Advanced Foundation Engineering
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Lecture - 10
Shallow Foundation: Bearing Capacity - V

Hello, now today I will start about the last class I have already explained that how to calculate the bearing capacity of the foundation in layer soil. And today I will solve one example on that particular type of bearing capacity calculation, and how to calculate the bearing capacity of that particular foundation, if it is resting or it is on the layering layered soil.

Now, next then I will discuss about the form bearing capacity calculation on foundation, if it is placed on the top of the slope. Now, first I will, so go for the the problem for this bearing capacity calculation in the layered soil.

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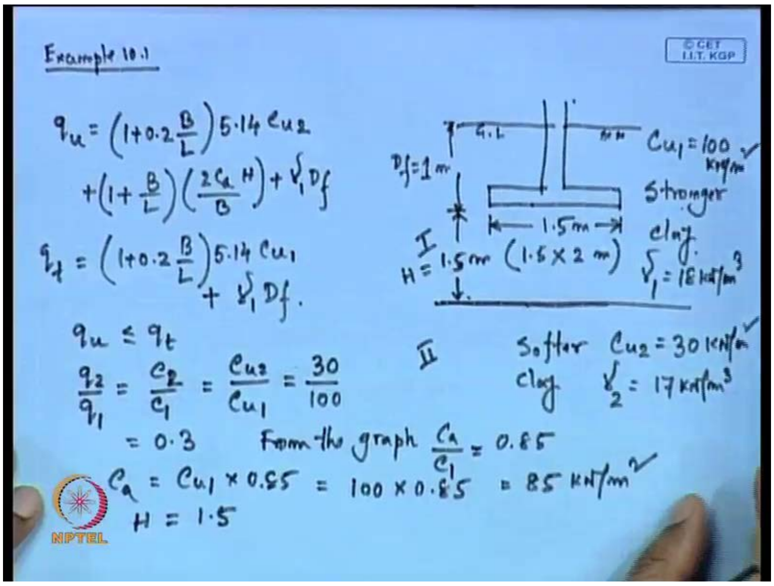

Now, in this example that is example 10.1. So, it is lecture one first example that if a square footing, which is ground line or ground surface. The depth of foundation D f is equal to 1 meter, and the it is a foundation, it is not square, it is a rectangular footing of dimension say width of the footing is 1.5 meter and dimension is 1.5 cross 2 meter.

Now, this footing is placed on a layer which is stronger clay with C u value, C u 1 is equal to 100 kilonewton meter square, and gamma 1 is equal to 18 kilonewton meter cube, gamma is unit weight of the soil, C u is the cohesion of the layer 1. So, this is layer 1 which is stronger clay, and this is layer 2 which is softer clay with C u 2 is equal to 30 kilonewton meter square, and gamma 2 is 17 kilonewton meter cube.

The distance from this base of the foundation up to the layer 1 is 1.5 meter. So, this is the depth of the soil from the base of the foundation. So, this is the layer 1, layer 2. Layer one is stronger clay, layer 2 is softer clay, the cohesion of the layer 1 is 100 kilonewton per meter square and gamma 1 is 18 kilonewton meter cube, cohesion of layer 2 is 30 kilonewton meter square and gamma 2 is equal to 17 kilonewton per meter cube and dimension of the footing 1.5 cross 2 meter, depth of foundation is 1 meter and the depth of the lower of this of this first layer is 1.5 meter from the base of the footing. Now, we have to determine the bearing capacity of this soil, of this foundation in the layer soil system.

Now, as I have already derived the expression for this ultimate bearing capacity calculation for this type of, if it is a stronger clay and the softer clay, when both the layers are clay then this ultimate bearing capacity considering the size effect will be 1.2 B by L into 5.14 C u 2 plus 1 plus B by L into 2 C a into H by B plus gamma 1 D f. And q t where bearing capacity of the top layer is 1.2 B by L 5.14 C u 1 plus gamma 1 D f. And condition is I have already explained this thing that q u 2 should be less than equal to q t. So, q u ultimate load carrying capacity is less than equal to q t.

So, now the calculation part, here from this it is derived that q 2 by q 1, that if the footing is placed in the surface and this is the bearing capacity of that surface footing in the second layer and this is the bearing capacity of the surface footing in the first layer. So, under this both the clay condition, if the both the layers are clay then q 2 by q 1 is equal to 2 by c 1. Now, here c 2 or C u 2 or we can write C u 2 by C u 1. Now, here C u 2 is equal to 30 divided by C u 1 is 100. So, this is 100.

