Foundation Design
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Lecture - 12B
Design of Foundation-Part 1

So last class, I have solved 3 examples to calculate immediate as well as consolidation settlement and also bearing capacity.

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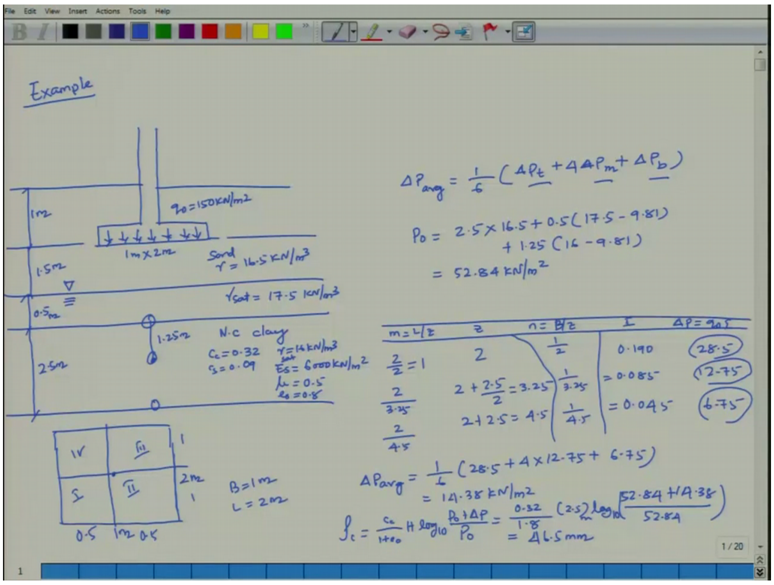

One more example I want to solve for particularly consolidated clays as we have discussed earlier during your settlement analysis. There is a footing, here it is footing 1 meter, then here it is 1.5 meter there is a water table here. Then pressure intensity on the footing is 150 kilo newton per meter square. Then sand gamma is equal to 16.5 kilo newton per meter cube. And here it is 0.5, gamma saturated is 17.5 kilo newton per meter cube. And there is a soft clay normally consolidated clay nc means normally consolidated clay. This step is your 2.5 meter. And these properties are given Cc is equal to 0.32 Cs is equal to 0.09. Gamma is equal to 16 kilo newton per meter cube. Es is 6000 kilo newton per meter square. Mu is equal to 0.5 e 0 is equal to 0.8.

So, find it out the consolidation settlements. So, in this case to find it out the consolidation settlement, generally we have to calculate delta p average which is equal to 1 sixth of delta p at top plus 4 time delta p at middle, plus increase in stress delta p at bottom. This is what your consolidation settlement to do it. Then for these find it out p 0. P 0 up to your 1.5 means up to this layer or at the middle; that means, this will be 1.25 meter.

So, your p 0 is equal to 2.5, 1.51 2.5 into gamma is 16.5 plus 0.5, 0.5 into 17.5 minus 9.81 plus 1.25. Your gamma saturated gamma saturated, is your 60 which is equal to 16 minus 9.81. It comes out to be 52.84 kilo newton per meter square.

Now, make it a tabular form. This is your m is equal to L by z. This is your z then this is your n is equal to L by z, then this is your influence factor, and this is your delta p is equal to q 0 into i. Size of the footing is given 1 meter by 2 meter. Now the footing size is 1 meter by 2 meter means this is 1 meter. 1 meter and this is your 2 meter

Now, increase in stress once you are going to find it out this is a rectangular loaded area and at the centre you have to find it out. So, basically you have to make by m by m and n and z what depth you want to find it out. And based on that because 3 z 1 is your at the top what is the z at the middle and at the bottom, top, middle and at the bottom.

