Foundation Engineering
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Lecture - 11
Shallow Foundation - Bearing Capacity I

In the last class, I have discussed about a various geophysical exploration. So, and today this class I will discuss about the Bearing Capacity of Shallow Foundation and what are the different types of shallow foundation, how we will calculate the bearing capacity and other factors related to the bearing capacities.

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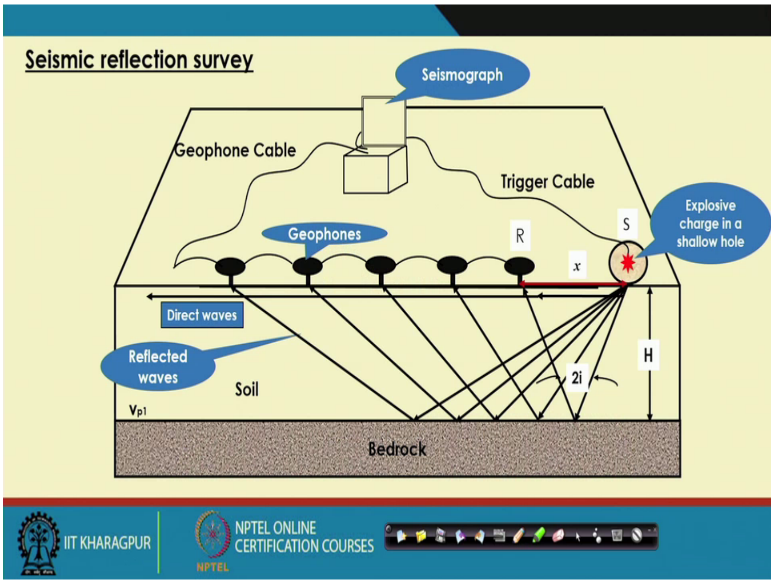

Now, before I start today's topic. So, last class I have discussed about the different types of geophysical exploration. The first one seismic reflection survey and where we can determine the thickness of soil layer and the velocity of the wave. And I have already discussed how this wave can be generated whether it is a shear wave or the primary wave or the p-wave.

And then we can determine the velocity and the thickness of the soil layer, but this method has several limitations that here we have to determine or we have to note the travel time of 2 waves; one is direct wave, another is the reflected waves and here this method is suitable; suitable for the homogeneous soil.

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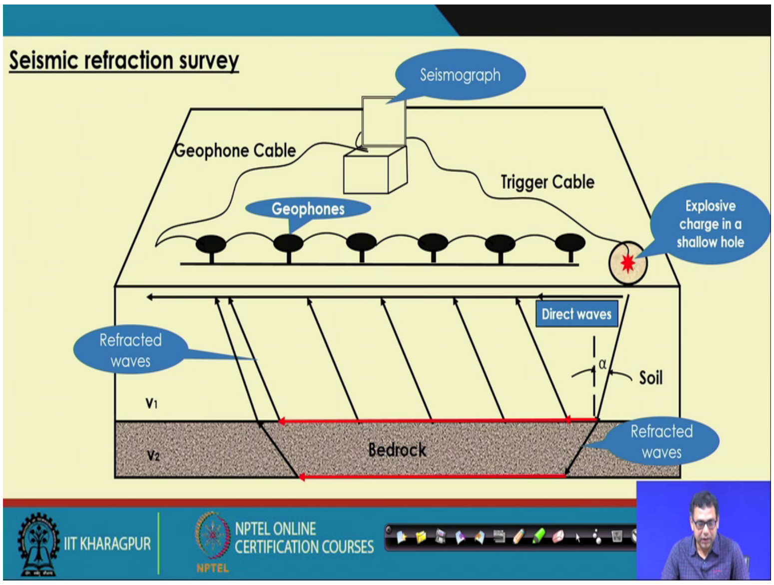

Now, if there is a layered soil and determination of the 2 different waves are sometimes very difficult then we go for the seismic reflection survey which is more popular compared to the seismic reflection survey. So, here we can determine the thickness of n number of layers and we can determine the velocity of the number of layers.

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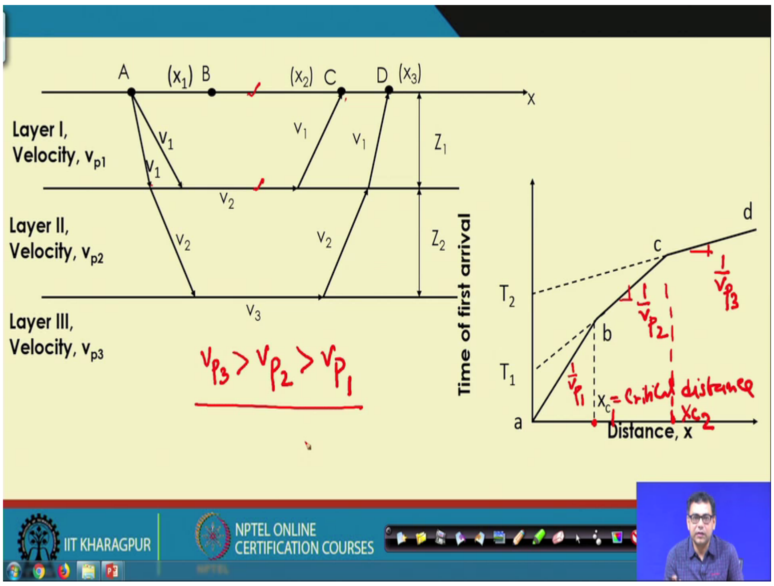

