Rock Engineering

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Lecture - 50
Rock Slope Stability - Wedge Failure

Hello everyone, in the previous class, we discussed the analysis of the rock slope stability when there is a probability of the occurrence of plane failure. We saw that how to take care of the tension crack. And if it is filled with water, then also we saw that how can we find out the factor of safety considering the water pressure. Now, today we are going to discuss about the next type of the failure mode which is quite common in case of rock slopes.

That is the wedge failure. You know that the plane failure is a particular case of the wedge failure. So, we will take up the similar kind of philosophy as we took in case of the plane failure. However, here the plane along which this wedge is going to slide they are going to be 2 planes rather than one single plane. And there is going to be one line of intersection of these 2 planes which is going to give us the direction of the sliding of the wedge of the rock.

Let us see how to proceed with the analysis as far as wedge failure for the rock slopes is concerned. Some of the aspects we have already discussed in the earlier chapter where we discussed about the spherical representation of the geological data. And also when we saw that the applications of the graphical representation. So, the basic mechanics of the failure in case of the wedge type of failure.

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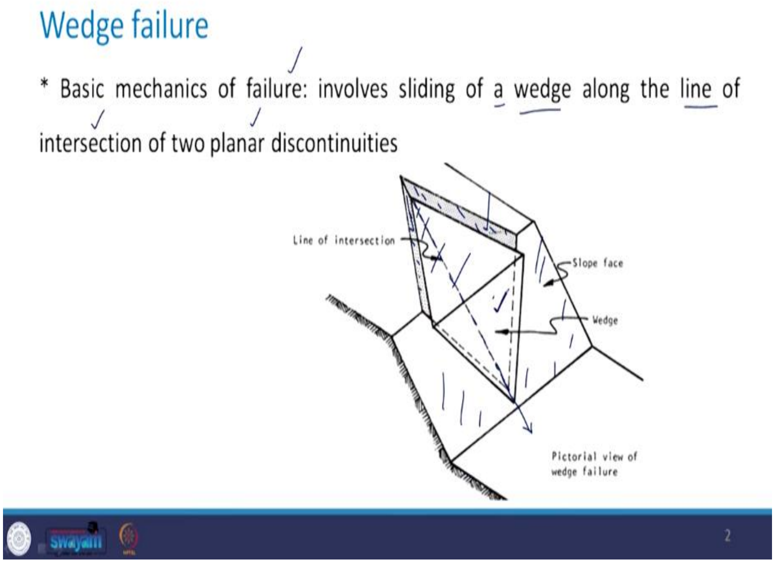

It involves the sliding of a wedge along the line of intersection of 2 planar discontinuities. Take a look at this figure, this portion is the slope face and this shaded portion which you can see they are the 2 planes of discontinuity. In between these the wedge is being formed. And this is the line of intersection of these 2 discontinuity planes. That is this one and this one. And along this line of intersection only the sliding of this wedge which is formed here will take place.

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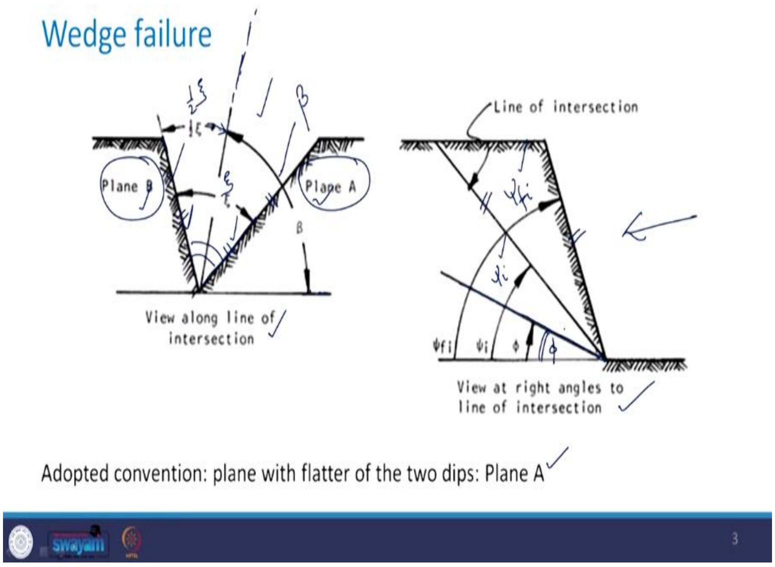

Now, if we take a cross section along the line of intersection, this is how the view is going to look like. This is the angle bisector of the angle between the Plane A which is this plane and the Plane B which is this plane. The convention which has been adopted is the plane which has the flatter dip of these 2 planes that would be given the name as Plane A. So, you can see here that this plane has smaller dip or this is flatter than this particular plane.

