Foundation Engineering
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Lecture - 12
Shallow Foundation - Bearing Capacity II

I have discussed about the different types of Shallow Foundation.

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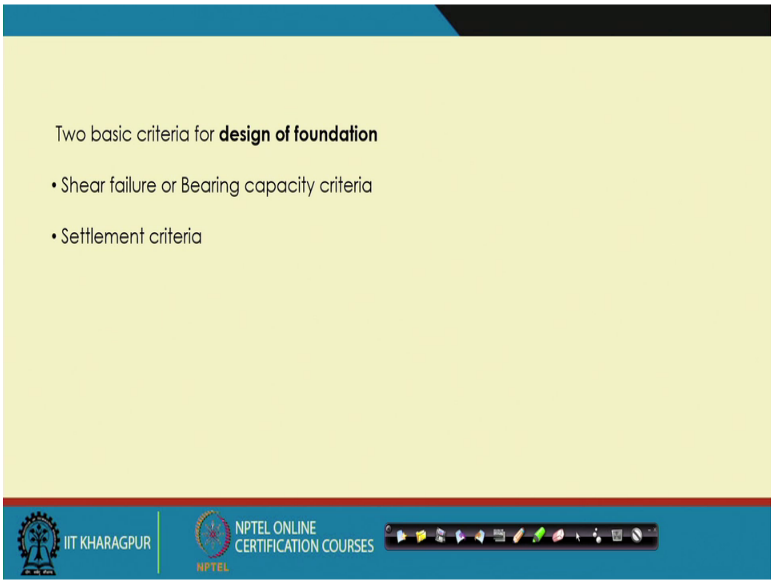

And, then I have discussed about the two basic criteria of design of foundation; that is shear failure or bearing capacity criteria and the settlement criteria.

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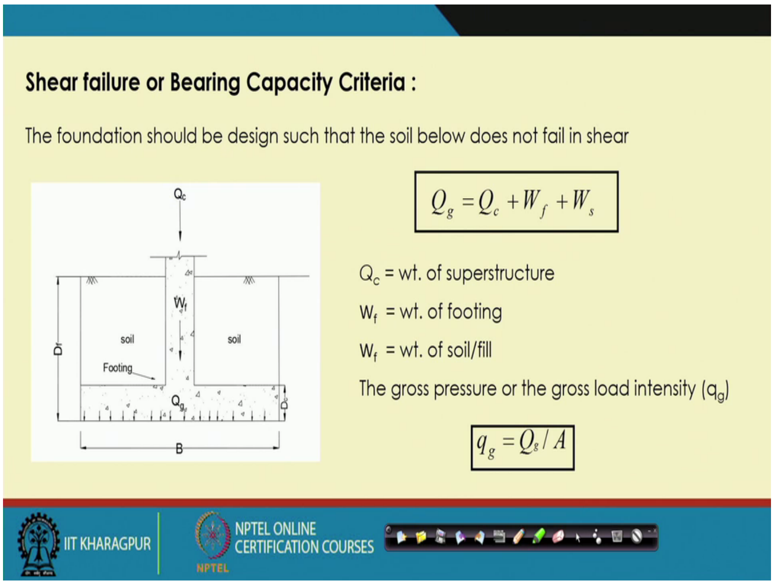

And then we have discussed about the bearing capacity criteria, then what is the gross load? What is the gross pressure?

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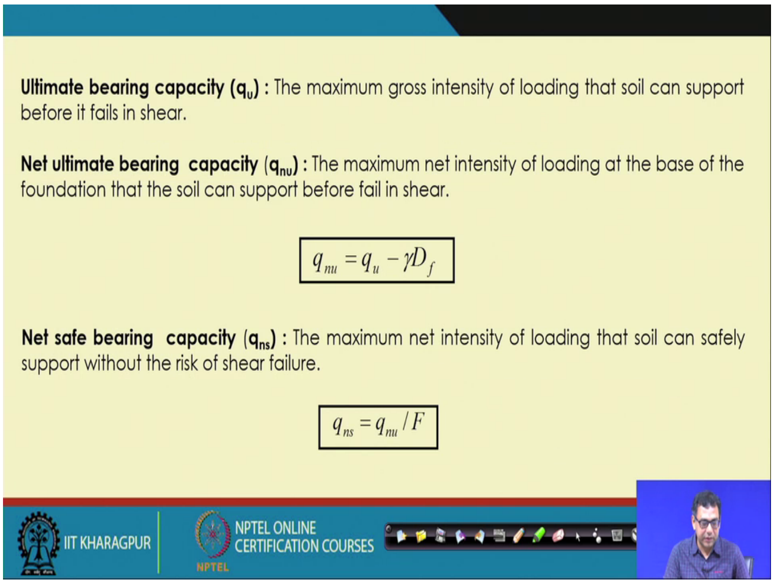

Then what is the ultimate bearing capacity, in net ultimate bearing capacity, net safe bearing capacity, then the gross safe bearing capacity.

