Rock Engineering
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Lecture - 45
Structurally Controlled Failure: Sidewall Failures - 2

Hello everyone. In the last class, we had the discussion on structurally controlled failure in case of the tunnels with special reference to the failure in the sidewall. I was discussing with you that how the construction of this full view of the wedge, which may slide from the sidewall of the tunnel can be carried out. So, we will continue with that discussion today. And we will try to see that what all are the methods which can be used for the analysis of such type of failure?

So, we had discussed about the method number 1. So, in continuation to that, take a look here on these figures.

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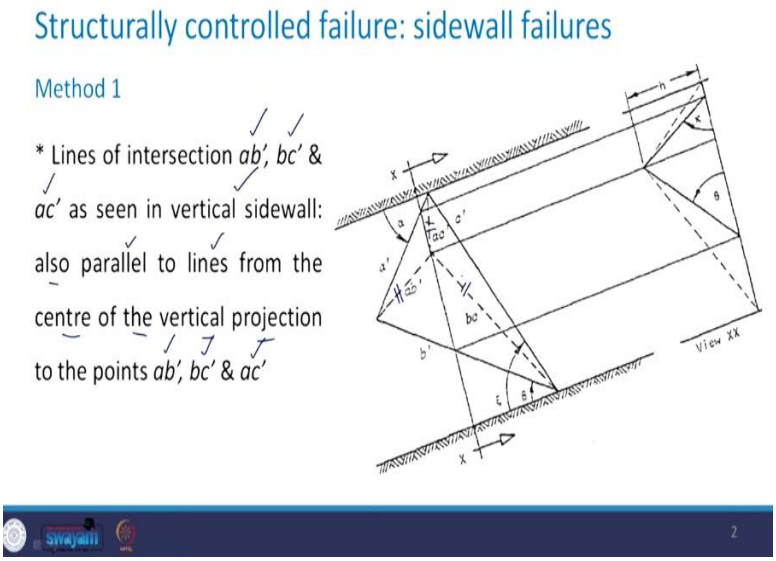

That these lines of intersections ab', bc' and ac' as they are seen in the vertical sidewalls. These are also parallel to the lines from the center of the vertical projection of the points ab', bc' and ac'. So, we are talking about these 3 lines. You see first one, second one and the third one. Let us try to see these along with the stereographic projection.

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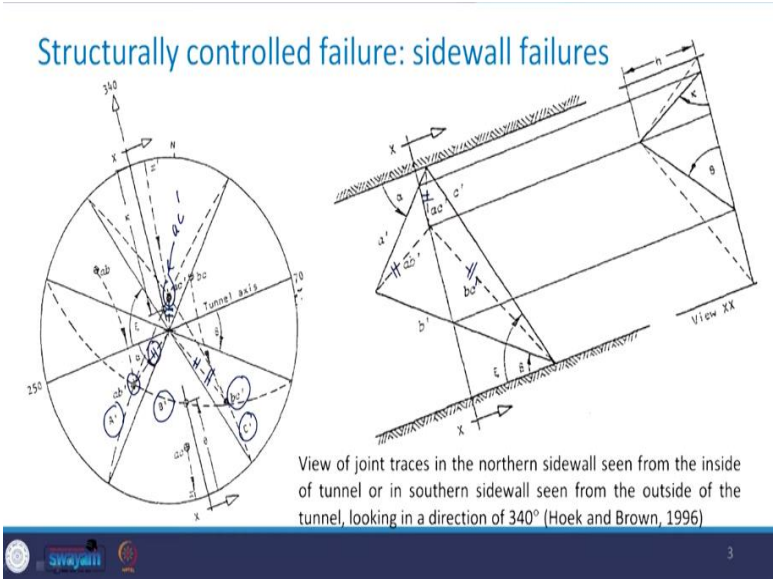

So, here you can see that this is your circle great circle A'. This is great circle B' and this third one is great circle C'. So, wherever this B' and C' they are intersecting that point is bc'. A and B here which is ab' and A and C this point is your ac'. Now, just join these points with the center and you will get here this dotted line this dotted line and this dotted line.

So, the statement that has been mentioned in the previous slide means that this line here ac' is parallel to the line here. bc', this is parallel to this. And ab' is parallel to this line.