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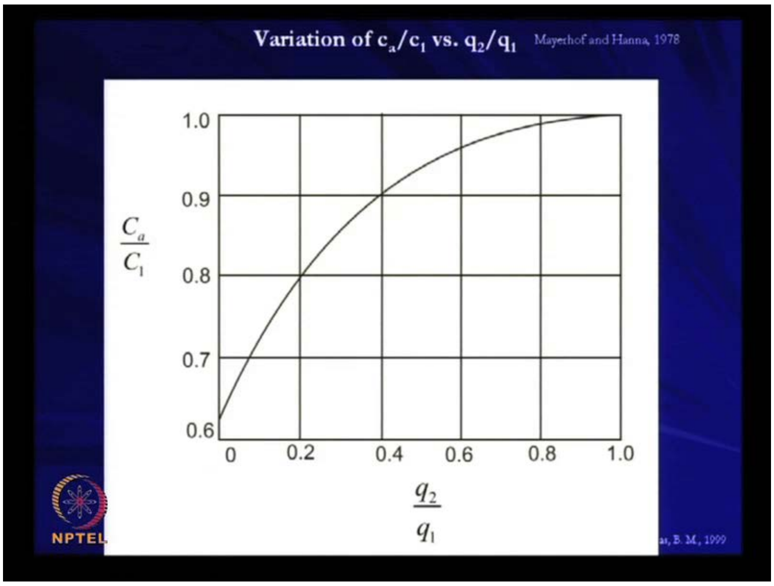

So, this value is equal to 0.3. Now, in the in this previous lecture I have shown this graph, where this is the graph that is presented. So, this is q 2 divided by q 1, now from this particular problem that q 2 divided by q 1 is equal to 0.3. So, these are actually 0.3.

So, corresponding C a by C 1 is equal to 0.85. So, this is the value 0.85. So, corresponding this value we can say from the graph, C a by C 1 is equal to 0.85, where C a is the addition of the soil. So, from here we can calculate or we can write that C a is equal to C u 1 into 0.85. So, C u 1 is 100 into 0.85. So, this is coming out to be 85 kilonewton per meter square.

Now, so from this expression we know B L. So, C u 2 is 30 gamma 1 is 18 kilonewton per meter cube, D f is 1 meter and C u, Ca we have calculated this is 85 and H value this H value is equal to 1.5. This H value is basically the depth of the second layer, first or starting point of the second layer from the base of the foundation that is equal to a.

So, from this particular case H is equal to 1.5 meter. So, that the starting point of this second layer is 1.5 meter below the base of the foundation. So, this H value is 1.5 meter. So now, if we calculate so, there we we will get the q u value and q t is the top layer bearing capacity this is the total bearing capacity considering both the layers.

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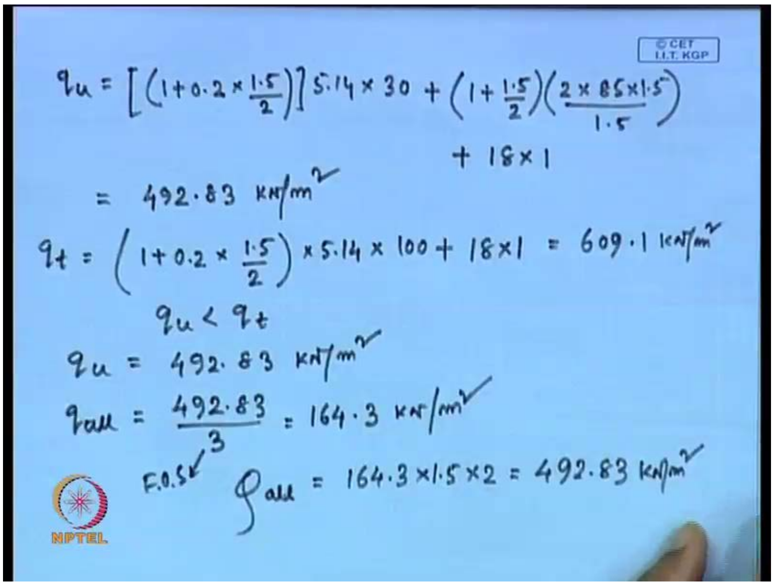

Now, if we put this value in our calculation that q u, that is, equal to 1 plus 0.2 into 1.5 by 2, here into 5.14 into C u 2 that is 30, plus 1 plus 1.5 divided by 2 and 2 into C a is 85, H is 1.5 divided by B 1.5 plus gamma 1 is 18 into D f is 1.

So, now if just we are putting this value B is equal to 1.5, L is equal to 2, C u 2 is equal to 30, then C a is 85, H is 1.5, B is 1.5 and gamma 1 is 18 kilonewton per meter square gamma D f is 1 meter. So, the total value after the calculation, we are getting 492.83 kilonewton per meter square.

Similarly, qt we can calculate just putting this value, 1 plus 0.2 into B is 1.5 divided by L, that is 2 into 5.14 into Cu 1, that Cu 1 is 100 plus gamma 1 is 18 into 1, 1 is the D f. So, the after the calculation this value qt is coming 609.1 kilo newton per meter square.

So, from this calculation we can say that qu is less than qt. So, it is satisfying this condition. So, we can write that qu, that load ultimate load carrying capacity of this foundation on resting on this layer soil is 492.83 kilonewton per meter square.

Now, if we apply the factor of safety that is q safe or q allowable that 492.83, we consider the factor of safety 3, this 3 is the factor of safety. So, we will get this value is 164.3 kilonewton per meter square. So, ultimate load carrying capacity or q allowable for this total load carrying capacity will be 164.3 into 1.5 into 2. So, this value is in 492.83 kilonewton per meter square.

