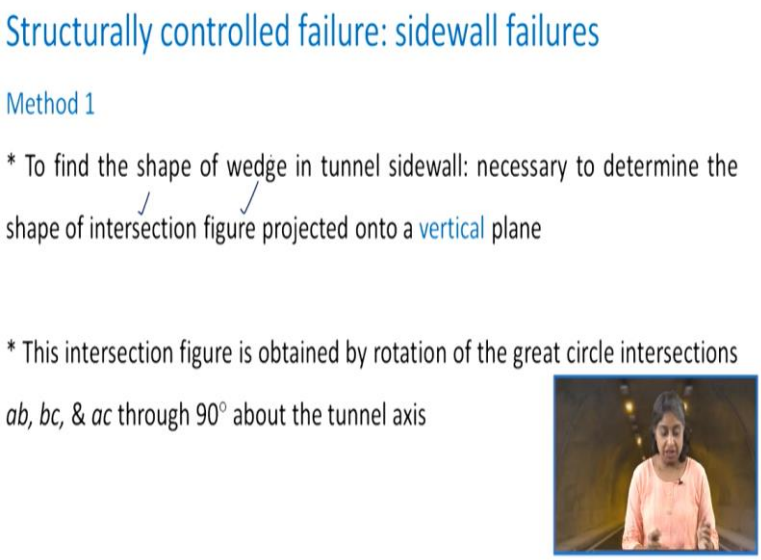
Underground Space Technology
Prof. Priti Maheshwari
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Module No # 03
Lecture No # 15
Application of Stereographic Projection Method: Sidewall Failures – 2

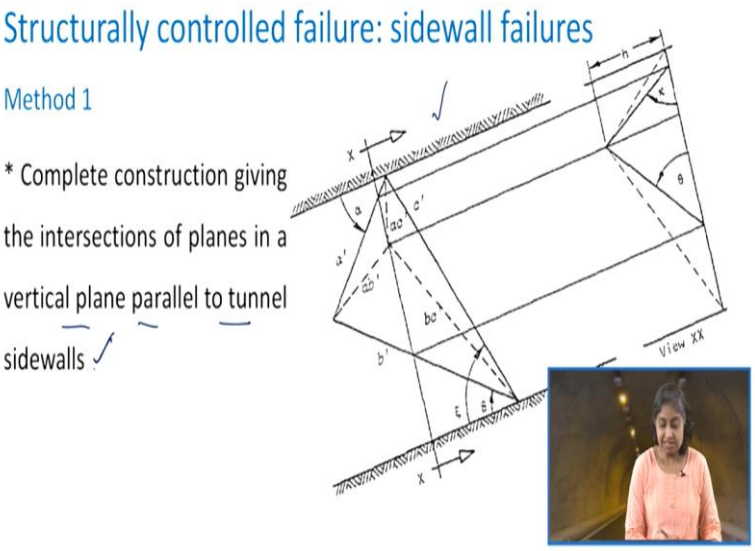
Hello everyone, in the previous class we learned about the application of stereographic projection method with reference to the failure of the sidewalls of the underground excavation. Let us continue with the same discussion, and then try to see that, how using the 2 methods we can determine the size and the shape of the failure wedge, that is being formed in the sidewall of an excavation. So, this we learned in the previous, that to find the shape of the wedge in the tunnel side wall.

(Refer Slide Time: 01:05)



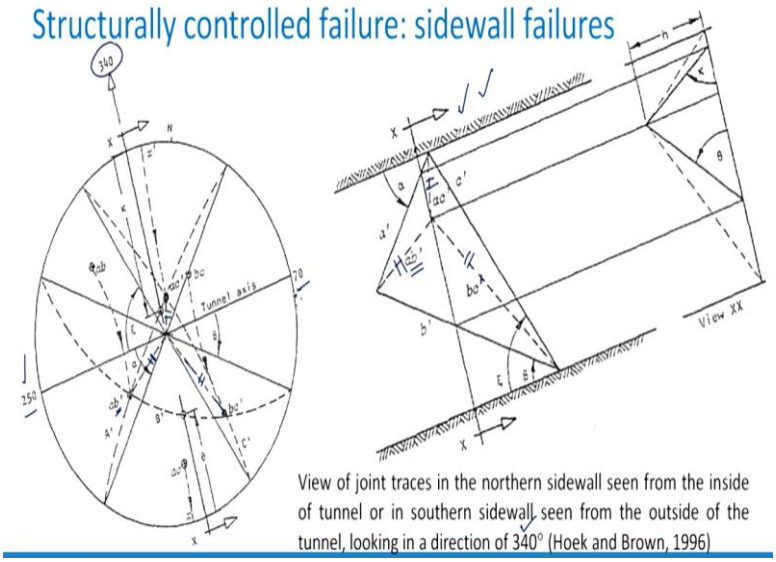
It is necessary for us to determine the shape of the intersection figure, which is projected on to vertical plane. Now, this intersection figure was obtained by the rotation of the great circle intersections through 90^0 above the tunnel axis.

