Geotechnical Engineering II / Foundation Engineering
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Lecture - 11
Shallow Foundation and Bearing Capacity (Contd.)

Once again let me continue with bearing capacity of Shallow Foundation. And in the previous lecture I have tried to show the impact of water table on bearing capacity where I have shown that if the water table it is significant in the great depth. That means, not within the shear zone then whatever bearing capacity we get and if it comes by some means to the surface then it water bearing capacity becomes just almost half.

So, that is the quite noticeable difference. So, one has to keep that in mind that while designing the foundation that the variation of water table; that means, throughout the year what is the vast possible location of water table has to be considered and accordingly bearing capacity should be considered. Otherwise, if you estimate the bearing capacity considering ignoring the water table and finally, water table sometime comes to the surface of the footing.

And then in that case water bearing capacity will be significant reduced and that may result in your failure sometime. Of course we have we use to keep, we keep generally the significantly large value of factor of safety because of that sometime it may be same. But still we need to keep a sufficient margin of safety and to make sure that one has to consider the water table effect and how to consider that I have shown in the previous lecture.

And now I will try to show various terminologies we use in bearing capacity theories.

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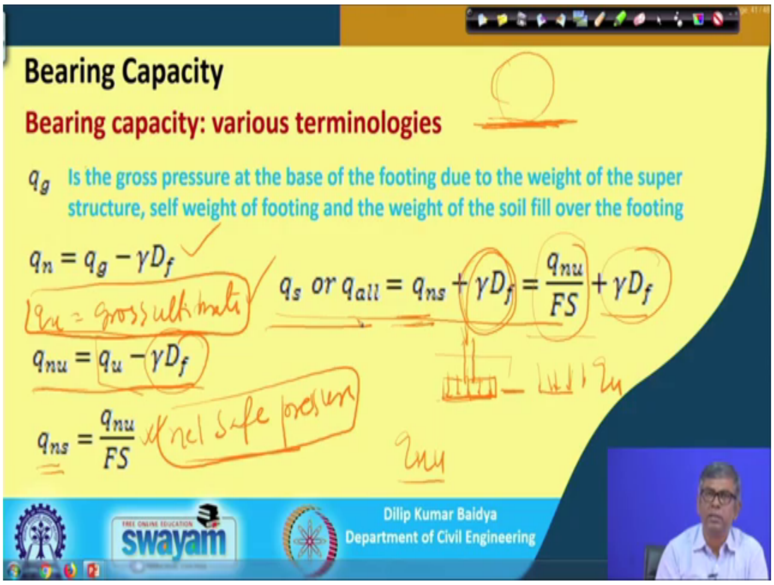

And let me go to the slide that and let me see that various terms that we use actually that is one sometime we call gross bearing capacity. Sometime we can say net bearing capacity, net ultimate, net safe and then allowable or safe bearing capacity there are different terms.

And if there is a suppose if there is a ground surface somewhere here and finally, if you dig and finally, place a foundation somewhere here then here this footing will impart some pressure on this on the soil here through this footing. And that pressure actually will be nothing, but the gross pressure; that means, because of this soil over here therefore, structure load and self weight of the footing and color all together whatever is giving in on this soil that is actually gross pressure ok. So, the gross q g is the gross pressure at the base of the footing due to the weight of the super structure, self weight of the footing and the weight of the soil fill over the footing. So, that is the one.

Now, if this pressure is slowly increases then finally, what will happened soil will fail and that actually when it fail then that will be actually gross ultimate. So, q u sometime we can write q u as actually ultimate, but that can be considered as gross ultimate. So, gross ultimate. So, q u I just take as gross ultimate and in that case that is one definition; that means, gross pressure and then if you subtract this the soil weight from here then that become net pressure. And if I now consider as a q u as a gross ultimate then similarly net ultimate I can visualize net ultimate. So, at this point this is a ground surface at this level what is the bearing capacity ultimate bearing capacity that I suppose g q u.