So, here we can calculate the bearing capacity of the foundation for the layer soil system. So, similarly for the other conditions also if the one layer is clay and one layer is sand, if both the layers are sand in those cases also we can calculate the bearing capacity of the foundation in similar process.

So, next thing is that if bearing capacity we want to calculate for the, here we have calculated the bearing capacity of the foundation for layer soil system. Now, if the foundation is placed on the top of the slope then how to calculate the bearing capacity of this soil.

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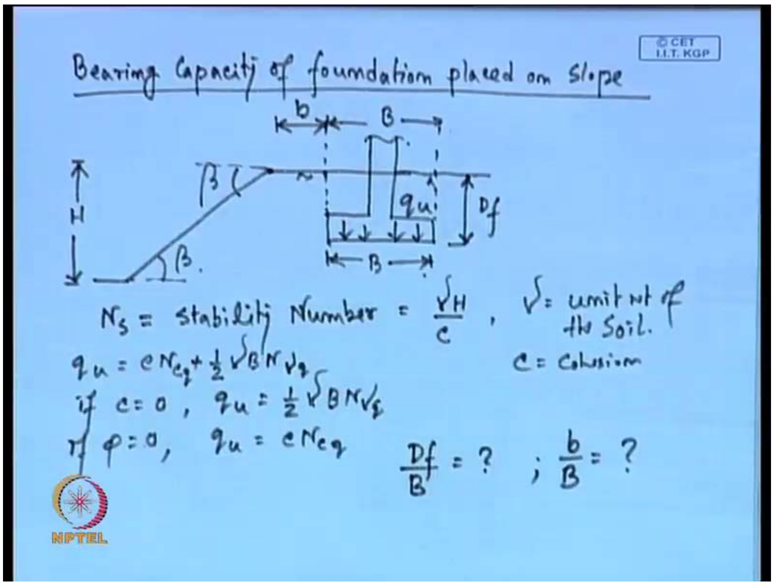

So, now for this we can write, that is bearing capacity of foundation placed on slope. For this, this is the slope. So, beta is the slope angle and H is the slope height and if one foundation is placed near the slope. So, this is the foundation which is placed near the slope. Now, this foundation width is B and qu is the ultimate load carrying capacity of this foundation and D f is the base of the footing or depth of the footing form top of this load.

Now, if we can extend this H. So, this distance is equal to B and we can write this or this distance from the H of the slope to the H of this footing. So, these distances say b, small b. So, small b is the distance between the H of the slope to the H of the footing and capital B is the distance or the width of the footing.

Now, first we have to calculate few things that first we can calculate the N c which is stability number or we can write this is gamma H divided by c, where gamma is the unit weight of the soil and c is the cohesion. Now, next condition that we can, we know that q u is c N c plus half gamma B N gamma or N gamma q for the surface footing.

Now, if c is equal to 0, then q u will be half gamma b N gamma q for surface footing. Now, if phi is equal to 0 then q u will be c N c q. So, this is also q. So, q is this N gamma q N c q these are the also bearing capacity factors. Under this condition; that means, when the foundation is placed on the or near the slope.

So now, how to calculate the bearing capacity? So now, for this two conditions if c is equal to 0; that means, if this this is a granular soil; that means, this case ultimate load carrying capacity is half gamma B, n gamma q and if phi is equal to 0 then q u will be c N c q. So, here we know the cohesion value that is the properties of the soil, this embankment soil and b is the width of this footing, gamma is the unit weight of this soil. So, only unknowns are this N gamma q or N c q. So, these two unknowns or two bearing capacity factor we have to determine under two different condition; that means, c equal to 0 and phi equal to 0.

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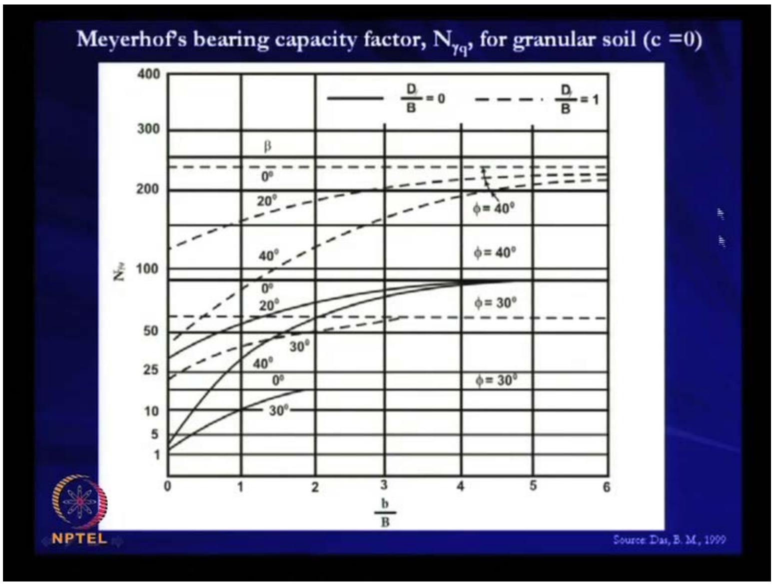

Now, for this calculation we have to calculate that different parameters that D f divided by B, this is one ratio that we have to calculate and another 1 is b small b divided by capital B. So, we have to calculate the stability numbers value that we can calculate then D f by B and then B by B, and we have we should know the value of phi also.