And therefore, we are calling this plane as Plane A and the other one will automatically become Plane B. So, whatever is this angle that is being represented as zeta (ξ). This is the angle bisector of this angle zeta(ξ). And therefore, this angle is half of zeta ($\xi/2$). The angle from this angle bisector to this horizontal line is represented by angle beta (β). If we take a look at the right angle to the line of intersection, this is how the view is going to look like.

This is the slope face which is making an angle psi fi (ψ_{fi}) with the horizontal. This is the line of intersection and making an angle of psi i (ψ_i) with the horizontal. And here it has been shown that how the friction angles magnitude is as compared to psi i (ψ_i)a nd psi fi (ψ_{fi}) with the help of this line. And this angle is angle phi (ϕ) which is the friction angle.

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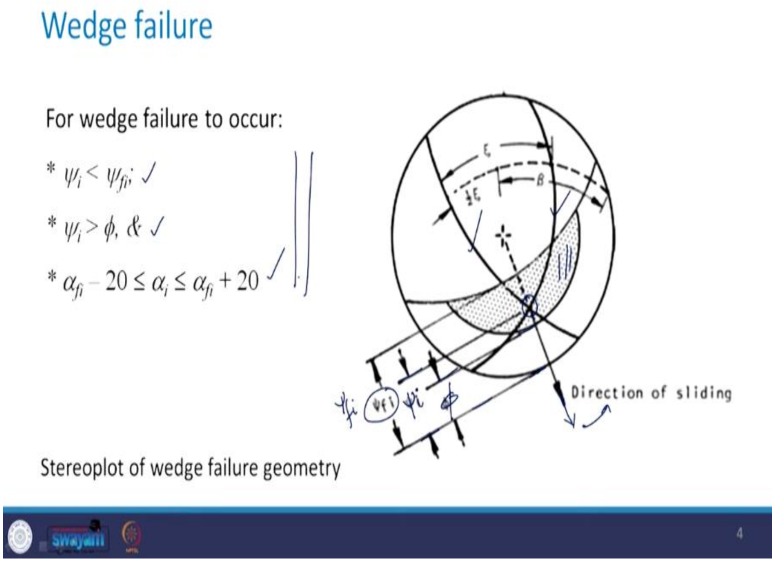

Now, you know this that as far as the kinematic analysis of wedge failure is concerned for the wedge failure to occur, these 3 conditions have to be satisfied. This we have discussed in detail when we discussed the graphical representation of the geological data. So, here you can see that the 2 planes have been represented by these great circles. And this is the point of their intersection. And this is going to give us the direction of sliding.

This is a friction circle that has been represented by this angular distance from the outer circumference as has been shown here as angle phi (ϕ). Now, this dip of the line of intersection has been shown by this angle psi i (ψ_i). And this angular distance is psi fi (ψ_{fi}). So, this is how all the 3 conditions have to be satisfied for the wedge failure to occur.

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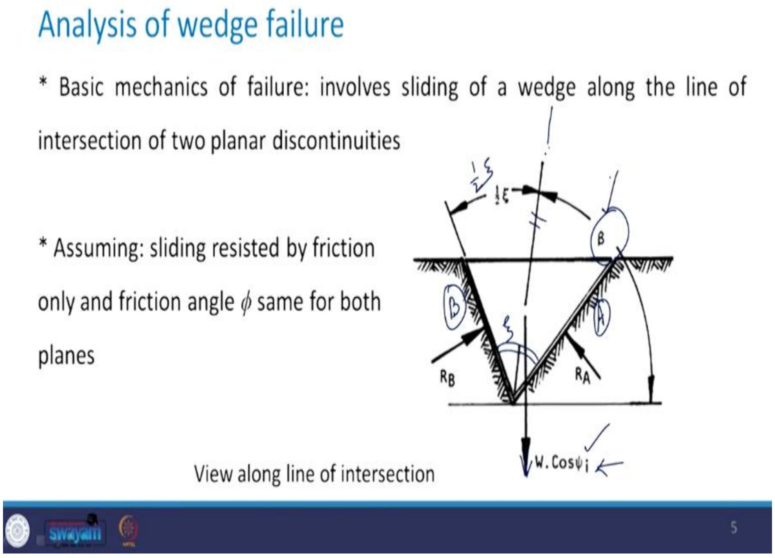