Then similarly at this level I can find out q net u; that means, net ultimate and net ultimate is how? q ultimate minus because of the soil weight has to be subtracted, soil weight to be subtracted and from there I get net ultimate and ultimate pressure actually is the pressure at that point actually failure may occur ok. So because of that we never go up to the ultimate pressure so we how much ever you go you have to be we used to go we can go up to safe load, safe pressure so then if we introduce a factor of safety on this then q ns means net safe net safe pressure. So, q net safe; that means, q ns how to find out? q nu divided by a suitable factor of safety then I will get q ns; that means, net safe pressure. So, that is nothing, but q nu by FS and now qs; that means, q safe or q allowable final will be q ns plus gamma D f because that much pressure can be added because there is no need to apply what factor of safety.

So, in the net pressure I have applied a factor of safety, but this gamma D f is known. So, because of that there is no need to apply factor of safety directly you can add. So, ultimately allowable pressure which can be obtained by q net factor of net u by factor of safety plus gamma D f. So that means, there are number of things can be there, but you have to understand what is what, one is actually gross and one is net. Gross is what is we are applying total and if you subtract the surcharge. That means, from the base of the footing to the surface whatever the soil weight in to subtract then that become net pressure.

And similarly now I can find out that any depth ultimate pressure and I can find out net ultimate pressure. So, ultimate pressure actually how to find out I can apply bearing capacity theory and then I will get q u and then if I subtract surcharge that gamma times D f then I will get q net ultimate and now, if I want to find out q net safe. That means, how much net safe net pressure. So, then I have to apply a factor of safety.

And finally, if I want to find out what is the safe allowable pressure then q net safe plus surcharge ok. So, ultimately that is that much; that means, what were allowable pressure we are considering at a while designing the foundation allowable bearing capacity mean whatever pressure; that means, pressure of foundation superstructure and everything together with the water soil pressure everything together is the bearing capacity. So, because of that ultimately by calculating net safe I can add this gamma D f to get the allowable pressure or safe bearing capacity of the soil.

So, these are the few terminologies to be remember in while doing this calculation and I will try to show by these by showing example.

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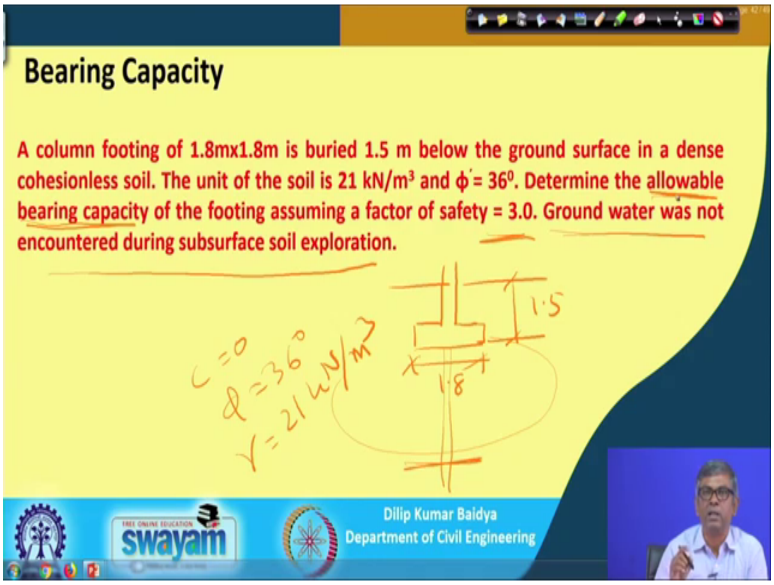

You can see that in this problem a column footing of 1.8 meter by 1 meter 1.8 meter by 1.8 meter is buried, 1.5 meter below the ground surface in a dense cohesion less soil. That buried means what the depth of the foundation is 1.5 meter; that means, it is something like this.

