Geotechnical Engineering II / Foundation Engineering

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Lecture – 10
Shallow Foundation and Bearing Capacity (Contd.)

Welcome once again to this lecture on Foundation Engineering. And today it is a 10 lecture, in fact 10th module. And in this I am so far I was discussing on bearing capacity; first of all I have introduced what is shallow foundation and then bearing capacity or shallow foundation. And bearing capacity or shallow foundation there are number of theories and we have started with terzaghis bearing capacity theory. And what are the assumptions in terzaghis bearing capacity we have mentioned and based on that we have shown that bearing capacity of a footing can be expressed in the form of equation with 3 components.

And one component is cohesion another is for surcharge another is unit weight of the soil. And these 3 components are expressed in 3 by 3 factors they are called bearing capacity factors. One is bearing capacity factor for cohesion, bearing capacity factor for surcharge and bearing capacity factor for unit weight N c N q N gamma. And if you know this N c N q N gamma is a function of phi; that means, angle of internal friction of the soil. And if you know the c and phi of the soil then using that bearing capacity equation and you can find out corresponding N c N q N gamma from the phi and then using c this and then putting in the equation you will get the ultimate bearing capacity of the soil.

And in this equation and one of the important assumption was that that bearing water table is at a very great depth; that means, effect of water table was ignored. But if you have water table at different location sometimes it may affect the bearing capacity value. So, the today I will try to give you the some concept how the bearing capacity can impact the bearing sorry the water table location can impact the bearing capacity of the footing.

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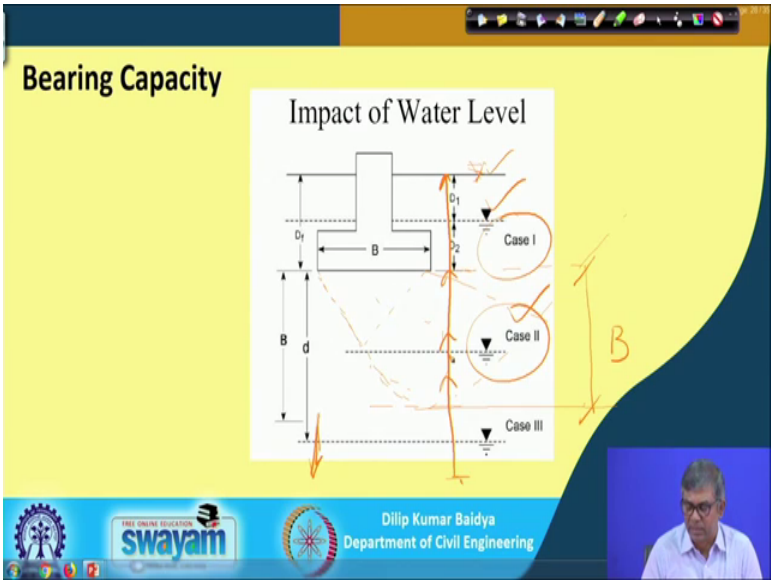

So, let me go to the slide that is this is the one and I have I have told you that as per assumption in your tarzaghis bearing capacity that water table there is at a great depth; that means, sufficiently great depth.

And this sufficiently great when what I will considered as sufficiently great that we have shown we have seen that bearing capacity that when it fail then we see that in the below this footing it form different ways. And that 1 2 and 3 we have shown before and these actually that that will when it will fail the effect goes reach up to a depth certain depth and that depth actually from the foundation base to this actually this is B.

That means if the water table located below the depth equal to the equal to or greater than the width of the footing. That means, the water table is suppose here and water table is suppose here and this is actually depth B;. That means, in that case bearing capacity will that water table will not have any impact on the bearing capacity. But, water table can be because of seasonal variation water table can be at various location that and be suppose these that: is a case actually where no impact on bearing capacity, but if water table during rainy season is go it goes up here then it is entering to this zone.

That means where that shear zone; that means it may have some effect how to incorporate that effect. Similarly, it may further go up and it may reach here then again it is entering to this entire shear zone entire shear zone is under water. So, it may impact then how to incorporate this impact in the bearing capacity that has to be seen or it goes further off suppose it is here, then again that the surcharge portion also get saturated. So, because of that it can impact the ground bearing capacity. How to compute that impact you have to see that or it may go further up and it may come to this ground surface also.

So that means, water table at a very great depth and slowly particularly it rainy season it generally happens summer actually it may be here. rainy season suppose it goes up here and there and between and different time at different location and can be there. And so, because of that bearing capacity value will change and there that change how to find out that we have to discuss now. And so, here basically I will I am showing in 3 cases.

