Underground Space Technology
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Module No # 03
Lecture No # 13
Application of Stereographic Projections Method: Roof Failure

Hello everyone, in the previous class we discussed about various failure modes in the case of an excavation, it may be a roof failure or it may be the side-wall failure. As far as the roof failure is concerned, there can be the fall of a wedge under gravity into the excavation. And, I mentioned to you that what exactly is that condition, that there is going to be the fall of this wedge in the excavation under gravity from the roof.

And, there can be the formation of the wedge, which can slide through the side walls of the excavation causing the side wall failure. So, today we are going to see that how, using the stereographic projection method, we can find out that what is the size of the wedge, its height as far as roof failure is concerned. So, take a look here, this we discussed in the previous class as well that at least 3 discontinuities are needed for the wedge to be formed in roof.

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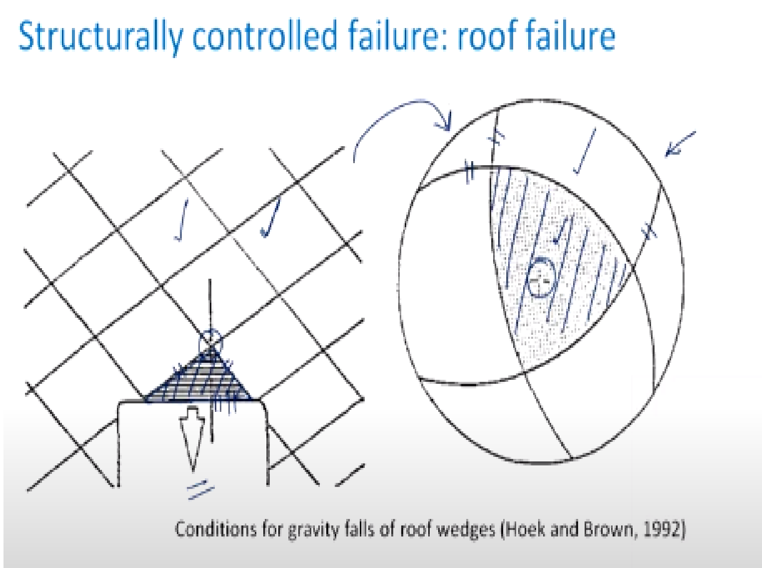
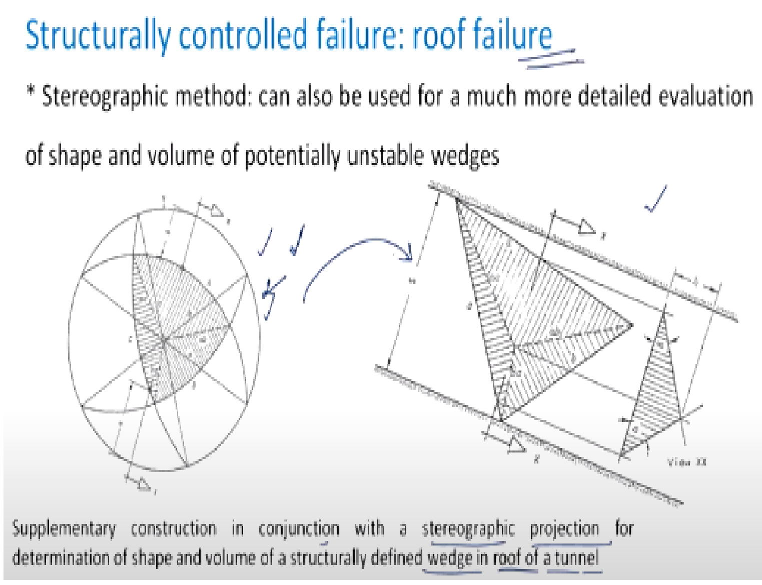


So, you see here we have these 3 planes that this wedge is formed, and a vertical line which is drawn from the apex of this triangle you see that it is passing through the base of this wedge which is this. And, therefore we saw that if this is the situation, then in that case this switch will fall under gravity from the roof to the excavation or inside the excavation.

Now, this particular condition of the field can be represented by the stereographic plot in this manner. You know that each and every discontinuity can be represented by a great circle in the stereo plot. So, take a look here these are the 3 discontinuities and the corresponding great circles they have been drawn in this particular manner. And, the intersecting area is this, the apex of the wedge is represented by the center of this circle which is lying very much within this intersection area.

And, therefore if we have this type of situation which can be plotted in this particular manner in the stereographic projection, and if you have this situation that the center lies within the intersection area of all the 3 great circles. Then, in that case we can say that there is going to be the gravity fall of the wedge which is formed in the roof to the excavation. Now how can we find out the shape and the volume of this potentially unstable wedge that is shown in this figure? **(Refer Slide Time: 04:00)**



So, these are the 2 figures so this is the one where you are plotting all the details of the discontinuity planes and the wedge in the stereographic net. And here, taking the information from this we try to get the plan dimension as well as the height of the wedge that is being formed in the roof. So, basically, this gives us the idea about the supplementary construction in conjunction with the stereographic projection, for the determination of shape and volume of the structurally defined wedge in the roof of a tunnel. Please note that, we are discussing about the roof failure and not the side wall failure. So how do we go about it?