Footing is something like this and ground surface is this and; that means, this depth is 1.5 meter and this width is 1.8 meter and this is the soil is dense cohesion less soil. That means, c is 0 and phi is having value of 36 degrees and unit weight gamma actually is 21 kilo Newton per meter cube and determine the allowable bearing capacity of the footing assuming factor of safety of 3 and groundwater table was not encountered during the subsurface soil. That means, we can consider the we generally while design the foundation or constructing the foundation, we generally carry out the subsurface exploration or investigation.

And while doing that we go sufficiently depth the sufficiently great depth to find out the layering and all those thing and that this in this problem it is mentioned that during subsurface investigation the water table was not encountered. That means, even we go at certain depth which is some significant deep there also you have not seen water table; that means, water table effect can be ignored.

And if you ignore that then you I have to find out now what is that, determine the allowable bearing capacity allowable bearing capacity. I have defined there are so many that means, ultimate bearing capacity then net ultimate bearing capacity the net safe bearing capacity, then I have then I had different allowable bearing capacity of or safe bearing capacity. That means, it is asked the last part, this last one is asked so you have to; that means, I have to calculate one by one all step and finally, go to the last step.

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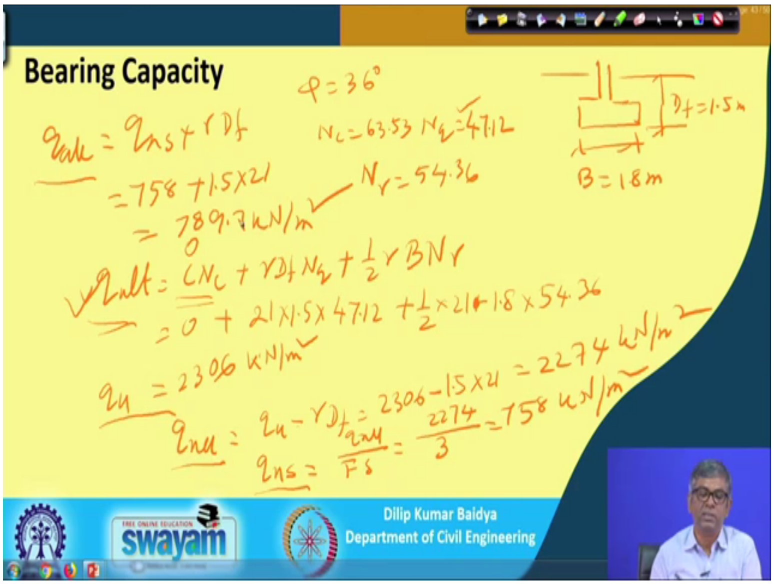

So, let me go to the next slide and do that step by step and. So, I will show the footing first, the footing is somewhere here and your D f equal to 1.5 meter and B is, B equal to 1.8 meter and phi equal to 36 degree. From there actually I get N c equal to N c equal to 63.53. 63.53 N q equal to 47.12, 47.12 that is coming that will come from table and n gamma will be equal to 54.36.

So, and water table is not there. So, q ultimate I will calculate, q ultimate will be equal to CN c plus gamma D f N q plus half gamma B N gamma. So, c is 0 so this part will become 0 plus gamma is actually here is given something gamma is given 21 and so 21 multiplied by depth is 1.5 multiplied by N q is 47.12 plus half gamma is here again 21 plus b is 1.8. So, this is multiplied by multiplied by n gamma is here 54.36.

So, q ultimate or qu become your 2306, 2306 then I can find out q nu equal to q u divided minus gamma times D f. So; that means, 2306 minus 1.5 multiplied by 21 that will be equal to 2274, 2274 and then I can find out q net safe that will be equal to q nu divided by FS. So, how much it comes? 2274 divided by FS is given 3. So, this value comes 758, all has everywhere you have to you have to write kilo unit kilo Newton per meter square this is kilo Newton per meter square, kilo Newton per meter square.