Case 1: where actually water table is shown here. Case 2 where water table is shown here that means, case 1 is within the depth of the footing. So, depth of the footing is this and within the depth of the footing somewhere water table is there that I am considering as a case 1 and within the shear zone the case 2 and case 3 out of this zone case 3. And again case 1 and 2 I can modify to 2 different cases like one special case here that meant it in between, but it may be here similarly it is in between, but it may be here or here.

So, corresponding bearing capacity equation I will try to show also separately.

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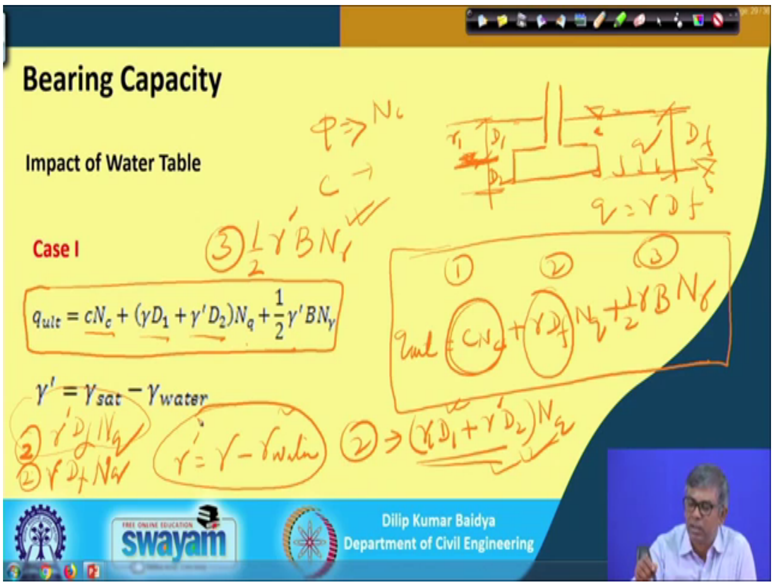

Now let me go to the next slide. you can see the case 1 as I have told you I let me draw once again. The case 1 is something like this, footing is something like this and water and this is actually D f. This is suppose D f and water table is suppose somewhere here.

And then you have this is suppose D 1 and this is suppose D 2. And this is of course, water table is here then this zone also what it is under water therefore, it is saturated. So, our bearing capacity general bearing capacity equation q ultimate equal to c N c plus gamma D f N q plus half gamma B N gamma.

So, this is the general equation bearing capacity equation when there is no effect of water table on the bearing capacity. This is the equation now I have to now water table is somewhere here then how I can modify this. So, this part actually suppose c and N c N c value depending on value of phi, I can find out what is the value of N c and c also by a large may be constant for a particular soil. And what may vary that that we generally consider that at this level there is a surcharge equal to q. And this q is actually nothing but gamma times D f.

So if there is a no water table this is gamma times D f gamma soil time D f. Now this surcharge above the base of the footing now 2 different types of soil is there one is D 1 which is dry and one is D 2 what which is under water underwater submerged. So, in that case what we it will be N q will be same as it is before because N q is depend if N q is function of phi. So, phi is not changing. So, N q will be unchanged. So, gamma D f can be replaced by gamma 1 D 1 plus gamma submerged multiplied by D 2 and multiplied by N q it will be there.

So, second component this is the part one and this is part 2. So, 2 will be modified by this the gamma 1 D 1. That means, if this is this level unit weight is gamma 1, gamma 1 and D 1 the surcharge plus from here to here surcharge will be calculated as gamma submerged into D 2, gamma submerged is what gamma submerged equal to gamma soil minus gamma water. When water when the soil is submerged then we generally take effective unit weight or gamma submerged submerged unit weight and gamma submerged is this one.

So; that means, I will be taking second part instead of gamma D f N q I will take gamma 1 D 1 plus gamma dash D 2 multiplied by N q as the second part. And then this if this is third part this third part also will be this third part also will be also will be modified. The third part: if we have gamma B and gamma since entire zone that is actually this part is coming for this zone. So, this zone actually gamma is submerged. So, instead of gamma;

third part also I will be taking third part I will also taking as half gamma submerged B N gamma.

So, N gamma also will not change. So, that is why. So, you can see one modified to this 2 modified to 2 is modified to this one is without modification 2 is modified this 3 is modified to this. Now I if I take all of them together then you can see gamma ultimate become c N c plus gamma D 1 plus gamma submerged D 2 N q plus gamma submerged B N q. So, this is actually your, now the bearing capacity equation when the water table is somewhere here. Now if the water table is goes up here it is here then the there can be further modification that will be equal to. So, all the change will be here only.

So, second part will be the part 2 2 second component will be changed to suppose total depth is D f. So, that will be gamma submerged D f multiplied by N q gamma submerged D f N q. So, second part when the water table will go here. Then your second part second part with the this position this is the value, when second the water table goes here then your second part will modified these third part remain unchanged. Similarly, if the water table goes here water table is going to this place then second part other part will be unchanged.

