blow so, R D 1 I will get from here R D 2 I will get so, this is the R D 1 R D 2 and N is the SPT blows and this SPT blow is the corrected N value. So, remember that there in few cases in this empirical expression, you will find this is called N field, N field means the observe without any corrections and N means it is corrected.

So, in sometimes you will find the N without applying the overburdened pressure; that means, this is uncorrected so; that means, the measured value that you are getting from the field, you may have to apply directly or after the correction depending upon which way it is been represented. So, here it is N means it is corrected.

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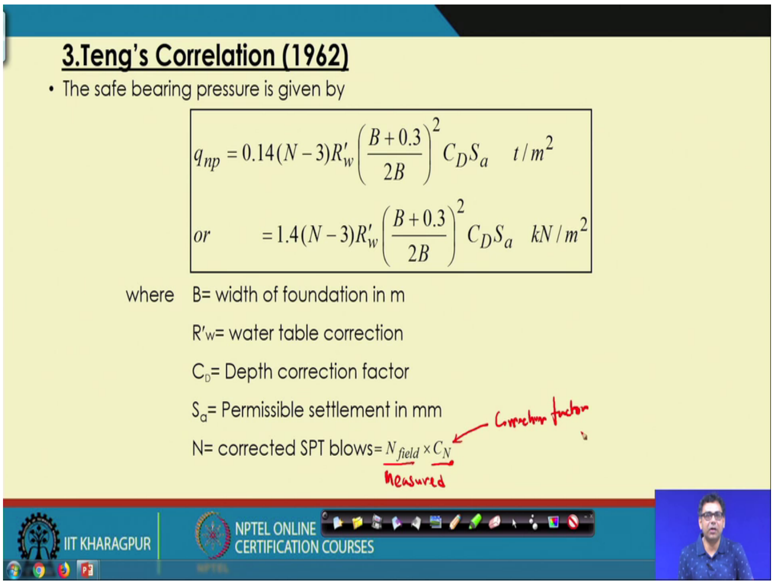

And here the another correction correlations is given by 10 in 1962, where also this is the N value which is corrected, but N field which is the measured. So, C N is the correction factor so, C N is this correction factor this is the measured so, N field means measured. So, C N is the correction factor so, I have discussed this correction factor, when I discuss all the SPT. So, these are the overburden, corrections, or dilatancy correction depending upon which code you are using or then it can be other corrections also.

So, here C N is the correction factor so, I will discuss latter and what is how we will get the C N value. So, here this expression B is the width of the foundation in meter again I am telling you keep in mind this units, then C D is the depth correction factor S a is the permissible settlement in millimeter and this is the N corrected SPT value, this is in this equation in terms of turn per meter square this is in terms of kilo Newton per meter square.

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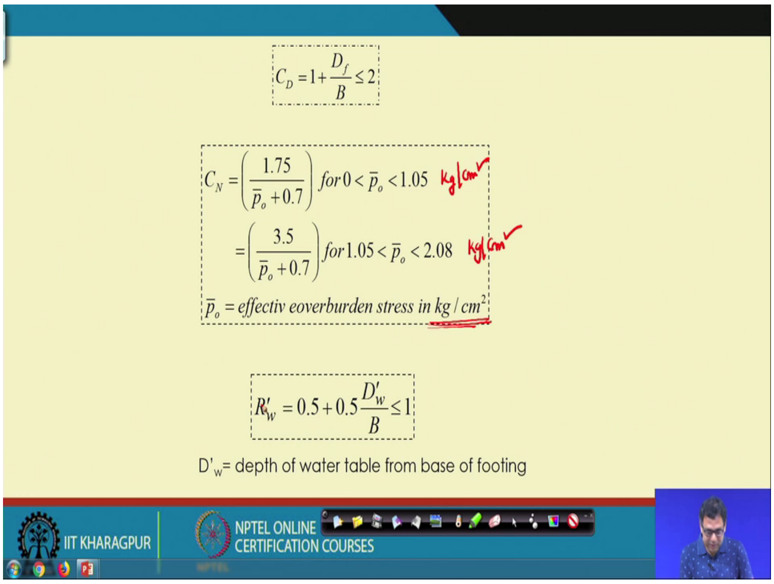

So, now, how I will get this C D, C D is the again 1 plus D f by B again C D cannot be greater than 2. So, if the maximum value is restricted as 2. And C N this correction factor is this is p 0 bar for e p 0 is less than 1.05 so, remember that this is in terms of kg per centimeter square, again this is in terms of kg per centimeter square, if it is within that range and this range is sufficient for a shallow foundation within the influence zone so, that is why it is given within that zone. So, this why we can this is effective overburden stress in kg per centimeter square.