So, if we know these parameters. So, then we can use this chart. So, these are the two different conditions that is one for c equal to 0 and 1 for N gamma q and another one phi equal to 0. So, Meyerhof proposed this bearing capacity factors for foundation resting on flow.

So, now for if c equal to 0, then we have to calculate this N gamma q, now here for to calculate the N gamma q we should know the value of the ratio between the small b by capital B and this chart are presented for various values of phi. So, this phi and beta beta is the slope angle. So, this varies from 0 degree to forty degree, so 0 degree, 20 degree and 40 degree.

Similarly, phi is for three different phi value; phi equal to 30 degree, phi equal to 40 degree at this two different phi values these charts are presented and this formula in presented that d f by b is equal to zero; that means, if the depth of foundation is 0; that means, it is placed at the top of the slope and another this dotted line which represents the D f by b is equal to one, if the depth of foundation is equal to width of the foundation.

Now, for first one the dotted lines for the, if the depth and width of foundations is same and these are the beta value from 0 degree. So, for if the phi is 40 degree and beta is 0 that this is the line. So, if we know that b small b by capital B value then and corresponding to phi and beta value. So, that the condition is that D f by B as 0 or 1, say we can calculate what would be the value of N gamma q or bearing capacity factor which is proposed by the Meyerhof's.

So, once we get this value then we have to calculate, we can easily calculate the ultimate load carrying capacity of the foundation under this condition. Now, these values are for 0 degree, this is for 20 degree and this is for 40 degree corresponding to phi equal to 40. So, similarly for this form lines corresponding to phi equal to 40, this is beta equal to 0, beta equal to 20 and beta equal to 40 degree.

Now, if phi equal to 30 degree then this dotted lines, this is for beta equal to 0 degree and this line is beta equal to 30 degree. Now for the phi equal to 30 degree, then this line is beta equal to, this line is beta equal to 30 degree and this corresponding beta equal to 30 degree and this is beta equal to 0 degree. So, this is 0 degree and this line is for 30 degree. So, similarly by using this chart we can determine this bearing capacity factor of the foundation.

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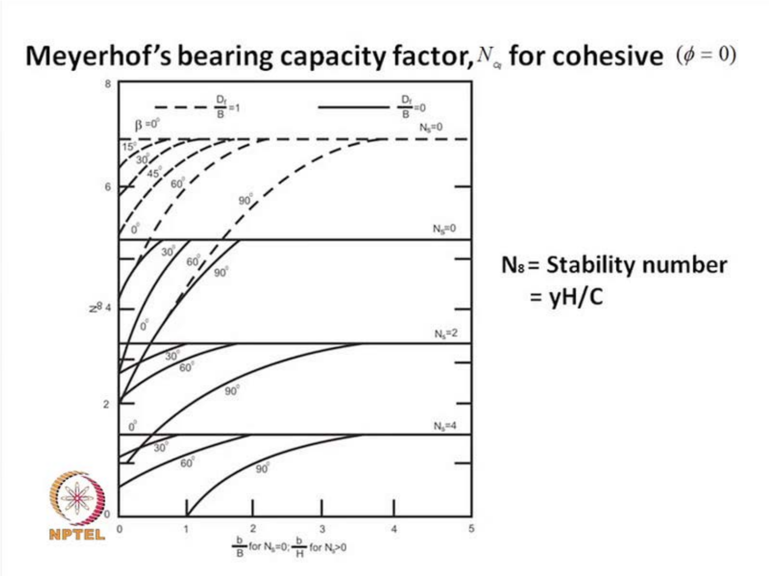

Next that if phi is equal to 0, then in this case we have to calculate the stability numbers. Now, B by f so here again these are the corresponding to different stability numbers that N s equal to 0, this N s equal to 2 and N s equal to 4 and these are the beta value 0 degree, 15 degree, 30 degree, 45 degree, 60 degree and 90 degrees and corresponding here 30 degree, 60 degree, 90 degrees; here also 30 degree, 60 degree, 90 degree; here also 30 degree, 60 degree, 90 degree.

So, different from 0 to 90 degrees this is also 0 degree. So, these are the curve. So, again the dotted line represents the D f by b equal to 1 and form line represent D f by B equal to 0 degree. So, once we know stability value then b by small b by capital B value, then then this stability number or b by H value then we will get calculate the bearing capacity factor N c q, which is proposed by Meyerhof by using this chart.

So, once we get these two bearing capacity factors for two different types of soil, then we can by using the expression we can easily calculate the ultimate load carrying capacity of the foundation. So, these are the different bearing capacity calculations. So now, I have calculated this bearing capacity we have to calculate the bearing capacity of the soil in layer soil if it is placed on the slope which is proposed by Meyerhof's.