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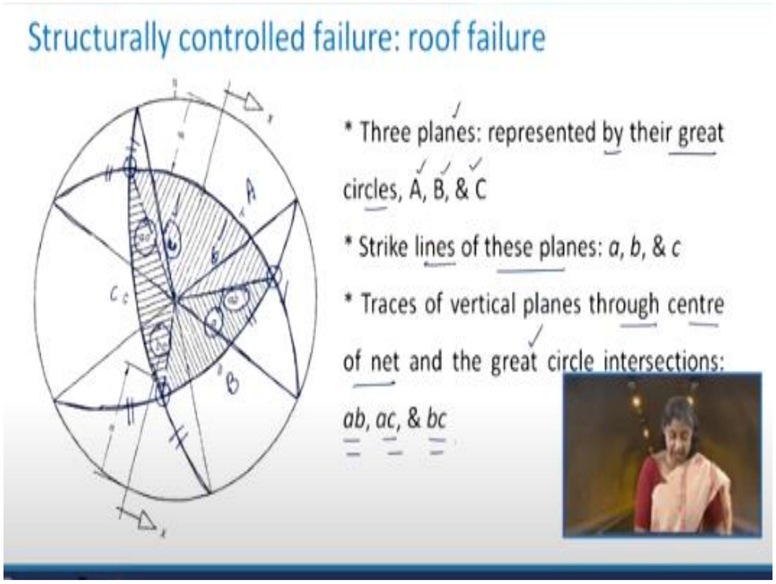

So, basically, we have three planes as I mentioned that minimum 3 planes are needed for a wedge to form in the roof. So, let us say we take these minimum 3 planes so these are represented by the corresponding great circle’s a, b and c. Take a look in this figure, this is what is your great circle a, similarly you have here this as great circle b and the third one is this which is the great circle c. So, 3 discontinuities shown as 3 respective great circles a, b and c.

Now how do we get their strike direction? So, see if you join this so this is what is the strike line of plane a that is the strike line of plane b and that is the strike line of plane c. a, b, and c they are representing strike lines of these planes a, b, and c respectively. Now the traces of the vertical planes through the center of the net and the great circle intersections they are given as ab, ac and bc. How can we determine these take a look see this is the great circle a, and this is the great circle b.

So, wherever they intersect it is this point and if you join this point with the center that is this line, so this is going to give me the trace ab, similarly intersection of this great circle a and great circle c that is this point you join it and you will get ac. In the similar manner great circle b and great circle c this is the intersection point if we join these we get bc. So, this is how we can get the traces of the vertical planes through the center of the net and the great circle intersections which are ab, ac and bc.

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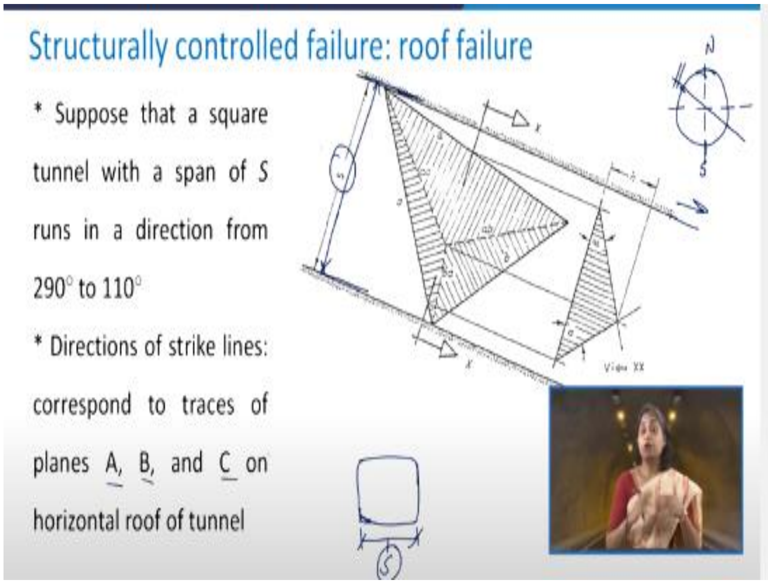

Now, what is the next step I assume that it is a circular tunnel, with a span of s so let us say that it looks like this. So, the, this particular dimension is S, now this tunnel is running in the direction from 290^0 to 110^0. So let us say that if you have this as a stereo net so here you have north and this is south so you will have 290^0, somewhere here and say 110^0 somewhere here. You just join these 2 points, so this is what the direction of the tunnel axis.

So, basically this direction is showing you the direction of the run of the tunnel and the span S is the distance between these 2 as shown here. Now, the direction of these strike lines they will correspond to the traces of planes a, b and c on the horizontal roof of the tunnel.

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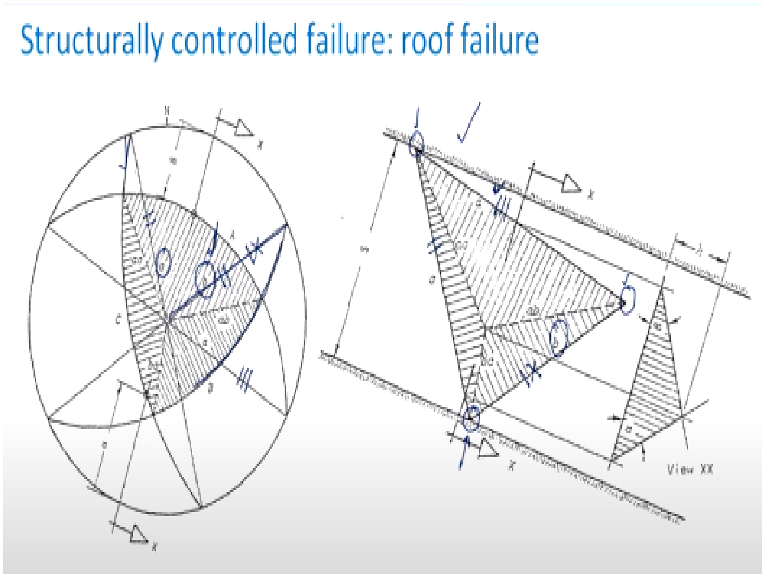

So, how can we plot it? So, take a look here that we have these strike as a here, the strike is b this is the great circle b. So, this is the strike line and this is the great circle c and this is the strike line c. So, what we do is on this figure what we do we take a point, and then from this point we draw a line parallel to this c. So, let us say this is what is your c, so, I draw a line parallel to this, and it intersects the other side of the tunnel at this particular point.