So, remember that if you are using this expression you have to follow this unit again I am telling ok, you the way it is represented you have to follow and here this is the R w dash. So, this R w dash value was this R w dash value has given here. So, this is the water table correction. So, how I will get the R w dash previous one if it is R w, then the water table is measured from the from the G L and if it is R w dash then the water table is measured from the base of the foundation.

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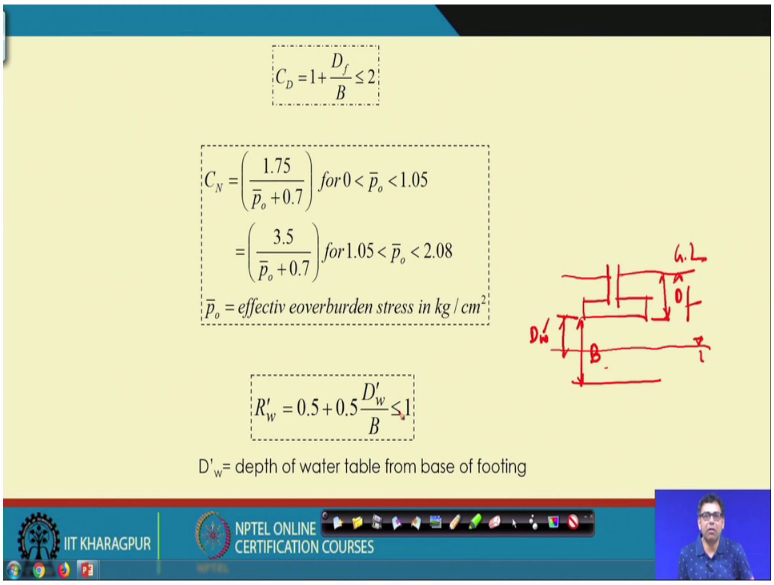

So; that means, if it is D w dash so; that means, if it is foundation because this thing this is the G L or ground level this is the base of foundation D R. So, and this is the B up to which the water table effect is there. So, if it is your water table is here. So, you have to measure D w dash from the base of the foundation. So, in that case if your water table is as the base and above then R w dash will be 0.5 and, if it is below the base of the footing, then you have use this expression ok. So, this is the w dash is this one and then and it cannot be greater than 1 again this is restricted as 1.

So, these are the all empirical expression by which you can directly calculate, what would be the net allowable bearing capacity of a foundation; that means, here as I mentioned most of the cases the settlement criteria is governed. So, these are permissible settlement so, based on the settlement. So, that is why if you use them you can directly calculate what would be net bearing net allowable bearing pressure of the foundation.

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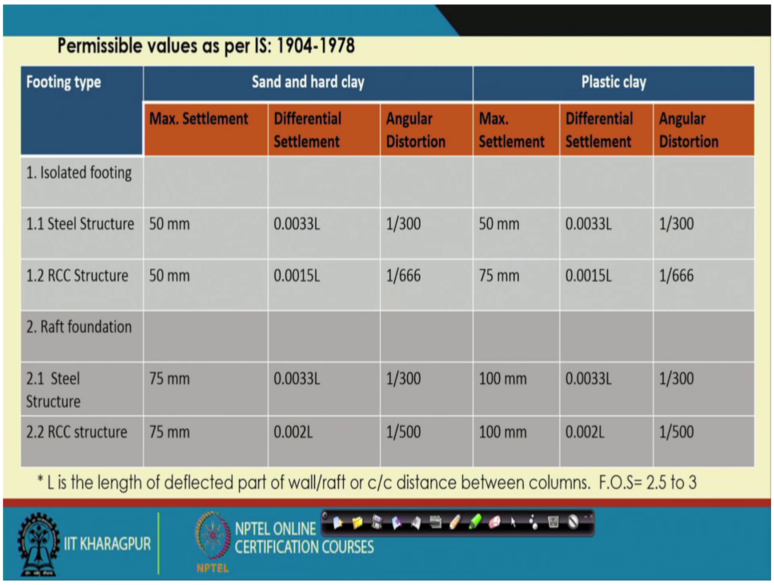
Permissible values as per IS: 1904-1978