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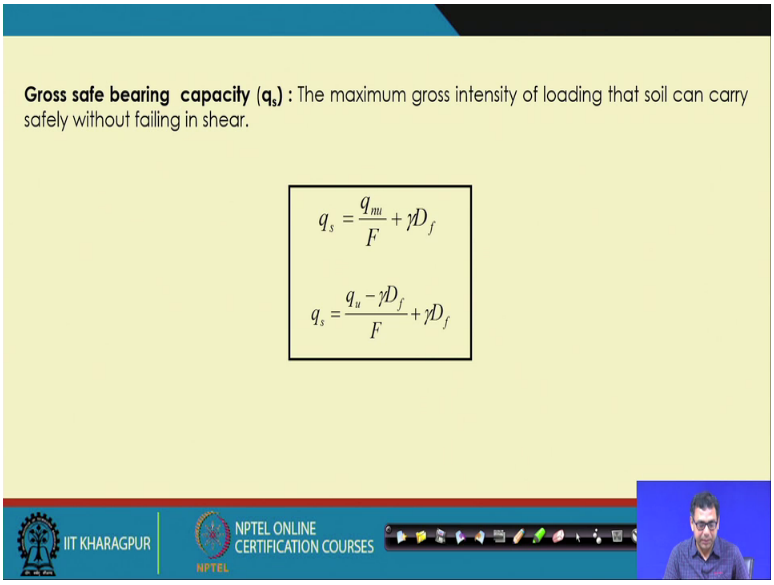

Then, the in terms of settlement criteria what is the safe bearing pressure?

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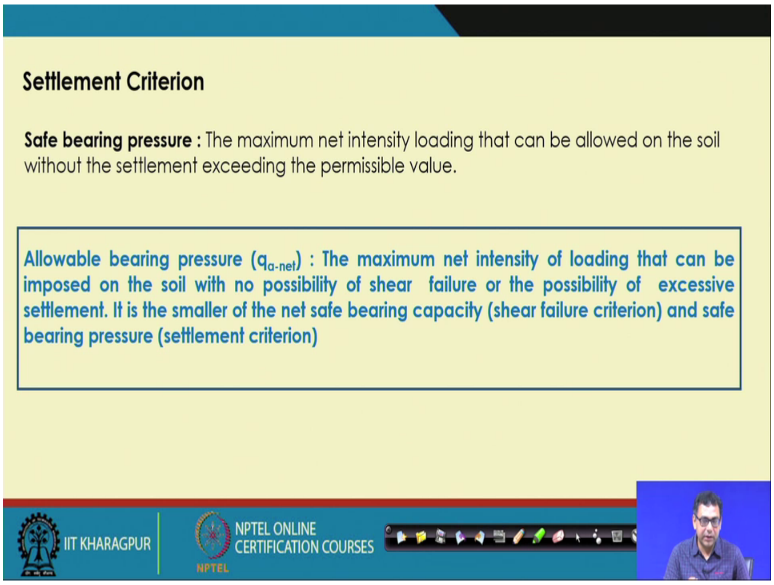

And then so, finally, the allowable bearing pressure, which is the maximum net instant intensity of loading that is coming, we can allow on a foundation in terms of bearing criteria and in terms of settlement criteria and minimum of these 2 will give me the allowable bearing pressure.

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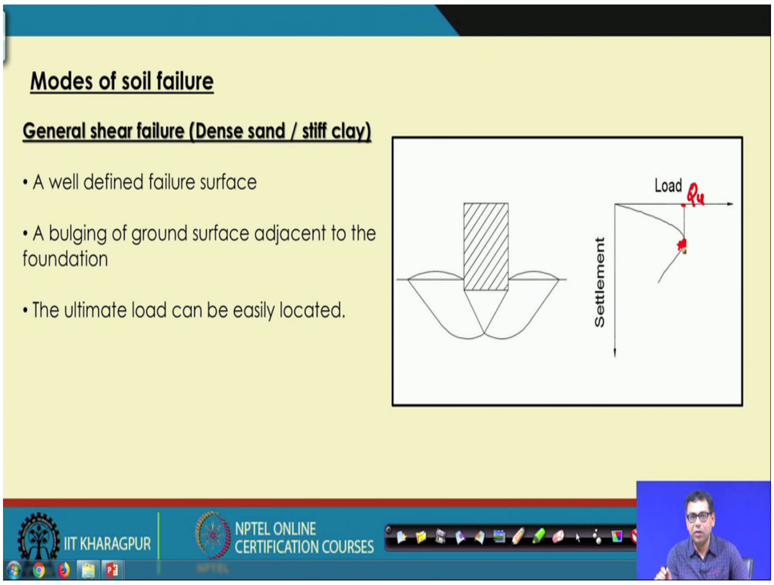