So, here ah; so, this is the different reflect reflected and the direct waves and we are we will get ultimately by using n number of geophone this type of curve. So, slope of this curve will give 1 by vp 1 then the slope of this curve will give 1 by vp 2 then this one will give 1 by vp 3. So, these I have discussed the how I will get these expressions and then these are the different reflected waves and the direct waves

And there is a term that is the X c; it is critical distance and so this is the critical distance; so if we place geophone in between the critical distance from the source then the direct ray will reach first. And if we place the geophones beyond the critical distance then the reflected ray will reach first to the geophone and here the advantage of this method is that here we can we are determining the first arrival wave travel time.

So, that is very easy to identify and if there is a 3 layer system then we will get another critical distance. So, this is also X c; so this is X c 1, this is X c 2; so X c 1 means if I take these wave and this wave. So, if I place geophone within the X c 1 then the direct wave form A to C will reach first. And then if I place geophone beyond the X c 1, but within the X c 2 then this reflected wave will reach first.

But if I place geophone beyond the X c 2 then this reflected ray will reach first as the primary condition of this test is that vp 3 should be greater than vp 2 should be greater than vp 1. So, that is why as we will go in the deeper layers. So, velocity of the wave will increase; so there is a possibility the reflected ray will reach first

Now, this is the primary condition of this test and another one that if I want to cover more depth then you have to increase the distance of the geophone from the source. So, and we have to satisfy this condition; if this condition is not satisfying then we will not get the proper result. Now if, but most of the cases we satisfy this condition that is why this is most popular seismic reflection survey because here with very less time we can complete the survey. But if we do not get this type of condition in the soil layer then we have to go for seismic cross hole survey.

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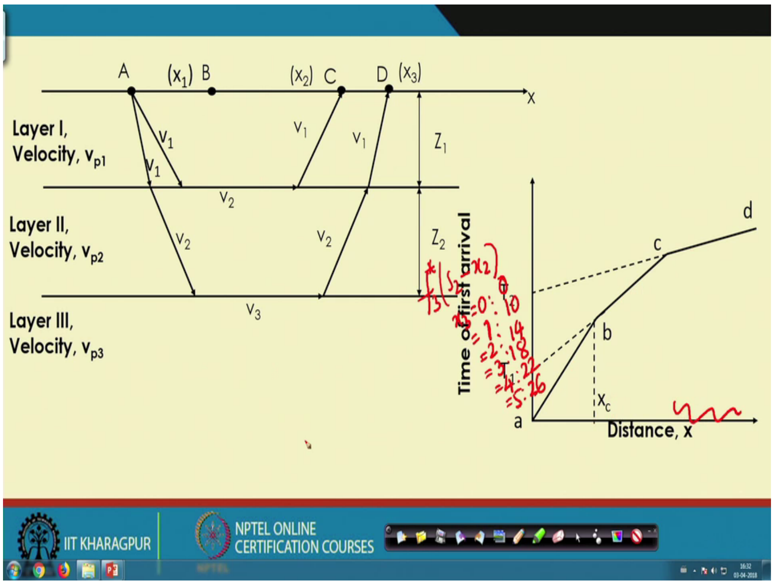

So, where we have to go for the borehole and then we place geophone.

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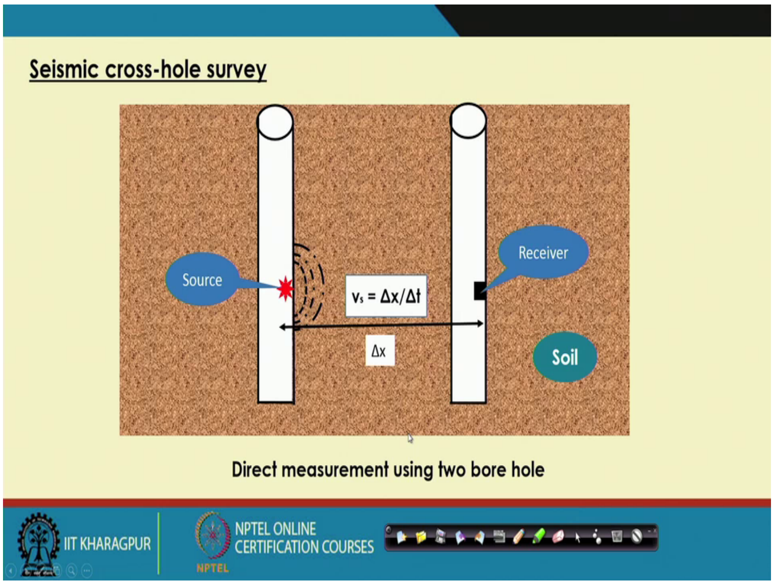

And the source and the receiver and we measure the time interval and this till then we directly get the velocity. So, the problem is that here you have to go for the borehole. So, which is more time consuming and, but if we do not have the soil condition which is required for the seismic reflection test then you have to go for this survey, because here the velocity increasing decreasing it does not matter because here we are going for the borehole.