Footing type	Sand and hard clay			Plastic clay		
	Max. Settlement	Differential Settlement	Angular Distortion	Max. Settlement	Differential Settlement	Angular Distortion
1. Isolated footing						
1.1 Steel Structure	50 mm	0.0033L	1/300	50 mm	0.0033L	1/300
1.2 RCC Structure	50 mm	0.0015L	1/666	75 mm	0.0015L	1/666
2. Raft foundation						
2.1 Steel Structure	75 mm	0.0033L	1/300	100 mm	0.0033L	1/300
2.2 RCC structure	75 mm	0.002L	1/500	100 mm	0.002L	1/500

* L is the length of deflected part of wall/raft or c/c distance between columns. F.O.S= 2.5 to 3

So, now so now, we are talking about that we are talking about the. So; that means, now we have not discuss the bearing capacity and, you have discuss the settlement and, then we were talking about the permissible settlement permissible settlement what is permissible settlement.

So, permissible settlement that in different codes as given what would be the permissible; that means, your settlement will be maximum for a particular foundation. So, you cannot design your foundation more than this value of settlement so; that means, you have to restrict your foundation settlement within that limit. So, that is the permissible settlement. So, here as I mentioned that we are basically in the first class of the settlement, that we have total settlement we have differential settlement or the angular distortion and we have the tilt.

So, tilt that if the total building is settled so, that generally is not given in this chart so, the things that generally we follow are that this are the permissible value. So, for the isolated footing, or if sand or hard clay, then for the steel structure your maximum permissible value is 50 millimeter this is as per IS code. And for the RCC structure, it is also 50 millimeter and for the differential settlement is 0.0033 L and for the RCC is 0.0015 L. But, if it is on clay plastic clay I mean the soft clay, or then this value is 50 millimeter for steel structure and RCC structure, it is s75 millimeter and these are the other values angular destruction and differential settlement.

And if it is raft foundation or rigid foundation, then we can go for higher settlement. So, this value is 75 as a millimeter for RCC and for the steel both and for the plastic clay it is 100 for RCC and for the steel structure. And here, remember that this L value is the length of the deform part of wall, or the raft or the centre's to centre distance between the column.

So, it is the deformed part of the wall or the raft or the centre to centre between two columns; that means, if there is a differential settlement of two columns you are measuring for isolated footing that will be difference between the two columns, centre to centre, or if it is a raft where there is a differential settlement in two parts of the raft, then the distance between two portion is will be the L ok. So, now what we will do that we will solve now design we will design the foundation.

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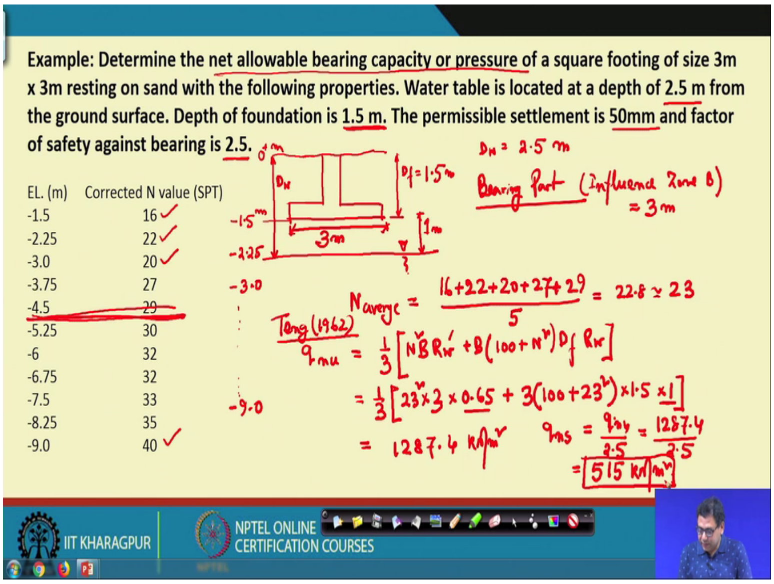

So, first problem that I have taken the determine the net allowable bearing capacity, sometime it is called allowable bearing capacity also, or pressure of a square footing of size 3 cross 3 meter, resting on sand with the following properties, what are the following properties. So, this is the N value and remember that this is the corrected N value is given with the depth wise ok. So, suppose we have a foundation, we have the foundation.