So, now in the today's class I will discuss about the modes of shear failure, because we are talking about when you apply the; a load on the foundation; so there will be shear failure. So, there are different modes of shear failure there are basically 3 modes of say shear failure, they are the general shear failure, a local shear failure and the punching shear failure.

So, first one is the general shear failure. So, what is general shear failure? Now this general shear failure can occur in dense sand or the stiff clay.

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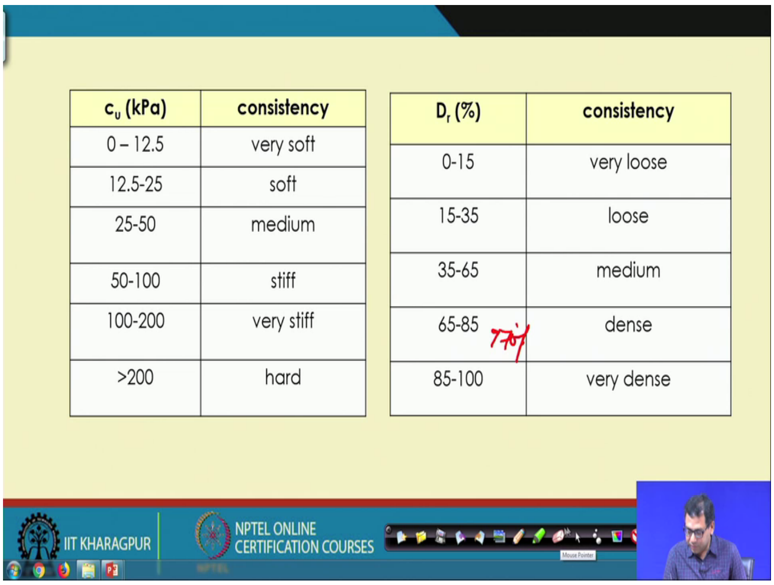

c_u (kPa)	consistency
0 – 12.5	very soft
12.5-25	soft
25-50	medium
50-100	stiff
100-200	very stiff
>200	hard

D_r (%)	consistency
0-15	very loose
15-35	loose
35-65	medium
65-85	dense
85-100	very dense

So, I have given you the all the concentration consistency chart for the clay and the sand.

So, from here you can see that the stiff clay means if the cu value undrained cohesion value is 50 to 100 k P a. So, if your cu value is more than 50 k P a and then we will expect a shear failure a general shear failure. And if your consistency of the sand it is in dense that mean 65 to 70 generally if it is greater than 70 if it is greater than 70 percent then you can expect a general shear failure.

So, now, what are the characteristics of general shear failure? So, if this is the; so, when we apply a load. So, there will be a failure and this there will be the these are the failure line. So, this is the failure plane or the shape of the soil.

So; that means, here if and this is the load if I load the apply the load on a soil through the footing, if we measure the settlement then we get a loads, but settlement curve. So, if I apply the load settlement will increase and then we will get a load versus settlement curve and the characteristics of general shear failure is that here the failure the well-defined failure surface.

So, this is the failure surface that we are talking about these are well defined, then the bulging of the ground surface adjacent to the foundation will occur so; that means, the soil adjacent to the foundation because we are applying the load here the soil adjacent to the foundation, they will bulge because it is the dense sand or stiff clay. And then we will get a prominent peak in the load settlement curve, this is the prominent peak so; that means, we have this load increases then after the fail it is indicate the soil has failed.

So, after this failure it will decrease so; that means, we can have a prominent peak in the load settlement curve. So, the ultimate load can easily be located; so, this will be the ultimate load. So, this is the Q ultimate. So, this is the ultimate load that soil can take before the fail before it fails in shear. So, that is why we can locate this ultimate load very easily. So, these are the characteristics of general shear failure.