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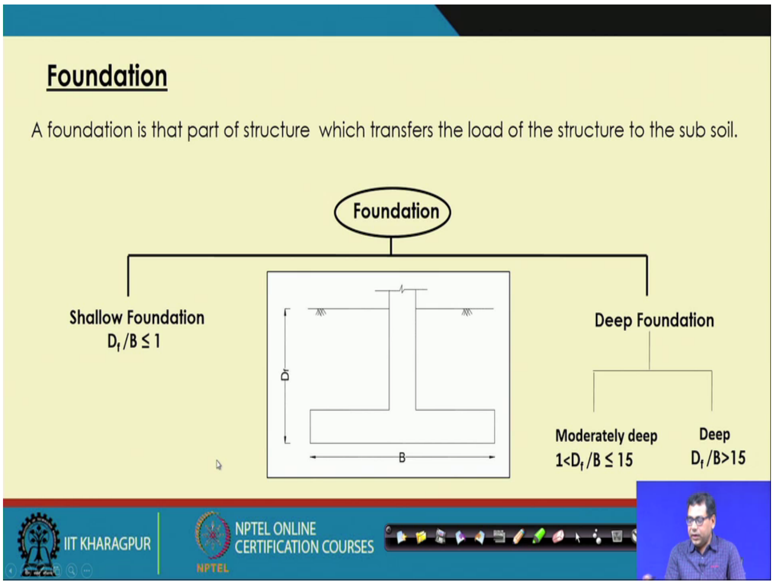

And so, next one that we will discuss about the foundation so now last 2 weeks or the last 10 lectures, we have discussed that how will determine the soil properties; now with the help of laboratory testing and of in situ test. Now here how we will use those soil properties for determination of bearing capacity of a foundation or the settlement of a foundation and then how will design the foundation?

So, before I go for the design part; so, now what is foundation? Now foundation is that part of structure which is which transfers the load from the superstructure to the soil or the subsoil, so; that means, here it will transfer the load from the soil structure to the soil. So, to design the foundation we should know what are the loads coming from the superstructure and what are the sub soil properties. So, these are very important.

So, now the foundation it is generally 2 types; one is the shallow foundation, another is the deep foundation. So, here you can say this is shallow foundation is defined as if the depth of foundation is less than equal to the width of foundation. So, this is a typical foundation where D is D f is the depth of foundation; so, this is the base of foundation. So, the depth of foundation is the depth from the ground surface to the base of foundation and width of foundation is the B. So, now, if it is satisfying this condition then this is called as a shallow foundation.

Now, in other way deep foundation is there; that means, if the depth of foundation is greater than the width of foundation. So, but if it is within the 1 to the 15; if it is greater than 1, but less than equal to 15 then it is called moderately deep, but if it is deeper than 15 then it is called the deep foundation. So, now, in this lecture I will discuss about the shallow foundation and then the coming lectures I will discuss about the D foundation also.

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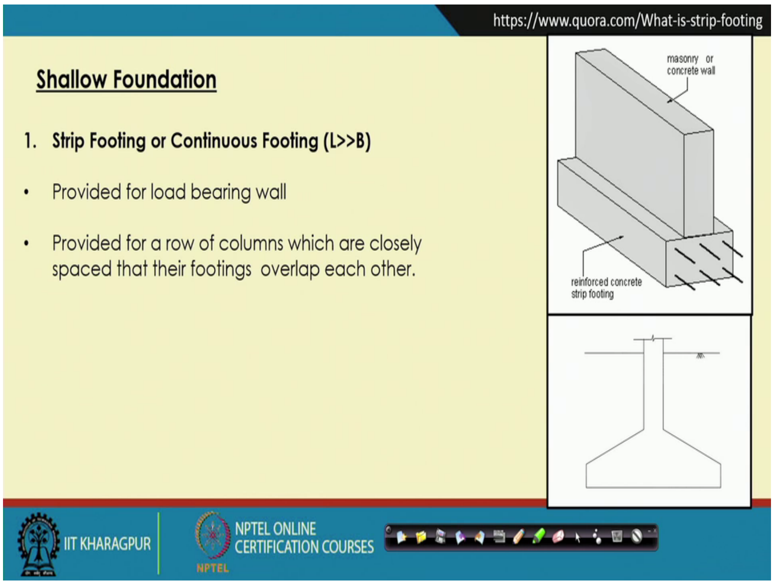

Now, the shallow foundations are in different types. So, these are I will discuss what are the different types of shallow foundation? The first type is the strip footing or the continuous footing. So; that means, you can see this is the photograph of a strip footing where the length of the footing is much greater than the width of the footing. So, this is the typical strip foundation strip footing where you can see the length of the footing is much greater than the width of the footing. So, because this is the width of the footing, this direction this is the length of the footing

Now, where it is being used? So, it is been provided for load bearing wall. So, this is the example of a typical load bearing wall which is the continuous type of a foundation. So, here length is much higher than the width of the footing; now it is also provided for a row up column which are closely spaced and their footings overlap each other. Now if you have a very closely spaced row up columns; then if I provide the footing for each column, then there is a possibility that the each footing may overlap.

So; that means, one footing may overlap to the another one; so, instead of going for individual footing in that case then we can go for a long footing or the in that where the length of the footing is much higher than the width of the footing. So, that type of foundation is called the strip footing or the continuous footing.