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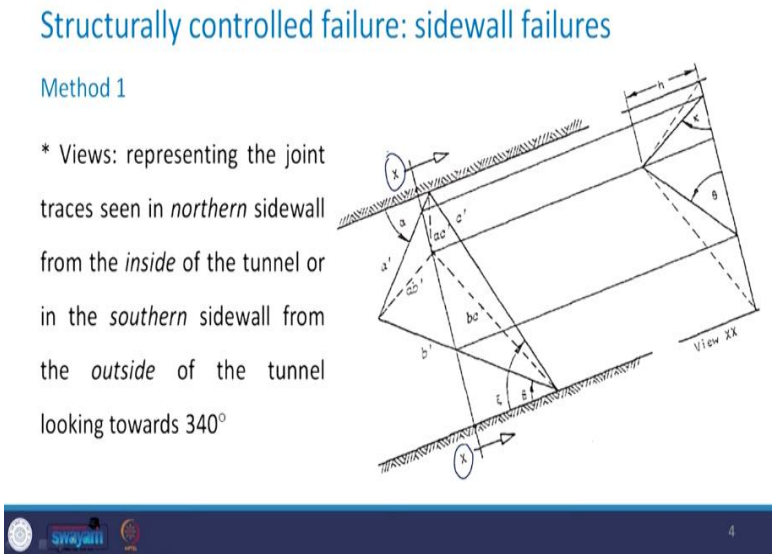

Now, these views these are representing the joint traces, which are seen in northern sidewall from the inside of the tunnel or in the southern sidewall from the outside of the tunnel if we look towards 340°. Remember that the tunnel was running in the direction from 250° to 70°.

And we have taken this section XX which is perpendicular to the tunnel axis and passing through the center of the net.

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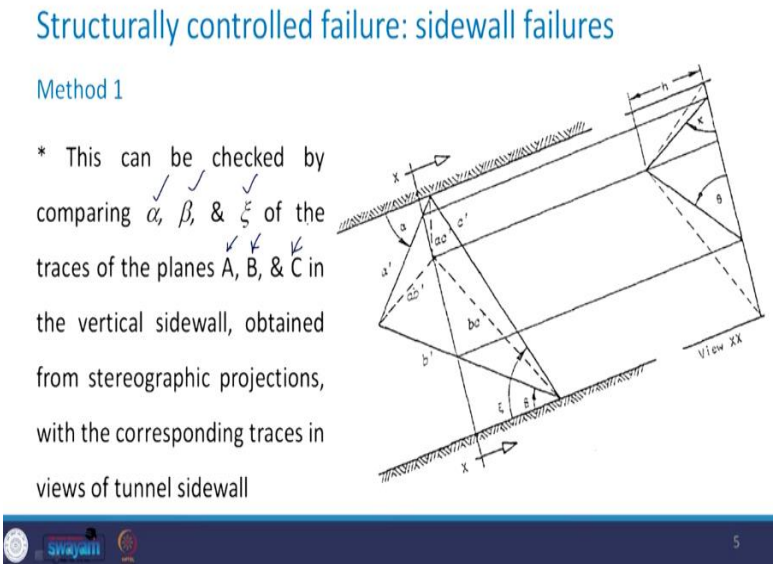

Now, it can be checked by comparing these 3 angles α, β and ξ of the traces of the place respectively for A, B and C in the vertical sidewall obtained from these stereographic projections with the corresponding traces in the views of tunnel sidewall. Again, we take a look to both the views together.

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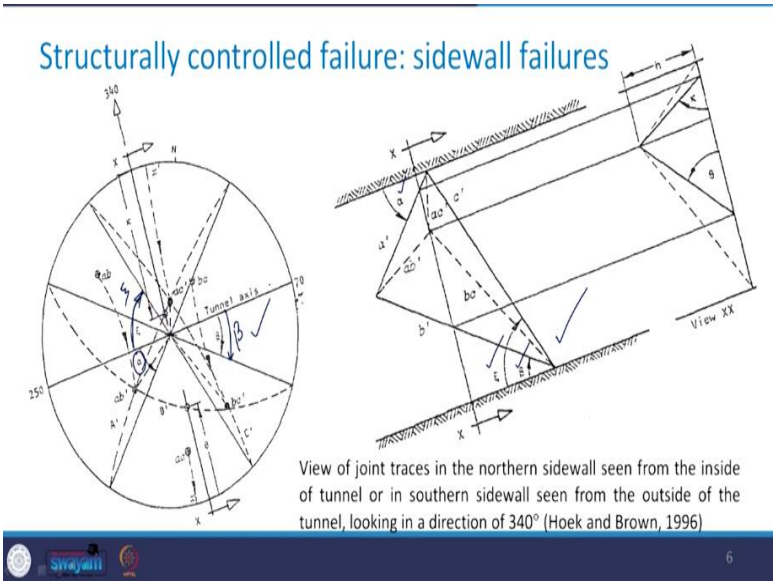