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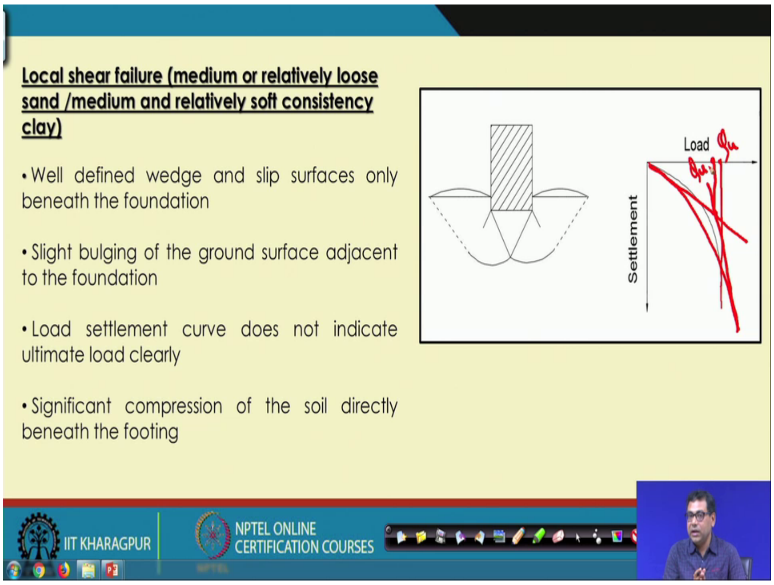

Now, what are the characteristics of local shear failure? So, this local shear failure this may happen for medium or relatively loose sand or medium and or relatively soft consistency clay.

So, now here if you look at this failure and the load settlement curve. So, similar here this failure surface is well defined, but it is below the footing zone only. Because outside the footing zone this failure surface is not well defined so; that means, the well-defined oh or a slip surface only beneath the footing, outside the footing it is not well defined and the thus the bulging that will occur the, but that is not that the significant amount as compared to the general shear failure. So, here bulging will occur, but that is a slight bulging will occur.

But, in case of general shear failure a significant amount of bulging will occur, but in the in the load settlement curve like the general shear failure, here we do not have any prominent peak. So, because here load if you increase the load settlement will increase so, there is not a pre prominent peak.

So, we cannot determine the ultimate load very easily; so, that mean the load settlement curve does not indicate ultimate load clearly. So, we cannot have that the clear indication like the general shear failure what is the ultimate load? And the significant compression of the soil directly beneath the footing.

So, we have a significant compression of the soil directly beneath the footing. So, here these are the characteristics of the local shear failure and then the question is how we will determine the load; for incase of ultimate load, in case of this type of load settlement curve. Because there is there is methods by which we can determine the load with this type of load settlement curve. So, that is called the single tangent method or the double tangent method.

So, single tangent method means suppose we have if it is perfectly parallel to the settlement axis; load settlement curve after certain settlement, if it is parallel to the settlement axis, then we can draw a tangent over the last portion of the curve. So, we can get a Q u and if it is not parallel still it is increasing kind of thing, then we can go for the double tangent method. We can draw a tangent on the initial straight portion of the curve and a final state portion of the curve, then the intersection point will give me the Q u.

So, there are 2 methods one is single tangent method the first one is a single tangent method and the next one is the double tangent method. In the single tangent method, you are drawing the tangent. The last straight portion of the curve and in the when if the curve is parallel to the x axis or the settlement axis and or here settlement is the y axis.

So, if it is parallel to basically a settlement axis. And, in the double tangent if it is not parallel to the settlement axis. Now, then we can draw a tangent on the initial state portion of the curve and the final state portion of the curve, down the load corresponding to the this intersection point will give me the ultimate load.

So, in like the general shear failure, here we cannot directly calculate the ultimate load, because here there is no definite peak.

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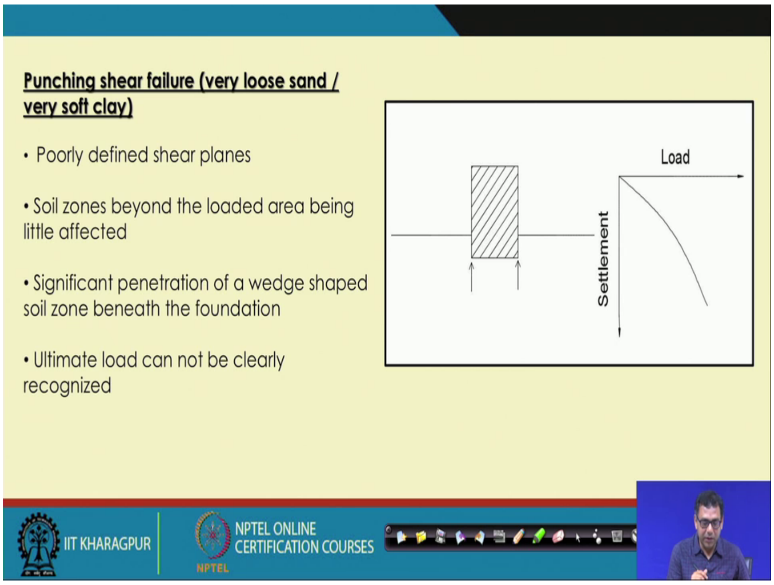