(Refer Slide Time: 01:26)



And, for your ready reference, this was the figure that we got, and we saw that how we can get this in the previous class. So, here you need to keep that in mind that in this method 1, we are considering a vertical plane which is parallel to the tunnel side wall.

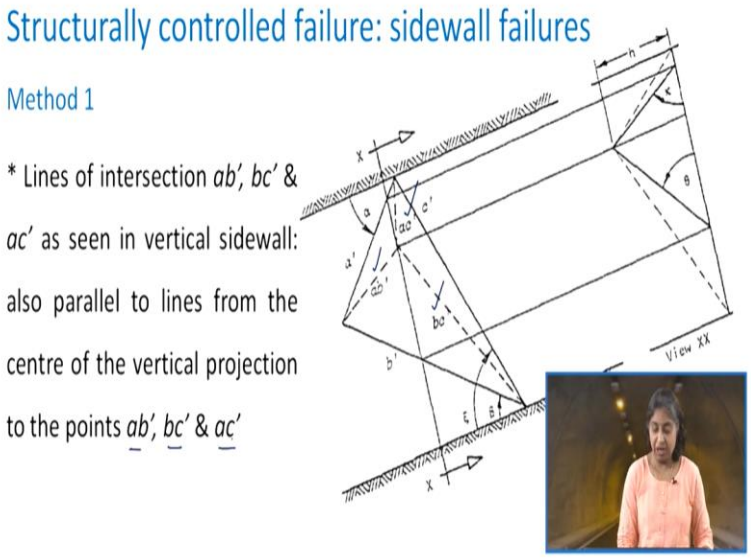
(Refer Slide Time: 01:49)



So, you see that whatever were the traces ab prime, let us say and if I join it through the center, I get this line then ac′, this line and bc′ is this line. And then, we construct is view there you can see that this, ab′ is parallel to here, this ab′, and ac′is here, and bc′ is parallel to this particular line. So, this is how we generated this view, so in this case, the view of the joined traces in the northern sidewall seen from the inside of the tunnel, or in the southern side which seen from the outside of the tunnel, will be the same.

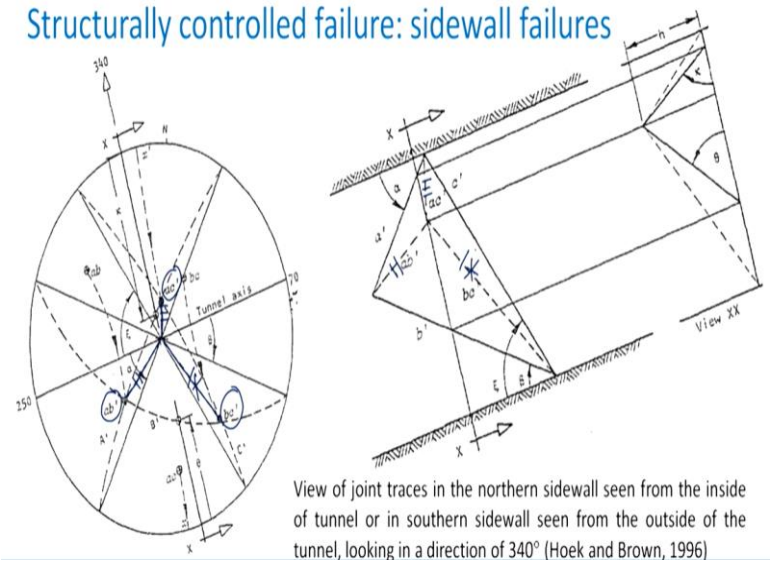
We look at the direction of 340^0, why 340^0? Because, the tunnel axis is 250^0, 70^0 and we are considering the axis perpendicular to the tunnel axis, and hence if you had 90^0 to 250^0, it works to be 340^0.