So, now if I want to summarize the, what are the factor by which the bearing capacity or or on which bearing capacity ultimate bearing capacity of the foundation highly dependent. So, first one is the factor influence the bearing capacity we can write.

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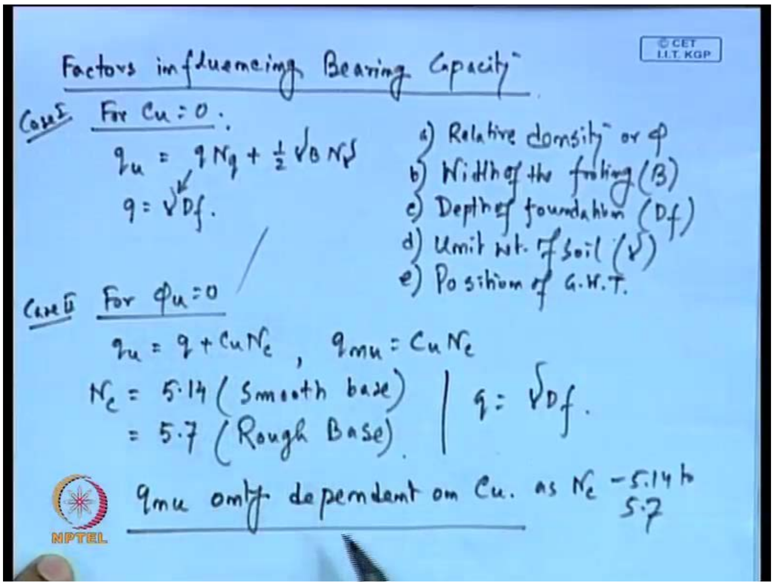

So, here we are dividing these factors in two different types of soils; one is for phi equal to 0 and one is for c equal to 0. So now, if phi equal to, first case for c u equal to 0 this is case one or so, here we can write that ultimate load carrying capacity value or q u will be q into N q plus half gamma B n gamma. So, here we know q is equal to gamma D f.

Now, from these expressions we can say that, now this N q and n gamma, this bearing capacity factors depend on the phi value. So, first influence factors we can say under this condition that for c equal to 0 that is relative density or phi value. Now, if relative density increases then phi value will also increase and if phi value increases then N q N gamma values those values will also increase. So, our ultimate load carrying capacity or q u that will also increase.

Now, the next one is we can say this b term is present there, so width of the footing, that is, B. So, B also influences the bearing capacity factor calculation; that means what the bearing capacity of the soil now, if here B is the factor, if B from this expression we can say the B also influences the bearing capacity. Next, factor that is our D f or depth of foundation or D f value, so that may give also influences the bearing capacity.

The next one is unit weight of the soil that is the gamma; it is the gamma values are there that is gamma. So, here we can see this this gamma represent the soil or the unit weight of the soil above the foundation base and this gamma representing the unit weight of the soil below the foundation base, and then next one is the position of ground water table.

So, I have already explained that if the ground water tables position changes, then this q u value that will also change or the ultimate load carrying capacity or bearing capacity value that will also change. Now, if it is position of the ground water table is at the ground surface. So, that will give the minimum bearing capacity of the foundation, and now if this position of the ground water table is below the width equal to the below the width of the foundation from the base. So, that means, in that case the no influence of the ground water table is observed in the bearing capacity calculation.

So, that means the if we position of ground water table is greater than or equal to the width of the foundation from the base of the footing, then the influence of this ground water table on bearing capacity is neglected.

So, next case for phi equal to 0 then we can write that q u is equal to q plus C u N c and this is ultimate load carrying capacity, this is similarly, we can say that net ultimate will be C u N c. So, now, N c value is given that 5.14 to 5.7. So, this is the range of this N c value if phi is equal to 0 now this 5.14, that smooth smooth base of the foundation and this is 5.7 is for the rough base of the foundation.

So, here we can say from this expression that for first we consider this is the two expressions. So, one is ultimate load carrying capacity of the soil and the next one is equal to ultimate bearing capacity of the soil. So, in these two conditions we will get, this is the net ultimate bearing capacity expression and this is the ultimate bearing capacity expression.

So, there are two expressions that we are getting now what will be the factor that is effecting that we can calculate considering this two bearing capacity expressions. So, first we consider that relative density or the phi value. So, here form these two expressions 1 is q u and 1 is q N q that is q u, q ultimate and q net ultimate.

Now, if the relative density of the soil; that means, here N c is 5.14 for smooth base and 5.7 for rough base. So, phi value is not influencing, this neither q or nor C u so; that means, it is not even for this other expressions also; that means, the relative density if it is a cohesive soil the relative density has not any influence on the bearing capacity.

Now, second one is the width of the footing. From these two expressions we can say that width of the footing is not influence in the bearing capacity of the foundation if it is resting on the clayey soil, because here this B term is not present. The next one is the depth of foundation here we can say that net ultimate capacity is is independent of depth of foundation; our depth of foundation is not influencing that to calculate the q N u or net ultimate bearing capacity of the clayey soil.