And now ultimately q allowable; that means, I can write here q allowable equal to q net safe plus gamma time D f. So; that means, equal to 758 plus 1.5 multiplied by 21 so that gives you 789, 789.7 kilo Newton per meter square.

So, this is the one; that means, I will get first q ultimate if there is water table I could have taken here there is no water table, if there is a cohesion I could have taken cohesion is not there. So, I ignored those all these Terzaghi's bearing capacity ultimate bearing capacity I have used and from there I got qu from qu I got q nu from q nu I got q ns and from q ns I hav,e got q allowable; that means, this one 789.7 kilo Newton per meter square

So, this is the first problem I just wanted to explain second problem let me see second problem is given something like this a column of a column footing of 2 meter by two meter is buried 1.5 meter below the ground and similar. That means, depth of footing is 1.5 meter in the in the dense in the dense cohesionless soil, the unit weight of the again 21 phi is again 36 and footing is a footing is to carry a total load of 2.2500 kilo Newton including column load and weight of the footing and weight of the soils are charged. So, total load 250 kilo 22 2500 kilo Newton determine the factor of safety against bearing capacity failure and groundwater table was not encountered during that the groundwater to be effect of groundwater table to be ignored.

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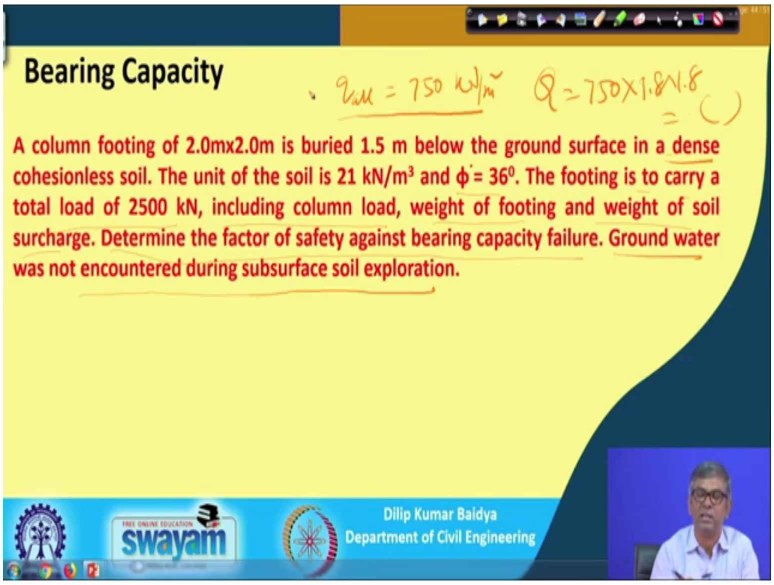

So, here actually what have what I have to do previous problem actually I have given q allowable I have got suppose some 750 or something kilo Newton per meter square so; that means, the load capacity of the footing could have been if the footing size is given. So, suppose 1.8 by 1.8 so, Q of the footing will be 750 multiplied by 1.8 multiplied by 1.8 whatever it comes that is the q.

Here actually the there actually I have calculated the allowable pressure and from there how much the load can carry by the footing that I have I can calculate, but problem here actually is given just yours; that means, all probably properties footing dimension everything is given now, I have to check what is the factor of safety available. There actually I have already used factor of safety and from there I got the pressure and from the pressure, if I know the footing size then I can find out what will the load carrying capacity of the footing.

Here the footing load is given soil property is given footing size is given depth of foundation is given now I have to find out what will be the factor of safety available. If I find the factor of safety is not enough then I have to redesign, I have to check if load will not change so that because of that how to change the footing size. So, that is the design process. So, I will show this problem, let me go to the next slide let me first draw the footing sorry.