Now, the basic mechanics of failure once again involves the sliding of the wedge along the line of intersection of these 2 planar discontinuities. We need to assume that the sliding is resisted by friction only and friction angle phi is same for both the planes, be it Plane A or be it Plane B. So, this we are doing for the sake of simplicity, but then methods are available now. If you have different friction angle for these 2 planes that also can be taken care of.

Now, the weight of the wedge and its component is going to act in this direction as has been shown in this figure as W cos of psi i ($W\cos\psi_i$). This is the angle bisector of this angle between the 2 planes in this view. And this angle is zeta (ξ). And this is half of zeta ($\xi/2$). And this angle of the angle bisector from the horizontal is angle beta (β).

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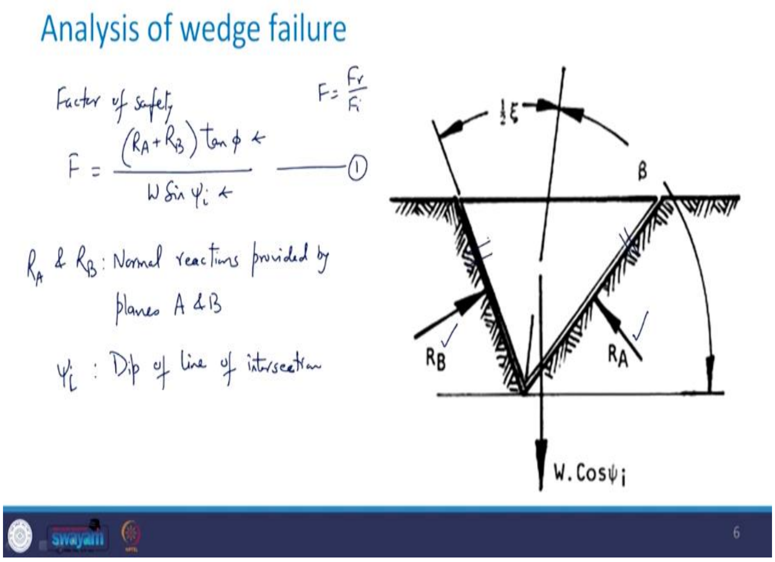

Now, the factor of safety for this case can be written as that is F is equal

$$F = \frac{(R_A + R_B)\tan\phi}{W \sin\psi_i}$$

Again the same fundamental concept that is F is equal to F_r / Fi. So, this is the force which will cause this wedge to slide. And this is what is going to be the resistive force. So, this R_A and R_B these are the normal reactions provided by planes A and B as has been shown in this figure.

You see R_A is here and R_B is here, where this (ψ_i) is the dip of the line of intersection of these 2 planes. That is Plane A and Plane B.

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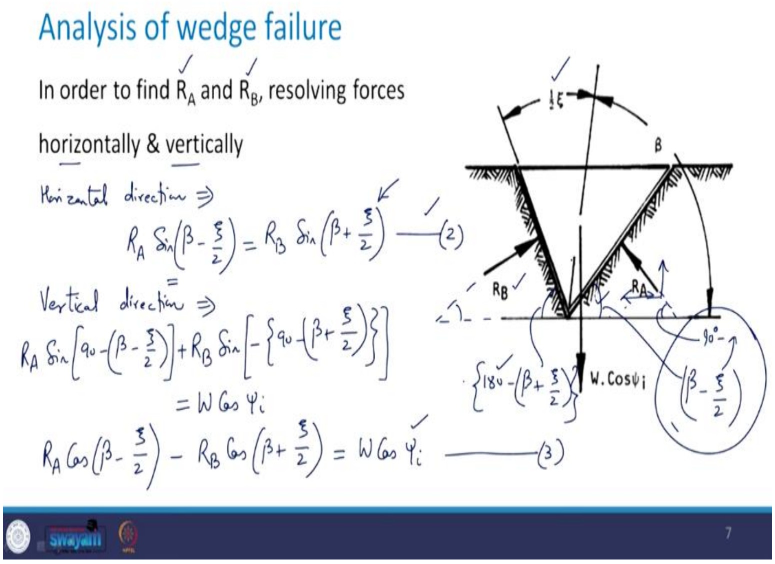