See here, this is the angle α. This is this angle is angle β and this angle is angle ξ. Now, if we try to get the α, β and ξ from this view and try to compare it, what we got from this view, they will work out to be same.

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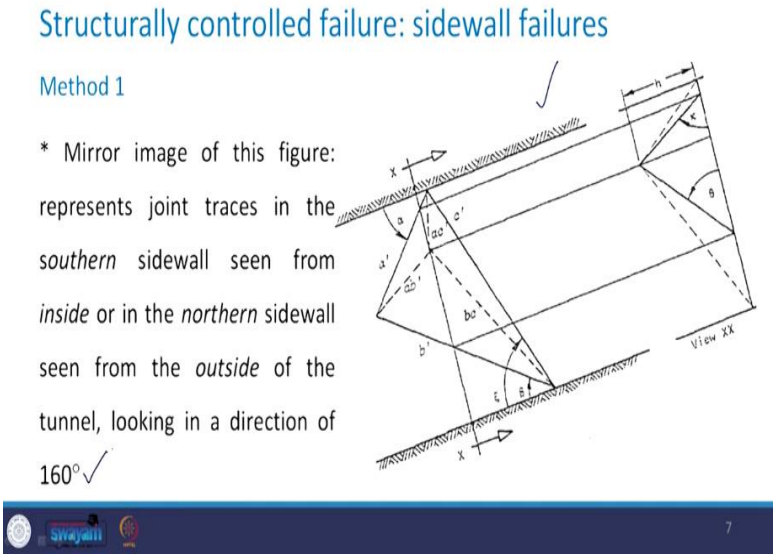

Mirror image of this figure is going to give us the view of the joint traces in the southern sidewall seen from inside or in the northern sidewall seen from the outside of the tunnel when we look in a direction of 160°. So, this is different than what we had earlier. In that case it was northern sidewall seen from outside and southern sidewall seen from the inside and the direction was 340°.

Now, it is extremely important for us to understand these views completely in order to avoid the error in an incorrect assessment of stability and in the application of the incorrect remedial measures. So, let us try to see that how we can find out the height of the wedge?

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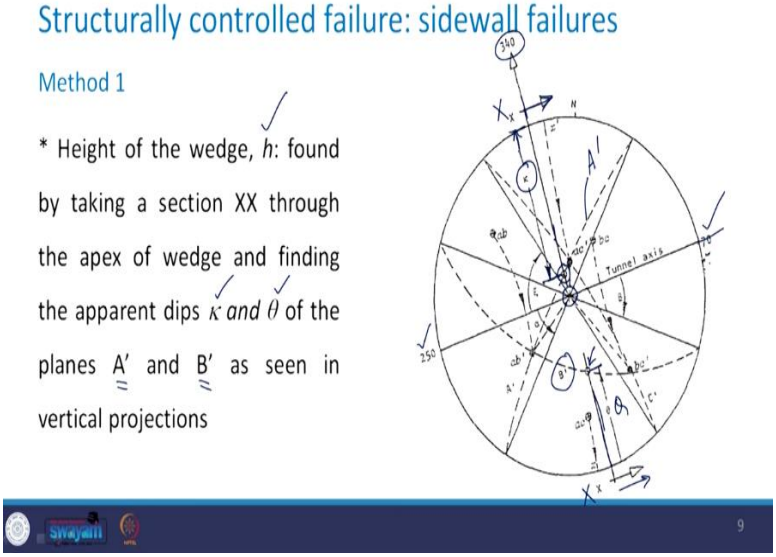

So, this can be found by taking a section XX. Take a look in this figure. That the tunnel axis is 250° to 70° perpendicular to that is this, 340° line. And we are looking in this direction, which

is the XX direction. And this is passing from the center of the net. We need to find the apparent dips κ and θ of the planes A' and B'. So, look at this how this is determined?