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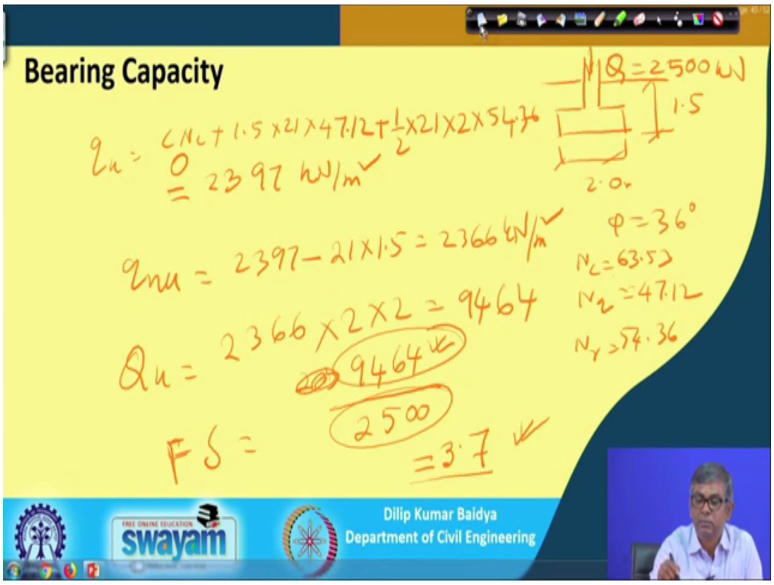

So, here let me draw the footing first, footing was something like this is 1.5 meter this is 2 meter and the q from here capital q is 2500 kilo Newton and phi is given 36 degrees. And when you given that N c is given N q also N gamma all three will be known. N c value will be 63.53 and N q is 47.12 and N gamma is 54 point 54.36.

So, this is there now I can find out from applying bearing capacity equation q u equal to c N c plus gamma again same thing actually it is 21, 1.5 multiplied by 21 multiplied by 47.12 plus half multiplied by gamma is 21 multiplied gamma b is 2 multiplied by n gamma is 54.36 and this part is 0.

So, if I calculate these this comes out to be 2397, approximately 2379 kilo Newton per meter square. And then your q net ultimate q net ultimate will become 2397 minus gamma is actually your 21 multiplied by 1.5 that gives you 2366 kilo Newton per meter square.

And so your Q u will become Q u become 2366 multiplied by 2 multiplied by 2 that gives you actually approximately 9464. And already Q u in the footing is known and then I can find out factor of safety Q u is actually 25 sorry, your available by demand. So, available actually 9464 this is the factor of safety is capacity by demand. So that is the available capacity available and your capacity are available is capacity is I means demand is 2500.

So, this ratio if I calculate then it will get factor of safety equal to 3.7 and which is quite large generally in foundation engineering we require a factor of safety at least between 2.5 to 3. Hints is that greater than 3.7 this is safe; obviously, and; obviously, if you want to make little economic then you can actually this much big footing size is not required in fact. Whatever we have used 2 meter by 2 meter it may not be required, we can reduce the size little bit and again check the capacity otherwise if we design with this it will be safe, but may not be economic. So, this is the one step for calculating the factor of safety; that means, what is the available capacity and what is the demand, the ratio is factor of safety.

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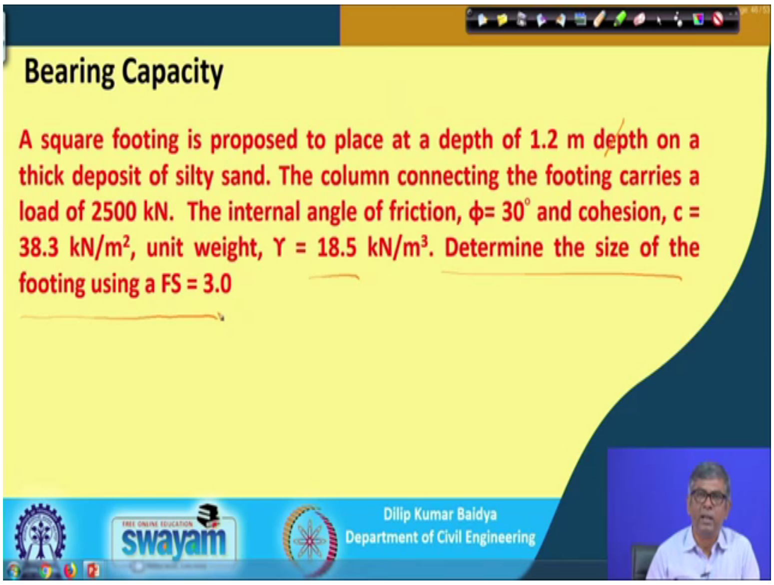