So, this is the ground surface and we have the foundation so, this is the base of foundation and here the depth of foundation is given 1.5 meter. So, this is plus 0 meter this is this is the depth of foundation is minus 1.5 meter and this is the D f, D f is given is 1.5 meter.

So, this is the foundation and at different depth, suppose it is if it is minus 2.2 meter, then minus 3 meter and so, on so up to say minus 9 meter. So, and the corresponding N value for all the depth wise so, it is the N value is given they 75 centimeter interval. So, this is 1.5 meter it is 16, then 2.25 meter it is 22, then for 3 it is 20 and for 9 it is 40. So, these are the N values and these are the depth wise N values ok, now water table location is given at a depth of say so, 1 meter from the base of the footing. So, total water table location is say 2.5 meter. So, if it is in terms of D w so, our D w this is D w. So, D w is 2.5 meter.

Ok. So, now, the water table is located 2.5 meter from the ground surface; that means, 1 meter from the base of the footing depth of foundation 1 (Refer Time: 19:16) permissible settlement is 50 millimeter and factor of safety against bearing is 2.5 factor safety. So, that ; that means, we have to check in terms of bearing as well as in terms of settlement and, then we will see what would be the net allowable bearing capacity, or pressure that we have to determine. So, first of all that first we are checking that for the settlement part and, then first we are checking the bearing part, or then we will go for the settlement part then we will check it.

So, first you are checking for the bearing part so, bearing capacity consideration. So, and when you are talking about bearing. So, we have to take the influence zone up to B so, for the bearing part influence zone is B. So, here the B is a square foundation so, B is 3 meter so, it is equal to 3 meter. So, the influence zone is from 1.5 to 4.5. So, this is the influence zone for the bearing up to 4.5. So, what we are taking we are taking the average N value of this total influence zone. So, average there are 5 N value 1 2 3 4 5 up to 4.5, because that is 3 meter is my influence zone. So, average N value will be 16 plus 22 plus 20 plus 27 plus 29 divided by 5 so, thus value is 22.8 or equal to 23.

So, average N value is 23. So, if the average N value is 23, then we can use the N net ultimate expression, because it here N value is given so, we can use the net ultimate expression that was given during the bearing capacity calculation. So, you go to your previous class lecture then you will find net ultimate expression was given by Teng in 1962 so, that expression was given, where we can calculate the net ultimate bearing capacity based on N value. So; that means, this is net ultimate so; that means, you have that expression was given for the isolated footing is one by 1 by 3 N square B R w dash plus B 100 plus N square D f in to R w ok.

So, this is the expression so, and the so, value I am getting that 1 by 3 N is 23 square B is 2 meter sorry 3 meter and R w is 0.65. So, I am showing how the I am getting R w dash plus B again 3 meter, then 100 plus N is 23 square into D f is 1.5 into R w is 1 ok. So, these are coming out to be 1287.4 kilo Newton per meter square ok. So, remember that we have two part 0.6 and 1 so, I will explain how I am getting this two value, because I have this curve in the next page so, but it is the net ultimate.

So, from here ultimate net ultimate is 2 this value and we have the factor effect is 2.5. So, the q net safe q net safe is equal to q net ultimate divided by 2.5 which is the factor of safety. So, that is equal to 1287.4 divided by 2.5. So, it is equal to 515 kilo Newton per meter square. So, we have value of 515 kilo Newton per meter square that we are getting from the bearing capacity consideration ok. So, we are getting 515 from bearing capacity consideration.