Then, the next type of failure is the punching shear failure, where it is happen for the very loose sand or very soft clay. So, if we you can see that here this is the poorly defined failure shear plane; basically this shear plane is very poorly defined. So, and the soil zone beyond the loaded area are being a little affected.

So, in the first one general shear failure soil zone beyond the load area is significantly affected, in the second case the soil zone beneath the footing is significantly affected and outside the footing also slightly affected, but here the soil zone outside the footing is not affected it is. So, only the soil below the footing zone is significantly affected and significant penetration of the wedge shaped soil zone beneath the foundation.

So, the penetration of the soil is significant below the foundation only, and again like the; like that local shear failure the ultimate load cannot be clearly recognized. Here also you can see there is no definite peak like the general shear failure. So, here also we have to go for the double tangent method to determine the ultimate load it is no definite peak. So, these are the 3 types of failure and there their characteristics.

So, and depending upon which type which type which type of soil on where we are designing our foundation. So, we have to consider that failure and we have to design accordingly, and in that basis we have to apply the recommended design guidelines or the bearing capacity expressions.

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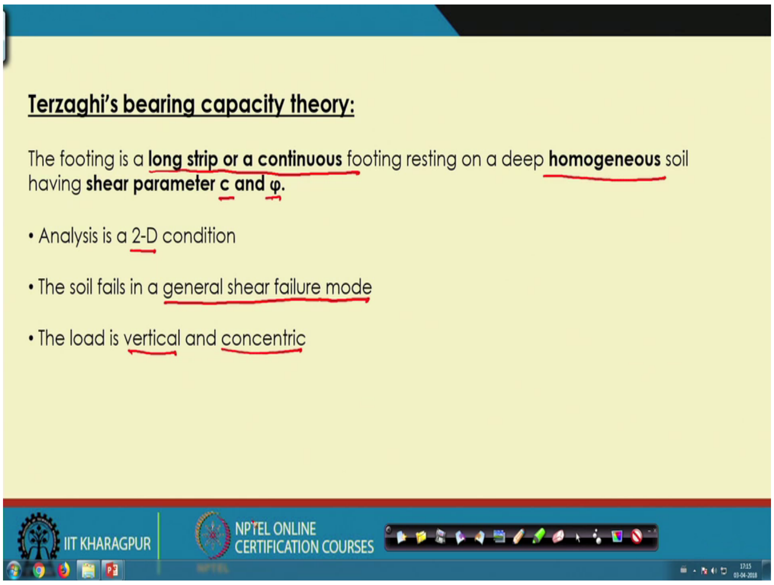

Now, the first bearing capacity expression was proposed by the Terzaghi. So, this is the first bearing capacity expression. So, now, we have to theoretically determine that what will be the ultimate load carrying capacity of the soil or the foundation.

So, now we have c and phi 2 strength parameters. Now, how we will use them with the you with the help of this strength parameter, how we can calculate? What would be the load carrying capacity of a foundation? So, first the bearing capacity theory was proposed by Terzaghi and this theory was very simple and that is why still we are using this theory very and this theory has some assumptions.

So, what are those assumption that this is applicable for strip or a continuous footing. So, which is applicable for remember that the theory Terzaghi's bearing capacity theory, that is originally developed is a applicable for the strip footing, resting on a homogeneous soil. It is not a layer soil it is the soil is the homogeneous and shear parameters are c and the phi.

Now, this is analyze as it is applicable for the strip footing. So, it is a 2-D analysis plane strain analysis. So, this is the 2-D analysis and the soil fail in general shear failure mode. So, here the other another assumption is that soil fails in general shear failure mode. So, this theory is originally developed for general shear failure mode and load is vertical and concentric so; that means, load is vertical and it is acting on the center of the footing. So, these are the assumptions of the Terzaghi's bearing capacity theory.

