Rock Engineering

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Lecture - 44
Structurally Controlled Failure: Sidewall Failures - 1

Hello everyone. In the previous class, we discussed about the structurally controlled failure with reference to the roof failure of the tunnel. We saw that how the wedge is formed in the roof. And, how the stereographic projection can be of help to us in identifying whether the wedge which is formed in the roof will fall in the underground excavation or whether it will slide or whether it will be safe.

So, today we will take up the failures which may occur in the wedges in the sidewalls of the tunnel. So, here we have 2 methods for the analysis. So, today we will discuss the first method and a part of it. And then we will continue with this in the next class. So, in the sidewall of an excavation in the jointed rock, the failure of wedges can occur in much the same way as it was in the case of roof.

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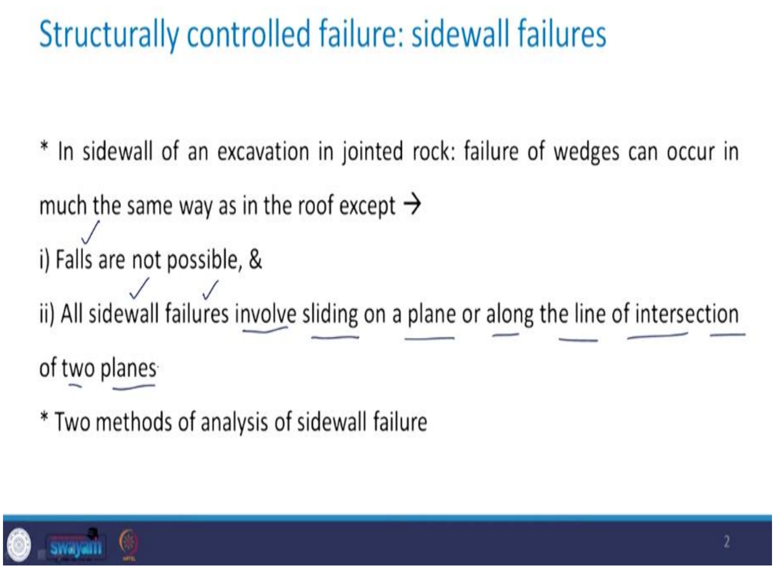

Except that in these cases falls are not possible. All sidewall failures will involve sliding on a plane or along the line of intersection of 2 planes. 2 methods of analysis they are available for the sidewall failure.

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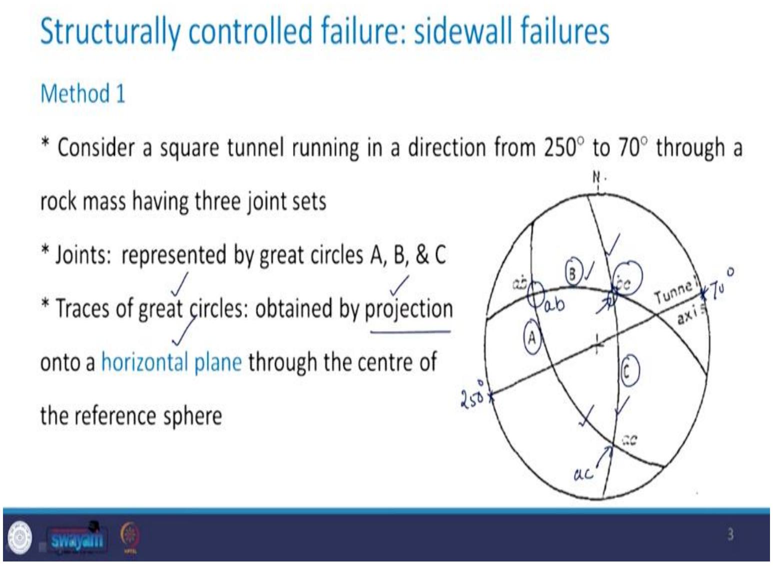

Let us have a look at the first method. So, here we consider a square tunnel which is running in a direction from 250° to 70° through a rock mass which has 3 joint sets. So, take a look here that this is north. So, 70° means, this angle and this is what is your 250°. So, if we join these 2 points that is going to give us the tunnel axis. The there are 3 joint sets, which are represented by the 3 great circles A, B and C. This is A, B and C.