So, m is equal to L by z. So, z is your L by z, if I take it z what is the distance, if you look at here z it is your 1.5 plus 0.5. So, then it is your 2, 2 by 2 is your 2. L by z is your 2. So, m is equal to 2, 2, ,2, z is equal to at the top up to it here it will be 2. Then here it will be your 2 plus 2.5 by 2 at the middle up to here to your one point plus 0.52. Here it is your 2.52, which is equal to 3.25. And here it will be again 2 plus 2.5 by at the bottom 2 plus 2.5 it will be your 4.5 m and n. You calculate also n. Then i comes out to be I is your 0.190, which is equal to 0.085 which is equal to again 0.045. Sorry m will be also varying n also will be varying m will be for depth L by z, if L is equal to if B is equal to 1 meter say L is equal to 2 meter m is equal to L by z L by z means L is equal to 2 by 2 2 by 2 which is equal to 1. Here it is your L by z L is equal to 2 by 3.25. Here it is your 2 by 4.5. And n is equal to n is equal to not L by z. This is your B by z, B by z is your how much your B by z B is equal to 1 by 2, 1 by 3.25. Then here it will be your 1 by 4.5.

This is what you are suppose to calculate it. This way you can calculate there are chart at the middle or you can do it. Or you can do it make in to 4 equal parts 1 2 3 and 4. Here it is 1 meter, 1 meter, here it is your 0.5 meter. 0.5 meter then sum it up. Then delta p is equal to q 0, i it comes out to be 28.5, 12.75, 6.75.

Now, calculate is your delta p average. Delta p average is equal to one-sixth 28.5 plus 4 into 12.75 plus 6.75. 6.75 is your at the bottom increase in stress. 12.75 is your middle 28.5 is your top. And one-sixth, it comes out to be 14.38 kilo newton per meter square you can check the calculations. I have done it you can use your calculators and check this whether this factors are i is correct or not. This is the procedure there might be small mistakes.

So, consolidation settlement is equal to Cc by 1 plus e 0 h log 10 p 0, plus delta p by p 0 which is equal to Cc by 1 plus e 0 Cc is equal to 0.32 by 1.8 because e 0 is 0.8 into h, h is your 2.5 at the middle and log 10, 52.84, p 0 plus 14.38 divided by 52.84 which comes out to be 40 6.5 mm.

So, this example why I have solved in many times you will be asked may be in a examination, you will be asked to find it out the consolidation settlement of a normally consolidated clay, where the footing is any shape footing is any shape it may be a square it may a rectangular it may be a circular. So, basically you have to find it out p 0, if it is a normally consolidated clay delta p average is one-sixth of this then based on the m and n your find it out, i and z then find it out your delta p then from there you calculate your delta p average, then find it out consolidation settlement Cc by 1 plus e 0 h log 10 p 0 plus delta p by p 0 h is your 2.5 meter total high. And Cc is your 0.32 and e 0 e 0.8 and it is 1.8 log 10 p 0 plus, delta p by p 0. So, it is coming out to be 46.5 mm

I think this is the last example and we will give may be in later part, I will solve many more examples once this design of this foundation completed. Then I can solve many more examples. So, typical examples I solve it earlier also I have solved few examples how to consider the pressure ball what depth we are going to consider how to calculate your bearing capacity.

So, let us start the next one that is primarily most important point means almost all part I have covered if you look at here, I cover your site investigation method of drilling sampling institute test, SPT, CPT, SPT, CPT plate load test dynamic test, ground water level, bearing capacity, general local punching, shear failures corrections for size shape depth water table compressibility ultimate and allowable stress method based on your institute test. Also I have finished settlement of foundations; that means, for sand for clay again for clay immediate as well as consolidation settlement for clay what are the different methods stress path method also I have covered.

Then stresses in soil last few class, I was covering that is by means of your boussinesqs theory by point load, then strip load then rectangular loaded then circular load then approximate method then equivalent point load methods up to this, I have covered, then I solve few examples.

Now, let us start with this design of the foundations. So, type of the foundations. So, so earlier I have covered; that means, your shallow deep isolated combined mat, this I have given a brief introductions what are the different types of this foundations