(Refer Slide Time: 03:19)



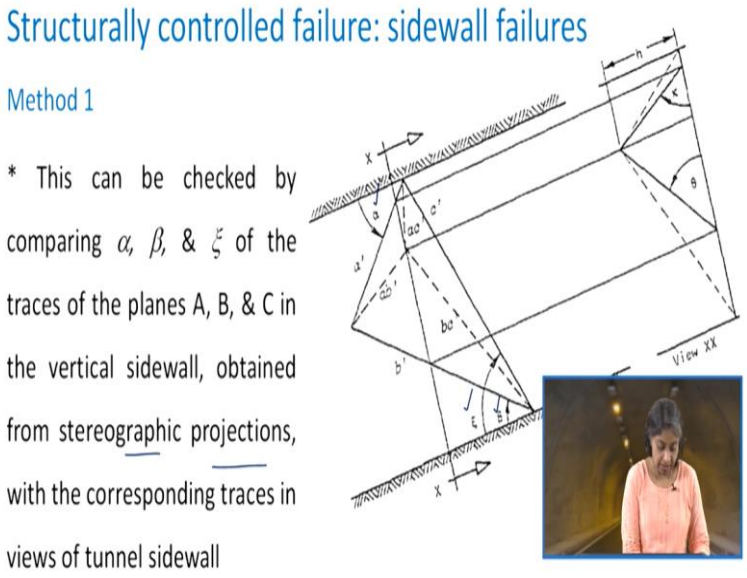
Now this line of intersections ab′ bc′ and ac′ they are also parallel to the lines from the center of the vertical projection to the points ab′ bc′ and ac′ prime respectively.

(Refer Slide Time: 03:35)



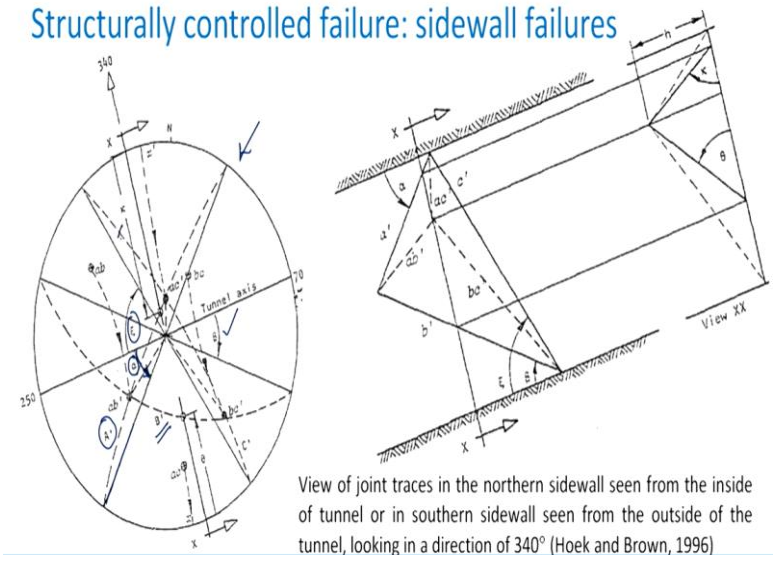
Take a look here, as I explained you earlier as well, see, this is the intersection ab′, and if I take or if I join this by the center. So, you see this is parallel to this particular line here, similarly this is ac′, and I join this and this is parallel to this ac′. And if I join here this is what is, bc′? So, this is the line parallel to this.

(Refer Slide Time: 04:25)



