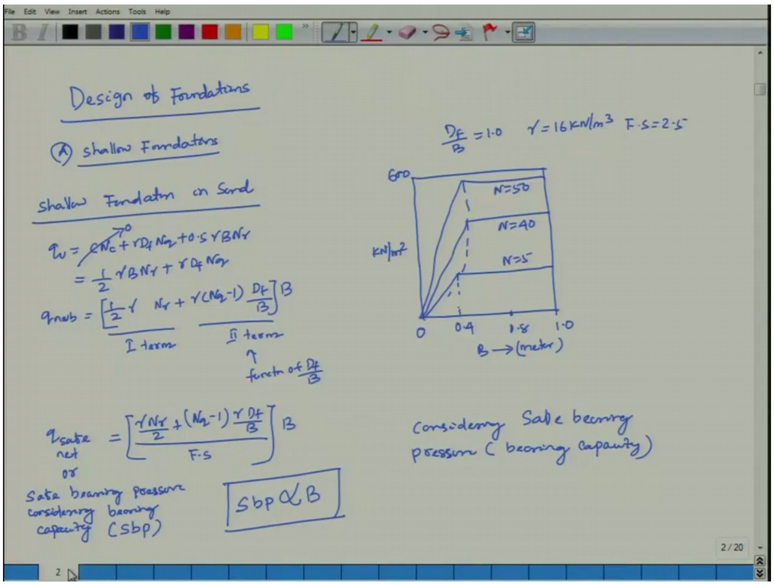
Foundation Design
Prof. Nihar Ranjan Patra
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Lecture - 13B
Design of Foundation- Part 3

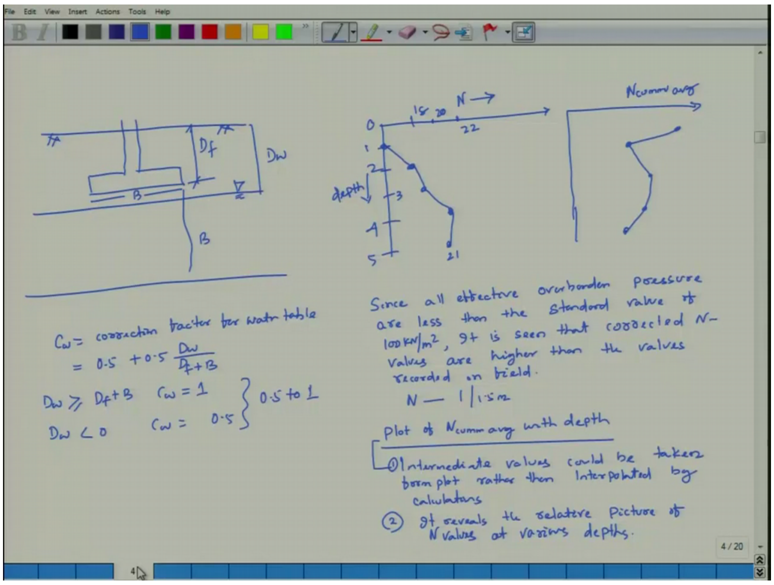
Last few class I have started design of foundations. And first one I have started shallow foundation, I have completed for shallow foundation in sand just recap. So, where I was there in last week?

(Refer Slide Time: 00:30)



So, shallow foundation in sand we are considering safe bearing pressure considering bearing capacity as well as soil bearing pressure considering settlement, and from there for a residential building 25 mm settlement industrial building 50 mm settlement. So, allowable soil pressure is you kilo Newton per meter square. And it has come with your 10.5 N as well as 21 N.