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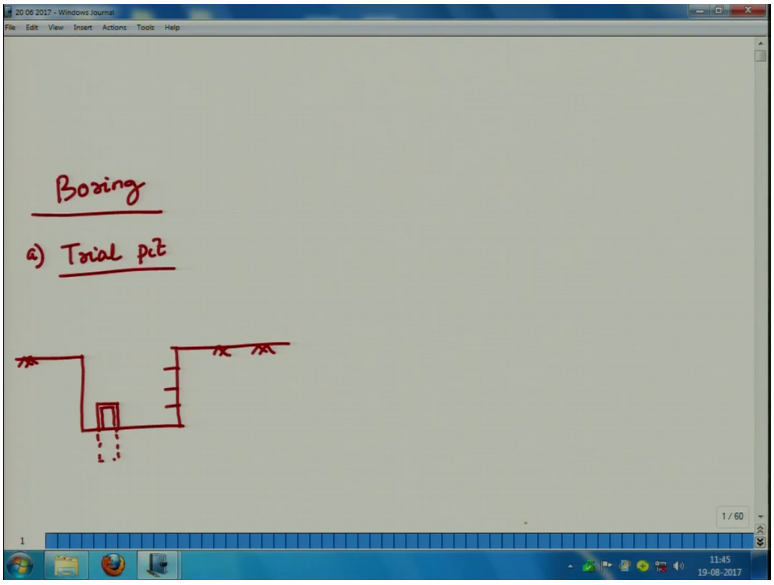

If I can I can show you just giving a very brief one, how for I have gone through it you can just see it yeah.

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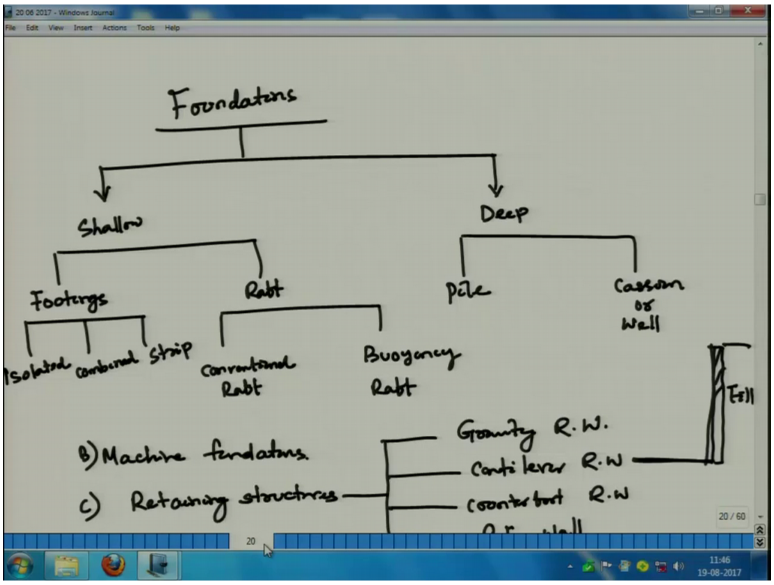

This is what I have covered in the beginning part foundations, shallow and deep and shallow is classified. Because I am repeating because I am going to start. Now design of this foundations foundation 2 types broadly, one is your shallow and deep shallow is shallow foundations. I can footing in rabt footing again isolated combined and strip rabt is convence conventional rabt and buoyancy rabt defoundation again 2 one is pile other is your caissons or well then there are also machine foundations retaining structures retaining structures, gravity retaining wall cantilever retaining wall counter fort retaining walls as well as reinforced earth walls RE walls this is called reinforced earth walls.

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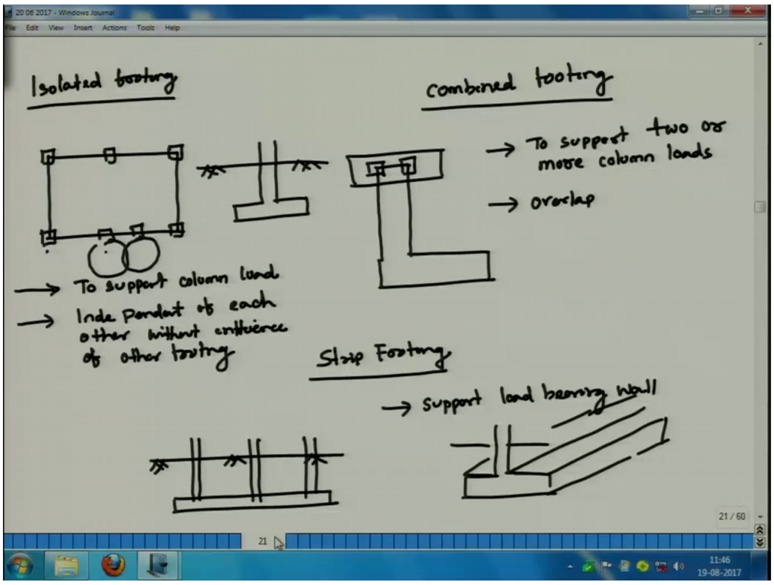

So, then I explain isolated footing where the case and to support your column loads and combined footings.