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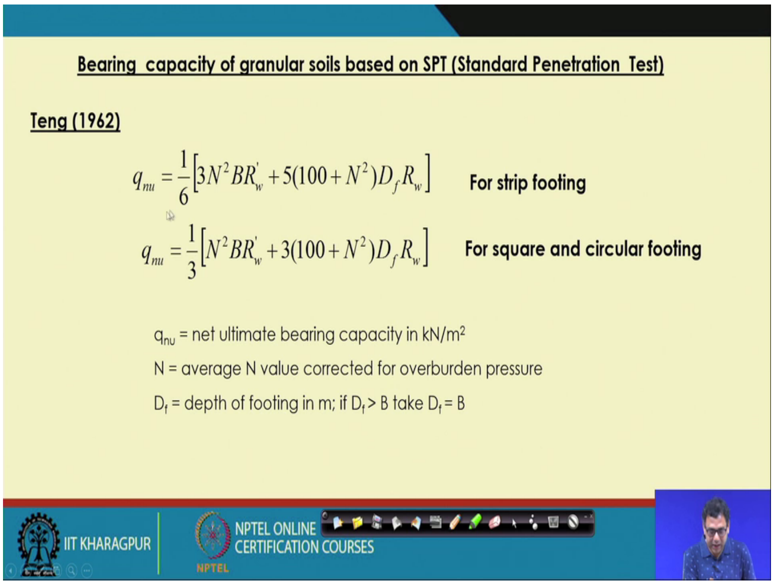

Now, so, let me explain this thing that I am using this expression sorry so, I am using this is for the strip footing. So, our case is square footing so, that is why I am using this expression ok. So, there is two terms R w dash and R w so, these two terms so, depth of the footing is e D f is greater than B, we are taking D f equal to B, but our case D f is less than B, because B is 3 meter D f is 1.5 meter. So, it is and so, and net bearing capacity is kilo Newton per meter square that we have taken.

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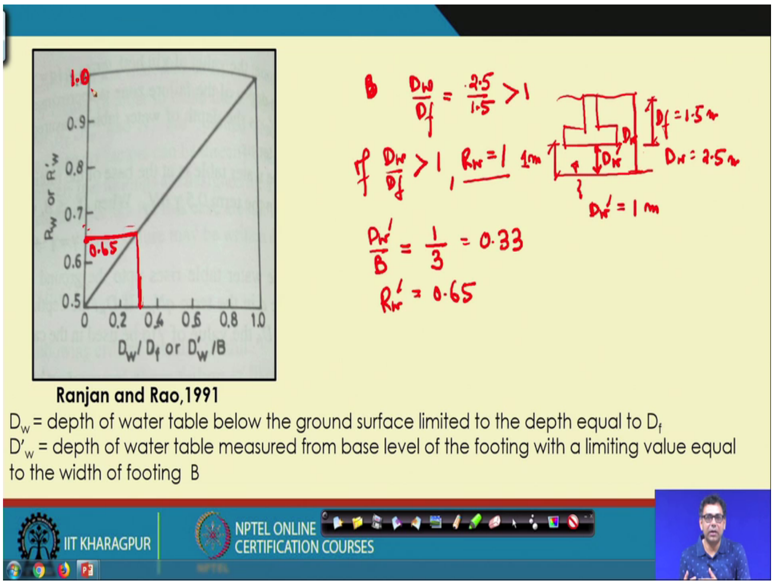

So, and the so but these are the two values R w R w and R w dash. So, from here I am getting so, what is R w R w we are getting that R w we are getting that here D w sorry D w divided by D f so, this is D w by D f corresponding is R w. So, D w is by D f is equal to is always it is this is 2.5 and this is 1.5 so; that means, here it is always greater than 1 so, if it is greater than 1 so, this will be this is remember that this value is 1 this is not 1.9.

So, this value is 1 so, this basically your D f is this 1 is D f that this is the as I mentioned this is that your water table is here, which is 1 point below the ground surface. And your D f is 1.5 meter and D w is this is D w, D w is 2.5 meter. And always remember that if your D w is greater than D f; that means, water table is below base of the foundation then the above soil will not be affected.

So, that is why if this value is greater than 1 so; that means, if D w by D f is greater than 1 then always R w is equal to 1, because you can see this is given up to 1. So, it is always 1 so, R w that is why 1, but your D w dash by B so, what is D w dash. So, from the base of the footing to the water table that is D w dash. So, here D w dash is equal to 1 meter. So, this will be 1 divided by 3 so, this is 0.33. So, if this is 0.33 will be somewhere here so, if I go to here. So, and these value is around point this is your, this is actually this is 3 3 will be somewhere here. So, this value is 0.65. So, actual value is this one.