Wherever this section XX is intersecting the great circle B' which is this point this angular distance is θ. And this is intersecting this great circle which is A' at this particular point and this angular distance is your κ. So, this we can find out from the stereographic projection.

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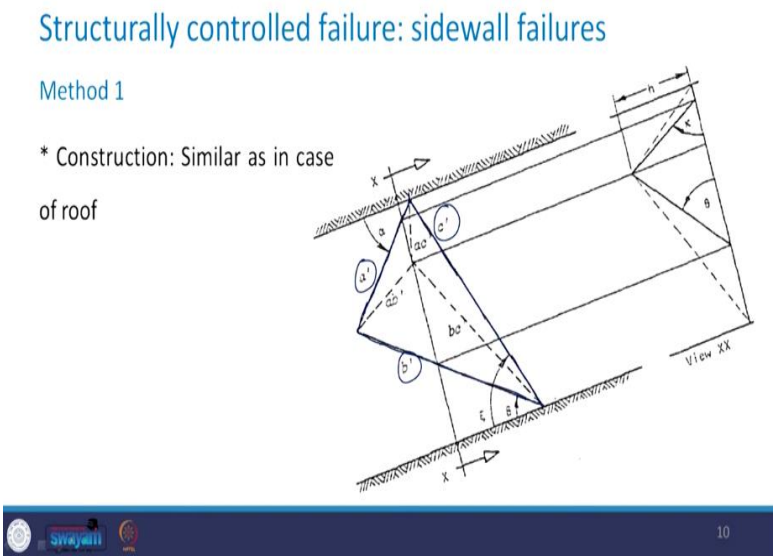

Then construction will be done exactly in the similar line as we did in case of the roof failure. So, we take any point draw the lines parallel to the traces a', b' and c'. And we get this shape of the wedge, triangular shape like this. And this is the third side.

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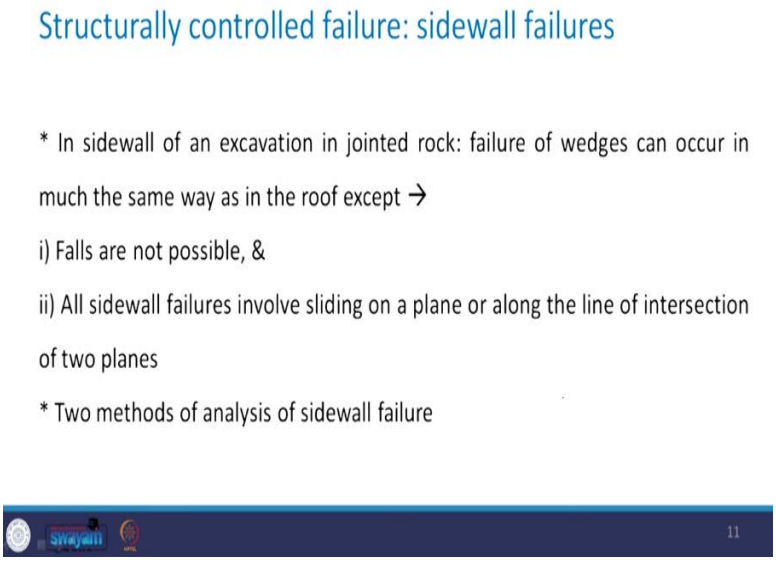

Now, as we mentioned that there are 2 methods for the analysis of the sidewall failure, we discussed about the first method, how the construction of the stereographic projection is done along with the projection on a vertical plane which is parallel to the sidewall? And then we saw that how the height of the wedge can be determined? So, let us try to have a look about the second method of the analysis for the side failure.