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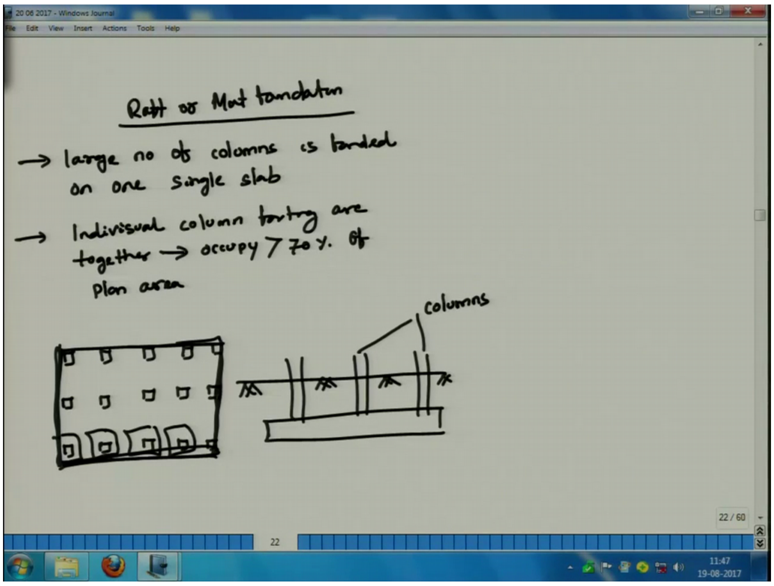

And strip footings then also I have gone through your rabt or mat foundations. Large number of columns are there, in that case one single slab is required rabt and mat foundations. Then I have covered your different rabt conven conventional rabt and buoyancy rabt, then pile foundations piers and caissons.

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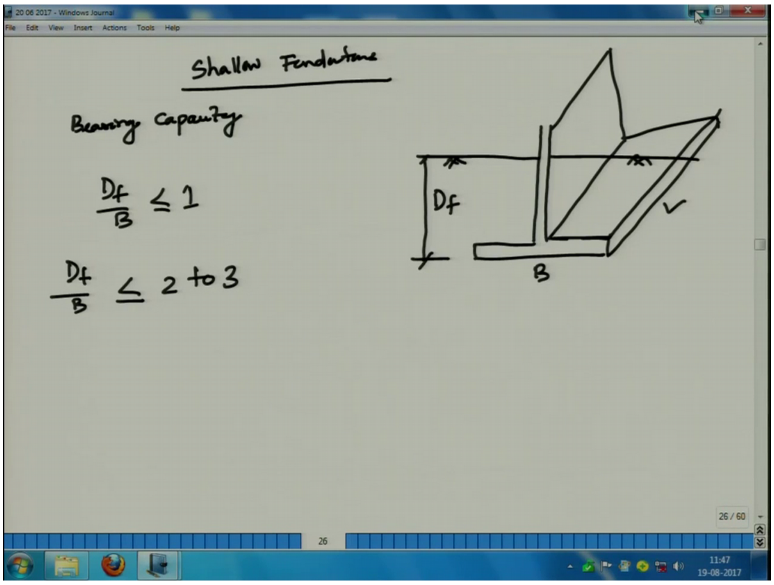

Then shallow foundations in definitions also, I have started if Df by Bs as per your terzaghi less than equal to 1, we can say shallow foundations, but it has been modified if Df by B strain between 2 to 3 then this comes out to be a shallow foundations.

Now, if I this this with this description, let me go to the next part. That is your design of foundations. Design of foundations in design of foundations.