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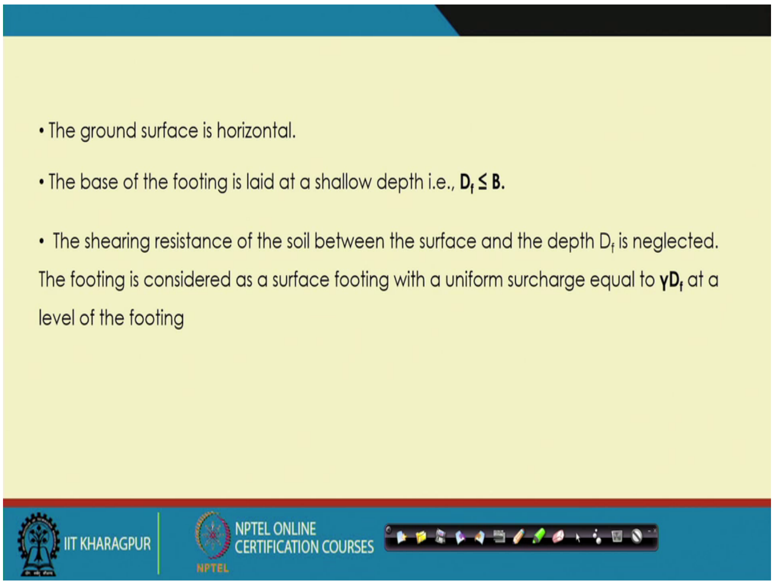

Then, the more assumptions are that that the ground surface is horizontal, then base of the footing is on shallow depth. So, it is valid for if your depth of foundation is less than equal to the width of foundation.

So, if it is greater than that in the Terzaghi's theory we cannot apply. Now, the another assumption is that the here, the soil above the base of the footing that will also give some resistance during the bearing capacity calculation. So, that resistance is not incorporated in the footing in the in this theory. So, next then what are the things it is included how it is been done.

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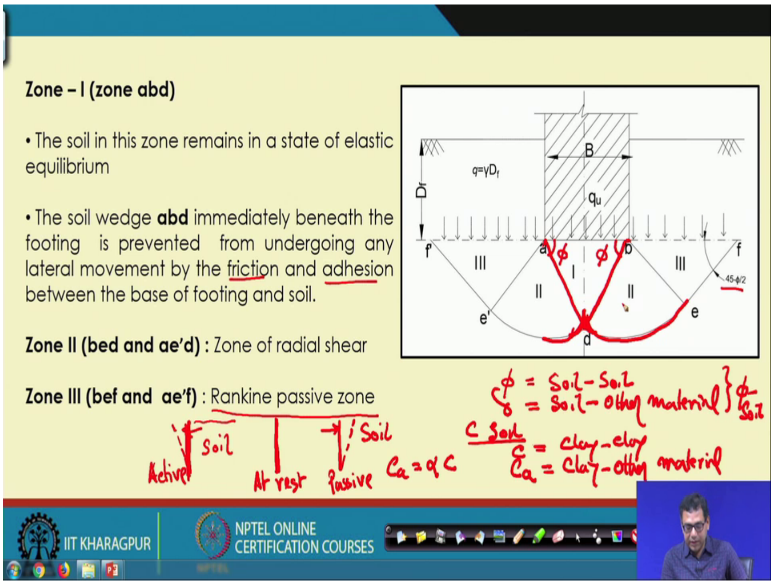

So, then the Terzaghi's bearing capacity theories is also based on our failure mechanism that is Terzaghi is assumed.

So, based on the your observation so, as assumed our failure surface. So, this failure surface it looks like this. So, it has the 3 zones. Now, as I mentioned that it is not considering the resistance that is given by the soil above the base of the foundation, because if you look at this failure surface assumption that failure surface. So, this is the failure surface, this is the failure surface. Now, this failure surface is extended up to the base of the failure, because the base of the footing, because this is the footing base and this is the soil above the footing base and this is the ground surface.

So, now the if the failure surface is extended up to the base of the footing only. So, the failure surface is not extended within the soil above the base of the footing. So, the contribution or the resistance provided by this soil is not incorporated in this theory. So, that is one assumption, but these things is incorporated indirectly. How it is been incorporated, because, the Terzaghi has assumed that, that this low this soil above the base of the foundation, which is acting as a searches at the base of the footing.

So, how we calculate the searcher? Searcher is the Q and Q is the depth of the foundation and the unit weight of the soil. So, if the unit of the weight of the soil is gamma and depth of foundation is D f, then a searcher Q Q is equal to gamma into D f will act at the base of the footing and then there is 3 zone. So, let me let me explain what are these 3 zones?

