Geotechnical Engineering II / Foundation Engineering
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Lecture – 14
Shallow Foundation (Contd.)

Ok. So, let me continue again on bearing capacity. So, so far I have what I have considered Terzaghi's bearing capacity which has considered only strip footing initially and then it is extended to square and circular footing. And of course, I have also mentioned that when the soil is loose how to incorporate, then again I have mentioned if there is water table how to incorporate the effect of water table that also I have discussed. I have also solve some problem in terms of Terzaghi's bearing capacity theories.

Later on to incorporate different effect of depth then safe of the footing and inclination of the loading we have discussed in terms of Meyerhof theory. And we have introduced so, many factors s c, s q, s gamma; d c, d q, d gamma; i q i q i c i q i gamma N c, N q, N gamma. Obviously, it was there everywhere and those thing also I have discussed and then when the load is actually supposed to be concentric so that pressure will be positive, pressure below the footing and uniform as for as possible.

But in various situation where loading is not possible to apply through the center or some time moment is there or there are some other loading because of that there is a movement and vertical loading is there and because of that resultant loading will be inclined. And if that happens then generally the footing pressure below the footing pressure, below the footing will not be uniform it will vary place to place.

And there are different situation I have shown that that eccentricity will be measure in terms of width of the footing, if it is less than B by 6 then pressure throughout the width of the footing is positive. But one side will be little more one side will be little less and if it is exactly become equal to one-sixth of the footing the width of the footing then your one side will pressure will be 0 and other side will pressure will be little high, because of the moment pressure moment loading and the compressive loading.

And if the eccentricity become more than the one-sixth of the footing then one side of the footing will become tension and other side will be compressive heavily. So, these are the aspect we have discussed and how to find out that, I have discussed and another thing is that whatever pressure we get ultimately that maximum pressure below the footing should not be more than the allowable bearing pressure of the footing. So, that has to be as designer one has to make sure that.

So, again that is in terms of one way eccentricity, similarly I have discussed in terms of two way eccentricity also when there is a the when there is a rectangular footing and it is acting not at the center it is 20 or 200 millimeter away from the y axis and again 300 millimeter away from the x axis. That mean e x and e y both are there, in that case how to find out the pressure at different that I have given the expression and you have to carefully use the that second moment of area. You have to see that footing is rotating with respect to which axis, if it is rotating with x axis then you have to consider i x and if it is rotating with respect to y axis then you have to find out i y.

And i x and i y how it is different only the second moment of area expression is B L q by 12, one is B and L and only because of a change of the width change of the axis, once it will become B L q by 12 and when change the axis it will be L B q by 12 that is the change has to be carefully noted.

So, you have to see that the footing is rotating with respect to which axis accordingly you have to choose B, if it is rotating with respect to x axis then with parallel to the x axis to be as taken as the base and other dimension to be taken as a y. So, these are the various aspects we have discussed, once again like one way eccentricity what is the limit that is one-sixth of the width of the footing and similarly when it is a 2 way eccentricity what is the limit that is a area. In fact, that is called kern within that area if we apply the load then your pressure suppose to be positive within the footing.

Now, by with these actually by and large I have covered what is a bearing capacity related issues, but now after introducing Terzaghi's bearing capacity theory I have taken one problem and I have shown how to find out the ultimate bearing capacity net and allowable etcetera. And then how to take care of water table effect also I have shown one problem like that I have taken. But after introducing Meyerhof equation, I need to take one problem, let me see the problem in the next slide.

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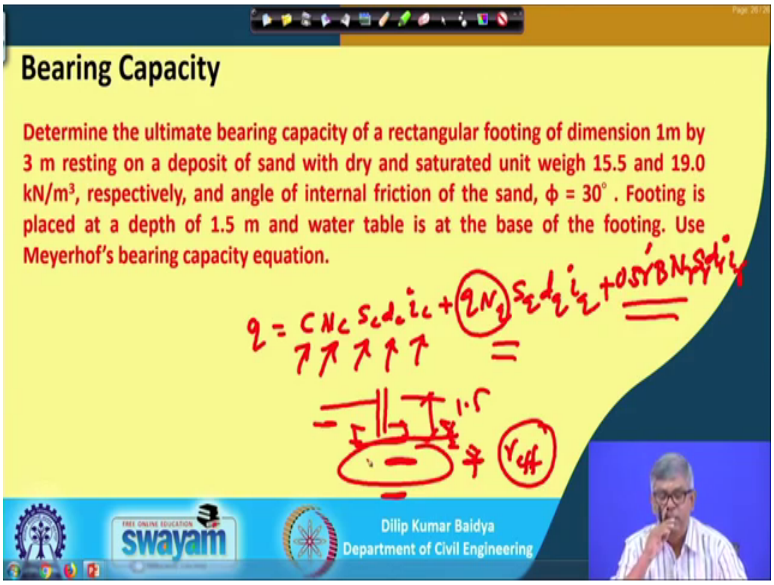