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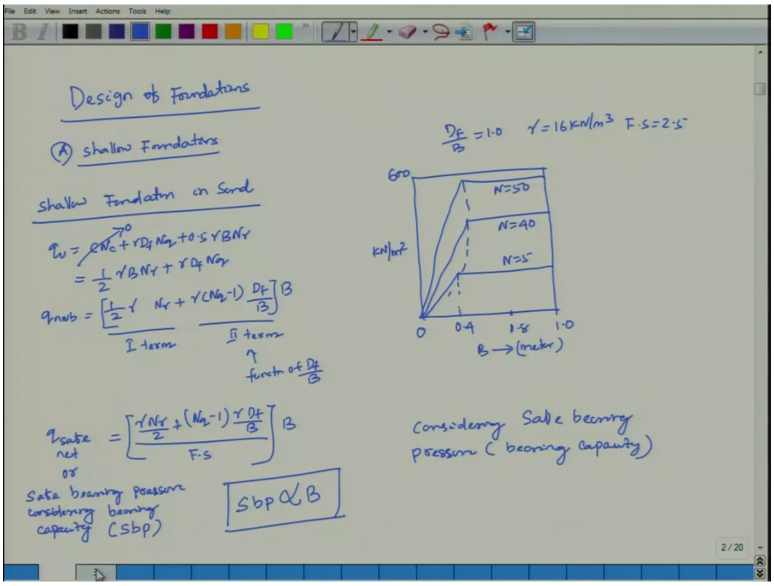

Let me start with a first one that is your shallow foundations. I have covered the basic parts. So, now, I will slightly go slightly faster. So, that I can cover the syllabus. And in the shallow foundation, let us start with shallow foundation, in sand. Start with first one is your foundation, in sand what is the bearing capacity bearing capacity is c nc plus gamma Df nq plus 0.5 gamma B n gamma, because in sand c is not there let it be 0 then it will be your I am just rewriting half instead of 0.5 half gamma B n gamma, plus gamma Df nq. So, net ultimate bearing capacity, met ultimate bearing capacity will be half gamma B n gamma plus gamma nq minus 1, Df by B Df by B, putting it into B, I am taking out the B outside your net ultimate bearing capacity.

So, this is my first term first term and this is the second term. So, if you look at here look at here. So, second term is a function of Df by B. So, now, net safe bearing capacity q safe, net which is equal to gamma n gamma by 2 plus n q minus 1 into gamma Df by B divided by your factor of safety into this is your B.

So, net safe bearing, net safe capacity also we called safe bearing pressure considering bearing capacity. Safe look at the what the write of I am putting it, safe bearing pressure, considering bearing capacity. It is called SBP safe bearing pressure SBP considering bearing capacity

Now, if I plot it how it looks like, SBF versus B kilo newton per meter square, and how it looks like say for example, said Df by B you take it 1.0 gamma is equal to 16 kilo newton per meter cube and factor safety is equal to 2.5.

now it is varying from 0 to 1.0, and here it is varying from 0 to 600. Now if you look at here let me put it vary 1 then 2 3, now let us (Refer Time: 23:17) 0.4, then 0.8, then 1.0. Here is equal to n is equal to 5, here n is equal to 40, here n is equal to 50 and this is your B, in meter B in meter.

how it looks look at the graph. So, safe bearing pressure considering bearing capacity, safe bearing pressure considering bearing capacity, particularly it is if all of the terms are constant, gamma is constant, n gamma is constant, phi is constant, nq is constant. Then what will happen SBP is directly proportional to B. It is directly proportional to B, then what will happen if it is directly proportional to B; that means, it will increase linearly with increasing.

So, there is ratio B means you cannot increase earlier also I said you cannot increase the B up to infinity, do not think that if B has been increase up to infinity it will increase infinity it has been seen up to certain B it is increased. Then there is no effect of the width of the foundations then it remains constant bearing capacity for different n values. So, starting from n is equal to 540 and 50. So, if I draw join it in this way fine, this is n is equal to 5 40 and 50. Now this is the case one this is considering, only considering safe bearing pressure that to bearing capacity.

Now, come to second part of the sand, soil pressure for settlement. There are 2 while calculating the capacity, one is considering bearing capacity other is considering settlement.