This part will be unchanged this part will be unchanged, but second part will be again unchanged will be changed. That will be your second part for this position for this position, when water table is here then it will become gamma times D f N q gamma time D f N q. That means, even the water table is here that is general and when water table is here modified to this second part modified to this. And when, water table is here second part is modified to this and third part obviously will be remain unchanged.

So, case 2 when water table varies between base of the footing to the ground surface. So, there be there can be 3 location it can be in between it can be at the ground surface and it can be base of the footing. So, 3 cases are.

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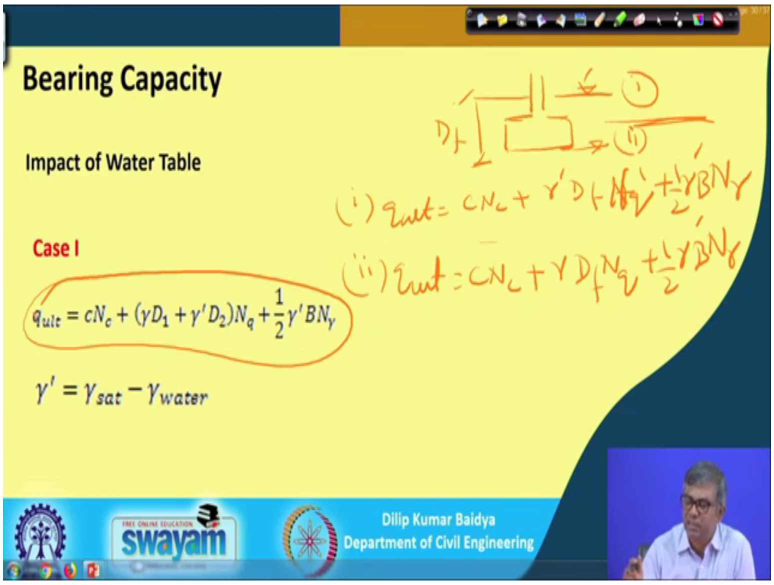

So, written. So, I will just neatly I can write once again say if it is suppose if the water table is somewhere here. Suppose, this is case 1, then your case 1 will be q ultimate will be equal to c N c plus gamma submerged D f. This is D f gamma D f plus gamma D f N q plus half gamma submerged B N gamma and if the water table is somewhere here.

Suppose 2: that will be your q ultimate will be equal to c N c plus gamma D f now this not submerged the normal gamma D f N q plus half gamma dash B N gamma. So, so this is one location for this equation this location. This location and if the water table is in between somewhere here this is the equation ok. So, these are the effect of water table on bearing capacity. Here actually surcharge is changing also unit weight is changing, but c N c component is not changing.

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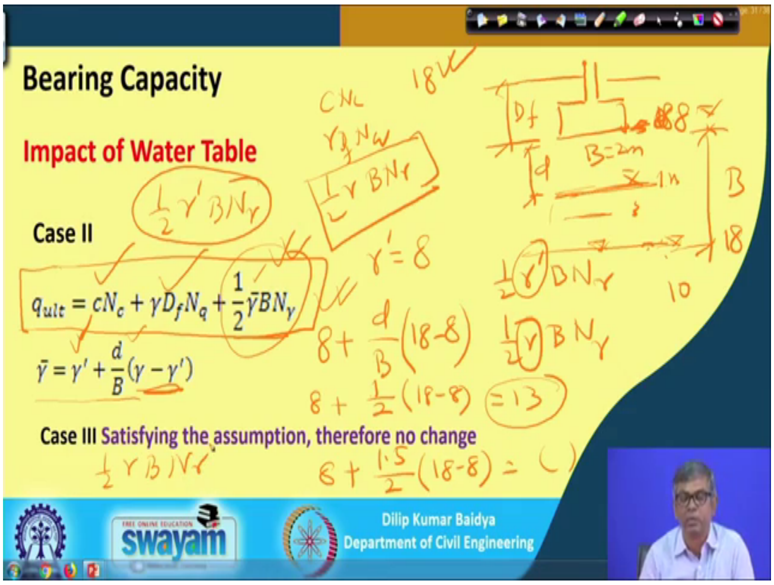

Now, go to the next case; that means I will be going to second one.

That mean when water table is somewhere here and water table is somewhere here. And this is suppose B this depth is B of the footing; that means, this is suppose B and this is suppose D and your this is suppose D f. So, water table somewhere here. And we can see now if the water table is here, if the water table is here then of course, if when water table is in between. So, this c N c not changing and gamma D f N q this is also not changing; that means, when water table vary between this to this then only half gamma B N gamma this component only will change.

