Advanced Foundation Engineering
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Lecture-16
Shallow Foundation: Bearing Capacity X

So, during my last lecture I have discussed that how we can incorporate the tilting base and sloping ground effect in the bearing capacity equation? Now I have discussed Hansen's factors and factors proposed by the Vesic.

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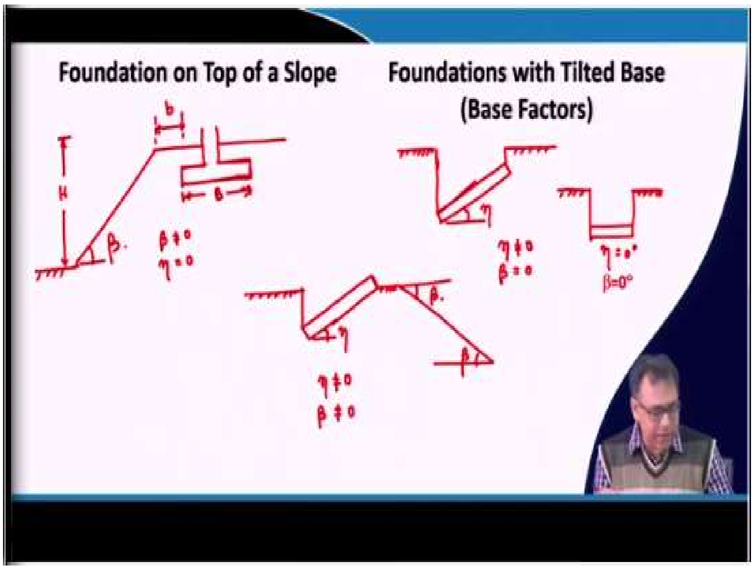

Now as I mentioned that in my previous class that these are the four cases possible, this is the first case where the η value, that means the tilting base η value is 0 and β is also 0, where, β means the sloping angle. So, that means it has no tilt and no slope and then the case 2 where the $\eta \neq 0$ and β is 0. That means, it is not a sloping ground but the foundation base is tilted.

And then the third case where the $\beta \neq 0$ but $\eta = 0$, that means it is not tilted but it is on the top of a slope. And the fourth case where both can be non zero component, that means a non zero value. That means it is on the top of the slope as well as the foundation base is tilted one. So, four cases are possible, so I will solve few of the cases.

That means, one is your sloping ground and another is tilted base, you can put both the effects at the same time, which is the fourth case. But I will solve problems on case 2 and case 3, case 1 is already been discussed in previous lectures or previous example problems. So, the fourth one is the combination of second and third, so that you can incorporate.

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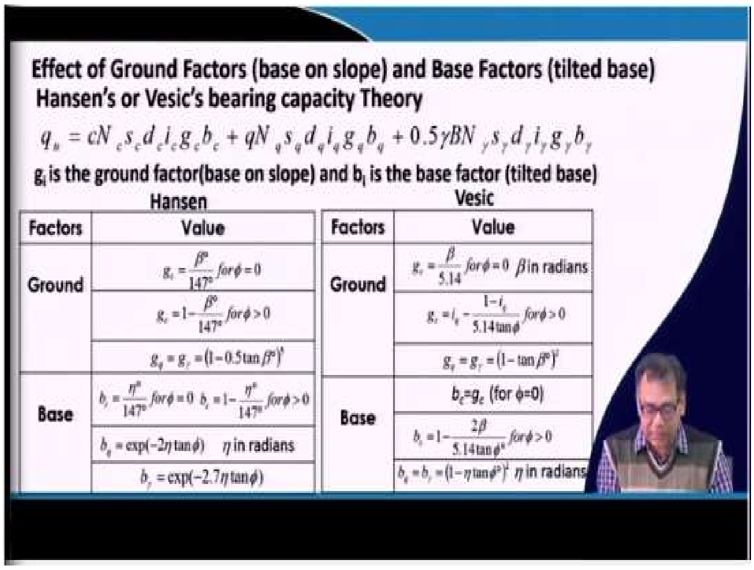

So, and then I have discussed these are the factors, those are proposed by Hansen and Vesic. So, these are called base and ground factors when the foundation is on the slope and in the base factors, if the foundation base is a tilted one, right, it is a tilted base. That means the g is the ground factor, b is the base factor. So, these are the values I have already discussed in my last lecture that these are the ground factors proposed by Hansen.