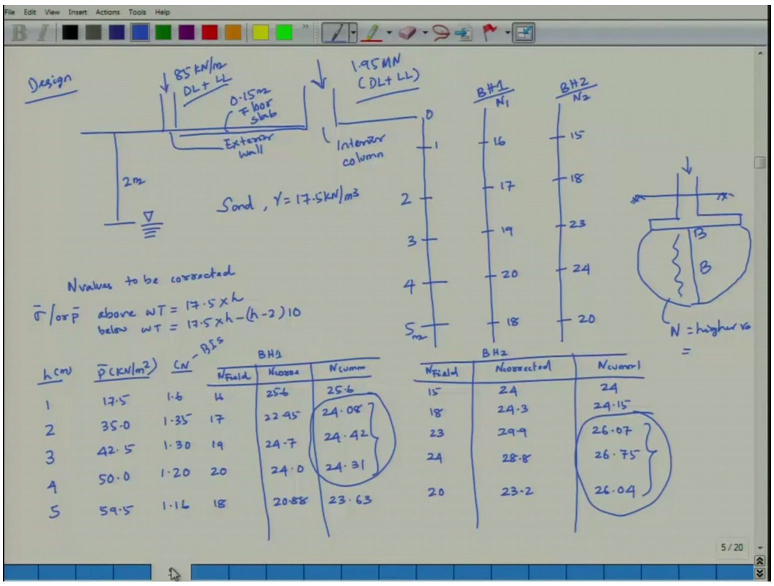
(Refer Slide Time: 01:00)



Then Correction factor, water correction factor, and water table correction factor also I have discussed.

Then why we are going to take N cumulative average. N is your SPTN value has being taken and cumulative average value, because the intermediate values could be taken from the plot rather than interpolated interpolations. And it reveals relative position of N at various depth that is the advantage should take N cumulative values. Then I have solved a one design problem.

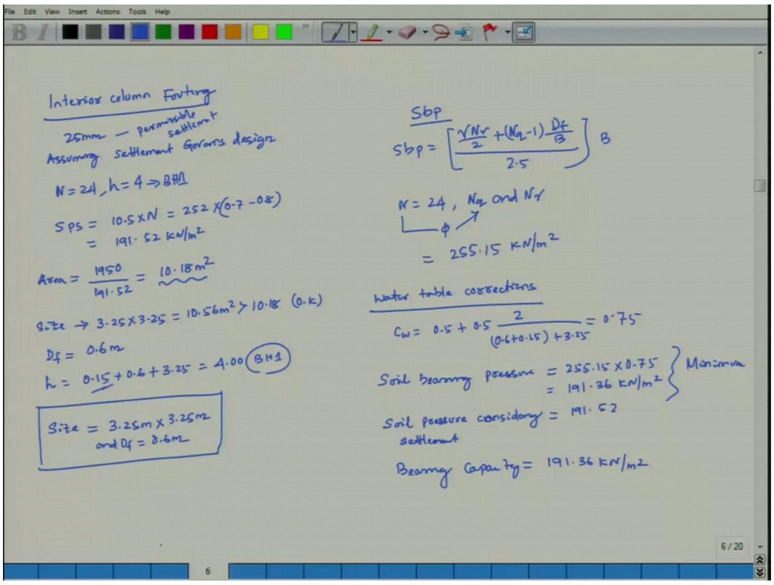
(Refer Slide Time: 01:35)



There is a building in that building one interior column, then another one is your exterior wall, dead load live load is given. There are 2 bore hole data, bore hole 1 is nearby from the interior column bore hole 2 is nearby from your exterior wall. And this design has been made and nothing has been assumed. We design considering where we are getting a consistent value of SPTN from the cumulative average.