How it will change that has to be seen. Now if the water table is somewhere here water table is here that mean that is the tarzaghis assumption. That value will be half gamma B N gamma. So, only change in gamma ok. And if the water table is here if the water table is here, then it will be again water table is here then entire soil is submerged there it will be half gamma submerged B N gamma. So that means, here also only change in gamma. So, when it is here it will be gamma submerged and when this is here full value of gamma.

So; that means, if this is in between then I have to find out effective unit weight. So, suppose if the unit weight is here if the unit weight is suppose 18 and or suppose unit weight of water is suppose 10 if I take then, your effective unit weight gamma submerged become 8 minus 10. So, 8 and here actually it is; that means, value is here 18 for when water table when sorry. When water table is here the value will be taken as 8 and when water table is here value will be taken gamma will be taken as 18. So, if the water table is in between then value will be interpolated between 18, 8, 8 and 18 between 8 and 18 how to interpolate.

So, if I go from this direction. So, it is increasing this direction; so it will be 8 plus if I come here distance d. And this total distance is B divided by 18 minus 8 so; that means, if we any location if I consider the water table is located then how to find out the effect of effective unit weight. So, first of all I considered here and then how much distance I am going from here that divided by total distance and the difference of that. So, this is the normal interpellation procedure. So, that is the thing only I have shown here in generalize the case 2 is water table somewhere in between the base of the footing to the depth B. So, if I take that then your ultimate bearing capacity will be c N c which will be unchanged gamma D f N q which will be unchanged, but only part the third component unit weight component will be changed that can be written as half gamma effective BN gamma ok.

And how to calculate the gamma effective? The gamma effective can be calculated by the equation assume the initially the water table is here at this point the water table then what is this gamma submerge. And suppose water table is moving from this side to this side. And then it is going here then value will be here actually it will be gamma. So, difference between these 2 gamma minus gamma submerge. So, the gamma minus submerge if I move from here to here the change of unit weight will be gamma minus gamma submerge that is there, and how it is changing if I travelled D distance from here. So, that is D and over total distance b. So, that way you have to increase.

So, numerically I have shown here if suppose footing width is B B equal to 2 meter, B equal to 2 meter and I, I want to find out exactly at one meter depth then effective unit weight will be 8 plus this D become 1 and B become 2 and 18 minus 8. So, it become 18 minus 8 is 10 and because by 2; that means, 5. So, it become 13. So; that means, when unit weight of the soil is 18, and water table is moving from here to here and when exactly at middle of these then your effective unit weight will become 13. If your water table is here effective unit weight supposed to be 18 sorry 8 and if water table is somewhere here, then it become 18. So, this is 8 13 18.

So, similarly if there is any other depth suppose it is one stop 1 meter if it is 1.5 then it will be 8 plus 1.5 divided by 2 18 minus 8 whatever maybe it comes it will be definitely more than this 13, because it is increasing in this direction. So, like that we can find out the effective unit weight when water table is in between at the base of the footing and the depth B by this using this equation I can find out the effective unit weight and by using effective unit weight I can find out the gamma component. And this is the only part will changed and this 2 part will be unchanged. So, ultimate bearing capacity will become this is the equation is the ultimate bearing capacity ok.

So, this is the effect of your water table when water table is here on the ultimate bearing capacity of the soil. So, this is actually case 2. And now as I have told already I have explained if water table is here then your second part will become half gamma submerge BN gamma. That means, when water table is at the base of the footing that at this base of the footing, when water table at the base of the footing this is the second the third part and when water table at a depth b. That means, that at that time it will be half gamma B N gamma.

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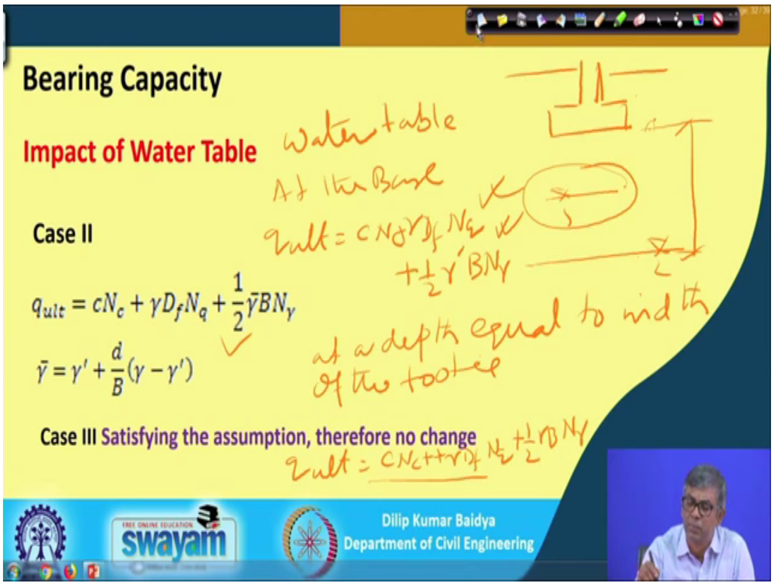

So, I will clean again and give you once again neatly this one once again. Suppose this is the footing and your water table B is this water table is here and this is suppose b. So, when at the base when the water table at the base then your q ultimate will be equal to cNc gamma Df Nq plus half gamma submerge BN gamma. So, this also I have got I have previous case 1 I have shown 3 cases 1 2 and 3.