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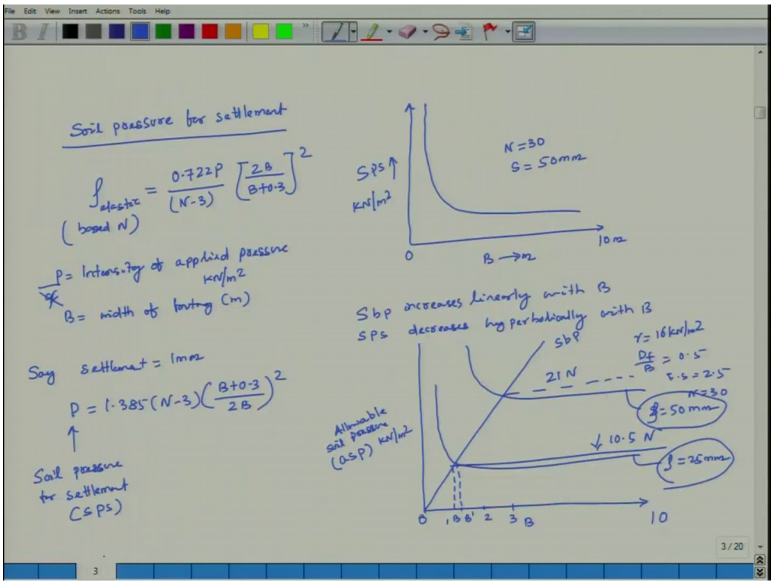

Soil pressure for settlement. Let us take it soil pressure for settlement as per code bs code elastic. It is based on your SPTN value which is equal to 0.722 p by n minus 3 into 2 B by B, plus 0.3 whole square, p is equal to intensity of applied pressure. Which is equal to kilo newton per meter square. Then it some books they say p some book say q does not matter, it is up to this. Because why be q, I am not taken q is generally it is your bearing capacity, that is why I have avoid this q then B is equal to width of width of footing in meter. Say for example, say let us say settlement is equal to 1 mm. So, then soil pressure from this equation you can calculate p is equal to 1.358 n minus 3 into B plus 0.3 by 2 B whole square.

So, p is your soil pressure, there are 2 p 1 is you small p 1 is your some small p another is your capital p this is soil pressure. Sorry this is same I am sorry. So, intensity of applied pressure p. So, this generally termed as soil pressure for settlement it is called S P S, earlier SBP, soil bearing pressure considering bearing capacity soil pressure considering settlement it is SPS.

Let us plot look at this SPS, kilo newton per meter square. How it is vary? It for typically n is equal to 30 and settlement is equal to 50 mm, B is equal to in meter, it 0 to 10 meter. So, what is the conclusion I can draw from this. One is your SBP soil bearing pressure considering bearing capacity, one is your soil pressure considering settlement; that means, SBP increases linearly with B. Then soil pressure settlement decreases hyperbolically, hyper cally with B. So, one is your SBP increase linearly with B, SPS decreases increases here decreases hyperbolically with B.

Let me super impose. How it look like both this allowable soil pressure out of these 2 which average minimum that is your allowable soil pressure, allowable soil pressure that is your ASP term kilo newton per meter square. And this is your B varying from 0 to 1, let us. So, one case I am putting it in this way this is your say SBP. Of course, SBP increases linearly for a particular value of B, beyond that it there is there is no further change in bearing capacity even if increase the width of the footing.

And let me take it ins in this way case one case 2. So, in this case what has been taken gamma is equal to 10 kilo newton per meter square for plotting this graph. Df by B is equal to 0.5, factors safety is equal to 2.5. Gamma is equal to 16 and n is equal to 30.

So, this is for considering settlement of 25 mm is as per our IS code requirement that is your permissible settlement for normal building. For other buildings multi storage permissible settlement is your s is equal to 50 mm sorry rho is equal to 50 mm.

Generally, what will happen. If I draw authenticate here let me put it in such a way that it will be vary, if you understand this the later there will not be any problem. So, this is your B. And this is your B prime, and this is 1 say, 1 say. And this is say suppose 2, then 3 then this is your 10. So, after certain part, as we have seen here after certain part it remains constant. Certain width if you look at here also your soil pressure for settlement it decreases hyperbolically with B.

Now, if I draw it a command form in this way here I am drawing also in this way; that means, this is your 10.5 into n, this is your 21, n generalize it. Because soil bearing pressure increases linearly with our B, and after certain B this will remain constant suppose say 0.4 meter. Suppose in this case 0.4 meter even if you increase the B there is not increase linearly rather it will be constant.