Now, let us try to find out the reactions R_A and R_B by resolving the forces in the horizontal and the vertical direction. So, here you need to just do some trigonometrical things. See, this angle is half zeta ($\xi/2$). This total angle is beta (β). So, what is going to be this angle? This is going to be beta minus zeta by 2 $\left(\beta - \xi/2\right)$, this angle. And, what about this angle? This is going to be 180 minus beta plus zeta by 2 $\left(180 - \left(\beta + \xi/2\right)\right)$.

This is what is going to be because this whole angle is 180 degree. And this much is beta and plus zeta by 2 $\left(\beta + \xi/2\right)$ and if we subtract this whole thing from 180 degree, this is what that we are going to get. So, when I take the horizontal equilibrium of the forces, horizontal direction, so, we are going to get

$$R_A \sin\left(\beta - \xi/2\right) = R_B \sin\left(\beta + \xi/2\right)$$

I marked this equation as equation number 2.

See, I have to take it in the horizontal direction. So, if I just extend it in this way, I know this angle. What will be this angle? This is going to be 90 minus this angle. And the component is going to be R_A cos, see its component horizontal component is going to be R_A cos of this angle 90 minus β minus $\psi/2$. So, 90 minus θ is sin θ. So, that is how that we will get this term.

Similarly, you can find out this angle and get the component of R_B in the horizontal direction. And you will get this expression. Now, if we take the force equilibrium in the vertical direction, this is what that we are going to get

$$R_A \sin\left(90 - \left(\beta - {}^{\xi}/_{2}\right)\right) + R_B \sin\left[-\left\{90 - \left(\beta + {}^{\xi}/_{2}\right)\right\}\right] = W \cos\psi_i$$

And from here, we will get

$$R_A \cos\left(\beta - {}^{\xi}/_{2}\right) - R_B \cos\left(\beta + {}^{\xi}/_{2}\right) = W \cos\psi_i$$

Mark it equation number 3. Simple trigonometry and you will be able to get the horizontal as well as the vertical force equilibrium equation. Now, from this equation number 2, we can write R_B in terms of R_A.

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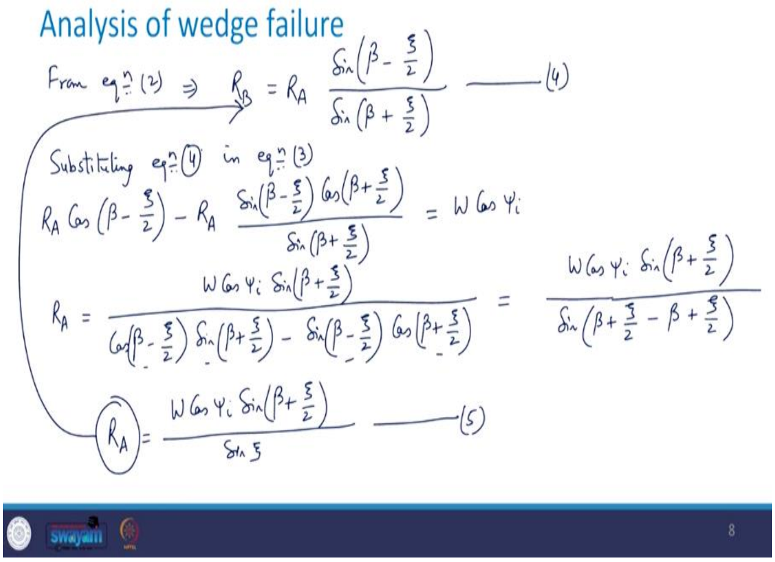