Then, from the same point, I draw a line parallel to the strike a, which is this so let us say I mark it with three small lines, and see like this, so, this line I draw parallel to this particular line I do not know what will be its extent. So, right now, I leave it as it is and then I come to this particular point, and from here, I draw a line which is parallel to the strike of b. So, let us say that it is this one, so I draw this line parallel to this b here and the extent of this strike is also not known, so I just draw a parallel line to this b here.

And, wherever these 2 intersect that will give me the third point of this triangle. So, this is how that we can determine the plan dimension of the wedge.

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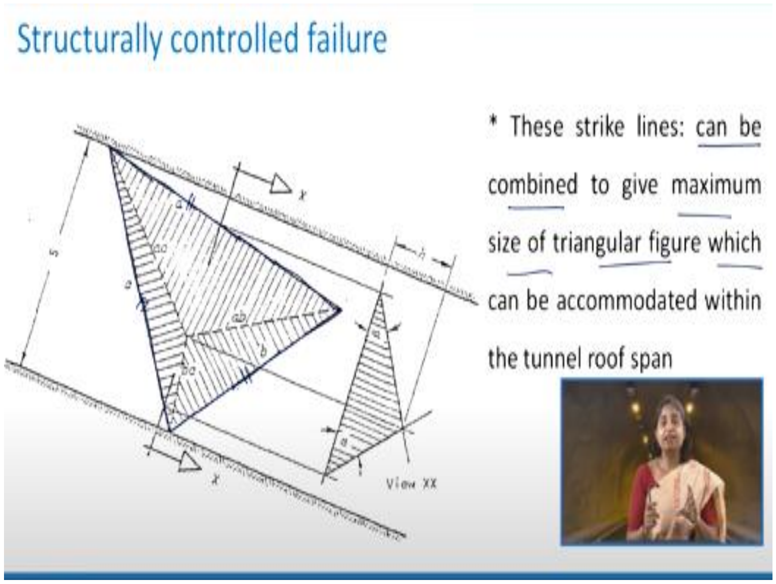

So, these strike lines, we can combine, which will give us the maximum size of the triangular figure which can be accommodated within the tunnel roof span. So, I mentioned to you how we can draw these parallel lines and how we can get or how we can complete this triangle. Now the question is this is the plan dimension how I can get the height of this wedge?

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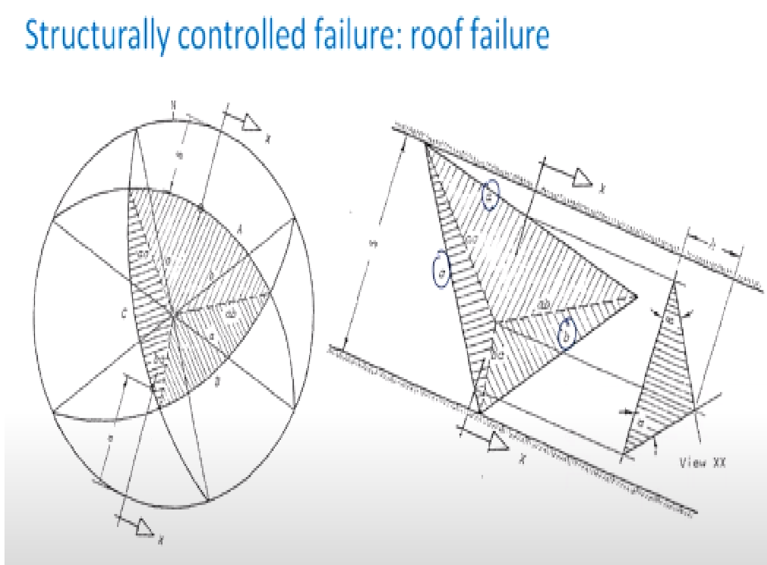

So, we will learn that as well so what we are going to do here is that once I get this a, b and c here on this, so, first thing is that we need to find out the apex.

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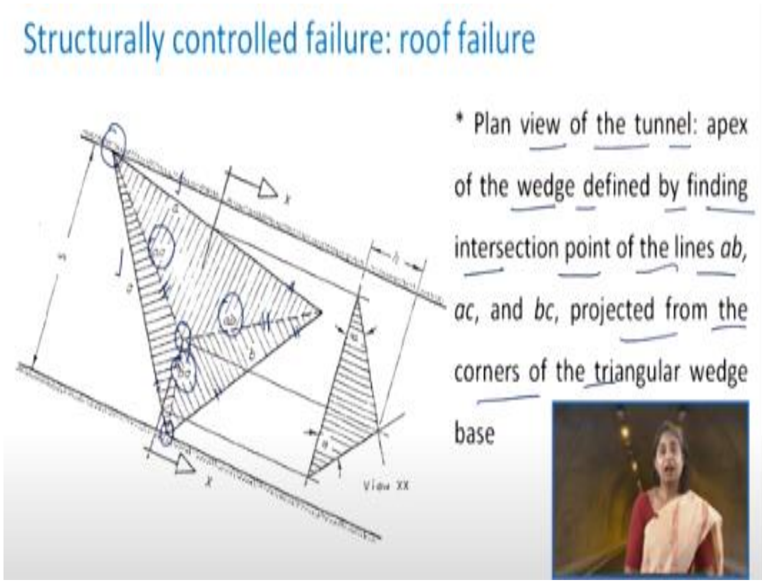

So, for that first, we have the plan view of the tunnel, so apex of the wedge it will be defined by finding the intersection point of lines ab, ac, and bc, which is projected from the corners of the triangular wedge base. So, you see that this is b and c, so, from the intersection of b and c what I will do is I will draw a line parallel to bc, from this stereo plot. Similarly, from the intersection point of a and b, I will draw a line parallel to ab, and from the intersection point of a and c which is this point I will draw a line parallel to ac.