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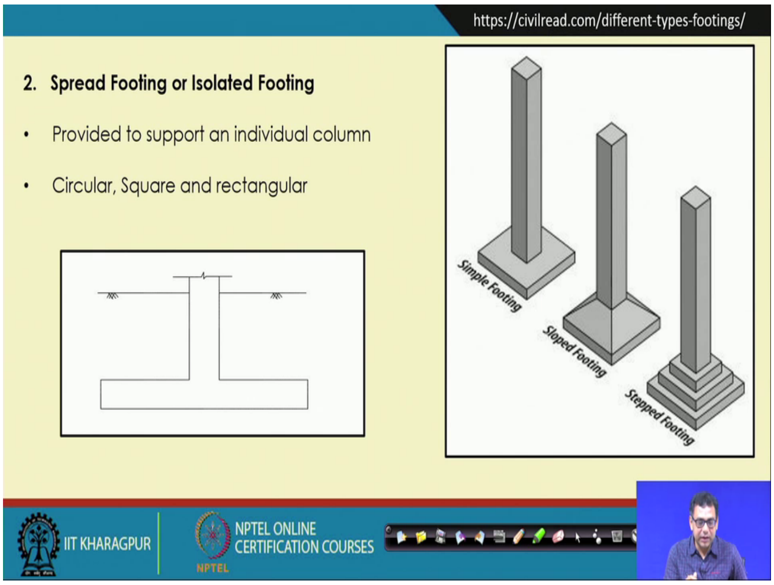

Next one is the spread footing or the isolated footing; now you can see the these are the different one square type of spread footing. So, this spread footing can be circular, can be square or rectangular. So, here the photograph is showing it is a particular square type of spread footing with different type of arrangement or you can say this is a simple one, this is a sloped type of arrangement or this is a stepped type of arrangement, but all the cases it is isolated footing.

So, each footing is given under a particular column. So, here there is no overlap and there is a particular clear spacing between the 2 footing; so this is that is why it is provided to support an individual column and as I mentioned it can be circular square or rectangular.

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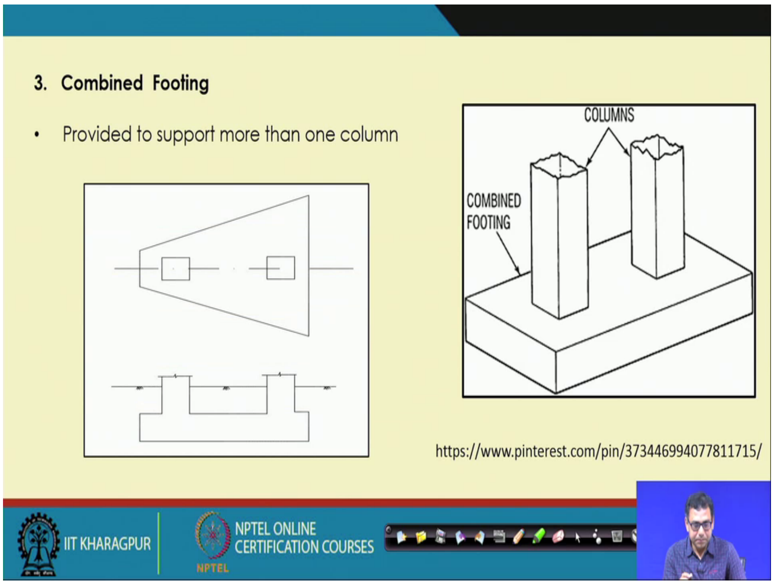

And the next one is the combined footing; so, when we provide footing for more than 1 column. So, here this combined footing is provided for 2 columns. So, here this can be different shape it can be in triangular form, it can be in the rectangular trapezoidal form depending upon; so, the site requirement. So, we can provide the footings were more than 1 column. So, that type of footing is called the combined footing. So, this is a typical photograph or the figure of a particular combined footing.

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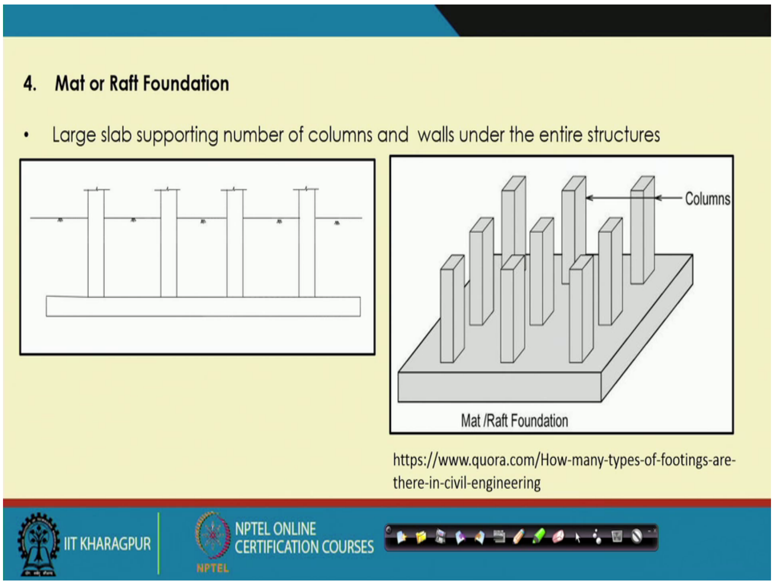

Then the next one is the Mat or the Raft foundation. So, the large slab supporting number of columns and wall under the entire structure is called the raft or the mat foundation. So, you can see; so, this one particular one footing is provided for the entire column covering the all the walls or the columns that is coming on the soil. So; that means, t from the superstructure the all the columns we are covering under a single footing. So, this is a large slab; so, you can see this is a large slab which is covering all the columns. So, this type of foundation is called the raft foundation.