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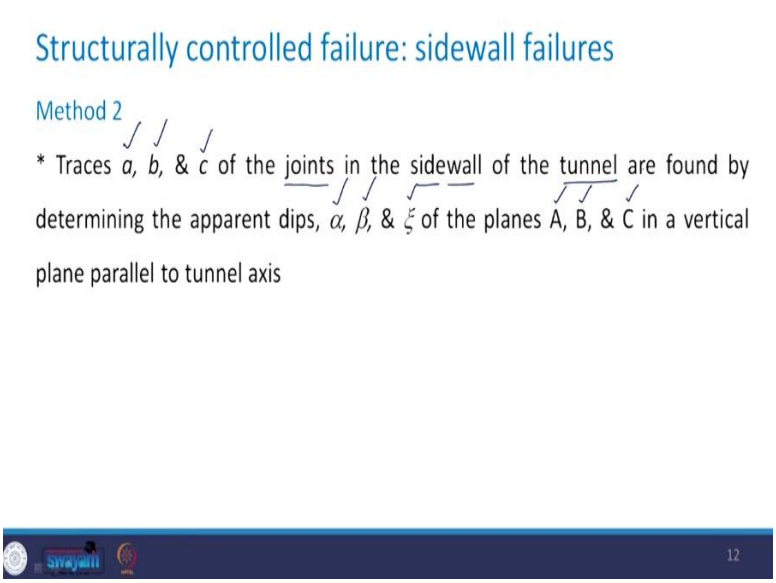

In this case, these traces a, b and c of the joints in the sidewall of the tunnel, they are found by determining the apparent dips α, β and ξ of the planes A, B and C in a vertical plane which is parallel to the tunnel axis.

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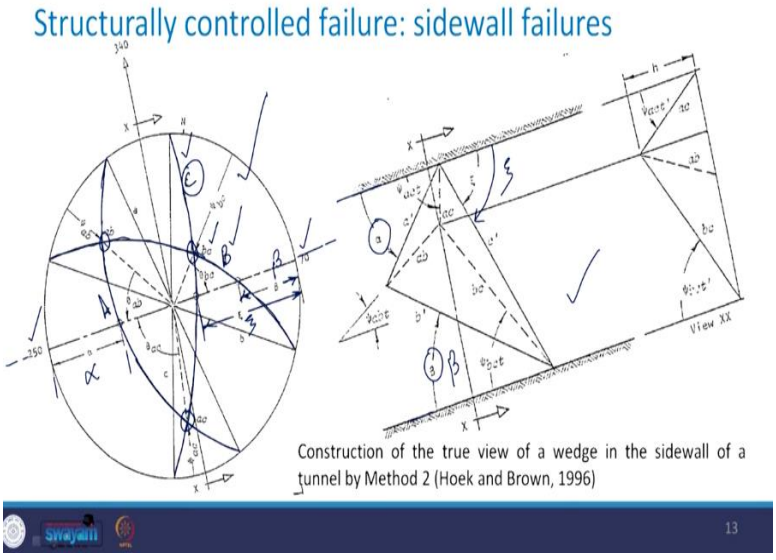

Take a look. How? So, we have the 3 great circles again which are representing these planes. So, this is the first great circle which we are denoting by great circle A. Then this is the second

great circle denoted by the great circle B and the third one is this one, that is great circle C. B and C intersecting here. So, this point is being represented by bc, this is ac and here this is ab. Now, how to determine this apparent dip?

So, you see that the tunnel axis is running in this direction 250 to 70°. So, wherever this intersect this great circle A this angular distance is α. Come to the great circle B and along this axis whatever is this angular distance from here to here, which is β. And with respect to the circle C, this distance is ξ. So, this is how we can determine this α, β and ξ.

And the construction of the true view of a wedge in the sidewall using this method 2 has been shown here, where you can take a look that this angle is α with the tunnel side. And this angle here it is β and this angle is ξ. How to determine these? You can take a look here in the stereographic projection and can obtain that.