So, wherever all the 3 lines they intersect, that are this particular point, this will be the apex of the wedge.

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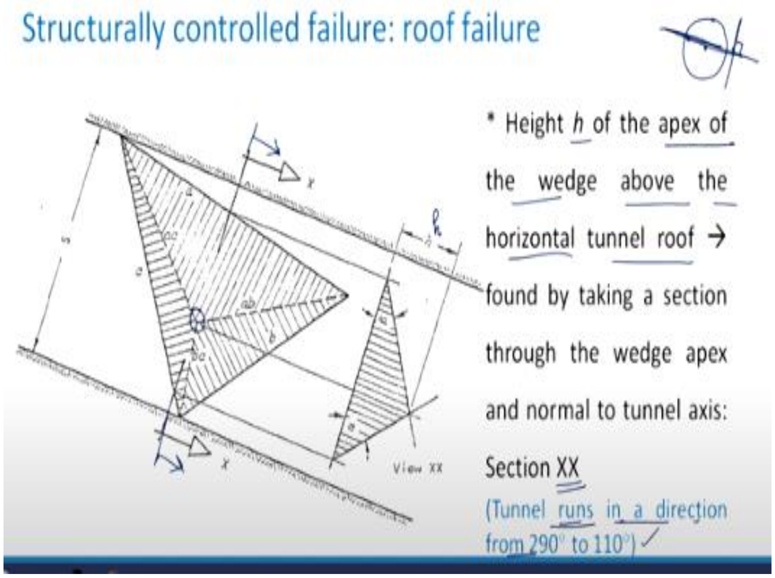

Take a look here, so, once I know this apex, I can find out the height h of the apex of the wedge, which is above the horizontal tunnel roof how to do that? So, what you need to keep in mind that tunnel runs in a direction from 290^0 to 110^0. So, what I am going to see is, the plane which is something like this. So, what I do is, I take a plane which is perpendicular to this, so, there I define the section XX.

So, basically, this is the tunnel axis as the tunnel is running in, in a direction from 290^0 to 110^0, so, normal to that tunnel axis I am going to consider a section XX, which has been shown in this figure in this particular manner. Now when I take that section which is normal to the tunnel axis, and if I take a view from that, that is going to give me the dimension h, which is the height of the apex of the wedge above horizontal tunnel roof.

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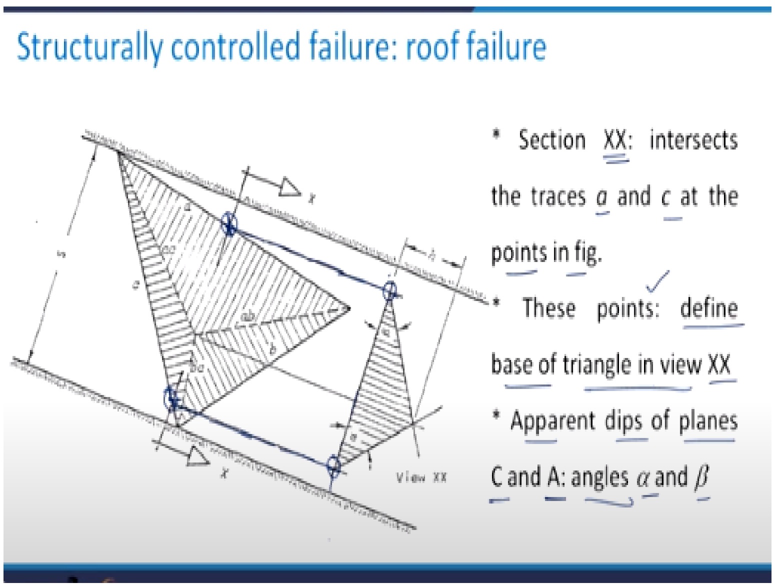

So, how to do that take a look this section XX this intersects the traces a and c at the points, that I am shown in the figure, this point and this point. Now these 2 points, these will define the base of the triangle, when you look in the direction XX so what we do is, we project these in this particular manner, and you take any line here so this is going to be, that is 2 points, and the distance between the 2 points. This is going to be the base of the triangle in view XX, that is when viewed in the XX direction.

Now, apparent dips of the planes c and a, they are defined by angles α and β, the question is how to determine? And, why we are taking the planes a and c and not the plane b? Take a look here, that here, this is what is the c point and a, one that is defining us the base of the triangle.