So, third part is second same as first part of this. So, this is the one equation you can get and when water table is here this is the equation and when water table is here. That means, at a depth equal to width of the footing then q ultimate will be equal to same cNc plus this is plus plus gamma D f Nq plus half gamma B N gamma. So; that means, it will not change and it will be changed to submerge totally. Here there is no change and in between there will be effective unit weight you have to find out.

So, this is second case can be again viewed in 3 different case 1 here, here and there. Case 2 is generalized 2 again I can find out sub part here sub part here. So, this 3 cases bearing capacity are given here.

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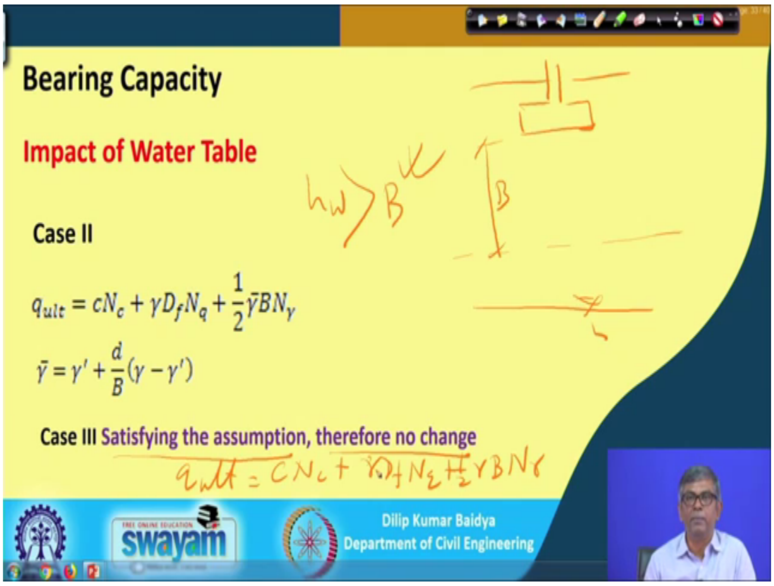

Now, suppose your case 3. So, case 3 means when water table is water table is somewhere here. somewhere here and B is this one this is depth B. So, how is greater than b. So, this is the assumption in bearing capacity theory or terzaghis theory.

So, there will. So, satisfying the assumption therefore, no change; that means, q ultimate will be equal to c N c plus gamma D f N q plus half gamma BN gamma. So, this is the one will be used.

So, these are the various effect or effect of water table or impact of water table on bearing capacity. So, far I am explaining the effect in terms of terzaghis bearing theories also theory, but later on I will take other bearing capacity theories also, but wherever whatever may be the theory that changed will be similar, wherever there is a unit weight. Or where there is a unit weight that will be replaced by appropriate unit weight the way I have shown here otherwise the same thing will be there whatever maybe the theories ok.

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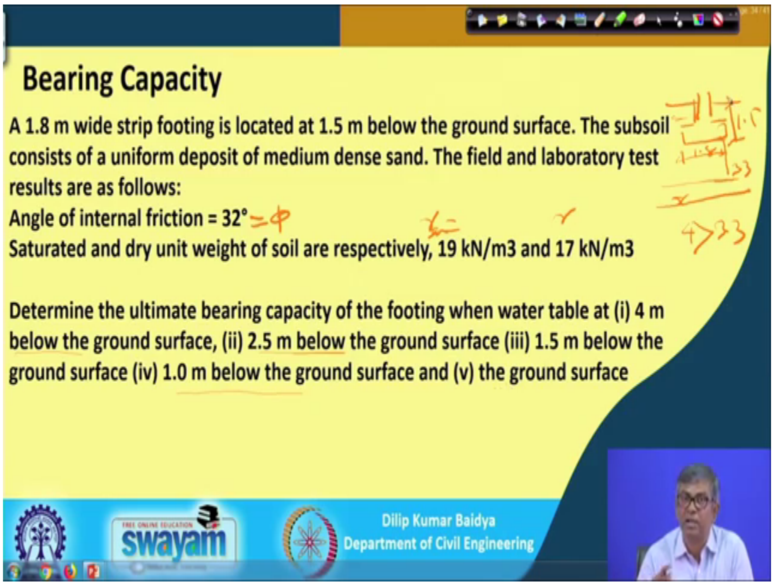