So, basically here in this course I will design isolated footing and a raft footing both. So, and then and then we can discuss about the strip footing and we can discuss about the combined footing also. So, in the shallow foundation part I will mainly discuss these 4 types of footing that is the strip footing, spread footing either circular square or rectangular or combined foot and combined footing and the raft foundation and the design procedure design guidelines are different for different kinds of footing.

So, and this type of footing has an advantage also because here we are taking the entire structure as under a one particular footing. So, when if I provide the isolated footing under a single column then there is a possibility then we have some differential settlement, I mean settlement and the different part of the structure may be different for different footing because your load is not same or throughout the structure soil condition may different from one side to another side of the building.

So, there is a possibility of the differential settlement now if we have the excessive differential settlement then if I provide this type of foundation then those that settle differences settlement also can be prevented. Because here we are taking the entire load under a footing and entire columns under a footing and then we are because this is a rigid type of footing.

So, isolated footing is a flexible type of footing and if you are providing the wrap with enter all the columns then this is a rigid type of footing. So, we are providing so rigid rigidity that is why the possibility of the differential settlement will also be reduced.

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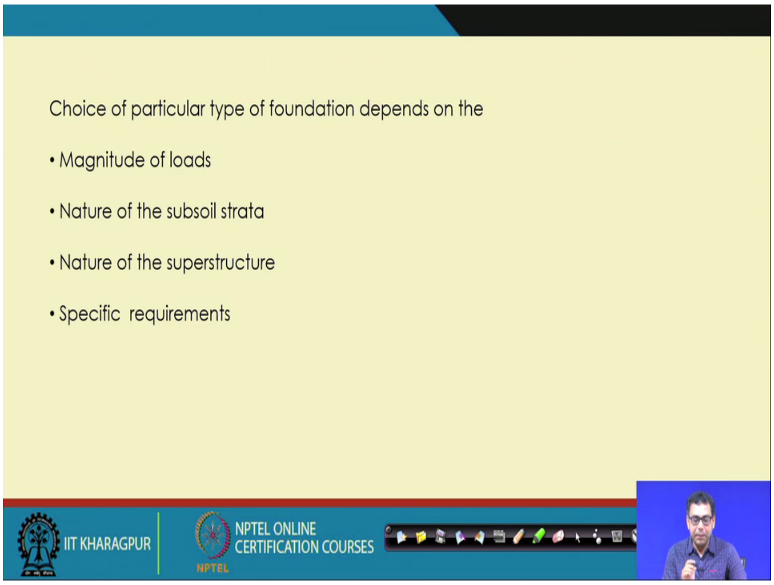

So, next one is the choice of a particular type of foundation so; that means, as I mentioned we are discussed about the different types of foundation shallow foundations. So, then which one we will choose that depends under the how much loading is coming from the superstructure, then the sub soil properties, then the nature of the super structure and specific requirement.

So, sometimes for the specific requirements also we have to choose the footing in the in the combined footing that we cannot go for a beyond the edge of the column in certain distance because of the restriction then we have to go, we have designer our footing in that way. So, in that is way we will decide based on these 4 factors that will decide whether we will go for the isolated footing or will go for the combined footing because if we have because the loading is one major factor and the soil properties are the also major factors? So, later on when I design all thing; so, you will see that that based on these properties we have to decide which type of footing we will consider.

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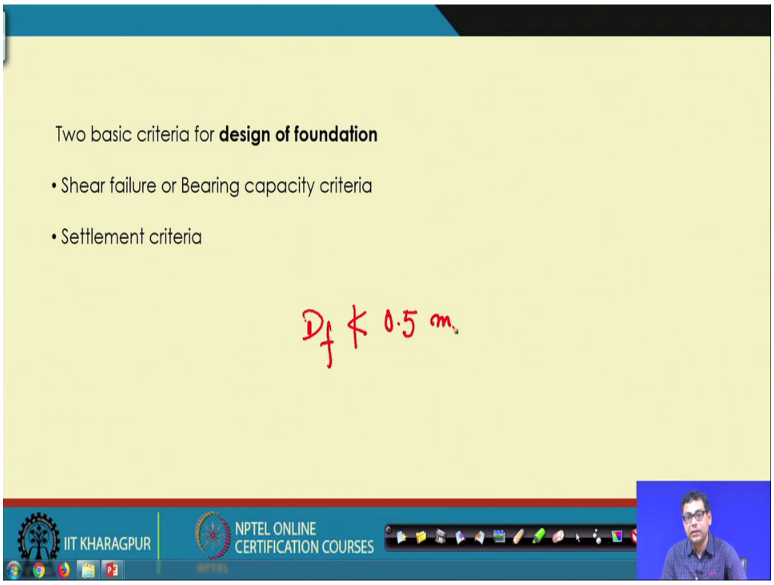

So next one the now when you design a particular footing; so, there are 2 basic design criteria's. So, one is the bearing capacity criteria or the shear failure criteria another is the settlement criteria. So, that when you design the footing you have to keep in mind that avoid the footing that I am designing it should capable to take the load that is coming from the superstructure. And at the same time there should not be a excessive amount of settlement in the footing.