Traces of these great circles, they can be obtained by projection on to a horizontal plane through the centre of the reference sphere. And the intersection point of these great circles have been given here. As you see, this is A. This is C. So, this is *ac*. This is B. This is C. So, this point is *bc*. Similarly, this point is *ab*. Now, since these traces of the great circles they are obtained by the projection onto a horizontal plane through the centre of the reference sphere.

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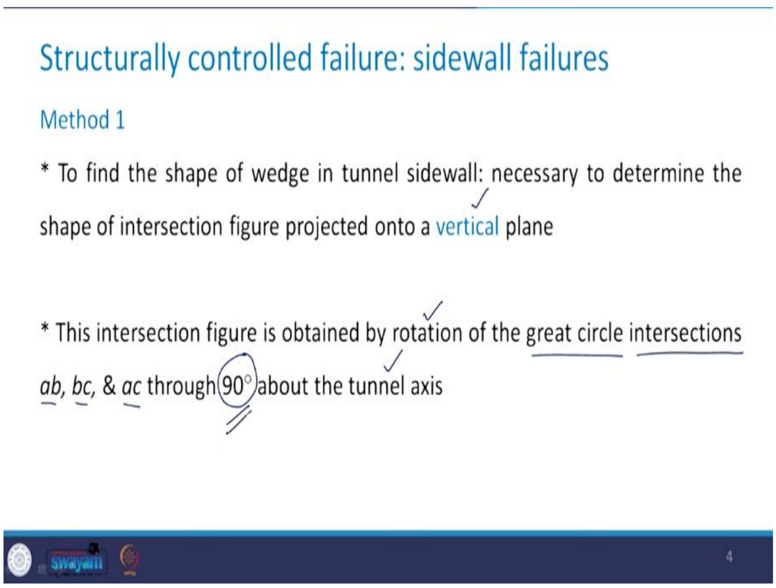

In order to find out the shape of the wedge in the tunnel sidewall, it is necessary to determine the shape of intersection figure which is projected onto a vertical plane. And how this can be obtained? By the rotation of great circle intersections, which is *ab*, *bc* and *ac* through 90° about the tunnel axis because in one case you are getting it on a horizontal plane. And to find out the shape of the wedge in the tunnel sidewall we need to project it in a vertical plane. So, one has to rotate these great circle intersections through 90° about the tunnel axis.

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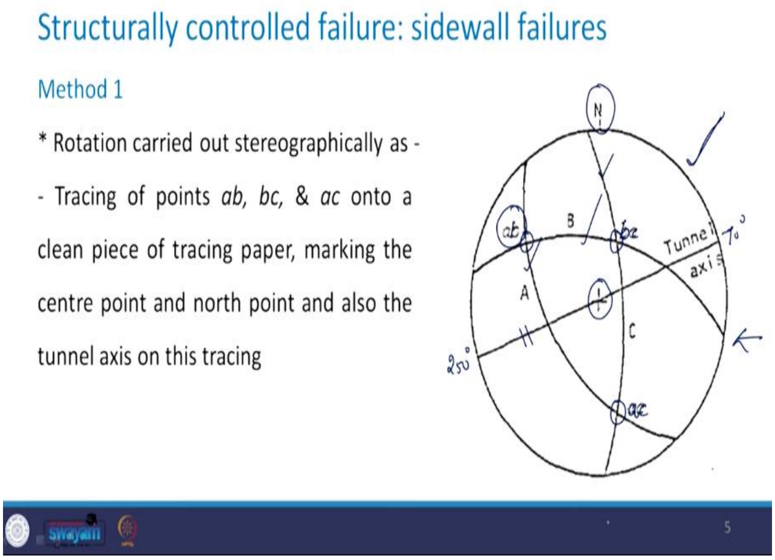

Let us see, how this rotation can be carried out stereographically? So, this is the figure. Here it is your tunnel axis 250° and 70°. We have these intersection points *ab*, *bc* and *ac*. So, what we do is we take a tracing sheet and on that we mark these 3 great circles their intersection points along with the tunnel axis and the centre of the reference circle. Also, we have to draw this north point.

So, on a tracing sheet, this whole construction will look like this figure. I do not need to explain you this because we already had detailed discussion in the earlier chapter when we learnt that how to project, how to draw these geological data using these stereographic projections?