So, if your this is 0.61 so, your R w dash is 0.65 so, this curve you can use for R w as well as R w dash, depending upon which value you are taking D w by D f or D w dash by B. So, if this D w by D f is greater than 1 or any value even D w dash by B also is greater than 1 then also it is 1. So, which means is D w by B greater than 1 it means that that your water table is below the base at a depth of greater than B so; that means, water table effect is not there.

If there is no water table effect then this values are 1 ok, this correction because there is no correction basically if I take the 1. Otherwise it will be the less than 1, because in bearing capacity it is less than 1 it will reduce the bearing capacity, because the water will give you an negative effect. So, that is why we have used R w dash 0.65 and R w as a 1 in the previous equation and, from there we find the q net safe is 515 kilo Newton per meter square.

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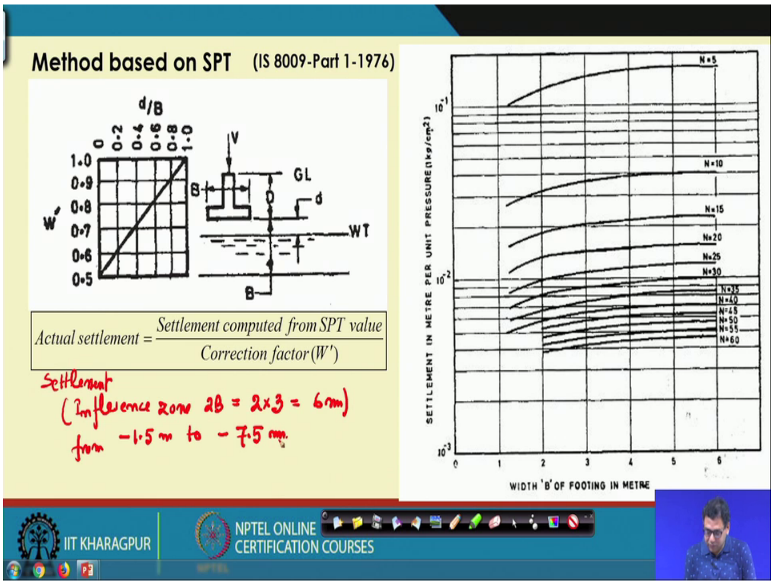

Now, next one what you will do that we have use the bearing capacity consideration. Now, I will use the settlement consideration ok, in the settlement calculation consideration here N value is given. So, I can use the N value chart to calculate the settlement and, then we from there we can go for the bearing capacity. So, here what we are doing that here we have N value, now when we have a ok. So, from this chart we will go for these values that for the settlement, we can go that here your influence zone will be twice B, because it is settlement consideration.

In the bearing consideration (Refer Time: 31:07) we are taken up to B. So, it is influence zone is twice B. So, your this will be 2 into 3 meter. So, this will be up to 6 meter so, it will go from minus 1.5 meter to minus 7.5 meter ok. So, settlement consideration it will go to minus 1.5 meter to minus 1.75 meter so, that will be the influence zone.

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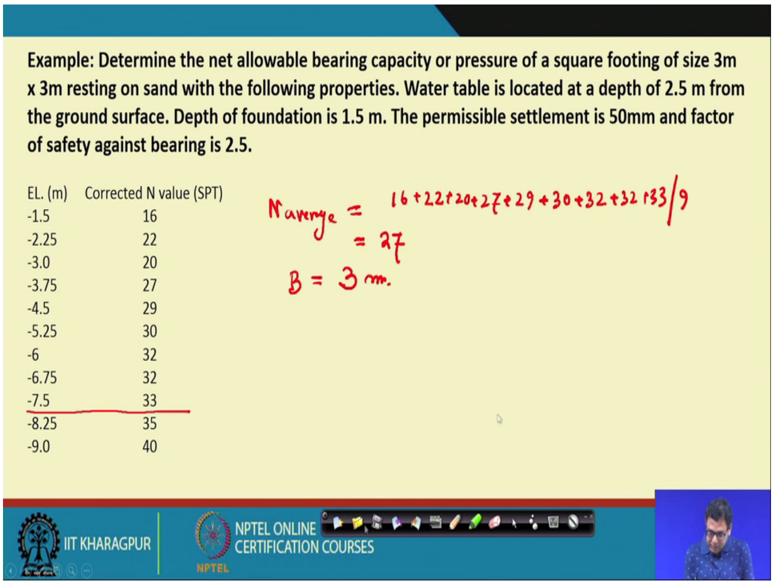

Now if I go back to my original problem that where this is the N value again. So, here now the influence zone is point 1.5 to your 6 meter 7.5. So, this is now the influence zone up to here. So the again N average value are this is 9 values so, 16 plus 22 plus 20 plus 27 plus 29 plus 30 plus 32 plus 32 plus 33 divided by 9. So, my influence N value is 27.