So; that means, you have to take care 2 things one is the bearing capacity; that means, your foundation can carry that load which is coming from the superstructure and then R should not be any excessive settlement. And we have to check these 2 criteria's separately and then you have to decide that what would be the amount of load you can put on that particular loading or vice versa; for a particular loading what would be the dimension or depth of foundation for a particular footing.

And these are the 2 criteria's in addition to that there is a depth criterion. So, we should know where you will place your foundation. So, for example, as per the is code recommendation that we have to provide at least 50 centimeter, or 500 millimeter depth of the foundation so; that means, your D f that depth of the foundation D f cannot be less than 0.5 meter. So, that is the minimum depth required of a foundation; the reason is that you cannot place the foundation is a very shallow depth, so and because you have to provide at least 500 millimeter or 0.5 meter depth below the ground level.

So, because as if there is a water flow or they in the soil above the foundation can wash away. So, if I provide a very small depth above the foundation. So, this is the recommend minimum recommend as per the is code; in addition to that then later on will during the design you can find that where I will place the foundation?.

So, if we have a layered soil then you have to design that decide where I will place the foundation? Suppose if you have a very soft soil and then a hard soil then it is better to place the foundation on the hard soil rather than the soft soil because then we will get the more bearing capacity. So, those things will be decided; so, that is why the depth character is also important thing that where I will place the foundation, but the major 2 criteria are the bearing capacity and the settlement.

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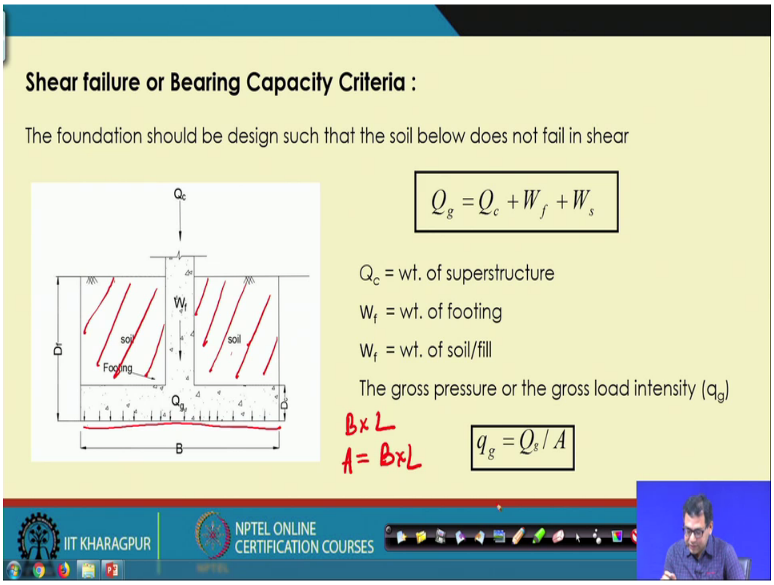

Now, as I mentioned that the bearing capacity foundation criteria; now that the foundation should be designed such that the soil below does not fail in shear. So; that means, as I mentioned that we have to design the foundation such that the foundation can take that load that it means that this foundation is transferring the load which is coming from the superstructure to the soil. So, when we apply the load on the soil; so, the soil will shear. So and there is a possibility that the fail shear failure will occur because soil always fails in shear?

So, whenever we apply the load this is a possibility the shear failure will occur so; that means, each soil has its own load carrying capacity or the strength carrying capacity stress carrying capacity based on the strength of the soil. So, and this is the strength parameter as I mentioned in the third lecture that the c phi equation and the friction these are the 2 strength parameter. So, based on the strength of the soil each soil has its stress carrying capacity.

Now, the stress which is coming from the foundation to the soil if more than the strength of the soil then it will fail. So, I am it will fail in shear so; that means, you have to design the foundation such that the soil will not fail in shear. So, what are the loads actually coming on the soil; so one load Q c which is coming from the superstructure through a column to the foundation and form the foundation to the soil.

Now, in addition to that there are other loads that is also acting that this is our; foundation and below the ground this is the ground level and below the ground this is the foundation. So, Qc's acting from the superstructure then W f is the weight of the foundation or footing itself that is also coming on the soil and the weight of the soil because this portion. .

So, when we construct the foundation; so, initially this is our virgin soil. Now you we have to excavate this portion of the soil for the construction purpose. So, we will remove this soil; excavated sea soil constructs the foundation then again we will fill this portion of the soil.

So, the total weight which is coming here is the summation of these 3 that the load which is coming from the superstructure weight of the foundation itself and the weight of this fill. So, that is the gross amount of load which is acting on the base of the footing or the soil. So, the total gross load is Q c plus W f plus W S; S is the weight of the soil or fill.

So, now if I divide this total loads with the area of the foundation. So, if there is B into L if the B is the width of the foundation, L is the length of the foundation then this will be the area of the foundation. So, if I divide it by the area of the foundation then we will get the gross pressure of that is coming on the soil. So, this is q capital Q g is the gross load and small q g is the gross pressure because we are dividing the gross load by the area.