Then the base factors proposed by Hansen and these are the ground factors and the base factors proposed by the Vesic. Now remember that here these η and this β all are in radians in these equations which we are using. For example, the first case where $\frac{\beta}{5.14}$, this type of case, β is in radian but when it is like these tan to the power tan β then β is in degree.

It is mentioned wherever it is in degree it is given in degree otherwise it is not given anything, that means like these $2\eta\tan\phi$, ϕ is obviously with tan it is in degree but η is in radians, so it is mentioned, so you put according to that. Now these are the recommendations proposed by Vesic and Hansen and remember that here both the base factors and the ground factors are incorporated.

But Meyerhof also suggested methods by which we can determine the bearing capacity of a foundation when it is resting on the sloping ground, but Meyerhof has not considered the tilting base effect. So, that means only you can consider that procedure if the foundation is on the slope, but it is horizontal not tilted.

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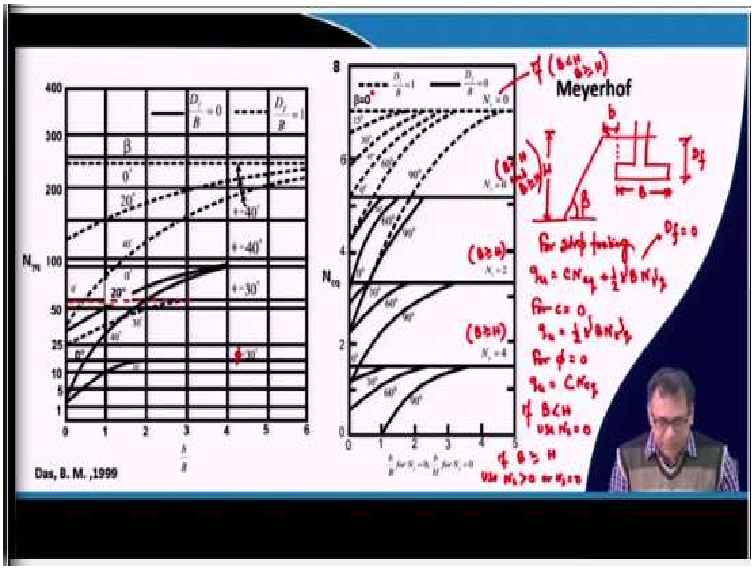

So, that procedure let me discuss first then I will go to the example problem. So, Meyerhof has suggested that if the foundation is on the slope, which is inclined at an angle of β with the horizontal. So, it can be on the slope surface or it can be at some depth also. So, if this is the D_f and this is the width of the foundation B, and the distance of the foundation from the slope is b and height of the slope is H.

And that distance is b and B is the width of the foundation and b is the distance from the base edge of the foundation or footing from the slope. Now we know that the expression of bearing capacity expression for strip footing is $q_u = cN_{cq} + \frac{1}{2}\gamma BN_{\gamma q}$. So, this is for the strip footing and for $c = 0$, your $q_u = \frac{1}{2}\gamma BN_{\gamma q}$.

And for $\phi = 0$ that $q_u = cN_{cq}$. So, now these N_{cq} and $N_{\gamma q}$ are the suggested bearing capacity factors. Now in this equation second term is not present. So, that means here it is assumed that your $D_f = 0$, that means this expression is valid if foundation is on the slope itself not with the depth. So, this equation was proposed by Meyerhof where D_f is taken as 0.

Because you can see that the second term $qN_q$is missing, so that is only possible if $D_f = 0$. So, that means remember that this equation is valid if $D_f = 0$ that means the foundation is on the slope. And then this is the height of the slope say, *H*. Now how we can calculate these bearing capacity factors?