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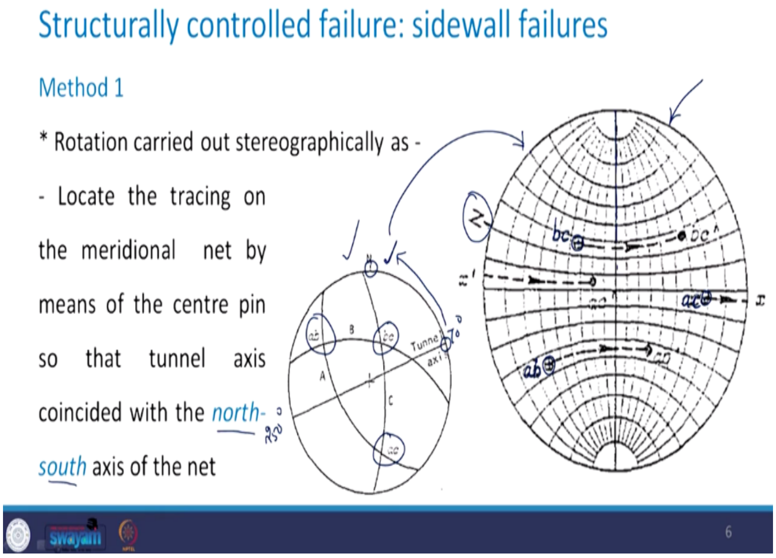

Now, how to carry out the rotation? So, what we do? See our figure looks like this. So, what we do is that we locate this tracing sheet on the meridional net like this, such that the tunnel axis which is 250°, 70°. Now, coincides with the north south axis of the net. So, what I have to do is I need to rotate this tracing sheet in the anti-clockwise direction by 70° so that this point of the tunnel axis gets coincide with the north.

So, you see that it will look like this. So, this is what is your tunnel axis now. And you can see that 10, 20, 30, 40, 50, 60 and this is 70°. And this north is here. So, let us see how these intersection points which are *bc*, *ac*, and *ab* these are rotated? So, when we rotate this figure in order to get this these points also get rotated by 70°. And look here that their original position after the rotation is this. This is your *bc*. This point is *ab* and this point is *ac*. So, once we know these points.

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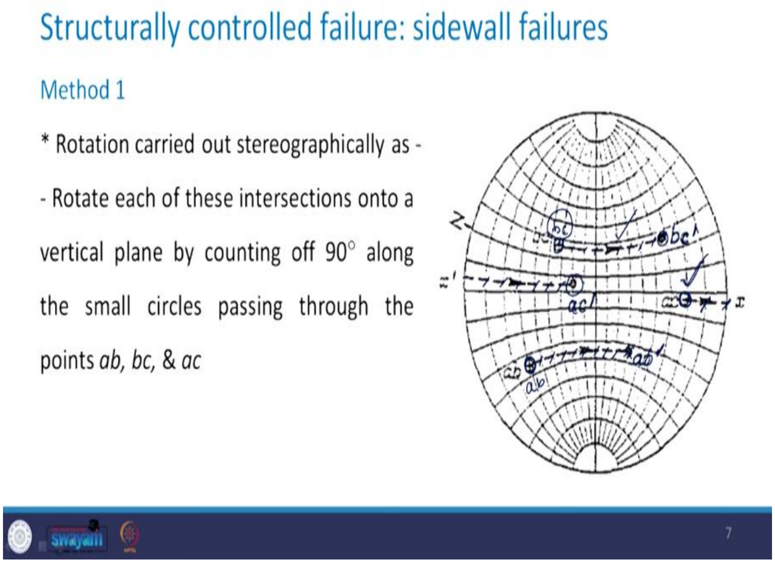

We rotate each of these intersections on to a vertical plane by counting off 90° along these small circles which are passing through the points *ab*, *bc* and *ac* respectively. Take a look here. This is the point *bc*. Now, see 10, 20, 30, 40, 50, 60, 70, 80 and 90. And here we get a point which is being rotated or which we have got by the rotation of this point *bc* by 90°. Similarly, the point *ab* which is originally here again it is rotated.