So, with this I will just go to the next slide. Next slide I will just try to explain the effect again by calculating a problem. A 1 meter wide strip footing is located at 1.5 meter below the ground surface the subsoil the subsoil consists of uniform deposit of medium dense and the field and laboratory test results are as follows angle of internal friction. That means, this is nothing but this is nothing but your phi phi 30 degrees. And gamma actually equal to 19 this is actually gamma gamma saturated and this is gamma dry 17. Determine the ultimate bearing capacity of the footing when water table at 4 meter below the ground surface you can see width of the footing is 1.8 meter 4 meter means it is much below the I will I will show this case; that means, you will be having footing something like this, this is 1.5 meter and this is 4 meter and this is 1.8.

So, 1.5 plus 1 point 8 that is actually 3.3: so 3.3. So, water table initial water table is 4 meter which is greater than 3.3; so that means, case 1 will be having general bearing capacity theories which is there. So, that can be used second case actually when the 2 meter below the ground surface as see at this 3.3 meter, but; that means, above that so; that means, you have to find out the we have to apply the second case. And 1.5 meter that mean exactly at the base of the footing and one meter below the ground; that means, in between the bearing there and at the ground surface that means here.

So, 5 cases are shown that will be explained one by one and I will show the next slide.

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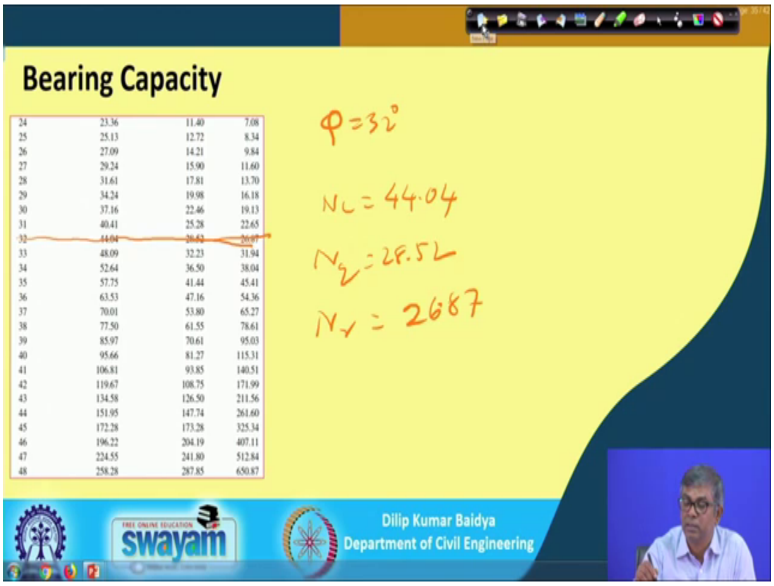

You can see that from phi value actually when it is given 32 degrees and corresponding to phi 32 degrees when 5 equal to when phi equal to 32 degrees. From here actually you can see from here you can see N c N c equal to 40 4 point 0 4 N q equal to 28.52 and N gamma equal to 26.87. So, these are the values to be used in calculation; that means, it is depends on phi.

And now I will be going case by case.

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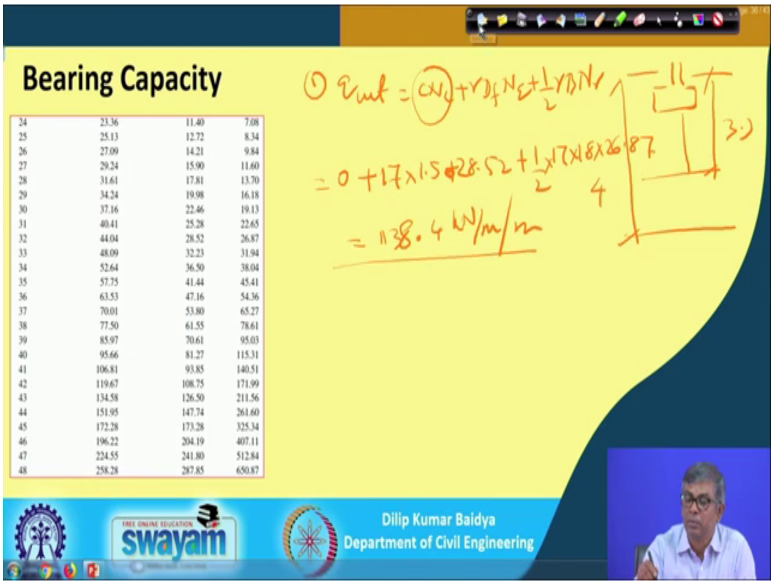

So, let me say case 1: case 1 when your footing is here water table is here and this is 4 meter from here and your shear zone is 3.3 meter. So, case 1 will be q ultimate will be equal to your c N c plus gamma D f N q plus half gamma B N gamma. So, here actually you can see only c is not there. So, it is a cohesionless soil. So, this since N c value is there was c is 0.