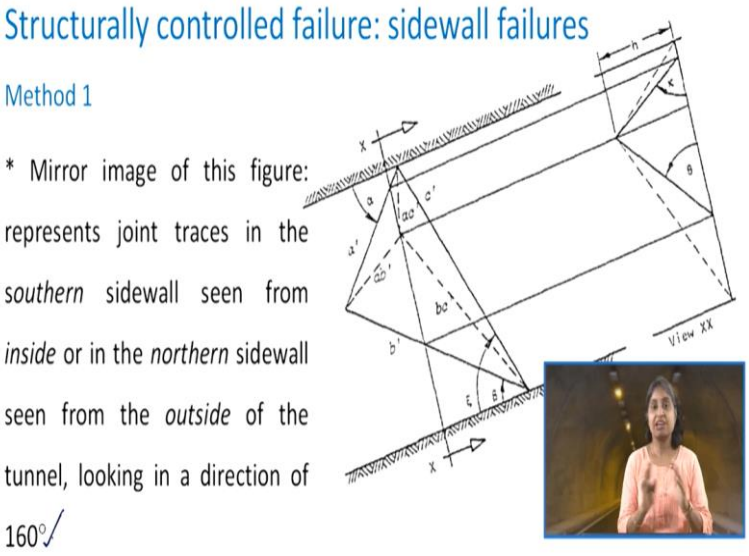
So, as I mentioned that these views, they represent the joint traces which are seen in northern side wall from inside of the tunnel or the southern side wall from outside of the tunnel. If we look towards angle 340^0 which is represented by this section xx and this is what is the direction. Now, this can also be checked by comparing the angles α, β, and ξ of these traces of these planes a, b, and c in the vertical side wall. We can compare these from the stereographic projections as well.

(Refer Slide Time: 05:09)



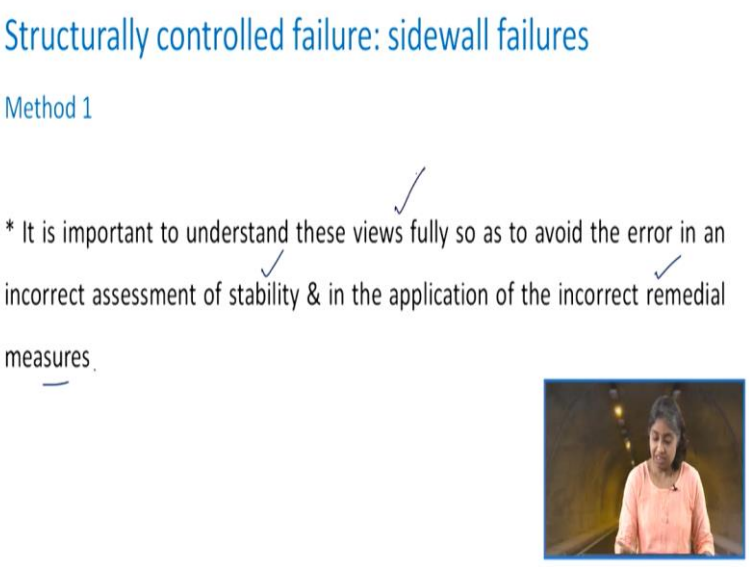
So, take a look here when we refer to the stereographic projection then see here α is the angle shown here. So, the strike of this a ′great circle that is making an angle with the tunnel axis. Similarly, β is with reference to the great circle b ′and ψ is the angle with reference to the great circle c.′

(Refer Slide Time: 05:52)



Now, if we consider the mirror image of this figure, so that will represent the joint traces in the southern side wall, which is seen from the inside of the tunnel, or in the northern side wall seen from the outside of the tunnel and you need to look in a direction 160^0, so that is how the mirror image is going to be.

(Refer Slide Time: 06:18)

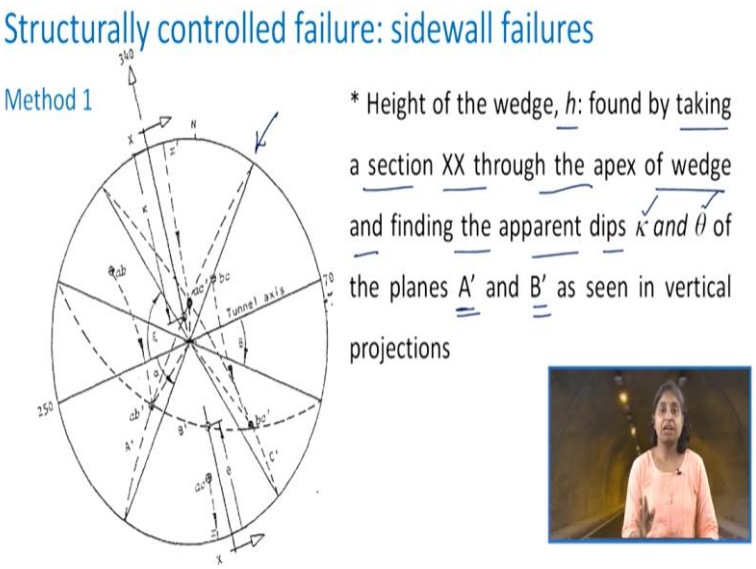


Then, it is extremely important for us to completely understand these views to avoid any error in the incorrect assessment of this stability, and in the application of the incorrect remedial measures. So, you see that depending upon the size of the wedges that are being formed, that are likely to you know slide in the excavation from the side wall of the excavation. The stability analysis of that underground excavation will be carried out now, if we do not

understand these views completely, or if we make any mistake in making these stereographic plots.