So, you see 10, 20, 30, 40, 50, 60, 70, 80 and 90. And this is going to be *ab'*. We write it as *ab'*. Now, this point *ac* which is here, and you see that only 10 and 20 and then it goes on the other side of the circumference, it enters from this point. So, you see 10, 20 then 30, 40, 50, 60, 70, 80 and 90. So, this is the rotated portion or the rotated location of this point *ac*.

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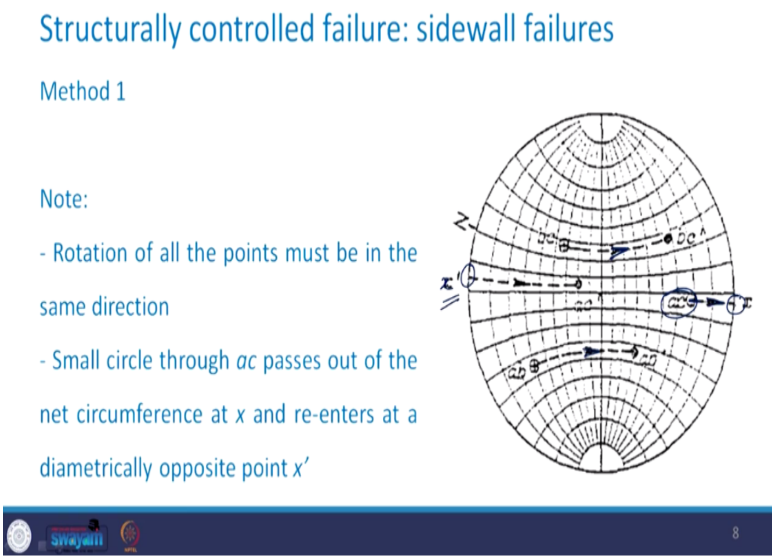

You need to keep in mind that rotation of all these 3 points must be in the same direction like we are following in this direction this direction. Now, this small circle, which is passing through this point *ac*, it goes out of the net circumference at this point *x*. And it reenters at this point *x*' which is diametrically opposite point *x'* diametrically opposite to *x*.

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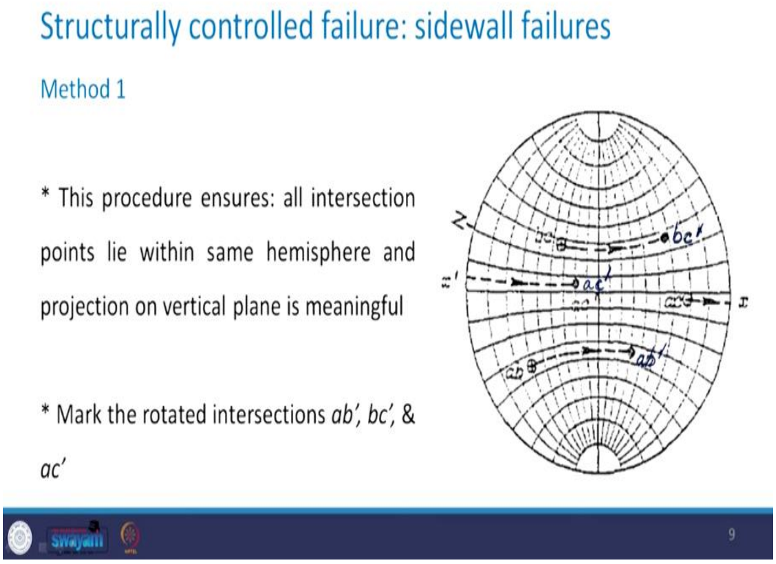

Why it, why we need to do it in this particular manner, is that if we do it in this manner, all the intersection points will lie within the same hemisphere and the projection on the vertical plane would be meaningful. So, we mark these rotated intersections as *ab'*, *bc'* and this is *ac'* .