So, this part will be 0 plus gamma is actually it is a 17 when it is a dry dap is 1.5 plus multiplied by N q value. N q value is actually 28.52 plus half gamma actually again 17 multiplied by bs 1.8 multiplied by N gamma is 26.87. So, if I multiplied this if I do this one it comes 1 1 3 1 1 3 8.4 kilo newton per meter per meter length. So, this way it will come this is the case 1. That means, the ultimate bearing capacity of the strip footing 11 30 8 kilo Newton per meter per meter length.

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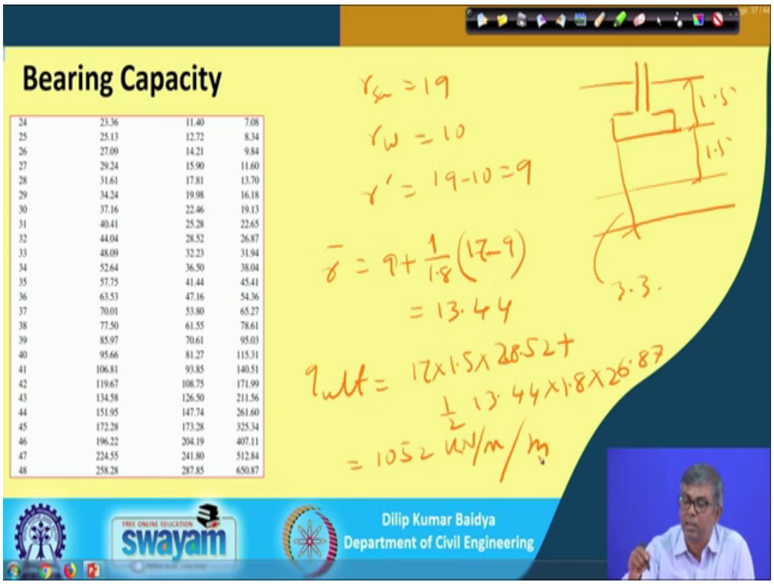

Now, go to the next case second case is somewhere here it is somewhere here. This is actually 2.5 meter. So, this is 1.5 meter; that means this is 1 meter and 3.3 meter this is 3.3 meter. So, you have to find out gamma effective sorry you have to find out gamma effective as you have if you go actually saturated unit weight saturated gamma saturated equal to 19, and gamma w equal to 10 suppose if I take then gamma submerge will be 19 minus 10 will be 9. So, at this when it will be here it will be 9.

So, gamma effective can be calculated gamma effective will be 9 plus 1 divided by 1.8. And this will be 17 minus 9. So, this will be 13.44. So, then q ultimate will be equal to first part will not be there. So, second part will be gamma is 17 multiplied by 17 multiplied by 1.5 multiplied by 8 28.52 plus half gamma effective is 13.4 multiplied by B is 18 multiplied by N gamma is 26.87. So, this value comes out to be 1052; 1052 kilo Newton per meter per meter length. So, this is case 2.

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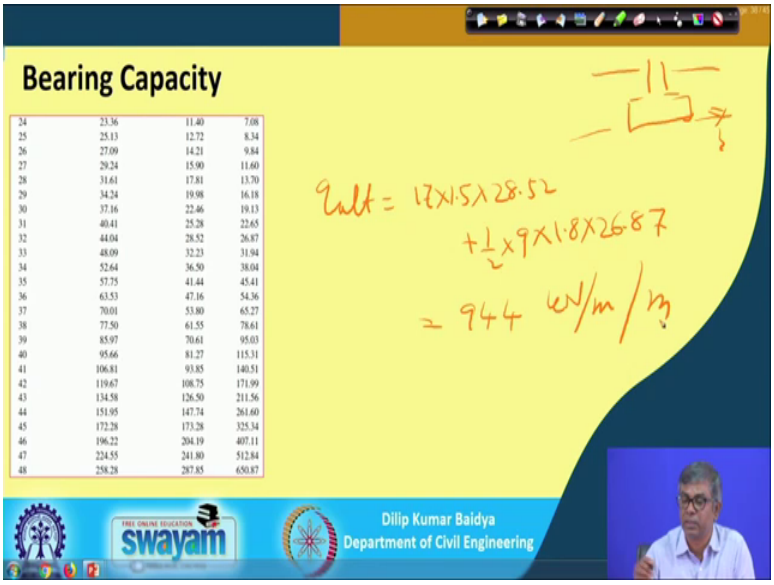

Now, if I go to the case 3, case 3 is something like this. And the case 3 is somewhere here water table is here water table is here. So, when water table is here then your gamma gamma will be use gamma submerge. So, q ultimate will be equal to 17 multiplied by 1.5 multiplied by N q is 28.52 plus half gamma become gamma submerge. So, this will be 19 minus 10 9 multiplied by half 9 divided by 1.8 multiplied by 26.87. So, this gives you that that gives you 944 kilo Newton per meter per meter length.