So, now, my N average is 27, B value is 3 meter so, let us go to the curve. So, N value is 27 B value is 3 meter. Now, let us go to the curve ok. So, this is the curve where my N B value is here B is the width of the footing B value is 3 meter and N value is 27 so, it will be around here so, my so this is the 0.27 this is the N this is the 25 is the N value and this is 30 is the N value. So, it is in between this two so, this is around this is the corresponding settlement.

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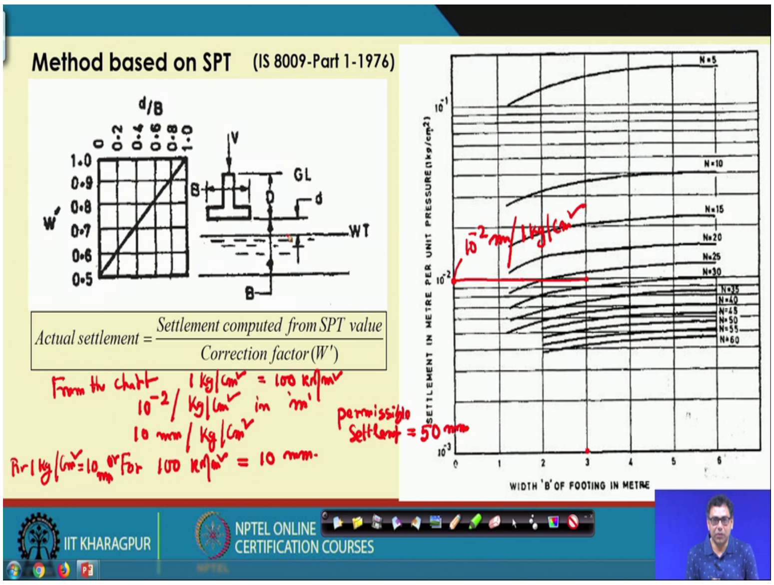

So the corresponding settlement from the chart so, from the chart your that your settlement for one kg per centimeter square is equal to or 100 kilo Newton per meter square. So, here it is per kg per centimeter square. So, the settlement that we are getting for the 10 this is for 10 to the power minus 2 per kg per centimeter square, that is the settlement 10 to the power minus 2 per kg per centimeter square it is in meter ok. So, in millimeter it will be 10 millimeter per kg per centimeter square ok. So, for per kg per centimeter square it has 10 millimeter settlements.

So, for 100 kilo Newton per meter square the settlement you are getting 10 millimeter ok, or you can write for 1 kg per centimeter square the settlement is 10 millimeter, or for 100 kilo Newton per millimeter meter square settlement is 10 millimeters ok, because your 10 millimeter we are getting it is 10 to the power minus 2 in meter. So, in millimeter it will be 10 millimeter, because this is 10 to the power minus 2 meter for per kg 1 kg per centimeter square so; that means, per 1 kg per centimeter square your settlement is 10 millimeter, or for 100 kilo Newton per millimeter meter square your settlement is 10 millimeter.

But your permissible settlement is so; my permissible settlement is settlement is 50 millimeter ok. Now, so this the 10 millimeter settlement and we have water table corrections also ok. So, now, we have to apply the water table correction and, then based on that we have to determine the based on this permissible settlement, you have to determine what would be the allowable bearing capacity ok. So, these things I will discuss today I am finishing here and, in the this part I will finish this problem in the next class, because here based on the bearing capacity calculation our net safe load is coming 515 kilo Newton per meter square.

And settlement consideration I am getting that for 100 kilo Newton per meter square stress, the settlement will be 10 millimeter, or you can so you can say for the 10 millimeter settlement will get for 100 kilo Newton per meter square stress. Now, in the that means, for what I will get for to get a 50 millimeter settlement and we have to apply the water table correction ok. So, next class I will finish this problem and, then I will also introduce the direct net allowable bearing capacity calculation part also.

Thank you.