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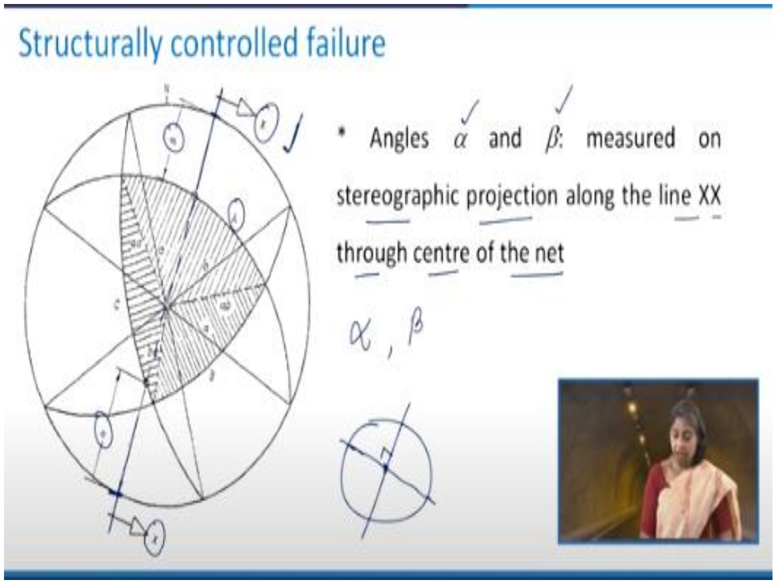

Now you see here, these angles α and β, these are measured on the stereographic projection along the line XX through the center of the net. So, you see that the axis of the tunnel was something like this that is 290^0 and 110^0. So, I draw a line that is perpendicular to this, which is this line, and that is showing the section XX here, and of course this has to pass through the center of the net.

Now, take a look here this α, how it is determined? So, from the outer circle we take wherever this plane XX intersects the plane c. So, that much division you can count and find out what is the value of α. Similarly, from this outer circumference wherever it intersects the plane a, that is the great circle for plane a, that is going to give me the value of angle β. So, from this stereo plot, I can get the value of angles α and β.

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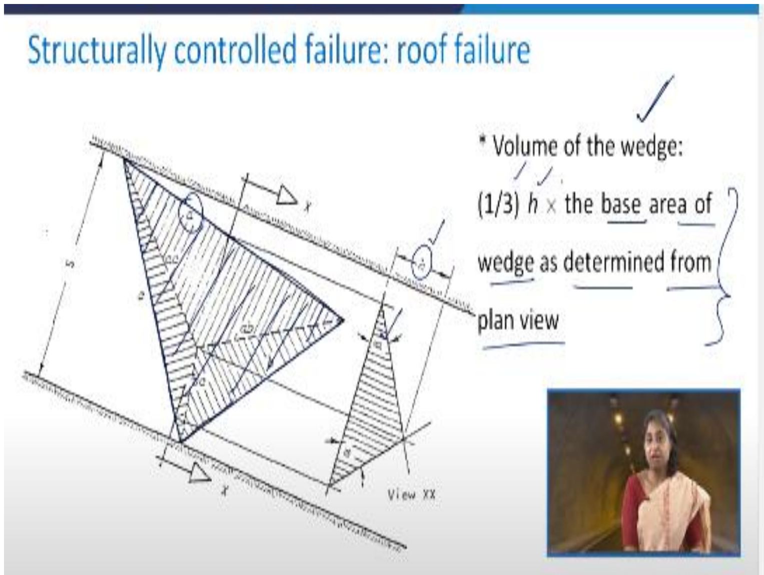

So, once I know that, what I will do is from this plane corresponding to this c, I will draw a line making an angle α and from the point corresponding to this a, I will draw a line making an angle β. So, wherever these 2 intersect, that is going to be the height of the wedge. So, we can find out the volume of the wedge, how it is one-third of the height, and multiplied by the base area of the wedge, as one can determine from the plan view.

So, how can you get the base area it is this, hashed to portion between the 3 lines, this one so this is the portion you can get the area from, And the height, you can determine from here, so after you get the height and the area all you need to do is, use this expression to get the volume of the wedge. So, this is how one can determine, in case of roof failure we can determine the volume of the wedge.

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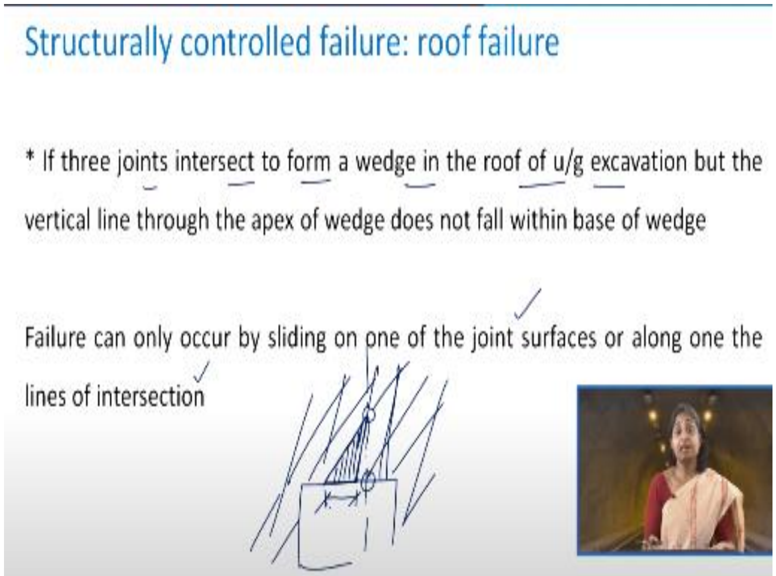

Now, there can be a situation which is little bit different than the situation, that we discussed although it is going to be the failure of the roof. But, then the, it can be bit different, there may not be typically the gravity fall of the wedge in the excavation. Now, if the that condition include, when the 3 joints they intersect to form a wedge in the roof of underground excavation, but the vertical line through the apex of the wedge, it does not fall within the base of the wedge.