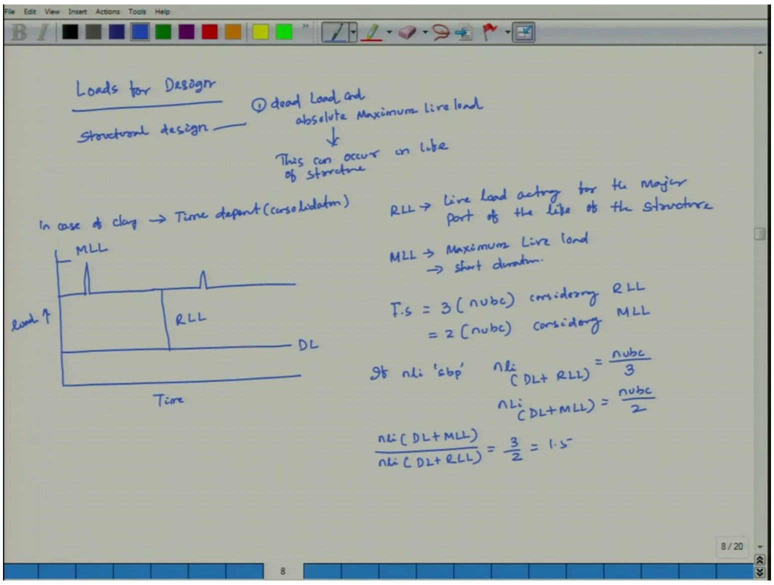
Based on that this which that part your pressure bulb will come into picture, based on that your depth of the foundation has come into picture.

(Refer Slide Time: 02:27)



Then from their your foundation size comes into picture, this is what we have completed this design, and we have calculated this what is your net load intensity or details wall footing as well as interior column we have calculated. Now next come to loads for the design.

(Refer Slide Time: 02:50)



So, for structural design, structural design generally we take it, dead load, dead load and it is your maximum dead load and absolute maximum live load. So, structural design we are considering dead loads and absolute maximum live load, it will look at here. This can occur in a life of structure corresponding of the duration. This can occur in life of structure. This is also equally applicable to soil design in sand.

So, in case of in case of clay if you look at in case of clay, it is a time dependent, time dependent; that means, that is your consolidations and it can be applicable to sand if I draw simple way, this is the load and there is a time. So, this is my dead load, dead load means the construction (Refer Time: 04:56) even if it is residential building whatever the dead load is their permanent dead loads, that has to be there. Then look at here, this is called RL, RLL. RLL is called reduced live load, reduced live load and this is your dispute particular here this is your MLL. If I say RLL reduced live load. So, it is a major part of the structures live load: live load acting for the major part of the life of the structure.

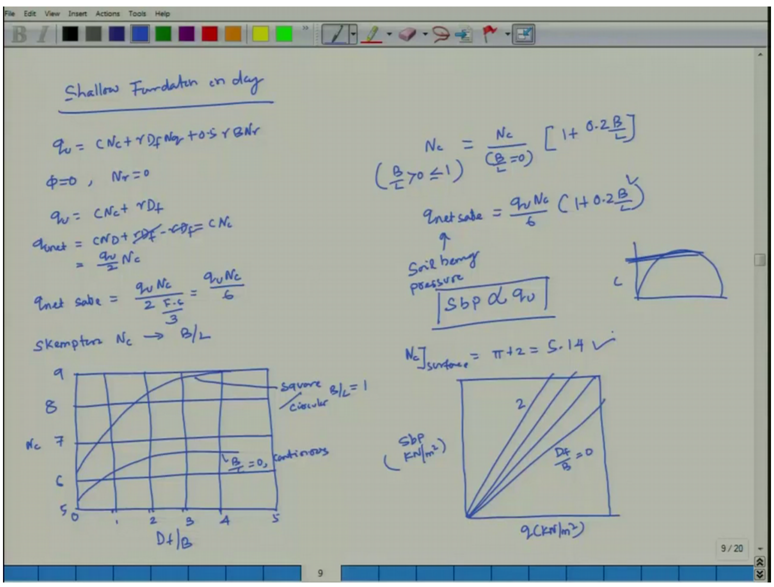
Now there is a possibility, there is a possibility so, sometimes maximum live load may occur in nature extra kind of pulse acting ML your maximum live load, it is a very short duration, it is very short durations. So, this are all we want to consider one is your dead load one is your reduce live load, and third one is your maximum live load. So, generally what happen generally factor of safety, factor of safety is 3 generally taken on net ultimate bearing capacity.