But if we want to find the ultimate bearing capacity of the soil then q term is there, where q is equal to gamma into D f and their depth is influencing. So, depth is influencing for q u not q N u. Similarly, unit weight of the soil the same thing it is influencing this bearing capacity calculation for q u naught q N u, because this q value is gamma into D f. And for net ultimate position of ground water table so, when we calculate the q value this position of ground water table will also influence this q u calculation; that means, it will also influence the bearing capacity.

So; that means, the position of ground water table influences the bearing capacity calculation for clayey soil if we want to calculate q u, but not on q N u. So, from this observation we can say that q N u only dependent on C u, C u value because as N c is varies from 5.14 to 5.7. So, only parameter that influences the bearing capacity calculation for N u, that is C u, so q u q N u only dependent on C u not any other factor.

So, now from this conclusion, we can say that these are the different factors which are influenced in the bearing capacity of the sandy soil, if C u is equal to 0 these are the factors and for phi equal to 0 for clayey soil.

So, next we will start new section that is, the settlement calculation because this now, till now I have discussed that what are the different methods by which we can calculate the bearing capacity of the foundation?

Now, next how to calculate the settlement of the foundation, because as I have mentioned that settlement and the bearing capacity two are the most important factors of criteria for design of any foundations, so then how to calculate the settlement of the foundation that we will discuss in the next section.

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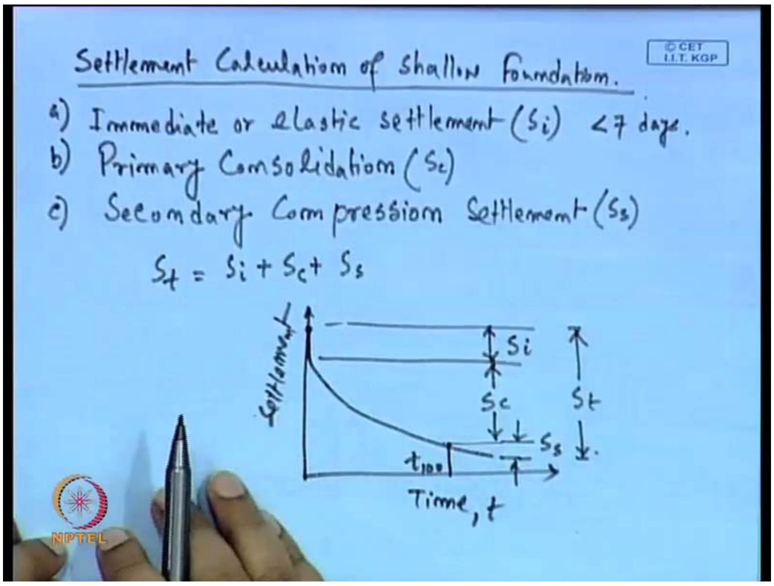

So, the settlement calculation of shallow foundation, so this is the how to calculate the settlement for the shallow foundation, first that part we will discuss. So, when you go for the settlement of the shallow foundation there are different types of settlement that we will get for the shallow foundation, that one is first settlement is immediate settlement or elastic settlement, that we can write that is S i.

So, this is the immediate settlement that when we apply the load on a soil through the foundation just after the application of load, the settlement that immediately will occur that is called the immediate settlement. Generally, if up to or less than 7 days or we can say this is for the 7 days, is it is that this immediate settlement basically is completed within the 7 days time.

So, this is the change due to the change in shape of the soil without change in the volume. So, this settlement is due to the change in the shape of the soil without change the volume. The next one is, that is the primary consolidation, this is S c and this is due to the consolidation process. So, so that means, once we we will get the immediate settlement then we will go for the consolidation settlement. So, then this is the time dependent settlement. So, next the third category settlement is secondary compression settlement or S s. This secondary first is due to the change of shape, the soil shape of soil without change in the volume, this is due to the consolidation and this is the volume change occurring due to rearrangement of the soil particle.

So, this this secondary compression settlement is due to rearrangement of the soil particle and volume change occurring due to this rearrangement of the soil particle. So, that total settlement that will get, this is the summation of immediate settlement, consolidation settlement and secondary compression settlement.

Now, from this different types of soil so; that means, the total settlement that we will get this is the the combination of this three or the summation of this three settlement. Now, form if the, if the contribution of this total settlement the contribution of each part on this total settlement that depends on the soil type. For example, if it is a granular type of soil then immediate settlement or elastic settlement is is much hard compare to this other two type settlements.

Similarly, for if it is a if it is a clay soil especially for inorganic clay then primary consolidation settlement is the maximum amount of settlement compare to the say other two types of settlements. Similarly, if it is the organic clay then secondary compression settlement is more compare to the other two types of settlement.

So, in short we can say that for the granular soil immediate settlement contribution is more and for the clay soil the consolidation settlement is more. Now if we draw this one graph that we can say that this is the settlement and this is the time and this is settlement, this is settlement, this is the time t. So, immediate settlement, suppose this is the point of application so, immediate settlement we get within seven days. So, we can say this is the the time requirement is very less.