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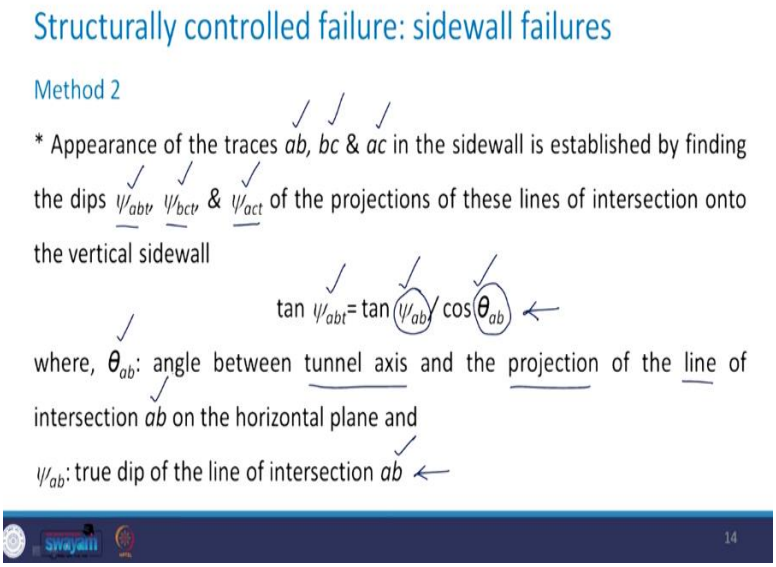

Appearance of the traces ab, bc and ac in the sidewall can be established by finding the dips ψ_{abt}, ψ_{bct} and ψ_{act} of the projections of these lines of intersection on the vertical sidewall. How can we determine these dips? Using these expressions, we can determine these 3 values of the dip of the projection. So,

$$\tan \Psi_{abt} = \tan \Psi_{ab} / \cos \theta_{ab}$$

The question is how to determine ψ_{ab} and how to determine θ_{ab}?

But before that we need to know what exactly are these? So, this ψ_{ab} is the true dip of the line of intersection ab where this θ_{ab} is the angle between the tunnel axis and the projection of the line of intersection ab on the horizontal plane.

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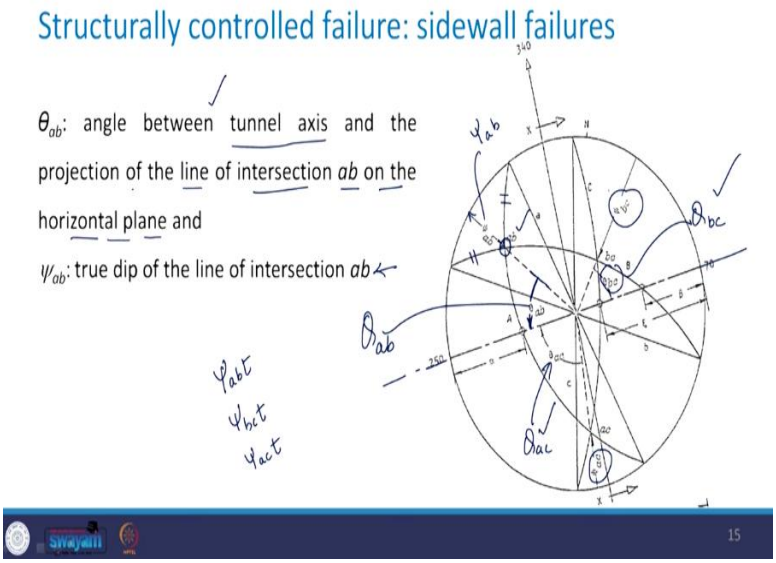

Take a look at this figure once again. So, ψ_{ab} which is the true dip, how will you find? Where is the point ab? Here it is. Because it is the intersection point of the great circle A and great circle B. So, this is point ab. And you measure this angular distance. This is going to give you ψ_{ab} which is the true dip of the line of intersection ab. Come to this θ_b and read it carefully that it is the angle between the tunnel axis. So, where is the tunnel axis?

This is what is the tunnel axis and the projection of the line of intersection on the horizontal plane. So, the horizontal plane its projection is going to be this one. So, the angle between these 2 is going to give me the angle θ_{ab}. Similarly, I can find out the angle θ_{ac} in this manner. And here, this angle is θ_{bc}. The expression that we are using to obtain ψ_{abt}, the similar expression we can write for the determination of ψ_{bct} and ψ_{act}. So, therefore, we would need θ_{bc}, θ_{ac} along with ψ_{ac} and ψ_{bc}.