Considering RLL that is your reduced live load, and factor of safety is equal to 2 on net ultimate bearing capacity, considering maximum live load. So, if I say if net load intensity nli we can call it is as safe bearing pressure. So, I can write it net load intensity considering dead load plus reduced live load, which is equal to net ultimate bearing capacity divided by 3, then net load intensity considering dead load plus maximum live load which is your net ultimate bearing capacity divided by 2.

Now, if I put it net load intensity, dead load plus maximum live load divided by net load intensity dead load plus reduced live load which is equal to 3 by 2 which is equal to 1.5. So, what does it mean? Net load intensity under dead load N maximum load is 1.5 times more than net load intensity under dead load as well as dead load plus the reduced live load. So, this is what loads for design particularly structural design, you have to consider, you have to consider in future.

So, while designing you consider if you are considering dead load and reduced live load then you take factor of safety of 3. If you are considering dead load and maximum live load you consider factor of safety of 2. So, this should be taken care, now next part come to here that is your shallow foundation in clay. Earlier I have finished shallow foundation in sand, now shallow foundation in clay.

(Refer Slide Time: 09:39)



So, if you look at this formula q u is equal to ultimate bearing capacity, CN c plus gamma D f l N q plus 0.5 gamma B N gamma. For 5 is equal to 0, 5 is equal to 0 means there is no cohesion. It is purely cohesive soil; that means, N gamma is equal to 0, in that case q u is equal to CN c plus gamma D f, and q u net is equal to net is equal to CN c plus gamma D f minus gamma D f.

So, this will go this will be only CN c. If I take into c undrained cohesion so that means, q u by 2 into your N c. Now q net safe, q net safe is equal to q u N c by 2 into factor of safety, which is equal to if I take factor of safety is equal to 3 t his is your q u N c divided by 6. So, Skempton as given N c, Skempton says Skempton says N c depends upon your B by L. So, if I plot it N c versus your D f by B, this is your N c this is your 0, this is 1, this is 2, this is 3, this is 4 and this is 5, if I put it here it is 6, then 7, then is your 8, then is your 9.

So, here it is it will start from 5, this will be your B by L is equal to 0 continuous. This is your square or circular or circular where B by L is equal to 1. So, this part is your D f by B, D f depth of the foundation B is equal to your width of the foundations. Now if I write it N c B by L greater than 0 less than equal to 1 which is equal to N c B by L is equal to 0 into 1 plus 0.2 B by L.

So that means, q net safe which is equal to q u N c by 6 into 1 plus 0.2 B by L. So, if everything is constant, suppose B is constant, L is constant N c is also there, what will happen? This is your soil bearing pressure; that means, sbp is directly proportional to your q u. So, N c for surface almost the value of N c for surface, N c for surface is equal to pi plus 2 generally it is 5.14. So, q u is your it is directly proportional to your q u, if I put it in terms of graphs in terms of graph, let me put it this is your sbp kilo Newton per meter square, and this is your q u kilo Newton per meter square, and this will be varying; that means, it is starting from D f by B is equal to 0 to 2.