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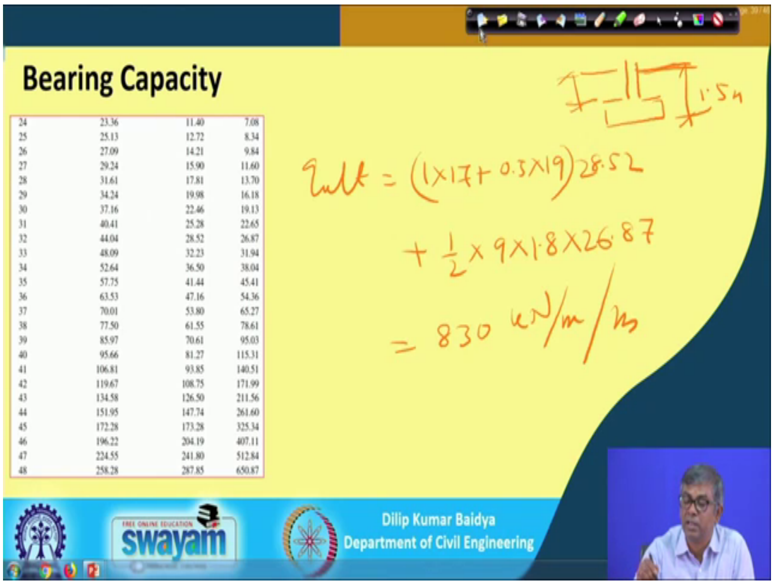

And similarly if I go to case 4; that means, water table is here. This is 1.5 meter, but water table is in between; that means, at 1-meter depth. That is 0 meter; that means, your q ultimate will be equal to 1 multiplied by 17 plus 0.5 multiplied by 19 multiplied by 28.52 plus half gamma submerge will be again 9 multiplied by width of the 18 multiplied by 26 point 8 7. So, it gives you the value equal to 8 30 kilo Newton per meter per meter length. So, this is case 4.

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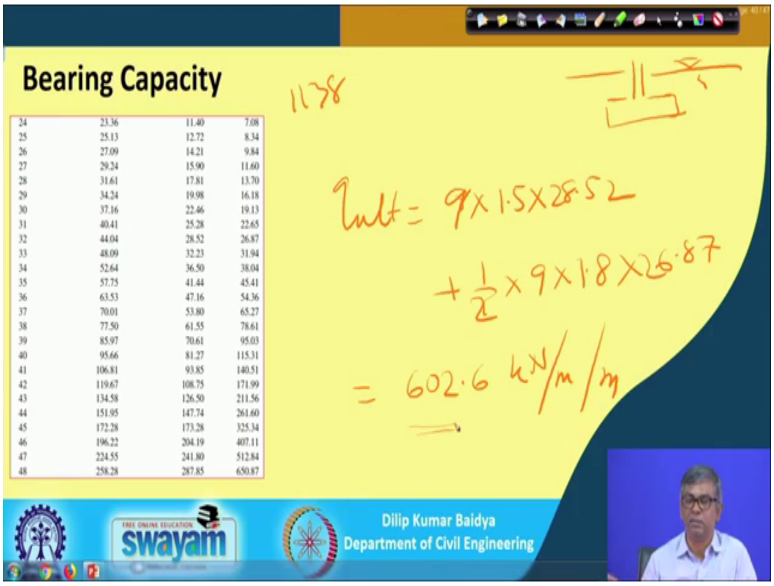

Now, case 5, I will do. Once again case 5 is something like this footing is like this ground surface. So, water table is somewhere here in that case what will happen q ultimate will be equal to your gamma submerge. That means, 9 multiplied by 1.5 multiplied by N q is 28.52 plus half here also gamma submerge 9 multiplied by width of the footing multiplied by N gamma actually 26.87. So, this gives you a value equal to 602.6 kilo Newton per meter per meter length.

So, you can see when you do not consider any effect; that means, if the water table is much below then it is 1138; it was 1138. And now when water table actually comes to the surface it become 600 almost like half. So, that is the thing I want to highlight in later on also some of the problem I will take.

So, with this example I will just stop here.

Thank you. So, I will stop here.