The problem is like this determine the ultimate bearing capacity of a rectangular footing of dimension 1 meter by 3 meter resting on a deposit of sand with dry and saturated unit weigh 15.5 and 19 kilo Newton per meter cube, that dry unit weight is 15 and saturated unit weight is 19.

And angle of internal friction of the sand is 30 degrees and footing is placed at a depth of 1.5 meter and water table is at the base of the footing use Meyerhof's bearing capacity equation. So, that is the one; that means, what I have to do I have to use Meyerhof equation; that means, q ultimate will be equal to cN c, cN c S c d c and i c plus qN q S q d q i q plus 0.5 gamma B N gamma and your s gamma d gamma i gamma. So, this is the equation I have to use.

And you can see now that c is not given. So, this component will be 0 n c anyway I have to if phi is given. So, automatically I can find out n c n q n gamma and s c since it is rectangular footing I can find out s c. Since it is a place and a depth I can find out d c and what about I c since it is a no inclination is mentioned; that means, a footing carrying a load means it is a carrying through the center.

So, ic iq I gamma will become 1. So, this effect of i c i q i gamma will not be considered. So, this is the way I have to take and another thing is the while calculating this part and this part you have to consider water table effect actually.

So, footing is somewhere here and this 1.5 meter and this is also water table location so; that means, this unit weight part that mean this part will be effected by water table. So, this will be gamma instead of gamma it will be gamma submerge will be used and since the surcharge is above water table. So, this will be unchanged. So, these are things to be noted. So, whatever I have discussed during Terzaghi's bearing capacity theory that water table effect here also I can take though I have not mentioned, but water table effect will be same.

Whatever was there in the Terzaghi, here also will be same, if instead of water table is here then I if it water table was here then what I have to do? I have to take effective gamma effective that is a equation I have shown how to take gamma effective at b depth the full gamma and when it is here it is half gamma almost and in between I have to interpolate, that way we have could have consider.

If the water table was here then what this, this will be unchanged and this part I could have changed, q instead of q N q, I could have taken as q gamma 1 h 1 plus gamma submerge into h 2, I could have calculated.

So; that means, water table effect will be whatever I have way I have shown, similar way to be introduced here only thing new thing added here at this S c d c i c S q d q i q and s gamma or d gamma I gamma these has to be calculated at properly incorporated in this calculation.

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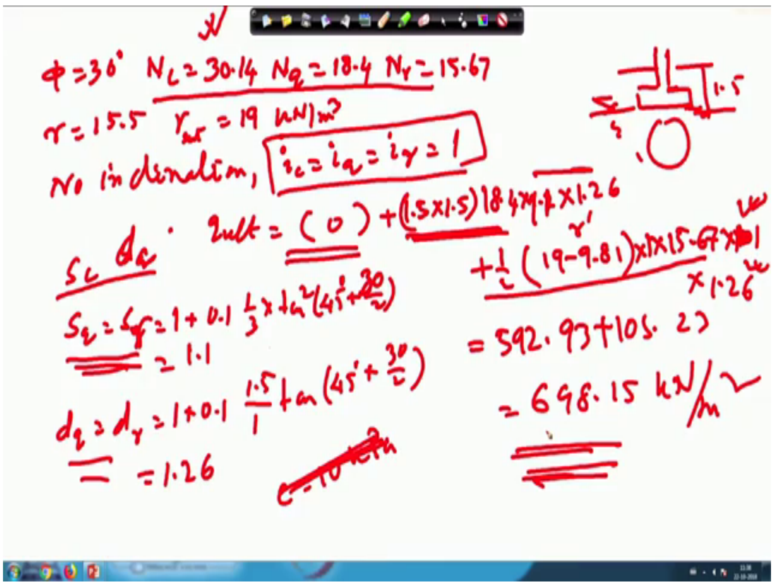

So, for this let me take a page and your footing is something like this. So, this is 1.5 meter and water table also here and your phi equal to 30 degrees and corresponding N c equal to 30.14 corresponding N q equal to 18.4 and N gamma equal to 15.67 and gamma equal to 15.5 and gamma saturated equal to 19 these are all kilo Newton per meter cube.