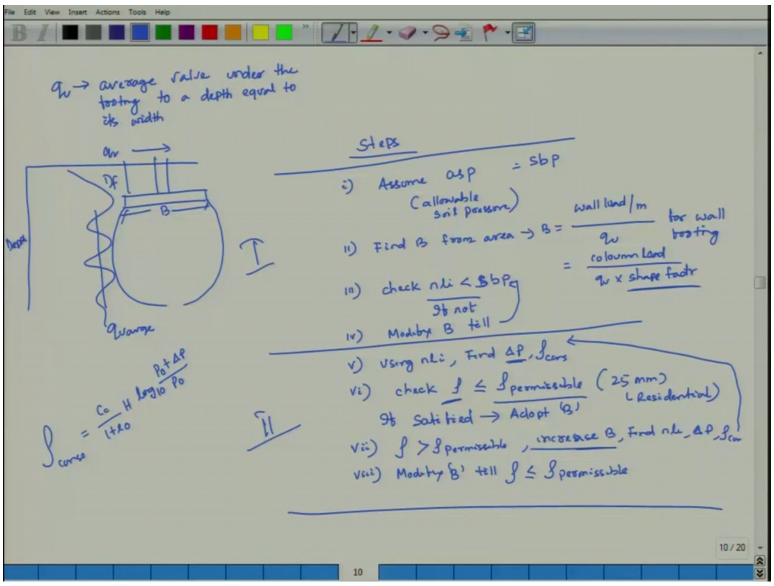
So, shallow foundation is clay, let me revise it if you look at this what is their q u is equal to CN c plus gamma D f N cube plus 0.5 gamma B N gamma, for purely cohesive soil 5 is equal to 0; that means, N gamma is equal to 0, then q u is equal to CN c plus gamma D f. So, q net is equal to CN c, c is your undrained cohesion; that means, is your undrained cohesion is nothing but if I go to their; that means, q u value q is your if I go for unconfined compression test from their you can find it out the value of the q u.

So, here if I go it then this will be your q u by 2 this is the value of your c. So, it depends upon q net safe which is equal to q u N c by 2 into factor of safety, factor of safety I put it 3. So, it is your q u N c by 6. So, Skempton as given a chart for N c, N c is what, bearing capacity factor for cohesion. And N c versus D a by B if I look at your N c at the surface how much Skempton as given, this is your 5.14. So, it will be for B by L continuous then for square and circular.

So, N c for square and circular N c for B by L is equal to 0 into 1 plus 0.2 B by L. Now q net safe is your q u N c by 6 into 1 plus 0.2 into by l. So, this is called your soil bearing pressure, soil bearing pressure is directly proportional to undrained strength q u. So, if I plot soil bearing pressure with your q u; that means, this is varying D f by B is equal to 0 to 2, either you can utilize the chart or you have a strength you have a strength value from there you can find it out your q u.

So, basically for shallow foundations in clay safe bearing pressure is directly proportional to your q u, let us start with this, what are the steps? Generally what will happen?

(Refer Slide Time: 18:36)



Q u you should take average value, look at here, average value under the footing under the footing to a depth equal to it is width. So, now, this is the case, this is my depth this is the variation of q u, I should consider the way we have done for foundation design in sand, I should consider in such a way that I should place the footing in such a way that, the pressure bulb should cover in a range where strength of strength will be slightly or higher side; that means, from here to here, if I take the q u average and if I compare this q u average over this range, I can say that this depth is absolutely fine for foundation design.

So, this depth will be consider of a zone of influence or pressure bulb. So, considering with this zone of influence then your footing size will come into picture. Once footing size will come into picture zone of influence will come into picture, what else left? You have left is your depth of the foundations. So, nothing has to be assumed here like other books they say, assume some footing size assume the depth of the footing it is not there, nothing as t o be assumed. It will be based on your q u average.

So, what are the procedure or what are the steps? Called designing, we will solve a problem also. First one assumes a s P allowable soil pressure, which is equal to soil bearing pressure. Then step 2 find b, B is what width of the foundations, find B from area; that means, B is equal to wall load per meter divided by your q u for wall footing right, then step 3 check net load intensity whether it is less than soil bearing pressure or not, right here either wall load meter per q u or it will be column load divided by q u into shape factor.

If it is not satisfied, if not, if not then modify the value of B value of B till next satisfy this condition. Then step 5 using net load intensity find delta p, delta P is what? Increase in stress I have covered it because of your loading, then rho consolidation settlement, consolidation settlement then step 5, step 6, check settlement should be equal to permissible settlement. This also I have given very beginning foundation design as per your buro of Indian standard, what is the permissible settlement of a foundations or footings. Depending upon whether it is residential building, industrial building or may be high rise building. I have given even if I have also given what would be the permissible differential settlement also?