Let me do one more problem and you can see the last 4 problem. A square footing is proposed to place at a depth of 1.2 meter twice is not required on a this depth is not required, on a thick deposit of silty sand and the column the column connecting the footing carries a load of 2500 kilo Newton. The internal angle of friction phi equal to 30 degrees cohesion equal to 38.3 kilo Newton per meter square, unit weight gamma equal to 18.5 newton per meter cube. Determine the size of the footing using factor of safety equal to 3. So, this is a problem design problem.

Now, the soil is given soil properties are given like what is the phi what is the c and what is the gamma unit weight, all those things are given what is the factor of safety is desired that is also given and the footing at what depth it will be placed that is also approximately given. Footing depth actually from the stability point of view required. So, 1.2 meter minimum is given and your what is the footing the footing ultimately connect to the column and column load suppose column and footing approximately taking all may be load is 25 kilo Newton is given.

Now, we have to find out the actual size of the footing. So, to do that the procedure is again similar.

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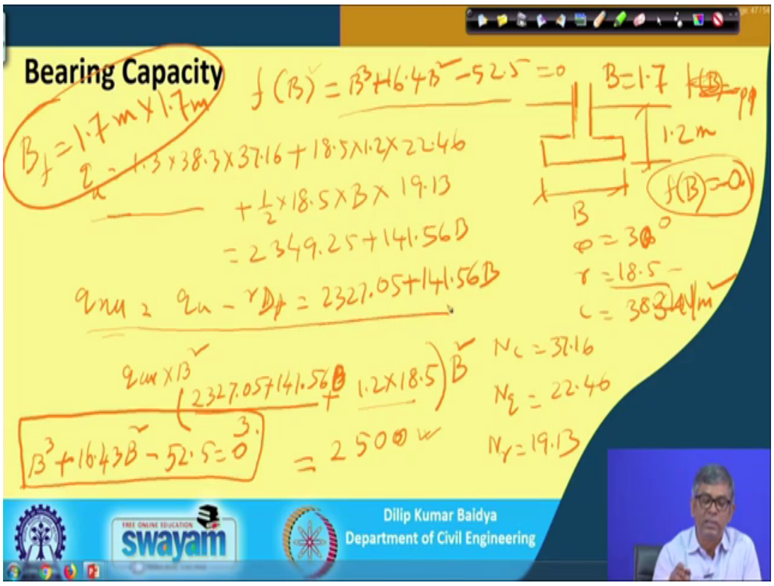

Let me go to the next slide and draw the footing first the footing is something like this. And this is 1.2 meter, again water table is ignored and this is actually square footing of width B not known and phi equal to 36 degree, gamma equal to as given 18.5 c is given 38.3 sorry, 38.3. And from the phi actually you can find out N c equal to 37 point phi equal to 30 degrees actually phi equal to 30 degrees, N c equal to 37.16 N q equal to N q equal to 22.46 and n gamma equal to 19.13.

So, these are the things are, now we have to find out ultimate bearing capacity qu equal to for square footing actually 1.3 c is 38.3 N c is 37.16 plus q is gamma is actually here 18.5 multiplied by 1.2 and N q is 22.46 plus half gamma is again 18.5, B is unknown multiplied by N gamma is 19.13.