The first zone is called the this is the zone a b d. So, a b d this triangle is called is the thus, which is static a state of elastic equilibrium. So, this zone means state of elastic equilibrium how it is in state of elastic equilibrium, because, when we apply the load on a footing now the soil b now below the footing, this zone is attached with the base of the footing, because of the friction or adhesion between the footing and the soil.

So, when there is a because new if your footing is rough then this there is a friction between the soil and the footing on if the this is a c phi soil. So, there will be a friction there will be a adhesion. Now, what is the friction and what is the adhesion so; that means, if you it is a granular soil then there is a 2 phenomena occurs, that the friction can occur between the grain to gain; that means, this in the soil to soil. Now, if there is a friction between to soil to soil, then it is then the angle is called the 5 or the friction angle.

Now, if there is a friction between soil to any other material light foundation, because your foundation can be a concrete so; that means, here the friction between the concrete and the soil. So, in that way this friction is called as a delta ok. So, that is the phi is soil to soil and delta is soil to other material. So, now, you can say that that delta is less than the 5 in most of the common material that we are using so; that means, here your friction between soil to any other material and if it is the granular soil this is for the phi soil or the granular soil.

Now, if it is the C soil, then also there is a so, then this is called the if it is the interaction between the soil clay particles and clay clay particle and the cay clay particle then it is called cohesion. Now, if it is the interaction between clay particle clay to any other material, then it is called the adhesion. So, now, if it is c is equal to clay to clay and adhesion c a is called is between clay to other material. So, again this adhesion is equal to alpha into c alpha is the adhesion factor.

So, now the most of the material that we use the alpha is less than equal to 1. So, now, if it is clay versus clay then alpha value is 1 and if it is to any other material and the clay then alpha alpha value can be less than equal to 1. So; that means, here the foundation and the clay so; that means, if it is a c phi soil then there is a friction between the soil and the foundation as well as adhesion between the soil and the foundation. So, because of these phenomena this zone zone one and the foundation they act in technique; that means that means when you deform this soil if you apply the load. So, this zone will deform because of their attached with the soil because of adhesion and the friction.

Then, this zone will not deform laterally they will deform in the downward direction. So, that is why it is in the state of elastic equilibrium. So, this wedge abd immediately beneath the footing is prevented for undergoing any lateral movement by the friction and the adhesion. So, this is the friction and the adhesion between the base of the footing and the soil. So, they will deform in the downward direction, but they will not deform in the lateral direction, because they are in the state of elastic equilibrium, because they have a interaction with the foundation and because of friction and the adhesion.

Now, this is the zone 1, now in the zone 2 these when so, this when we apply this load. So, this foundation and this zone one the deform in the downward direction. So, now, they apply this the radially the other zone of the soil of this other zone, they will deform in the radial direction. So, now, this soil zone is not deforming in the radial direction, but the this soil zone is deforming in the radial direction, because this thing is going in downward direction this wedge and the foundation is going in the out downward direction.

So, now so, that is why there is a 2 zone; one is the zone of radial shear zone 2 another is the passive Rankin passive zone zone 3 is the Rankin passive zone. Now, what is the why it is called the passive zone; so when I will discuss about the earth pressure theory so, there I will discuss in detail what the earth pressure theory, but for these todays class. So, I am you just should know that there are 3 types of earth pressure.

So, one is the active earth pressure one is earth pressure at rest, another is the passive earth pressure. Now what is active earth pressure active, earth pressure means if you have a wall say and this side is soil and this side is void.

So, because of the soil pressure the wall can move. So, if it moves in this direction; that means, if wall moves away from the soil then it is called active. So, this is called active. And, if it is not moving this is at rest. Now, if the wall is moving towards the soil then it is called the passive. So, here we are talking about passive how they talk why it is talking about the passive, because here this is the soil it is moving in this direction it is moving in this direction, because this side is soil. So, this is the passive, but it is not moving neither soil direction nor the opposite to the soil the soil direction.

So, why it is passive because here as I mentioned this abd zone is not deform laterally it is so; that means, it is in elastic equilibrium state. So, we are assuming. So, this is as a wall or this is a imaginary wall it is actually not a why it is a imaginary wall? And, this thing is moving towards the soil because this thing is moving. So, this is the soil and these are the wall. So, this is moving towards the soil so; that means, if it is we assume it is a wall. So, like this if it is a wall it is moving towards the soil. So, it is also moving towards the soil.