So, that case has been put it here, and here it has been put it for generalizing it has been drawn with port the graphs has been put it for considering residential building of settlement of 25 mm and other is your 50 mm, generally allowable soil pressure has been taken if I put it in very flat weight, this is your 10.5 n, this is your 21 n.

This is a kind of thumb rule and design. So, considering both SBP soil bearing pressure as well as soil pressure considering settlement out of these 2 minimum is your allowable soil pressure that comes out to be your 10.5 n and 21 n, 10.5 n and 21 n 10 point n. For your settlement of 25 mm and 21 n for your settlement of 50 mm. This is what this sand we have derived for particularly shallow foundations on in sand we will go shallow foundation clay then mat rabt all will go step by step.

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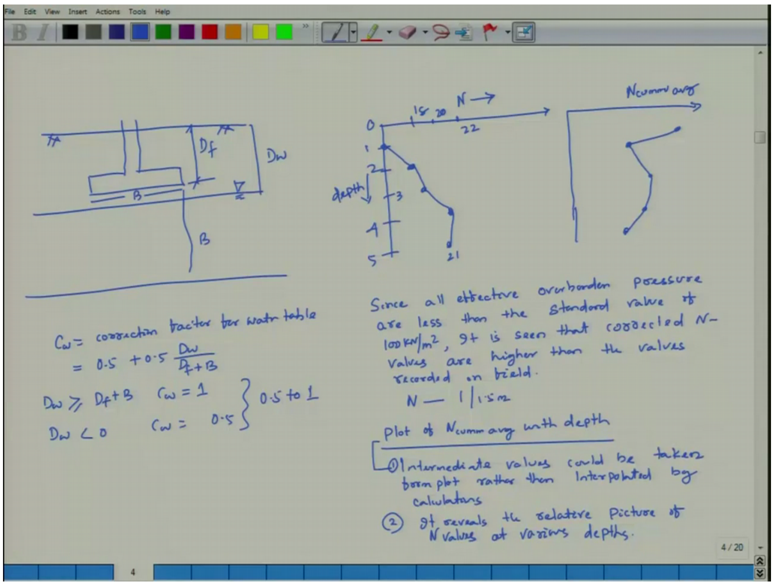

Now, what is the codal provision for water table corrections I have explained also earlier, but once again writing it for your you can just note it down. This is your B and this depth is your B. This I have been explained. This is your surcharge zone, this is your wedge zone and this is your Df, depth of foundation this is your dw.

So, if say cw is equal to correction factor for water table. Water table, then it will be 0.5 plus 0.5, Dw by Df plus B. This correction factor will be added I means multiply. So, if Dw is greater than equal to Df plus B, then correction factor is equal to 1. If Dw is less than 0 then correction factor is equal to 0.5, generally t varies between 0.5 to 1.

This earlier also I have discussed there is nothing new. So, water table correction has to be added another most important part try to understand another most important part. So, this is required for design because for sand, it is based on your SPTN nothing else.

Now, we draw a conclusion for settlement of 25 mm for settlement of 50 mm allowable soil pressure is based on your SPTN that is your 10.5 n and 21 n. Now draw this, n versus your depth. Why you will take cumulative average one is your whatever you are getting n from your spt after corrections, another is your n cumulative average. So, it is 0 1 2 3 4 5. Generally, it goes this way, whatever the way. Then cumulative average also plot it in this way. Why cumulative average, why you are looking for this cumulative average?

Since I am just writing how to you can note it down, since all effective overburden pressure are less than the standard value of 100 kilo newton per meter square. Then this is benchmark for bs code. It is seen that corrected n values are higher than the values recorded in field. Since n value recorded at an interval, generally n value how you have recorded at an interval of one or 1.5 meter.

So, varies enough cumulative average plot of cumulative average, plot of n cumulative average with depth. So, very easily intermediate values could be taken from plot rather than interpolated by calculations. Basically plot of the n cumulative average another 1, number 1. Number 2, it reveals the relative picture of n values at various depth. Are you getting do you understand what I want to say? All the effective overburden pressures almost in residential means all are less than this standard value of 100 kilo newton per meter square. It is means I am not saying that all are less because depending upon the depth and how the effective part is coming, but in normal in general effective overburden pressures are less than your less than your standard value of hundred kilo newton per meter square.