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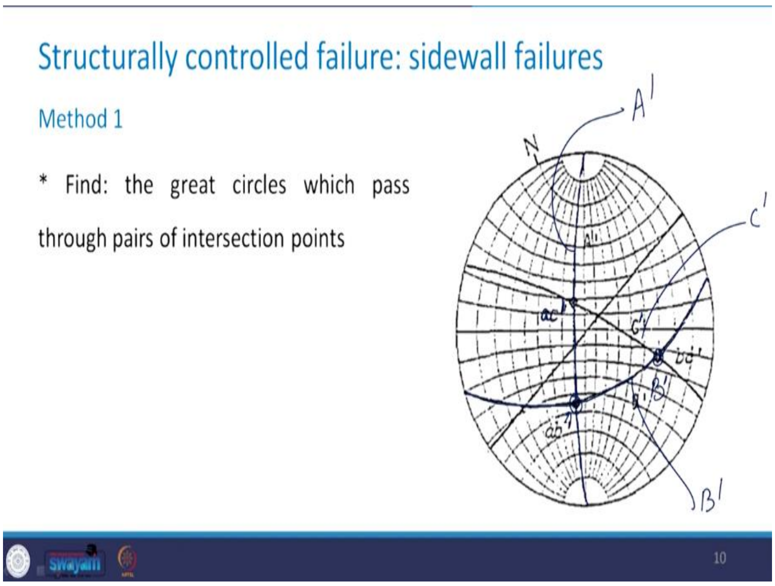

Now, we find the great circles which pass through these pairs of intersection points. For example, see, this is your *bc'* and this is *ab'* and we find out the common great circle which is passing through both of these. And we call this as the great circle B*'*. Like you see here the construction of the great circle is given for the intersection points *ac'* and *ab'*.

So, you see that this is the common great circle, which is passing through both of these points. And here you see that the plane A*'* is or plane A is common here. So, we are calling this great circle as A*'*. In this case it was B*'*. And similarly, this one is going to be represented as C*'*. So, this is how we get 3 great circles which are passing through these pair of intersection points.

Now, the strike line of these great circles is going to give us the traces of joint planes on the vertical sidewalls of the tunnel.

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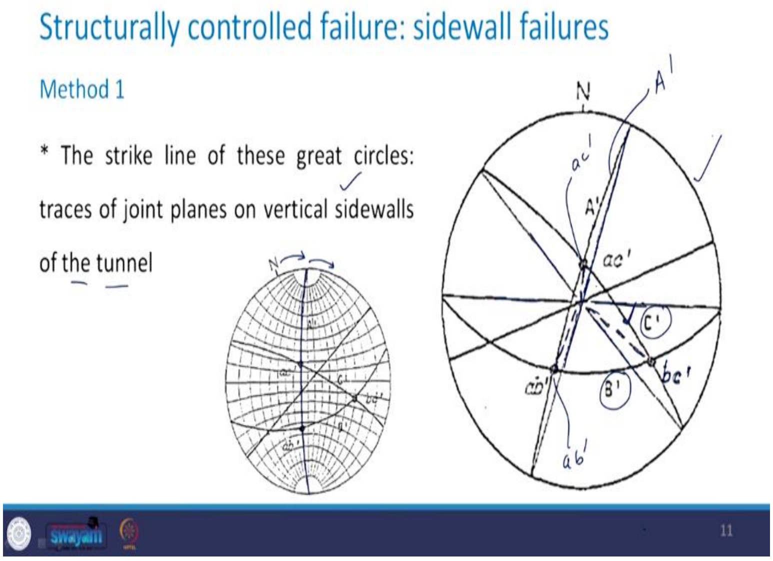

Take a look here. See this figure. We showed the construction of a great circle which was passing through the points *ac'* and *ab'*. Now, I rotate back this north to the original position. So, you see that this circle will also get rotated by the same angular distance. And it will look like this. So, here this is what is your A*'*. This is B*'*. And your this circle that is, this circle is your C*'*.

So, the strike of these great circles, they are going to give us the traces of the joint planes on the vertical sidewalls of the tunnel. So, this is how we can get the strike lines of these 3 circles. Now, wherever these circles are intersecting, obviously, these are the points like for this it is *bc'*. This this point is this is your A circle and C circle. So, this point is your *ac'*. And this point is your *ab'*.

So, if you join it with the centre, you will get these traces. See, because then we have to find out the size and the volume of the wedges. We will need all this information which we have to take from this stereographic projection and make a use of these in order to obtain the shape and the size of the wedge.