So, let me draw a figure, and maybe I will be able to explain it in a better manner. Let us see if this is what is your say, the excavation something like this and then you have may be another set of discontinuities are like this, so this is the plane. Now, which is formed 3 planes and they are forming a wedge like this in the roof itself. Now, if I draw a vertical line from the apex, which is this point so you see I draw a vertical line and it is falling outside the base, this is what is the base, but then it is falling outside the base.

So, in that case, what will happen that the failure can occur only by sliding on one of the joint surfaces, or along one of the line of intersection the failure is not going to be like the gravity fall of this wedge in the excavation from the roof. So, this is the check that one needs to see whether there is going to be the gravity fall or not.

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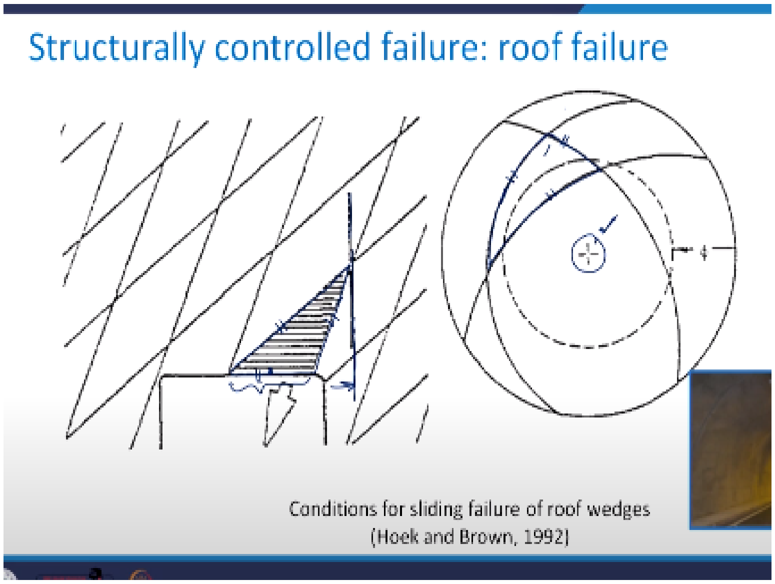

So, how to handle this situation? And, how we can show it in the stereographic projection? So, this, I explained you that in case, if you have this type of situation that the, although the wedge is formed in the roof. But, the vertical line passing from the apex is not falling in the base region, that is this much but outside the base. So, in that case this is going to be the situation, so all these 3 discontinuities can be plotted on the stereographic net with the help of their respective great circles.

So, you see that first, second and the third great circle, and it has, of course formed a closed intersection figure like this, but what is the situation as compared to the earlier one? In the earlier case, the center of this circle was falling inside this intersection figure, but in this case, what is happening is that this center is outside this intersection figure. So, therefore we can say that no gravity fall of the wedge from the roof will take place.

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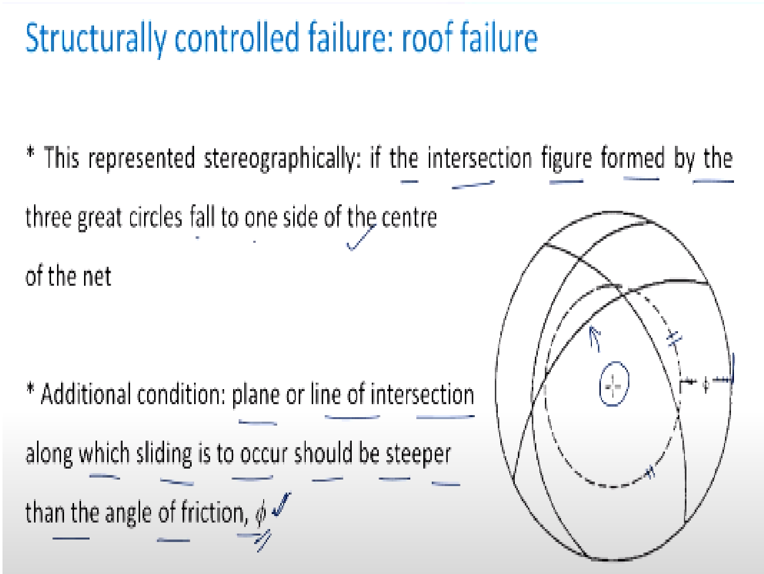

Now, there can be 2 situations that, if this intersection figures that is formed by the great circle fall to the one side of the center of the net. So, you see it has fall on a particular side, this side, then there is going to be the additional condition that is plane or the line of intersection along which the sliding is to occur, should be steeper than the angle of friction ϕ (phi). So, how can we check that?

So, what we do is we know the angle of friction, So, from the outer circumference, we count those many degrees, and then we plot or we draw this circle which is also called as the friction circle here. So, this has been represented with the help of a dotted circle, of course, the center will remain the same this is the center of the stereo net.

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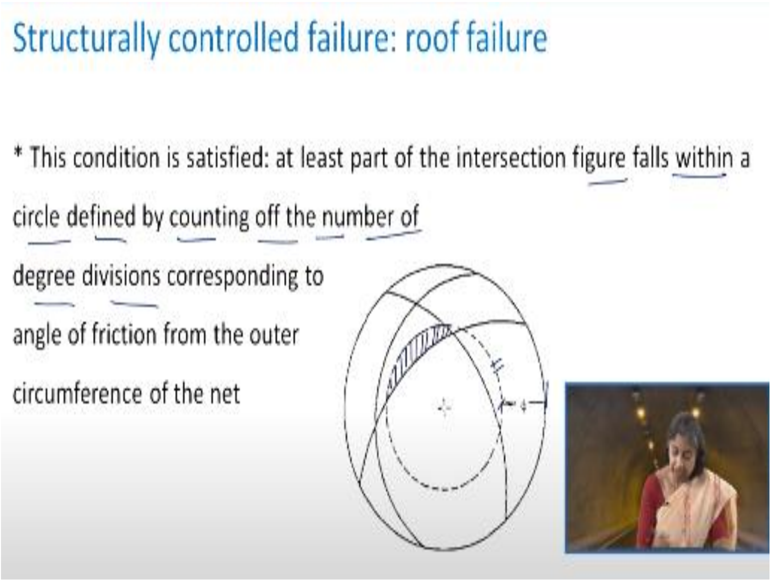

Now this condition is satisfied, if at least part of the intersection figure falls within the circle which is defined by counting of the number of degree division corresponding to the angle of friction from the outer circumference. So, you take a look from the outer circumference, I count and reach to this friction circle which is this dotted circle and you see some part of this intersection figure is within this friction circle.