So, I have from equation number 2. R_B can be written as

$$R_B = R_A \frac{\sin\left(\beta - \frac{\xi}{2}\right)}{\sin\left(\beta + \frac{\xi}{2}\right)}$$

Say, you write it as equation number 4. Now, what we do is we substitute this equation 4 in our equation number 3. So, see what we get is

$$R_A \cos\left(\beta - {}^{\xi}/_{2}\right) - R_A \frac{\sin\left(\beta - \frac{\xi}{2}\right)\cos\left(\beta + {}^{\xi}/_{2}\right)}{\sin\left(\beta + \frac{\xi}{2}\right)} = W \cos\psi_i$$

Or, from here one can determine the expression for R_A

$$R_A = \frac{W \cos\psi_i \sin\left(\beta - {}^{\xi}/_{2}\right)}{\sin\xi}$$

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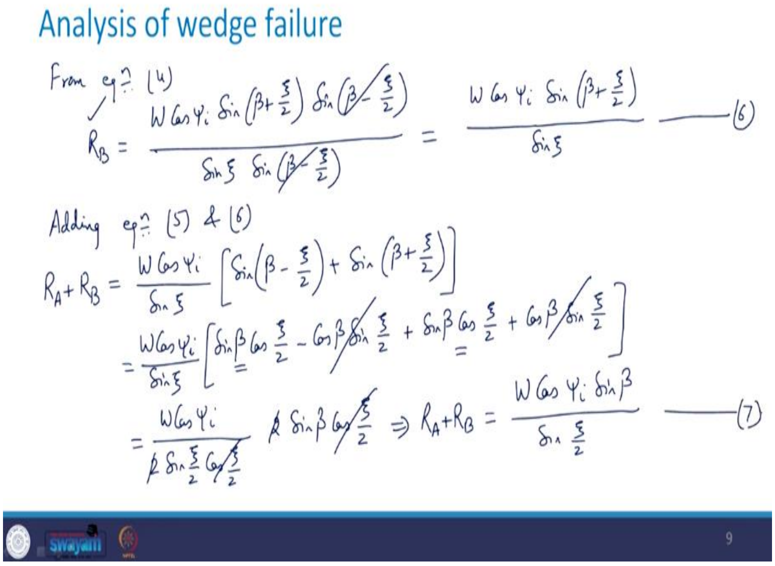

So, let us see. So, from our equation number 4, this R_B is going to be

$$R_B = \frac{W \cos\psi_i \sin\left(\beta + {}^{\xi}/_{2}\right)}{\sin\xi}$$

I mark this equation as equation number 6. Now, what we do is we add equation number 5 which was the expression for R_A and equation number 6 which is the expression for R_B.

$$R_A + R_B = \frac{W\cos\psi_i}{\sin\xi}\left[\sin\left(\beta - \frac{\xi}{2}\right) + \sin\left(\beta + \frac{\xi}{2}\right)\right]$$

So, what we are going to get here as R_A plus R_B will be equal

$$R_A + R_B = \frac{W\cos\psi_i \sin\beta}{\sin {}^{\xi}/_{2}}$$

So, this equation will become equation number 7.

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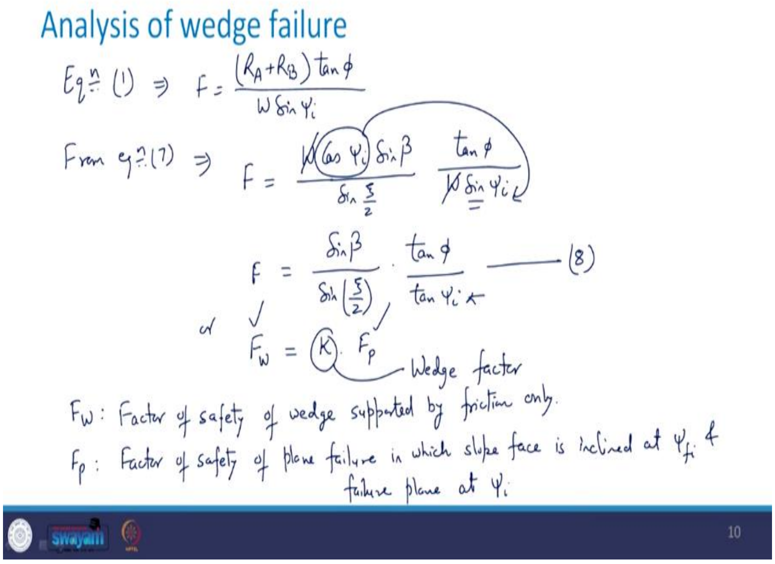