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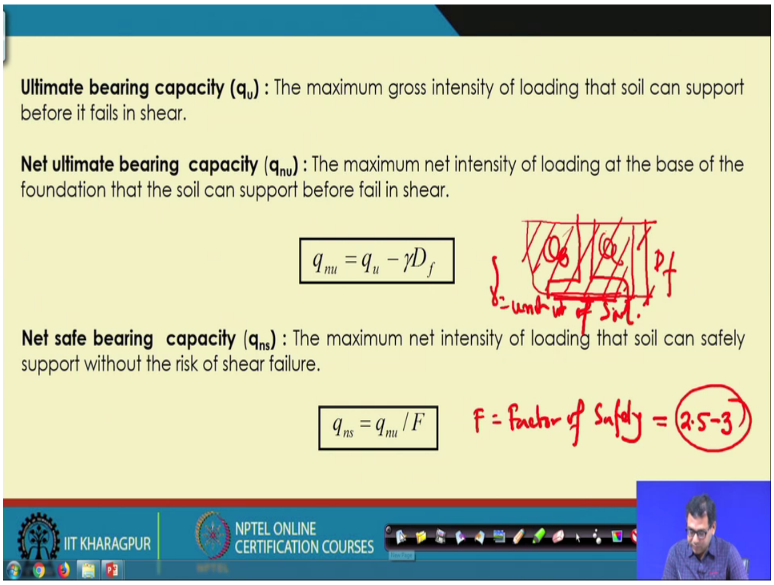

Now, this is the gross load and in addition to that we have different terminology that we will use frequently. So, first explain what are these different terminologies? Because in the bearing capacity one I have discussed about the gross pressure, the next one is the ultimate bearing capacity q u. So, what is ultimate bearing capacity? Ultimate bearing capacity is the maximum gross intensity of loading that soil can support before it fails in shear. So; that means, this is the maximum gross stress or gross pressure that is acting on a soil before its fail; so, that is the ultimate bearing capacity qu.

Then the net ultimate bearing capacity; so, as I have mentioned that if this is the virgin soil, so, and this is the depth of the foundation or the depth where you placed your foundation. So, initially there where stress of this soil because this overburden stress were there.

Now, when due to the excavation we are removing this portion of the soil. So, we are removing this portion of the soil; so, basically we initially we are releasing the stress over this base. Now we are constructing the soil foundation then the load is coming from the superstructure total then the total load is the superstructure load, then the load of the foundation itself. And then when there will be construction then we will fill this portion with again soil. So, these are the total gross, but this base is sub is subjected to the pressure which is not the gross pressure because initially there was a overburden pressure due to the soil.

So, the net pressure that or net stress this soil is subjected is the ultimate load or the gross load minus the gamma into D f the gamma is the unit weight of the soil. So, this gamma into D f were initially there on the soil now because of the excavation you are removing that now we are applying the total load which is the gross load.

So, the net load will be the ultimate bearing capacity minus gamma into D f because this gamma into D f initially was there. So, that is the net load which is the weight of the superstructure load or weight of the footing plus the load which is coming from the superstructure. So, that much of the net load we can apply on the soil because the gamma D f were always initially there, so the superstructure and the foundation load that will be the net load.

So, the net load the net ultimate bearing capacity will be the ultimate bearing capacity minus gamma into D f. Then the next one is the net safe bearing capacity. So, the maximum the definition is that. So, the maximum net intensity of loading that soil can safely support without the risk of failure.

So, there is the net bearing capacity is the maximum net intensity of loading at the base of the foundation that soil can support before it shear. But here we have not applied any factor of safety so; that means that if we apply some factor of safety then the net ultimate will become the net safe bearing capacity so; that means we are applying some safety factor.

So, that is why if I divide it with that net ultimate bearing capacity by a factor F; this F is called the factor of safety generally this value is taken as 2.523 in case of bearing capacity calculation. So, this is the range that we will use as a factor safety when we calculate the load carrying capacity or the bearing capacity of the soil.

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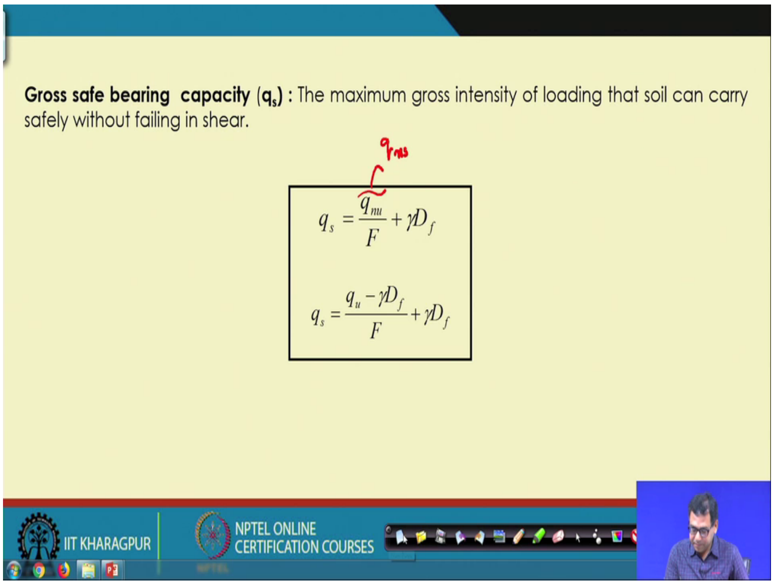

Next one is the gross safe bearing capacity. So, now the gross safe bearing capacity is the maximum gross intensity of loading that soil can safely take without failing the shear so; that means, here what is gross safe bearing capacity? So, gross safe bearing capacity we have the net safe bearing capacity; so, net safe bearing capacity is the load that is coming due to the footing load and the superstructure load; so, but soil can take the overburden pressure also.