So, that you can check from a earlier notes then, if satisfied if satisfied, then adopt your B. Again if I come back to here if rho is greater than rho permissible, then increase B, find net load intensity delta P and rho consolidations, which will go and repeat it again from here. Then modify B till your rho is less than equal to rho permissible. So, let me summarize and slightly explain it. So, while solving the problem after wards we will solve on design problem that will be better for your understanding, what it says? Assume allowable soil pressure is equal to your soil bearing pressure.

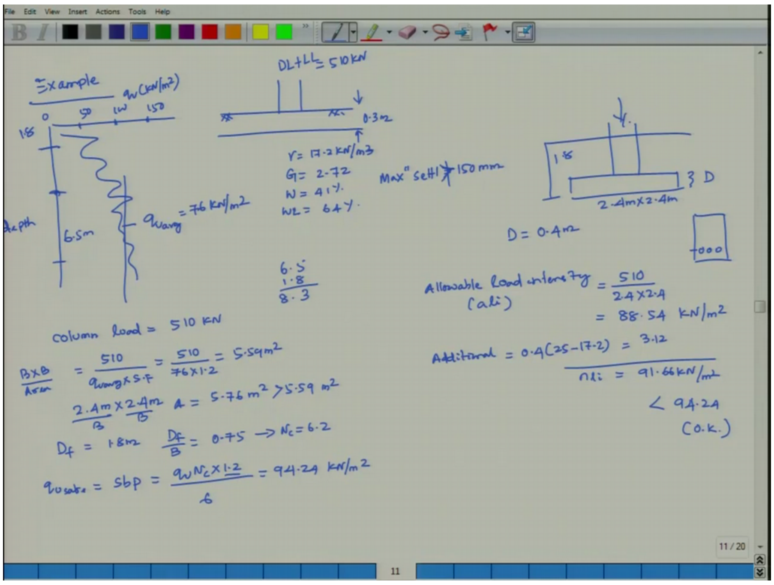
Soil pressure considering soil bearing pressure; that means, your settlement, from where you soil bearing pressure where it is your q u average has been taken, then find B from the area, B is equal to wall load if it is a wall per design is there, wall load per meter into q u for wall footings. For columns it is column divided by q u into shape factor, shape factor is what? 1 here I have discussed this is nothing but is your shape factor depending upon circular rectangular or whatever. So, it is 1 plus 0.2 B by L, and then check your net load intensity, net load intensity is what? Net load intensity foundation load is coming minus your safe water table foundations.

Whether it is less than your soil bearing pressure or not, if it is, then that B is fine. If not modify the B till you are going to get your net load intensity is less than soil bearing pressure. So, use net load intensity, once this is fine second step this is I can say broadly this is your first part this is your second part. Second step using net load intensity found it out delta P, delta P is your increase in stress. Depending upon your footings size whether it is rectangular square or anything else find it out increase in stress, that part also I have covered. Then find it out row consolidation, row consolidation is what? Consolidation settlement, which is equal to C c by 1 plus e 0 h log 10 P 0 plus delta P by P 0. Then correction factor for water if it is normally consolidated over consolidated that is there, this part also I have covered.

Then find it out actual settlement how much it is coming below the foundations. Then compare is your actual settlement with your permissible settlement. For residential building permissible settlement is 25 mm. It is for your residential. If it is coming rho is less than rho permissible that is fine; that means, whatever you have taken your B, based in your q u and water table that is absolutely find and you can recommend that has to be done in actual field.

If it is not there, suppose rho that means, your settlement calculated is greater than settlement permissible then increase B, then find net load intensity find delta P, find your row cumulative then it will go back to your original positions. So, you do it modify the B till you are getting rho is less than equal to rho permissible. Now come to next this is what I explain, let us start with a design, what is a problem it is given, A one of the example.