So, we can determine these bearing capacity factors N_{cq} and $N_{\gamma q}$ from this chart. These two charts are given, from the first chart we can determine the $N_{\gamma q}$ and the second chart we can determine the N_{cq}. So, let me first explain the $N_{\gamma q}$ part which can be used if $c = 0$, so that is the $N_{\gamma q}$ part where this β is the slope angle.

So, these dotted lines are given that if $\frac{D_f}{B} = 0$ that means foundation is on the slope. So, that can be written from this line. And if $\frac{D_f}{B} = 1$, so that can be determined by this dotted line, so what does it mean? That ideally you can see that if $D_f = 0$ that means this equation is valid for if foundation is on the slope but this depth effect.

So, this foundation depth effect is incorporated in the bearing capacity factors. If you look at these bearing capacity factors, so now if I have discussed the first part that it is valid if foundation is on the surface, fine. So, if foundation is on the surface, then you use this equation and then you use this bearing capacity factor. That means when $\frac{D_f}{B} = 0$ fine, but if your foundation is not on the surface with some depth D_f.

And then also you can calculate or you can use this expression by using these factors proposed for $\frac{D_f}{B} = 1$ case. So, that means two cases are given, one is $\frac{D_f}{B} = 0$ when the foundation is on the slope, another is $\frac{D_f}{B} = \mathbf{1}$. Now if your foundation is in between 0 and 1, then you have to linearly interpolate this value.

That means then you calculate the bearing capacity factors for $\frac{D_f}{B} = 0$ and $\frac{D_f}{B} = 1$, then you linearly interpolate those values between your case. That means it may be less than 1 also if it is in between 0 to 1 then you interpolate that value by calculating $\frac{D_f}{B} = 0$ and $\frac{D_f}{B} = 1$ case and then you linearly interpolate that value. So, that means you can use this expression if foundation is resting with the depth also but that depth is restricted up to width of the foundation.

That means you can use it up to $\frac{D_f}{B} = 1$, so you can use it for any depth if the depth is within width of the foundation clear. So, that means 0 to 1 you can directly get these factors but it is in between that you linearly interpolate those values and that you put, so it is clear. So, apparently if you look at this equation, then you will find that it is only applicable for foundation resting on the slope fine, that is applicable for foundation resting on the slope then you use that firm lines.

But you can incorporate that depth effect also by taking these dotted line values if your foundation is below the base of the slope, but that is restricted up to $\frac{D_f}{B} = 1$, clear. So, now we can see that β = 0°, 20°, 40°. So, up to 0°, 20°, 40° because your ϕ is given up to 40° because if your ϕ is 40° then you cannot make a slope in normal case more than 40°.

So, you can see if your ϕ = 40° then those values are given for β = 0°, 20°, 40°. Now if your ϕ is for firm line also if ϕ = 0° hence values are given, ϕ = 40° values are given for 0°, 20° and 40°. But if your ϕ = 30°, then these dotted lines are given for ϕ = 30° and there is a straight line also which is on this firm line. So, there is also a straight dotted line for ϕ = 30° case which is basically for β = 0°.

So, if your ϕ = 30° then β is given for 0° and 30°. And for the firm line also if ϕ = 30° then your β is given for 0° and 30°**.** If the ϕ = 40° then β is given for 0°, 20°, 40° for 30° as we cannot provide β value more than 30° because then your slope will be unstable. So, values are given for

0° and 30°. So, this is for N_q part where you can determine the N_q for $\phi = 0°$, but if your $\phi = 0°$, then you can use this N_{cq}. The value of N_{cq} we will get from this chart.

Again this N_{cq} we can get for two different cases, one is $\frac{D_f}{B} = 1$ and another is $\frac{D_f}{B} = 0$. So, your firm line is given for $\frac{D_f}{B} = 0$ and the dotted line is given for $\frac{D_f}{B} = 1$, as I have mentioned if it is within the 0 to 1 value, you can linearly interpolate these value. And for now for this $\phi = 0°$ case, if your B, I mean width of the footing is less than H, then you use $N = 0$ and now if $B \geq H$ then use $N > 0$.