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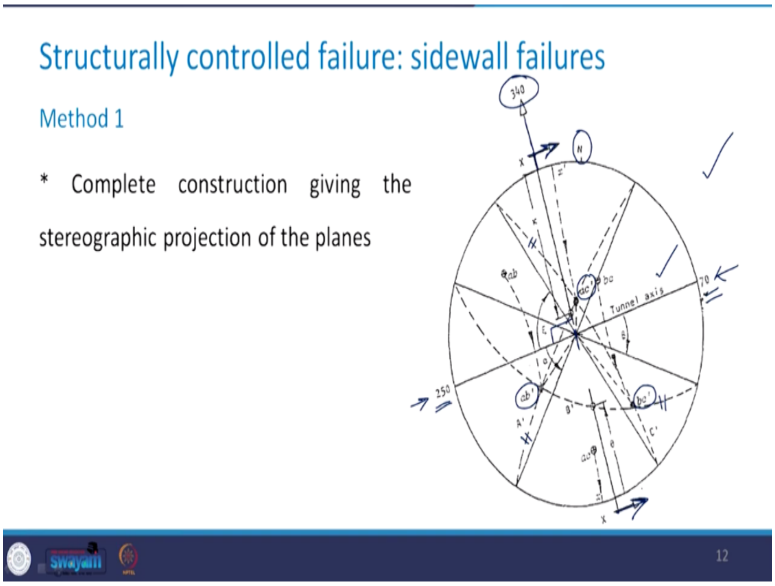

Now, the complete construction giving the stereographic projection of the planes is given in this particular figure. So, you can see that, this is the tunnel axis. The north position is here. And you have these dotted great circles which are A*'*, B*'* and C*'* wherever they intersect, you have these points *ab', bc'* and *ac'.* And if you join these, you are going to get these traces for these intersection points.

Now, here in this case, the tunnel axis is running from 250° to 70°. So, again in this case we take a plane which is passing from the centre and it is perpendicular to the tunnel axis. So, what does that mean? See here if I just add 90° to this, this is going to be your 340°. So, we take a section here and then this we look in this direction that is which is XX direction as we did in case of the roof failure. Basic philosophy remains the same.

That is how the construction is being done. That remains the same. It is there is only the difference that on which plane that we are projecting these in order to get the true shape of the wedge, its size and its volume.

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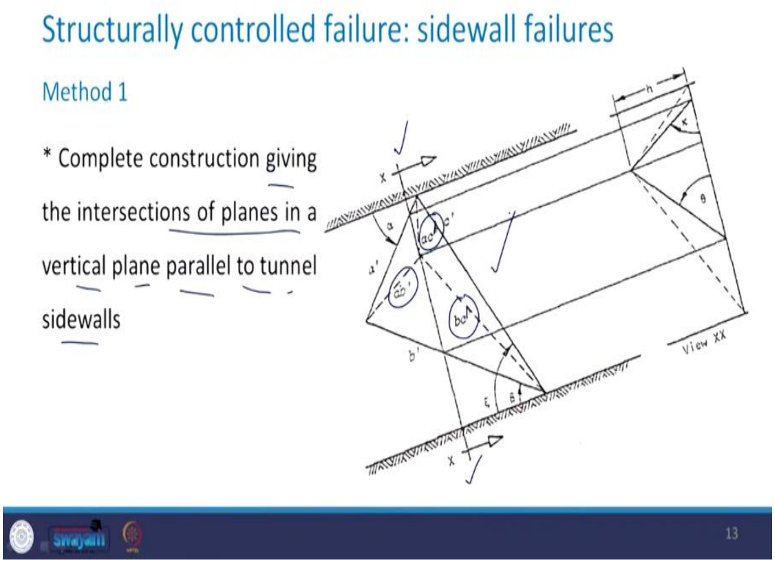

See the complete construction giving the intersection of the planes in the vertical plane parallel to the tunnel sidewall. So, this is how that we are going to plot this Section XX. And from the stereographic projection, we already have got *ab', bc'* and *ac'* directions. And we can draw the parallel lines as we did in case of the roof failure. Here also we can construct the shape of the wedge in the similar manner.