(Refer Slide Time: 29:08)



Example is given this is your ground surface; there is a load column load. It is dead load plus live load which is equal to 510 kilo Newton and there is a 0.3 meter water table is acting at 0.3 meter. And given gamma is equal to 17.2 kilo Newton per meter cube.

G is equal to 2.72 water contain w is equal to 41 percent; liquid limit WL is equal to 64 percent. And at the same time at the same time q u value is given it is a 0, 50, 100 150. Q u is equal to kilo Newton per meter square, and then this is a 0. Then this value is given it will be very difficult to plot up to this scale this is your depth. So, here to here this is your 6.5 meter the average value q u average is given 76 kilo Newton per meter square. Maximum settlement is also given; maximum settlement is given 150 mm. It should not maximum settlement should not greater than 150 mm.

Now, design it as been as no assumption. Here look at here like in most of the book if you say fine you assume the depth of the assumption you assume the width of the foundation no assumptions. So, let us start with column load, column load is equal to 510 kilo Newton it is given. So, B is equal to column load 510 divided by q average into shape factor, which is equal to 510 divided by 76 into 1.2. If you look at here what is your shape factor 1 plus 0.2, 1.2 B by L is equal to 1.

So, this comes out to be area is coming. So, column load is there. So, from there this is not a B, this you can say that B by B or area, which is equal to 5.59 meter square. So, considering 5.59 meter square, then you consider area which is equal to 2.4 meter by 2.4 meter. This is your B this is your B. So, area is coming out to be 5.76 meter square which is greater than 5.59 meter square.

Now, what will happen? Now this is the pressure bulb, will be 6.5 meter, within this pressure bulb we are getting the good strength 76 kilo Newton per meter square. Then what will happen? If this is 6.5 and this is 1.8 total will be 6.5 plus 1.8: 8.3. So obviously, what will happen once I am getting up to 6.5 meter depth good range then; obviously, your depth of the foundation; obviously, it is coming So, depth of the foundation is coming 1.8 meter.

So, D f by B which is equal to 0.75 D f by e is equal to 0.75. Now come to this chart. You have to calculate also and see, I have given Skempton as given, you can keep this chart for your examinations. So, taking into D f by B 7 point 0.75 N c is equal to 6.2. Now find it out what is the q u shape; that means, sbp soil bearing pressure, which is equal to q u N c into 1.2 it is your shape factor, divided by your 6 which is equal to 94.24 kilo Newton per meter square.

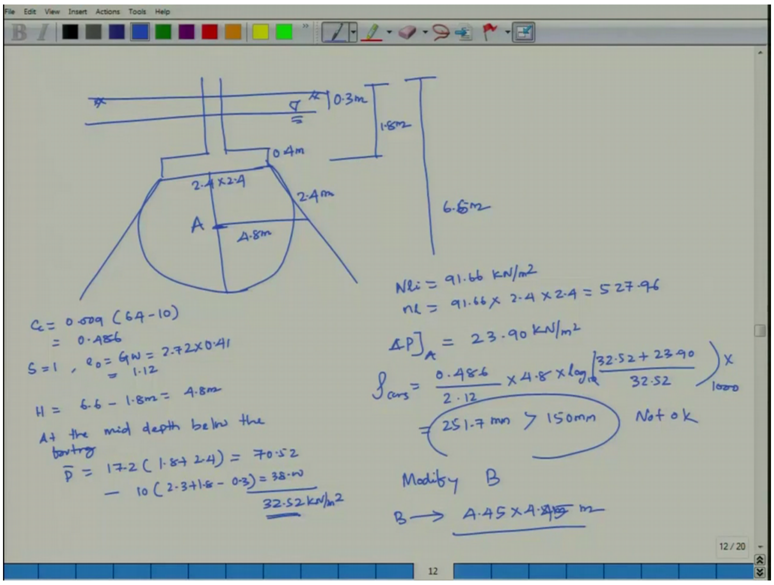
Now, if there is a footing, this is my footing. Say this footing B is your 2.4 meter by 2.4 meter and depth of the foundation is your, it is clear 1.8 meter, and load is coming like this here. Then what should be my D? This size, this size as per your I s code minimum value should be 0.4, because as for the I s code it what it says, if this is the case then there should be clear (Refer Time: 35:28) for your enforcement.