So, that means it indicates that if your all $N = 0$, so what does it mean? Suppose, if your B is the width of the foundation, H is the height of the slope. Now, if your B width of the foundation is less than the height of the slope. Then you have to use $N = 0$ that means, these dotted lines only are given for $N = 0$, that means these dotted lines for $N = 0$ you have to only use for this case.

So, that means your $N = 0$ you can use for this dotted line is for your $\frac{D_f}{B} = 1$. So, now if your $B < H$, then you use only $N = 0$, that means these 2 cases. So, this is also applicable if your $B \leq H$ and if $B \geq H$. So, for both the cases it is applicable but it is applicable for $\frac{D_f}{B} = 1$, remember that. So, that means if this $N = 0$ you can use for both the cases, if your $B \leq H$ or $B \geq H$.

So, but this is applicable for $\frac{D_f}{B} = 1$. Now if your N is again it is $\frac{D_f}{B} = 0$ then this $N = 0$ you can use for $B \leq H$ and $B \geq H$ for both the cases. But this $N = 2$ and $N = 4$ you cannot use if $B \leq H$. So, this is only applicable if $B \geq H$, clear. So, that means this condition you just understand this condition if $B \leq H$ then use only $N = 0$.

That means if $B \leq H$ then you only use $N = 0$ case, two cases this firm line is for the $\frac{D_f}{B} = 0$ and dotted line is for $\frac{D_f}{B} = 1$, clear. So, these two cases you can use if $B \leq H$ for $N = 0$, but if your $B \geq H$, then you can use $N = 0$ case as well as $N > 0$ case. So, that means, this $N = 0$ case you can use for any condition compared to H and B any condition.

Whether your $B \geq H$ or $B \leq H$, clear. But if this $N = 0$ and $N = 4$ case or $N > 0$ cases, you can only use if $B \geq H$ but not if $B \leq H$, clear. And that as I mentioned these dotted lines are for $\frac{D_f}{B} = 1$ and the firm lines are for $\frac{D_f}{B} = 0$. And these are the angle β for 15°, 30°, 45°, 60°, 90°.

Similarly this β is in degree, this is also for $N = 0$ case, this is 0°, 30°, 60°, 90°. Because now here your $\phi = 0$ so ideally you can go for a vertical slope also. So, that is why they have given β up to 90° so 60°, 40°. But if your $\phi \neq 0$ then you have to restrict the slope angle up to the ϕ value, but here ideally you can go for the 90° also that is why it is given up to 90°, so this is clear.

And another thing as I mentioned this b and B are also incorporated in the chart, that is horizontally $\frac{b}{B}$. So, that means first you have to calculate the $\frac{b}{B}$ ratio then corresponding to your ϕ value and the β value and $\frac{D_f}{B}$ condition, you determine the factors. Similarly $N_{\gamma q}$ and N_{cq}, and remember that these values are given for only strip footing.

Now if it is for different footing conditions suppose rectangular footing but no such recommendation is given. But you can use those shape factors and you can multiply with them and you can get the value. So, again as for different cases you can use those factors discussed in the previous classes with this basic equation which is given for the strip footing.

And you get the values for different conditions that means for different footing conditions and other different factors. Because I have now discussed total six factors, but the total six you may not use because your ground factor and base factor you have already used it on slope in different way. So, ground factor is no need to apply, but other factors you can apply for this one with caution because it is originally developed for this strip footing and then foundation on the slope. So, this is the value or the chart by which you can determine.