So, it has been observed corrected n values for higher than the value recorded in the field, whatever the value you have recorded because it is less than your hundred corrected n values are always higher. Generally, what will happen? How do you measure the n, n we SPTN as I discussed earlier every 1.5 for 1, 1 meter interval below the ground surface we measure?

Now, what advantage we are suppose to get from your n cumulative average? What advantage we should get it first one is your instead suppose here it is say 1 meter is your 0, suppose 2 meter some value suppose 2 some value say 18, 3 meter some value say 20 and 4 meter some value say 22, here it is 21 as you observed from the field.

So, what will happen, if somebody wanted to find it out between 1 to 2, one is your 0 2 is your 18 suppose 2, 2, 3, 2 is your 18 3 is your 20, in this case you have to interpolate depth wise which is not true while taking the n cumulative average intermediate values can be taken very easily because it is cumulative average rather than interpolations.

So, again it replace relative picture of your n values at various depths look at n cumulative average, how it is varying here, how it is varying that is why for design purpose in particularly sand if n is given, n cumulative average has to be calculated. I do not know how for I can complete this example because this will take time, let me start with this. There is an example let us start with a design.

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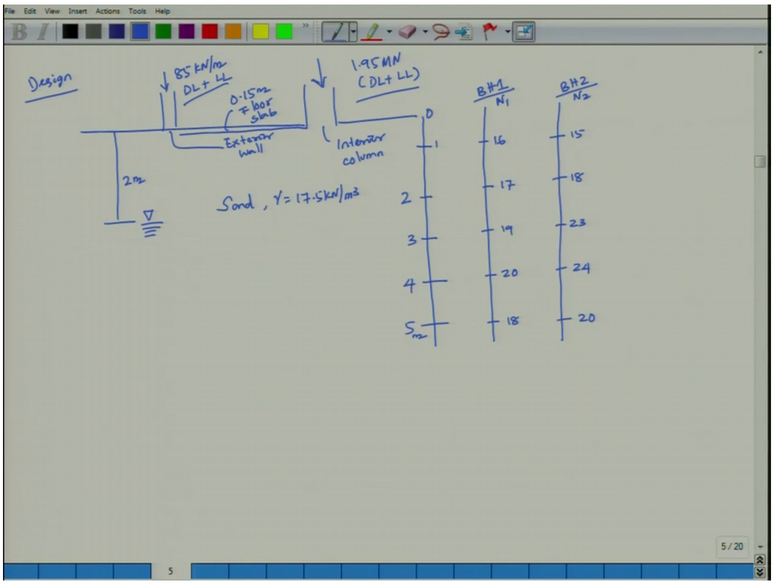

Just I am writing this, whatever is there is a building, in building, there are one is your interior column, other one is your exterior. Then there is also this is called exterior wall and this this is a interior column there is a outer column interior column load is given my inter load is given, that is your 1.95 mn mega newton. Considering dead load plus live load. And here it is given exterior wall it is given 85 kilo newton per meter considering dead load plus live load. And there is a gap this is generally used 0.15 meter of floor slab right.

And this is a sandy soil or sand. Gamma is given 17.5 kilo newton per meter cube. And this is your below 2 meter. There is a water table water is there. So, there is interior column exterior wall, wall loading is there interior column load is there dead load, live load, dead lad, live load. And there are depths where SPTN has been reported. 0, 1 this is your 2 3 4 and at the and it is 5 meter below the ground surface. There are 2 boreholes first one is your borehole one SPTN, 1, 1 is your 16, 2 is your 17, 3 is your 19, 4 is your 25 is your 18.

Then second one is your borehole 2. That is your n 2. This is your 15, this is your 18. This is 23. And this is 24. And this is your 20. This is what your given design suitable column footing in sand. There is a soil sand is there gamma is 17.5 kilo newton meter cube water table below 2 meter, there is one interior column, there is one exterior wall load is given dead load plus live load. I will discuss, next class dead load plus live load, what does it mean here, it is dead load plus live load these are all practicals.

Then boreholes in that site 2 boreholes have been made SPTN value has been reported up to 5 meter design a suitable footing. So, I want to keep it here, next class because this is a this will take complete more than a one lecture. So, next class I will completely design step by step and I will finish it out.

Thank you.