And since no inclination i c equal to i q equal to i gamma equal to one and your equation will be, your equation will be and since this part water table not effected your equation will be and since c is not there so your q ultimate will be equal will be equal to this c part will be 0 plus q here actually 1.5 multiplied by 15.5. This is q and N q is actually your N q is 18.4 and then I have to find out s c and d c.

So, I will just find out s c equation actually we have given s c equal to 1 plus 0.2 and then L by B so B by L. So, 1 by 3 10 square 45 degrees plus your 30 by 2 and if I do this, this value comes 1.2. So; that means, I will to put s c 1 point sorry this s c is not required actually s q, s c is not required anyway because this part is total 0, I will not just for showing I just showed we can I can just remove it I will take now your s sq sq equal to s gamma actually and that is 1 plus 0.1 1 by B by L multiplied by tan square 45 degree plus 30 by 2and that comes your 1.1. So, this will be multiplied by 1.1.

And d gamma so, you have to find out dc again I will not calculate. So, d q equal to d gamma for this also d q equal to d gamma as given by Terzaghi, I meyethof 1 plus 0.1 and 1.5 by 1 and tan 45 degree plus 30 by 2 and if you calculate that it comes 1.26. So, this will be multiplied by 1.26 and plus half gamma instead of gamma it will be gamma submerge because water table here this zone. So, it will be nineteen minus 9.81 half gamma and d actually is 1 meter, half gamma this is gamma submerge gamma b gamma n gamma is here 15.67 and your s s cube this s cube is 1 point multiplied by 1.1 multiplied by s sorry s q [FL] d gamma.

So, yeah s q 1.1 1.1 and s gamma d gamma also 1.26 1.1 and 1.26; so if I do this one then it will come finally, 592.93 plus 105.23. So, this total comes 698.15 kilo Newton per meter square.

So, in this problem you can see that c value is not given means we can assume phi given 30 degree and c is given not given we have to we have assumed that c equal to 0 and since c is equal 0 then this part become 0. So, I have not calculated s c s q sc d c s c d c and sc dc I have not calculated ok.

And. So, I have calculate s q s s q s gamma s q s gamma or d q d gamma because these two other two components are there. So, these two only I have calculate otherwise whatever way it is given in the Meyerhof equation I could have calculated s c d c if c suppose given c is given suppose 10 kPa. Then this part would have not become 0 in that case I have to I could have taken c equal to these multiplied by N c I have I could have taken this and then s c d c all I could have calculated and multiplied and added. But since this part is not there, I have not shown here otherwise I have applied the Meyerhof bearing capacity equation and finally, also I have applied water table effect also because water table was here so, because of that in this zone where gamma supposed to be use I have use gamma submerge.

So, ultimately ultimate bearing capacity came 698.15 and of course, if I if it is asked for allowable bearing capacity then I could have done some net ultimate net allowable then net then final allowable. So, the whatever procedure I have shown there same way I can do here. So, this is the way this problem can be done and so, the ultimate bearing. So, this is the application of Meyerhof equation what is the way is it different it was before only for phi corresponding to phi I to I have to determine N c N q and N gamma.

And here additionally what I have to do depending on the type of footing and depth of embedment and inclination of loading I have to find out those factor s c d c i c s q d q i i q and sorry s c d s c d c and i c and s q d q i q and s gamma d gamma i gamma. So, all three component 9 components additional components to be and those are empirical equations and given I have also shown previous lecture.

And here actually since c is 0. So, first three components not involve so other 6 components are involve. So, I have calculated you can see here four impact 1, 2, 3, 4 and i i i c i q i gamma already 1 because of no inclination. So, 3, 2 3 and plus this 3 6 gone. So, only remaining 4 are the 3 and 2, 5 gone only 4 to be determined. So, I have determined here and I have used here.

So, this so if it is a Terzaghi's bearing capacity it could have been ended here. So, this is 1.1 and 1.26 because of what it came s s q and d q. Similarly it would have been your Terzaghi's bearing capacity here actually it could have ended here, but I have added this one what is that s gamma and d gamma this two parts have happen and to take water table effect this similar to your Terzaghi's equation is taken. So, finally, the bearing capacity ultimate bearing capacity is comes out to be 698 approximately 700 and then you can apply your different factor of safety is set to find out the allowable bearing capacity. So, this is the application of Terzaghi's bearing capacity.