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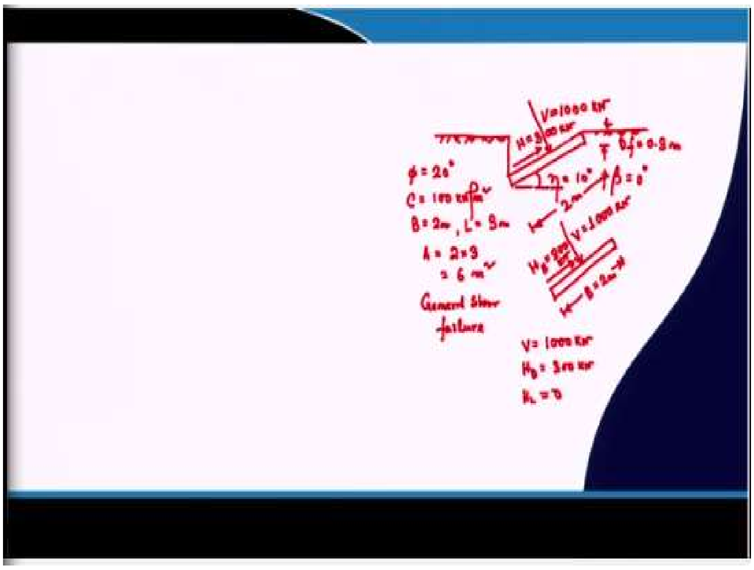

So, now I will solve one particular problem, first problem that I will solve is example problem that your foundation base is tilted. The first case I will discuss about the foundation base is tilted one. So, this is the ground surface and here the ground surface is again going in the same direction but now the foundation base is tilted. And this is your foundation where the tilt angle η = 10° and obviously β = 0° in this case this is the problem.

And a vertical load with respect to the footing which is acting at the center is equal to 1000 kN. and the horizontal load of 300 kN is acting, and remember that your width of the foundation, this is width of the foundation which is 2 m. So, I can write that this is your foundation with tilted base, this is the foundation width, B which is 2 m and there is vertical load acting.

And remember that vertical load is acting at the center, that means no eccentricity and this is 1000 kN and horizontal load which is parallel to this way is acting, that means it is parallel to B, so H_B = 300 kN. So, that means your V = 1000 kN, H_B = 300 kN and H_L = 0. So, that means no horizontal force parallel to length is acting, the horizontal force parallel to B is only acting.

So, previous example case I have discussed that horizontal load is acting parallel to L and no horizontal force was acting parallel to B, but it is opposite. That means horizontal force is acting parallel to B but no horizontal force acting parallel to L but there is a vertical force acting at the center of the footing that means no eccentricity. But if there is eccentricity also then you have to incorporate that effect as I discussed in my previous lectures.

So, your D_f has a very small value which is 0.3 m. And you know ϕ is 20°, c is 100 kN/m^2. And as I mentioned $B = 2$ m and $L = 3$ m. And you consider the general shear failure where $A = 2 \times 3$, that means 6 m^2. And you have to consider the general shear failure because it is a c-ϕ soil.

But as we do not have that compressibility factor calculation data, so those data are not available. That means the elastic modulus, the shear modulus and the Poisson's ratio, μ. Then you can calculate the compressibility factors and then check that due to the compressibility of the soil whether there will be any bearing capacity reduction or not. But here those data are not given and also general shear failure is assumed.

So, then we will solve according to that. So, this is $H_L = 0$ remember that, so as I discuss in my previous problem that if $H_L \neq 0$, then I have to go for two sets of equation, but here $H_L = 0$. So, then I have to go for only one set of equation if I use Hansen's bearing capacity theory. So, I will solve this question by using two bearing capacity theories, one is Hansen and one is Vesic.

And then you will find the differences between Hansen and Vesic. Because here as I mentioned Vesic's bearing capacity theories those horizontal load either parallel to L or parallel to B are already incorporated in the inclination factor determination part. But in Vesic it is not incorporated, so that we have to incorporate it by modifying the shape factor. If $H_L \neq 0$ then we have to take two sets of equations and two sets of factors.

But as here $H_L = 0$ then you have to go for one set of factors and the equation. So, these things I will discuss and I will solve this problem in the next class using the same conditions same problem we will solve in the next class, thank you.