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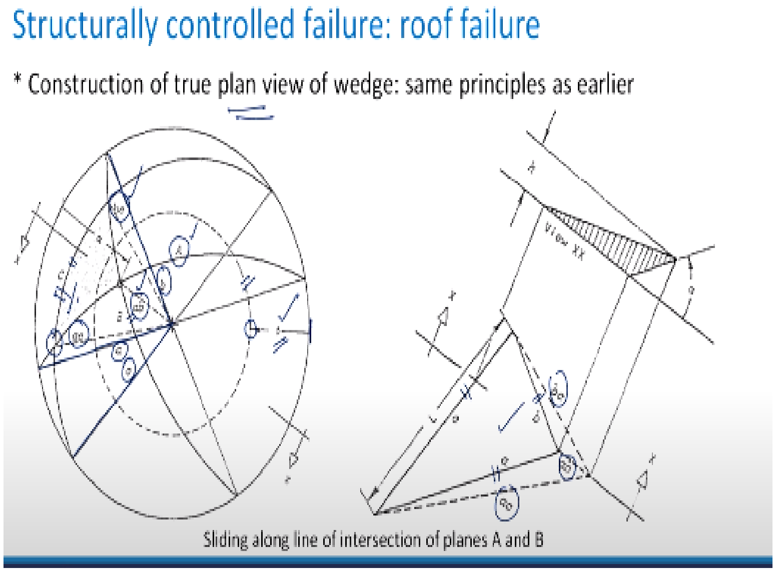

Now, in such situation the construction of true plan view of the wedge can also be made, but then it will follow the same principle. So, let us take a look so again here we have the 3 discontinuity planes, plane a, and then this is plane b, and then you have the third plane which is plane c. So, we can get there strike direction, take a look here if you just join this, this is going to be point a for the circle b, you join here and you will get this strike as b, similarly for this circle c, it is the direction.

Now, again in this case whatever is the tunnel axis, we take a section that is perpendicular to that, and we try to view in that direction to obtain these views. Now how to get the friction circle? So, from the outer circumference, I count the degrees here, and then I draw a circle that is the dotted one, which is the representing or which is representing this angle ϕ (phi). So, wherever there is the intersection say the intersection of great circle a, and great circle c, it is this point you join it with the center, and you will get the trace ac similarly you can get trace ab and trace bc.

So, what we now do is, we try and draw the lines parallel to a, b and, c and hence we will be able to get the, this triangle. And then, we draw the line parallel to ab, ac and bc these are parallel to the respective directions here, this is ab, this is bc, and ac. So, in exactly on the same principle, as we discussed earlier, we can draw this particular figure.

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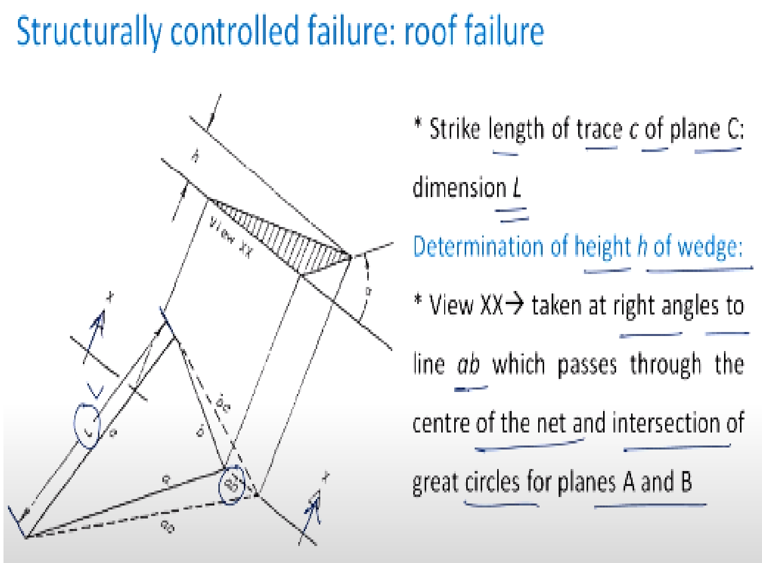

Now, here we take the strike length of trace c of plane c as the dimension l, so this has been shown here this is dimension l. So, how to determine the height h of the wedge in this case? So, we take the view XX again this is perpendicular to the tunnel axis as mentioned here. So, this is a right angles, to line ab which passes through the center of the net, and intersection of the great circles for planes a, and b, so you see that, this is what is the ab that is shown. So, you take it this XX perpendicular to this.