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Structurally controlled failure: sidewall failures

Method 2

* Angles ψ_{bct} & ψ_{act}: obtained in the same way ← ψ_{abt}

* Height h of the wedge: found by determining the angles ψ_{bct}' & ψ_{act}', which represent the dips of the lines of intersection as seen in a vertical plane at right angles to tunnel axis

So, as I mentioned that ψ_{bct} and ψ_{act} they can be obtained in the similar way as you obtained ψ_{abt}. Now, how to determine this height h of the wedge? So, this is obtained by determining the angles ψ_{bct}' and ψ_{act}' which represent the dips of the line of intersection as it is seen in a vertical plane at right angles to tunnel axis. So, that is why here a' has been added because these are the angles which are seen in a vertical plane at right angles to tunnel axis.

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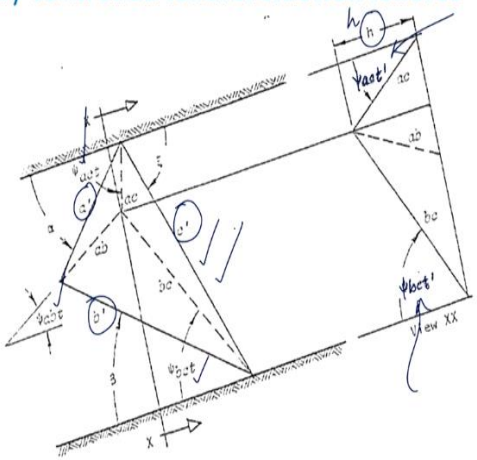
Structurally controlled failure: sidewall failures



Have a look here that you see that here it is ψ_{bct}' and here it is ψ_{act}'. The question is how to determine these 2 angles? Because until unless we know these angles, we will not be able to determine the height of the wedge which is *h*. Take a look on this part of the figure which can be constructed now, because we know these 3 angles ψ_{act}, ψ_{bct}, ψ_{abt} and then we know these traces a', b' and c'.

From the stereographic projection just draw the parallel lines. As I already explained you in case of the roof failure, follow the same principle and you can construct this.

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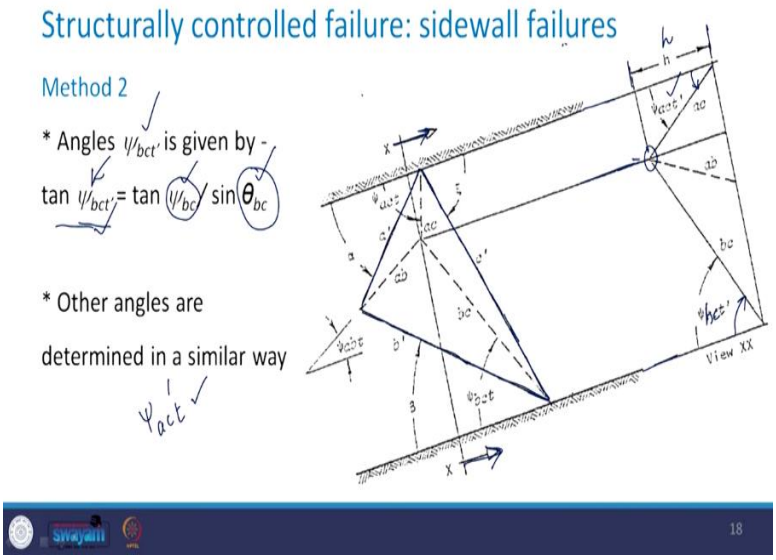

Now, this angle ψ_{bct}' is given by

$$\tan \Psi_{bct'} = \tan \Psi_{bc} / \sin \theta_{bc}$$

So, we can we know here what is ψ_{bc}? We have already obtained. And we know θ_{bc} also. So, we can determine these ψ_{bct}'. And similarly, we can get ψ_{act}'. Now, once I know this and this, I can just take the projection of these points in the direction which is the X-X direction.

And draw a line having an angle ψ_{act}' in this manner here and ψ_{bct}' in this manner. So, you will be able to get the location of this apex. Once you know this location of the apex just measure this distance and that will give you the height of the wedge. Once you know this height of the wedge and in the plan, you can get the base area of this sidewall wedge. In this view, you can get the area.

So, you can obtain the volume of the wedge which is formed in the sidewall and has a tendency to slide. So, these were the 2 methods for the determination of the size of the wedge which can be formed in the sidewall of the tunnel and has the tendency to slide. So, this was all about the roof failure and the sidewall failure as far as structurally controlled failure in tunnels is concerned.

In the next class, we will start our discussion on rock mass support introduction analysis. Thank you very much.