So, here a passive zone is developed; so, that is why it is a passive zone. So, the resistance that, we are getting from this zone ok. So, this passive resistance so, we had this; that means, when we are applying this wall is moving from here this wall is moving from here to this direction. So, there will be a passive zone is developed because this is the passive pressure. So, this passive zone will give you a passive pressure, because when you are moving you are moving a wall towards the soil. So, soil will give you a resistance. So, here also there will be a passive resistance will be given.

So, because of this passive because it is passive zone because it is moving towards the soil so, now if you have 2 zones so, you can see these 2 zones this zone this zone is start from one it is start from the edge of the footing and the lower part is logarithmic spiral, and here this angle is taken as 45 degree phi minus phi by 2 because this is in the Rankin's passive zone. And so, now, another thing is that in this figure actually this is it start vertically from here.

So, these when we start these things it vertically from here then it is propagate so, here also it is vertical in the in this zone this point. So, this point it is starting vertically this point. So, this is these are the 3 zones. So, now, and Terzaghi also assumed that angle of this wedge this angle is phi. So, both the angles of phi and this is a triangular wedge on where there is a there is a passive force is acting ok. So, now, if I want to derive the expression for this based on theory so, now if I take this wedge only ok.

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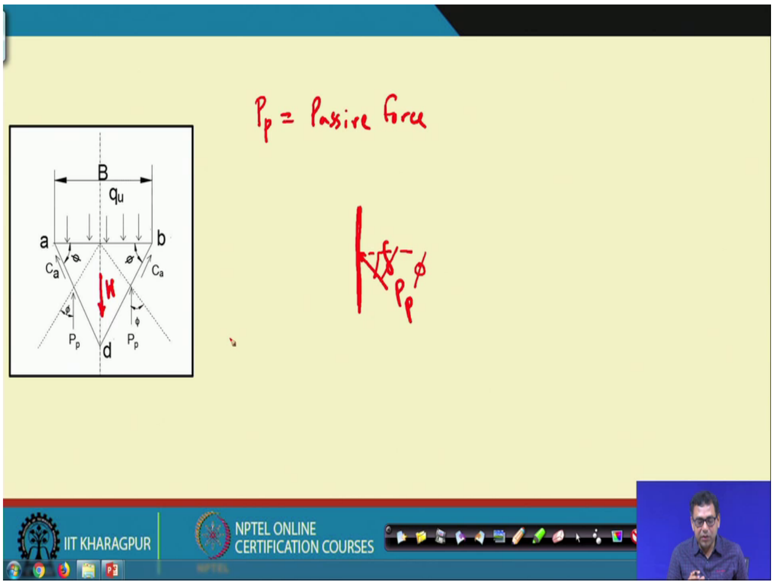

So, if I take this wedge and lead in what are the forces acting on this wedge? So, as I mentioned that there is a passive force P p is the passive force. So, P p is the sorry P p is the passive force; so, this is a acting. Now, this is acting as per these things that, if you have a wall and then this P p acts if a angle of delta with this vertical so; that means, this is the direction of the P p ok.

Now, here as the wall is the because this delta is the wall any other material to the soil as I have discussed, now this is the acting at a if I draw this is the wall if I draw a vertical line delta P p at as a angle of delta with the vertical line and, but this wall is the imaginary wall. So, basically it is not a soil to any other material, it is basically soil to soil. So, instead of delta it will be phi ok; so, here this instead of delta it will be phi.

So, here also this is the wall this is the your a perpendicular line. So, it is a acting angle phi with this perpendicular line, this is a perpendicular to this wall this dotted line this is acting with the with an angle phi. So, this P p is a acting this side under this side. And, then the another forces this q u is the ultimate stress. So, that is a acting on the base of the footing and then there is the adhesion acting between the wall and the soil. So, there is a adhesion is a acting because any if there is a material any material.

So, then if you put it in the soil if it is a c phi soil so, there will be definitely adhesion and that mean definitely the friction. So, that means, the adhesion one adhesion will acting act and there is a passive resistance that is also coming. So, that passive resistance will act with a angle phi and the weight of the wedge.

So, this weight of the wedge is also acting in the downward direction. So, what are the forces are acting? These weight of the wedge is acting in downward direction 2 passive resistance is acting 2 sides of this wedge, and the adhesion is a acting on the side of this wall and q u is the ultimate load carrying capacity or stress. So, these are the stress that is acting on this wedge, and then you have this you have to apply their limitive equilibrium approach is applied and then once this equation is solved and finally, we will get the ultimate load carrying capacity expression.

So, in the next class I will discuss about how this equation is formed? And then I will discuss how we will calculate the bearing capacity based on that equation?

Thank you.