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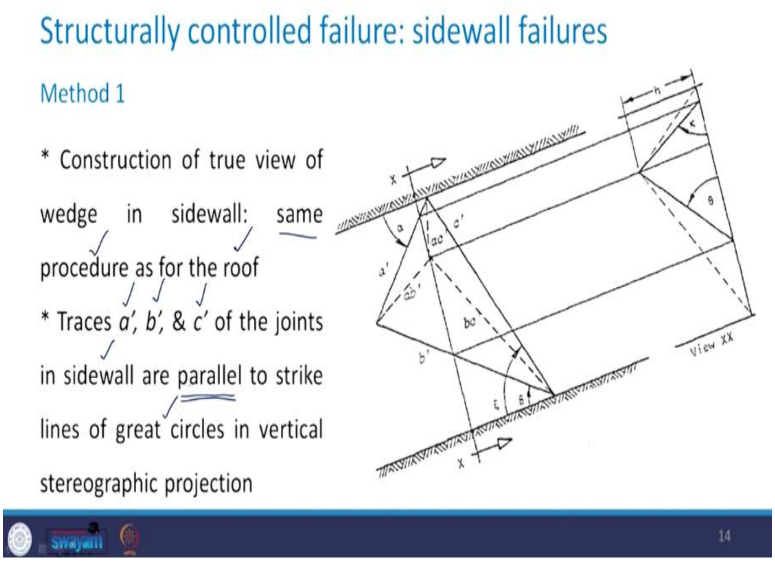

As I mentioned, the construction of the true view of wedge in the sidewall is the same procedure as for the roof. So, these traces *a', b'* and *c'* of the joints in the sidewall, they are parallel to the strike lines of the great circles in the vertical stereographic projections.

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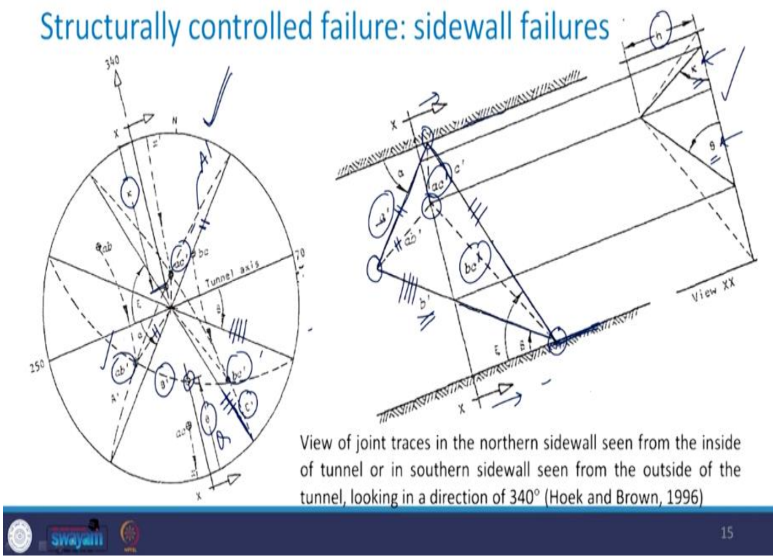

So, here you see that we have these stereographic projections. So, I have put both these figures side by side. Take a look here. You now know how to determine these *ab', ac'* and *bc'?* You need to rotate the original intersection by 90° and get these 3 points. Join these with the centre and that is going to give you the direction. Then here you see that this is what is your circle A'. So, its strike is this. So, I draw a line parallel to this here.

So, you see that this is what is A'. I take a point and from there I draw a line parallel to this. Then from the same point, I draw a line parallel to this C' because this is your great circle C' and this is going to this is the strike line. And this is going to give me the trace of this great circle. So, I draw the line parallel to this line here. Now, wherever this line intersects this end of the tunnel, then from that point you draw a line, which is parallel to this B'.

So, this is your B' circle and this is what is its strike line. So, I draw a line parallel to this line in order to get this B'. So, this is how I am going to get this complete triangle in this fashion. Then how to locate the apex of the wedge? What you need to do is, see from A', B prime, this is the intersection point.

From this point, you draw a parallel line to this ab' which is here this line. Then similarly, you draw these parallel lines *ac'* and *bc'* wherever these 3 intersect that point is going to give you the apex. And then you project it in this particular direction. And following the same procedure as we had in case of the roof failure, you can construct this. Now, as far as the determination of these angles are concerned that is θ and χ.

So, you see here that this is how this angle χ is determined and from here this angle θ is determined. This is angle θ. So, once you know this, do the all the projections and you will be able to get the height of the wedge h in this particular fashion. So, the detailed discussion of this, how to determine the volume of this and the height everything with respect to method one, we will continue in the next class.

And then we will also discuss about the second method for the analysis of these sidewall failures. Thank you very much.