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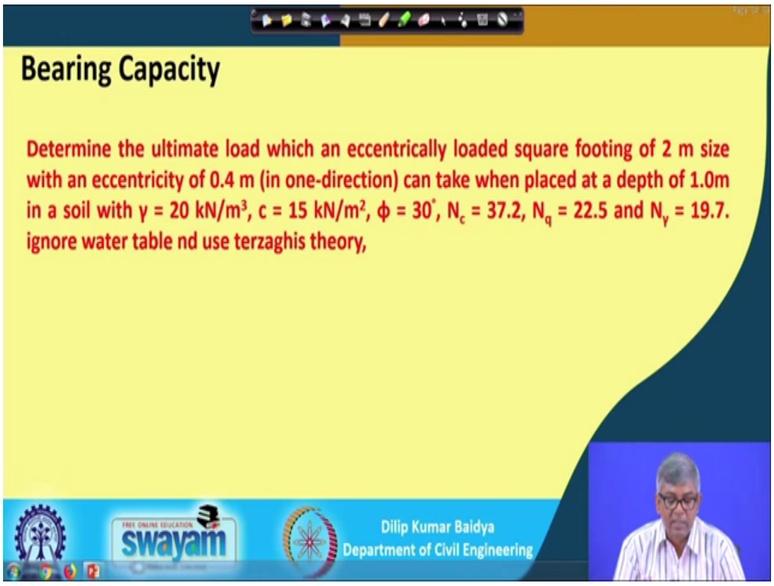

Let me take one more small problem where actually I have discussed about reduced width of the footing to find out the ultimate load carrying capacity of the footing and you can see that determine. Let me this determine the ultimate load ultimate load which an eccentrically loaded the square footing of 2 meter size with an eccentricity of 0.4 meter and that eccentricity is given in one direction can take when placed at a depth of 1 meter in soil with gamma equal to 20 kilo Newton per meter cube c equal to 15 kilo Newton per meter square phi equal to 30 degrees and N c N q n gamma is given and ignore water table and use Terzaghi's bearing capacity theory.

So, here actually there are number of typos actually and it is a spelling mistake and Terzaghi's supposed to be capital. So, I have done mistake here. So, let me see this problem here actually the problem is given a one it is of 1 meter, square footing of 2 meter size. It is 2 meter by 2 meter and eccentricity is point 40.4 meter.

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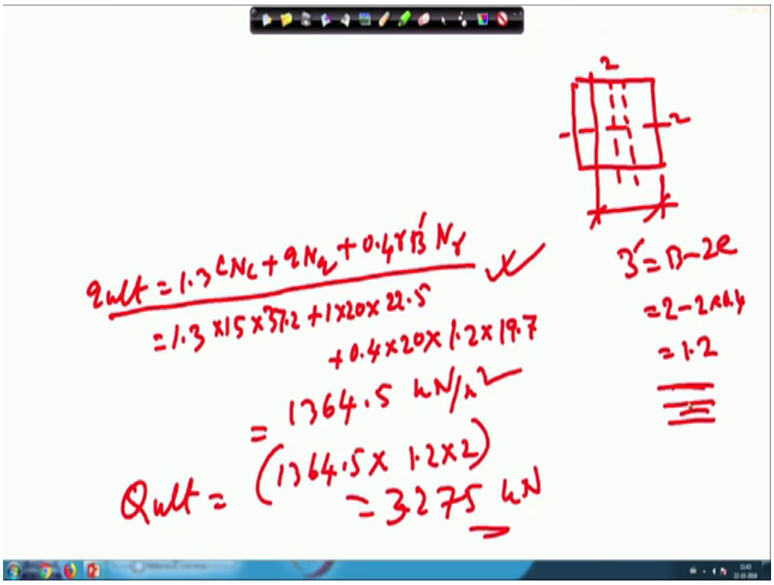

So, that means the footing is suppose this is 2 meter and this is 2 meter and eccentricity is 40 meter. So, what is the effective width actually that has to be you know B dash will be B minus twice e so; that means, B was 2 minus 2 multiplied by 0.4 ; that means, 1.2 meter. So, B dash is 1.2 meter and so in that case your q ultimate to be used as I have mentioned Terzaghi's theory is to be used and the square footing. So, 1.3 c cN c plus q N q plus q N q plus 0.4 gamma B dash N gamma.

This is the way to be used and so you can see 1.3 c is actually is given as 15 multiplied by 15 multiplied by N c is given 37.2 plus q is actually will be one multiplied by 20 multiplied by N q is given 22.5 plus 0.4 gamma is actually here water table is ignored. So, it will be same 20 multiplied by b dash actually to be used 1.2 multiplied by n gamma is given n gamma is given nineteen point seven.