After that, so we can say this primary consolidation settlement and secondary compression settlement both are time dependent settlement, but immediate settlement that is not time dependent settlement. So, if I draw this graph. So, we will get this type of settlement graph.

So; that means, from up to here this is equal to the immediate settlement and suppose this point which is the 100 percent consolidation or t 100. So, from here to here this is the consolidation settlement and this is secondary compression settlement. So, there is the three parts one is immediate settlement, then primary consolidation settlement, then compression settlement. So, these are the, it will give the total amount of settlement or S t. Now, we have to calculate this three settlements or the total settlement of different parts of this immediate settlement, then consolidation settlement to find the total settlement.

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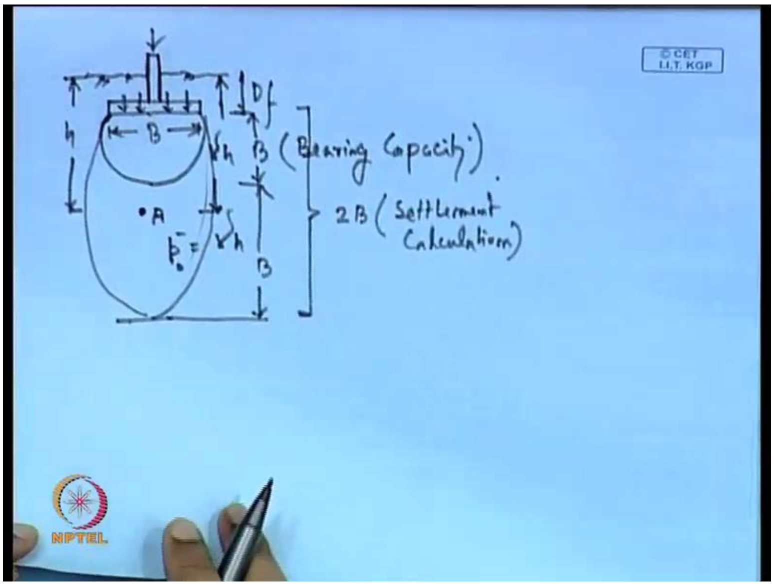

So, next one is that, that when we calculate the settlement so; that means, we are applying suppose this is the foundation. So, before we start the settlement calculation then we should know how to calculate the increment of load due to application of increment of stress due to application of this load.

Suppose this is the foundation and we if we consider that at a point A. Now, if in this condition if we can neglect the water table effect then this stress at A point that is gamma into H. Suppose, this height of this point from the ground surface is H. So, this is the stress at point A before the application of the load or we can say this is the effective overburden pressure of at point A before the application of the load. So, and and we are not considering water table effect here.

So, now once we apply this load through footing then definitely at A point additional load that will act due to this foundation load. So, this is the increment of this increment of load due to apply application of this foundation load at any depth below the base of the foundation.

So, from this foundation base, suppose this is the d s depth of the foundation. So, from this zone this stress increment will occur because of this foundation load application. Now, there is an influence zone that we consider when we calculate the bearing capacity and the settlement. Generally, for the bearing capacity calculation we consider the influence zone up to B for the bearing capacity calculation.

So, for the bearing capacity calculation we consider generally this influence zone is up to B which is width of the foundation. Say, suppose this is width of the foundation so, this is for the bearing capacity calculation.

Now, for the settlement calculation we consider this zone which is twice B from the base of the foundation. So, for the bearing capacity calculation this influence zone is B and for the settlement calculation we consider this influence zone is twice B. So, that means B plus this is for the bearing capacity so this for the 2 B for the settlement calculation.

And in this lecture I will consider this same thing that for the bearing capacity, I will calculate up to up to zone B and for the settlement calculation I will consider that zone 2 B in general case. So, that means now if any point within this we want to calculate the settlement of this total soil; that means, I have to calculate the stress increment at this zone twice B from the base of the footing.

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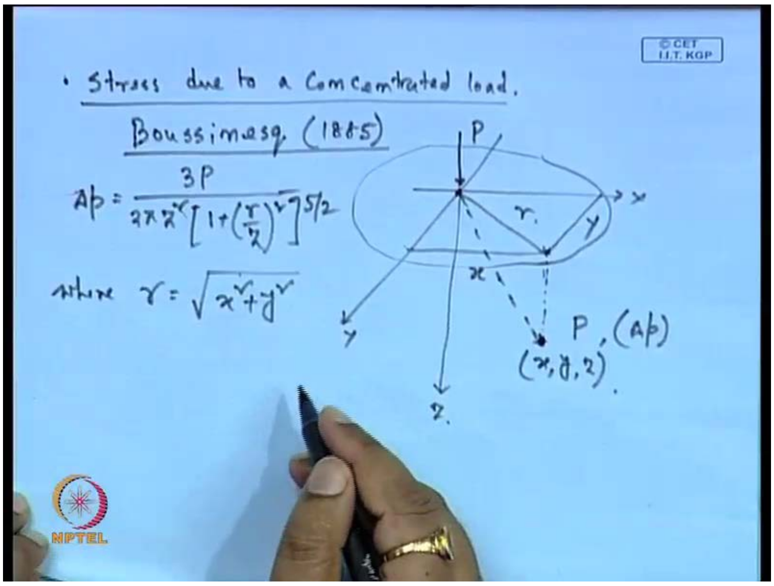

So, that means at any point within this zone if we want to calculate the increment of stress due to application of this footing load, then how to calculate. There are few methods by which we can calculate this increment of load or stress due to the increment load then how to calculate this thing.