Now, from the equation 1, we have the expression for your factor of safety. So, I just substitute that, so, equation 1 is going to be

$$F = \frac{(R_A + R_B)\tan\phi}{W \sin\psi_i}$$

And from 7, I can just substitute the expression for $R_A + R_B$. So, from equation number 7, what we are going to get

$$F = \frac{W\cos\psi_i \sin\beta}{\sin {}^{\xi}/_{2}} \frac{\tan\phi}{W\sin\psi_i}$$

And you are going to get here as the expression as

$$F = \frac{\sin\beta}{\sin {}^{\xi}/_{2}} \frac{\tan\phi}{\tan\psi_i}$$

So, this is going to be my equation number 8. Or, I can write it that that factor of safety for the wedge failure will be some factor K into F_P. Now, this K is the wedge factor. And F_W is the factor of safety of the wedge supported by the friction only.

$$F_W = KF_p$$

Because that was the assumption that we took in the beginning and F_P is the factor of safety of the plane failure in which the slope face is inclined at ψ_{fi} and the failure plane at ψ_i. So, this is how the factor of safety in case of the wedge failure can be connected with that of the plane failure.

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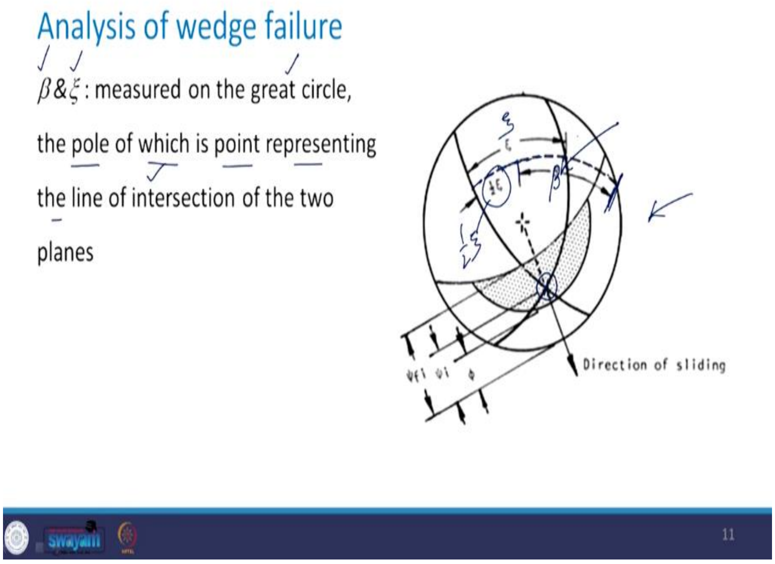

Now, how to determine these angles beta and zeta? That is the question. So, there we have to take the help of this stereoplot. So, these 2 angles, they are measured on the great circle, the pole of which is the point representing the line of intersection of the 2 planes. So, you see in this figure, that this is the line of intersection in this stereoplot. So, if this is the pole of a great circle, so, we will try to get the great circle. You know how to determine this.

So, once we get this great circle, see from this point to this angle bisector, this angle is going to be angle beta. And how will you find out this angle bisector? Along this great circle, you measure the angular distance which is zeta and half of that is going to be this half of zeta and the remaining portion with this is going to be the angle beta. So, once we obtain these angles beta and zeta, we can find out the factor of safety for the slope where the wedge failure is likely to take place.

Although I have discussed a very simple case with you, but I try to give you the basic behind the analysis of the wedge failure. Now, different type of combination you can further take but this is beyond the scope of this course for the time being. So, you should understand that what is the philosophy behind the wedge failure? What are the assumptions involved? And, how you can determine the factor of safety for a simple case?

So, this was all about the wedge failure. In the next class, we will take up the analysis for the next type of the failure mode, which is the circular failure, thank you very much.