So, here actually what I have done I have calculated reduced width or effective width and then applied all Terzaghi's bearing capacity equation. So, from here I can get it will be 1364.5 kilo Newton per meter square. So, if I want to find out q ultimate q ultimate since it is a one way eccentricity q ultimate will be 13.64 multiplied of multiplied by area of the footing will be 1.2 by 2. So, that become your 3275 kilo Newton loading ok.

So, this is a only application of bearing capacity is only how to reduce the footing size because of the eccentricity that is a application shown here and next one more problem.

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So, this is a A 2 by 3 meter rectangular footing loaded with 200 kilo Newton at an eccentricity of 250 millimeter and determine the maximum minimum contact stress below the footing. So, this is the problem we can see.

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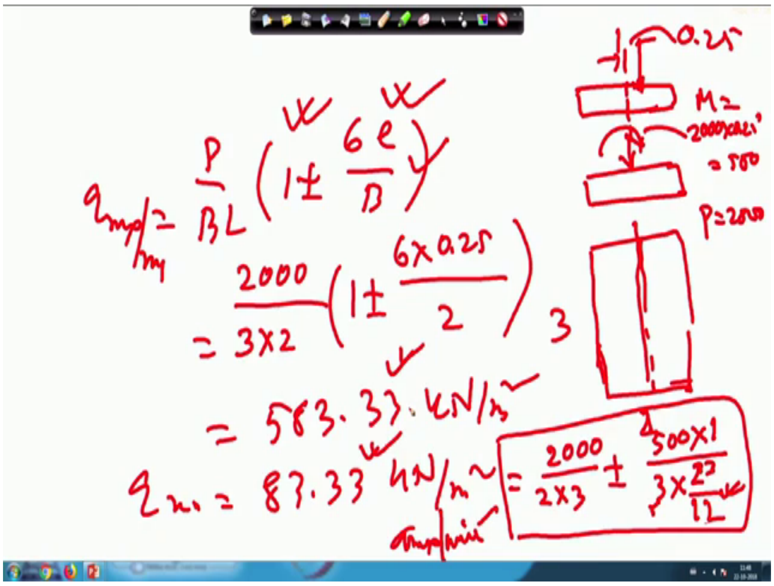

Footing is something, but low degree is applied here this eccentricity is 0.25 and this can be visualized as a concentrated load and there is a moment. So, moment become 2000 multiplied by 0.25 become 200 and this is two thousand p is p m equal to 500 p equal to

2000. And your footing dimension is this is 1 meter and this is this is 3 meter, 2 by 3 meter actually this is 2 meter and this is 3 meter.

And then your q max will be equal to you know that P by BL 1 plus minus q max or minimum 6 e by B so here. So, if you do that we can see p become 2000 divided by 3 multiplied by 2 1 plus minus 6 multiplied by 2.25 divided by B is 2 meter. So, if you do this calculation you will get q, q maximum q maximum it will be 583.33

Similarly, q minimum will be, q minimum will become if I use minus sign then it will become 83.33 kilo Newton per meter square. So, either directly one can use this equation or one can do this way 2000 divided by 2 multiplied by 3 plus minus m actually 500 multiplied by y is actually here 1 meter; m y by i i will be this with respect to this axis 3 multiplied by 2 cube by 8.

So, this way also by using this equation this is q max or q minimum. So, 2000 by area multiplied by m into y by b s cube by sorry this is not 8 this will be 12, this will be 12. So, by this actually whatever you get and by using this also whatever we are getting it will be same. So, I can either directly remember this equation or I can remember the, instead of remembering the equation I can do in this form; that means, because of the compressive load what is the pressure and because of the moment what is the pressure.

Because of the moment pressure is M y by i m is calculated load multiplied by eccentricity and y is maximum these distance that is half the width of the footing and what is the I the I should be since it is rotating with respect to this axis with respect to this axis then I have to consider this as a axis and then this will be base and this will be height. So, it will be 3 is the base and h cube by 2 cube by 12.

And then if I simplify this it will come also same value 583 and 83. So, this is another application where actually when the footing is applied with eccentric load then how to find out the maximum and minimum pressure because this maximum pressure should not be more than the allowable pressure of the footing. So, this has to be calculated and checked and so these are the various application whatever I have already mentioned those things and with this I will stop here may be next class I will just 1 or 2 aspect of bearing capacity I will consider and then I close the shallow foundation and then I will proceed to the next topic ok.

Thank you.