So, if I simplify this one then we will get 2349.25 plus 141.56 B then I can find out q net ultimate q net ultimate equal to q ultimate minus gamma D f and if I do that then you will get 2327 2327.05 plus 141.56 B.

Now, if I want to find out footing load, footing load actually how it will be done q allowable multiplied by B square is it not. So, how to find out q allowable? So, this is net ultimate net u. So, this will be I can do 2327.05 plus 141.56 B divided by factor of safety which is equal to 3, which is actually 3 plus 1.2 multiplied by 18.5. These become your q allowable and these multiplied by B square then this will be equal to footing load ok.

And this footing load has to be equated with what? This has to be equated with 2500 kilo Newton. So, this was net ultimate is this net ultimate by factor of safety plus gamma D f is the q allowable multiplied by the footing area that gives you the total capacity of the footing and already applied 2500. So, if I equate this two then from there I can get the unknown value of B which is not given.

And if I simplify these then you may get a equation you can check actually I may have there is a calculation mistake. So, it will be coming approximately equation final equation may come something like B cube plus 16.43 B square minus 52.5 equal to 0. So, this equation, if I if I equate this two then I will get a equation ultimately B cube plus 16.43 b square minus 52.5 equal to 0, this is the equation I get a cubic equation and if I can solve this cubic equation then I will get the unknown value of B.

So, this problem actually what I can do I can consider f B actually f B is nothing, but B cube plus 16.4 B square minus 52.5 and I have to find out I can assume different values of B and try to find out f B value and f B value has to be 0, this has to be 0.

So, that means, I can nowadays actually there is a equation solver if I put in the equation type and those coefficient I can find out by single step the value of B. But in the examination hall you will not get the that type of calculator that is where equation solver will be there, what I can do I can assume different values of B and try to find out the f B value and when the f B value will be become close to 0 then that is the value of B for the actual value of B.

So, how to them choose the value initial value of B, the footing size generally vary from 1.5 to 2.5. So, approximately you can assume first the B value is 2 then you can find out that using B value of 2 then you can find out the this value f B value it is not equal to 0 it is something greater than 0. So, like that if I find the positive value then b value you can reduce, if I value large negative value you can increase the value of b like that trial and error method you can do. And finally, if I use b equal to 1.7 if I use B equal to 1.7 in this equation B equal to 1.7 in this equation I get f B close to 0 that is equal to minus 0.0 0.1 actually, I am getting minus sorry f B equal to minus 0.1.

So, that can be considered as or close to 0 so; that means, I can assume different values of B and then find out the f B and when I find the f B value is close to 0. That means, that is the value actually B is correct. So, by using B equal to 1.7 we are getting f B value close to 0; that means, that B actually is the correct B of this equation so; that means, from this equation finally, I get the width of the footing required actually equal to B equal to B of the footing required is 1.7 meter by 1.7 meter. So, for this problem the solution is that when the footing is placed at 1.2 meter depth and it carries a load up to 2500 kilo Newton. And the soil is with phi equal to 30 degree and c equal to 38.3 kilo Newton per meter square this is kilo Newton per meter square and gamma is 18.5 for that situation the required footing size is 1.7 meter by 1.7 meter.

So, this is the procedure for solving this problem, I hope it is clear enough I will take some more problem also later on. So, what I have to do? I have to do first q ultimate from q ultimate I have to find out net ultimate from net ultimate I have to find out net allowable net allowable multiplied by the area of the foundation become the load and that load should be compared with the given load that is done here and if you do then I will get a cube equation here and if I solve the cube equation, how to solve the cube equation?

Assume a trial value of B and try to find out the value of the function close to 0 when value of the function become close to 0 that assume value of b is the width of the foot actual width of the footing. So, by that actually I have got b equal to 1.7 meter; that means, since it is proposed a square footing; that means, size of the footing is 1.7 meter by 1.7 meter. With this I will just close here.

Thank you.