Now, first concept that I will apply that is a stress due to a concentrated load. Now, Boussinesq equation we can use, 1885 proposed this expression that if one load, suppose this is the ground surface and here this is x axis, this is y axis and this this is z axis. This is on the surface of the ground x axis, y axis, z axis and if one load is applied here at this point.

So, what will be the load or stress increment at this point that we have to calculate. So, now this point is at a depth of z, so that means the coordinate of this point x y z then how to calculate this load; that means, this is y and this is x and radially this is r, and from this point this is the position of the point from the application of the load.

So, that means this point is x distance and y distance and z distance from the origin, origin means where this concentrated load is applied. So now, according to Boussinesq expression that del P the increment of load at this P point, say that, P point this is the del p, we can say that 3 P divided by 2 pi z square, 1 plus r by z to the power square divided to the power 5 by 2.

Now, where we can say r will be given by root over x square plus y square. So now, if we know this x and y, so similarly we will get the r value root over x square plus y square and we know that z value. So, if we apply this expression put this value then we will get the stress due to the concentrated load at any point below this point of application of the load.

So, similarly by using the Boussinesq expression we can use the, we can calculate the stress increment for circular loaded foundation, then we can calculate for rectangular loaded region then at any point what would be the stress below this loaded region. So, this we will get in the soil mechanics course that you have already done this thing, then how to calculate this stresses for circular loaded area or rectangular loaded area for the point load.

Then, that means for the footing if it is a circular footing or steep footing or rectangular footing or square footing, then using those technique by Boussinesq proposed by this Boussinesq. We can determine the stress at any point below the loaded region. So, that we will we have done for any soil mechanics course that technique we can use to calculate this stress.

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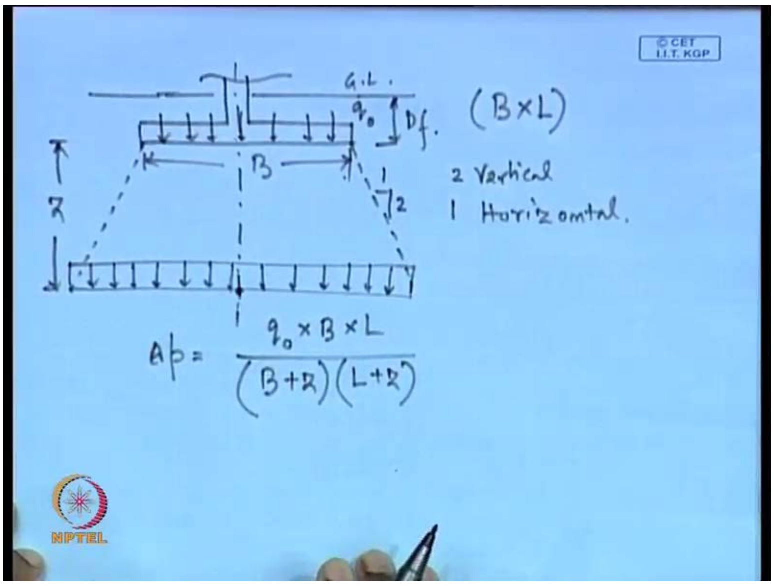

The next technique that the approximate method which is very useful to calculate this stress at any point. Suppose, this is the foundation and this is ground surface, this is q 0 is the load and D f is the depth of the foundation. Here, we consider this load is distributed by 2:1 pattern. So, at any depth if we want to determine the stress at any depth suppose this at the center of this point. So, at any depth so this will be the stress and the stress amount will reduce as we increase the depth.

So, as depth is increased then the stress which is acting at this foundation base level that will reduce and here it is assumed that this distribution is 1:2 that means, two vertical and one horizontal. Now, if that depth is z from the base of the foundation, depth is the base of the foundation, then the stress increment will be q 0 into B, if this is the width of the foundation is B and dimension of this foundation B cross L is the dimension of the footing.

So, D P will be P 0 into L divided by B plus z into L plus z. So, that means in this way we can determine the increment of stress due to this footing. So either, we can use the

Boussinesq procedural or by use you can use this approximate method, this is one approximate method to calculate the increment of stress at any point below the foundation base.

So, in next class I will explain how to calculate the settlement; that immediate settlement and consolidation settlement, what are the corrections that we have to apply to calculate those settlements, for different types of soil. So, that settlement calculation I will explain in next class.

Thank you.