So, minimum value they have recommended 0.4. So, assume D is equal to 0.4 meter. Then you have to find it out allowable load intensity, allowable load intensity; that means, ali which is equal to 510 divided by 510 is your column load 2.4 into 2.4 which is equal to 88.54 kilo Newton per meter square.

Now, additional it is a allowable load intensity additional because of this, additional will be 0.4, right into 25 minus 17.2 taking into consolidation of 0.4. So, this will be 3.12. So, your net load intensity will be 91.66 kilo Newton per meter square, which is less than 94.24 then this is your ok.

Now, step one is over, one step one is over then you size is size is 2.4 by 2.4 meter, come to the second step.

(Refer Slide Time: 37:21)



Settlement calculations, this is your ground water ground level. And there is a water table here. And this length is your 0.3 meter, and there is a footing here. And the size of the footing is this is your 2.4 by 2.4 meter. And this is your 0.4 meter. And this part is your 1.8 meter, and total will be your 6 point sorry here it will be your total from here to here from here to here total is your 6.5 meter.

Now, then the pressure bulb is coming up to here is your 4.8 meter, this is your 4.8 meter. So, half will be this will be your 2.4 meter. Now we have to check sorry 6.6 meter it is we have to check settlement is find or not. Now C c is equal to 0.009 64 minus 10 WL minus 10. WL is 60 is given, based on that C c I am getting 0.486, considering degree of saturation is equal to 1, e 0 is equal to GW which is equal to 2.72 into 0.41 which is equal to 1.12.

Now, h is equal to 6.6 minus 1.8 meter, which is equal to 4.8 meter. So, this is your 4.8 meter. So, at the mid depth below the footing, at the mid depth below the footing P prime is equal to 17.2 into 1.8 plus 2.4 which is equal 70.52 minus water table is their 10 into 2 point 3 plus 1.8 minus 0.3 (Refer Time: 40:02) which is equal to 38.00 which is equal 32.52 kilo Newton per meter square.

So, net load intensity net load intensity is equal to 91.66 kilo Newton per meter square. So, net load is equal to net load is equal 91.66 into 2.4 into 2.4 which is equal to 527.96. So, now, you have to find it out what is the delta P at a this is either you can do it by 2 is to one distributions or square footing you can do it exact solutions.

So, delta P at this is my point a delta P at a comes out to be 23.90 kilo Newton per meter square. This is what I am giving you can check. So, consolidation settlement consolidation settlement is 0.486 C c by 1 plus e 0; that means, 2.12 into your 4.8 this is your height then log 10 32.52 plus 23.90 P 0 is your 32.52 delta P 0 23.90 by 32.52 into 1000, which is equal to 251.7 mm greater than 150 mm.

If you come back here stage one has been satisfied, stage 2 has not yet been satisfied. Now if I go here then what will happen if it is not satisfied, then it is not, then modify B value. So, then B value has been increased from 2.42 it has been increased 4.45 by 4.45 meter. So, that this settlement criteria as been satisfied. More I will explain in the next class.

So, what I have done I have solved one example whatever this steps I have described step one and step 2 with this example my step one has been satisfied, and I am getting a size of 2.4 meter by 2.4 meter, then at the same time settlement criteria has not satisfied. Hence the value B has been modified to 4.45 meter by 4.45 meter, considering this again entirely all calculations has to be carried out.

We will see we will discuss more in the next class.

Thank you.