So, that is the net if I add that overburden pressure; so, then that will be the gross load; so or the gross capacity. So, that is the thing this is the net safe this is actually this is the q net safe, this is that q net safe then plus gamma D f. So, this net safe is net ultimate divided by factor of safety and net ultimate is q u minus gamma D f divided by a factor of safety plus gamma D f.

So, when you we are calculating the bearing capacity there a different form of bearing capacity. So, we have discussed that; so, if you have to express them in that form which is been asked to determine. So; that means, there is a gross ultimate load carrying capacity then net ultimate load carrying capacity or bearing capacity, then net safe bearing capacity then the gross safe bearing capacity. So, these are the 4 terms which will be very useful and we will use them frequently.

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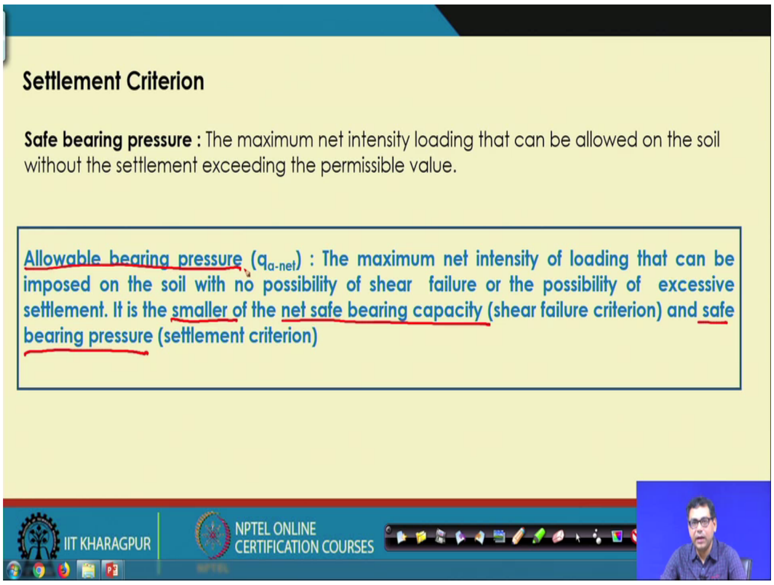

Then so, these 4 terms that I have discussed it is in terms of shear failure or the bearing capacity failure, but in terms of settlement there is another term which is called safe bearing pressure. So, the maximum net intensity loading that can be allowed on the soil without the settlement exceeding the permissible value.

So, as I mentioned that every foundation we are designing with the permissible settlement. So, the different code has given the permissible settlement; so, we have to follow the code under which we are designing the foundation. So, thus the maximum net intensity; remember that is the net intensity or the net intensity of loading that is allowed on the foundation so, that there should not be a settlement which is beyond the permissible one.

So, that load or is or the pressure is called a safe bearing pressure so; that means, here we have 2 based on the 2 criteria we have the pressure one is the in terms of bearing capacity or in terms of settlement. Now, then the next one is very interesting that is the allowable bearing pressure you know how much stress we can allow on the soil. So, this allowable bearing pressure is the minimum of these criteria's; that means, the pressure that we can apply on a soil the minimum pressure that we can apply on a soil in terms of bearing capacity criteria or in terms of the settlement criteria and the minimum of these two.

That means, the maximum pressure that we are applying on a soil in terms of bearing capacity criteria and the settlement criteria and minimum of these two will give you the allowable bearing pressure. That means, the maximum net intensity of loading that can be imposed on the soil with no possibility of shear failure or the possibility of excessive settlement; it is the smaller of net safe bearing capacity in terms of shear failure criteria and the safe bearing pressure in terms of settlement criteria.

So; that means, it is the smaller of the net safe bearing capacity. So, we have discussed among these 4 this there is the net safe bearing capacity in terms of shear failure criteria and then the safe bearing pressure in terms of settlement criteria. So, the smaller of these 2 will be the allowable bearing pressure.

So, when we determine these thing; when we design these foundation will use this allowable bearing pressure and then this allowable bearing pressure is the maximum intensity that that we can the intensity of load that we can apply on a soil in terms of bearing failure criteria and the maximum intensity of load; we can apply in terms of settlement criteria then minimum of these two will give me the allowable bearing pressure.

Another thing I want to mention that in terms of when you are talking about bearing criteria; we have applied the factor of safety f, but when we are talking about the settlement criteria we are not applying a factor of safety because here we are determining these in terms of a permissible settlement value. So, here the settlement value is given we cannot exceed that settlement value during our design. So, factor of safety we apply on bearing capacity not in the settlement because here we are designed the load based on a particular permissible settlement.

So, these are the all terminology. So, next class I will discuss how I will determine the bearing capacity of a soil. First we will discuss the bearing capacity criteria then I will discuss the settlement criteria. So, first in the next class I will discuss how we will determine the bearing capacity of the soil, what are the different theories are developed to determine the bearing capacity and what are the difference between them and how we will determine the bearing capacity of a soil?

Thank you.