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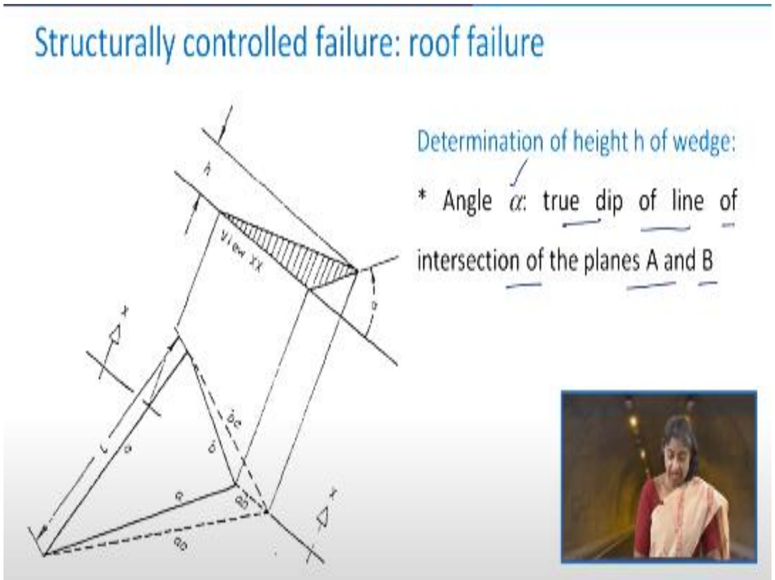

And then, how we can get the angle α? which is the true dip of the line of intersection of the planes a and b?

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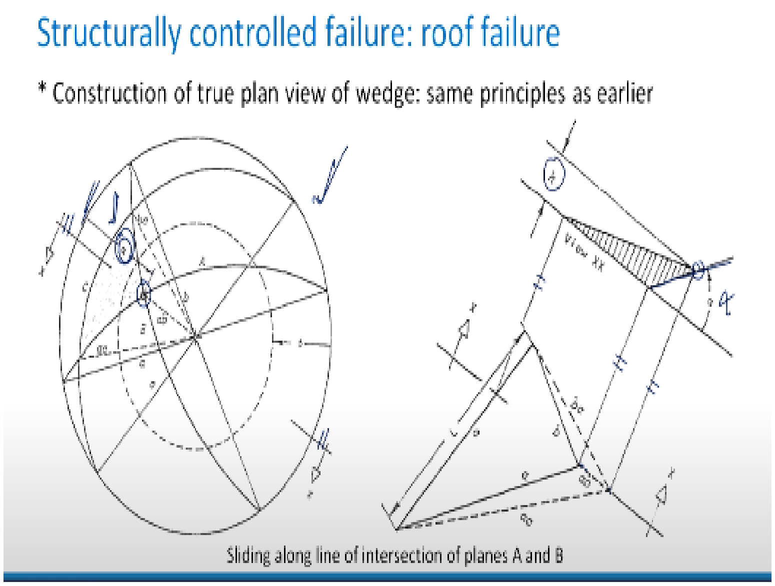

That, we can get from the stereo plot, here take a look this is the intersection ab and from the outer circumference, I measure this angle α in the direction of the section XX, so this is how from this figure, I can determine the value of α. So, I take the various projection lines here, and from this particular point, and so we really do not know that what will be the orientation of this ab. So, I take this value α from the stereo plot, try to draw the line which is making an angle α here wherever it intersects, that is going to give me the height h, that is the height of the wedge.

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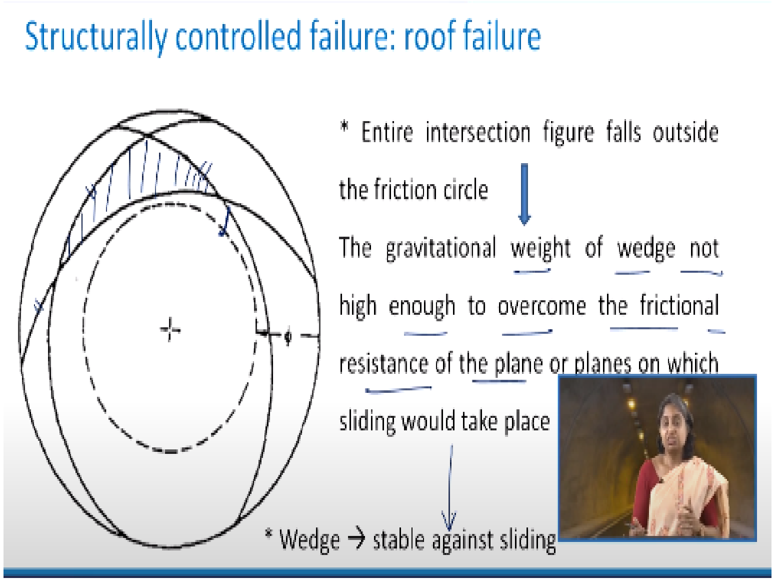

Now, there can be another situation that the entire intersection, figure it falls outside the friction circle. As, has been shown in this figure, so you see that the 3 great circles are 1, 2 and then the 3 and their intersection figure is this, and which is just lying outside the friction circle, which is represented by this dotted circle. So, this represent that, the gravitational weight of the wedge is not high enough to overcome the frictional resistance of the plane or the planes on which the sliding would take place.

So, what does that mean? This signifies that the wedge is going to be stable against sliding. So, that is how we can determine whether there is going to be the gravity fall of the wedge that is formed in the roof, or there is going to be the sliding of the wedge, along any discontinuity plane or the wedge is going to be stable against sliding. So, in this class, we learnt about, the stereographic projection, and its application with reference to the roof failure.

We saw the conditions, that when there is going to be the gravity fall of the wedge, or there is going to be the sliding along any discontinuity from the roof, or the wedge is going to be stable, as far as roof failure is concerned. In the next class, we will continue this discussion with reference to the side wall failure, thank you very much.