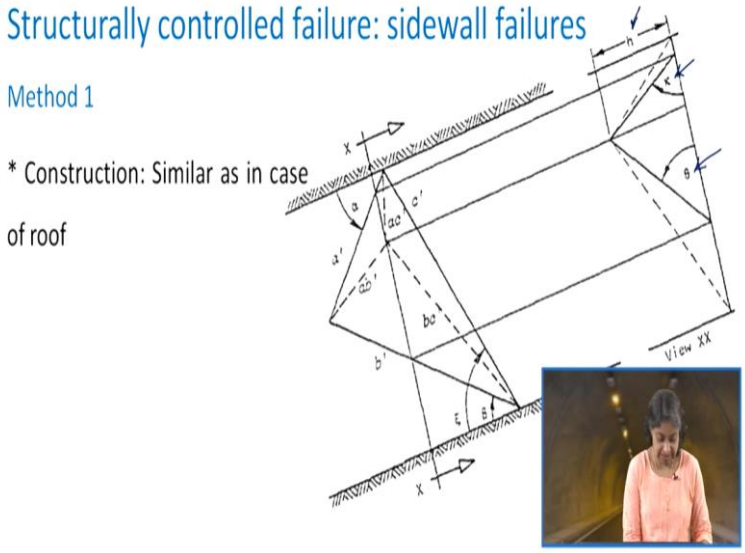
Then, these stability analyses will not be accurate, this will lead to the incorrect stability analysis and based upon that incorrect stability analysis, you will never be able to get the proper support measure, which are to be installed for the stability of that tunnel. So, it is extremely important for us to understand these views completely.

(Refer Slide Time: 07:36)



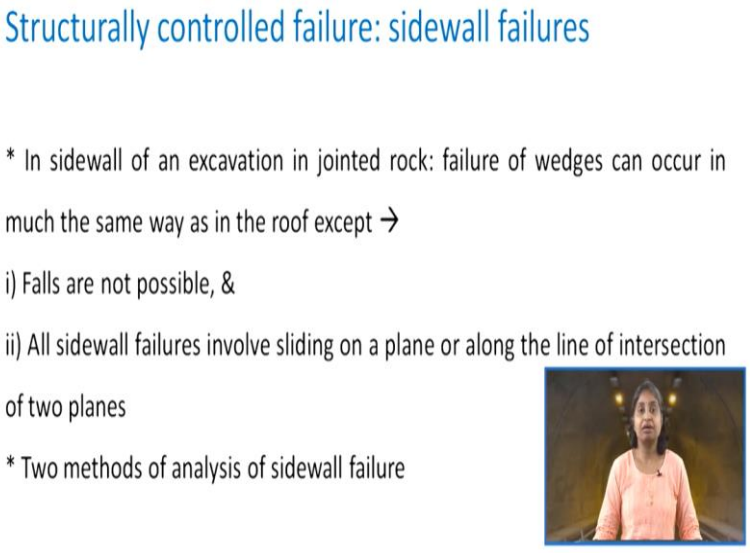
Now, how to determine the height of the wedge? So, what do is we take the section xx, through the apex of the wedge and we find the apparent dips χ, and θ of the planes, a ′and b′. So, right now this is a view as far as this stereographic plot is concerned, let us take the view that how it will look in the vertical projection.

(Refer Slide Time: 08:08)



So, you see here that this is what is the angle kappa and angle theta and we have discussed these things in detail, that in case of roof how do we determine the height of the wedge, or the area of the base of the wedge that can be accommodated in the roof. So, we have to follow the same procedure to get the similar aspects here with reference to sidewall failures.

(Refer Slide Time: 08:46)



Now, this we learnt earlier also that in the case of the side wall failure falls are not possible and all the side wall failures will involve the sliding on a plane or along the line of the intersection of 2 planes. And, we saw that there were 2 methods so first method we discussed in which we were taking the projection on a vertical plane which was parallel to the side wall. Now, let us take a look that what is the second method and how we can get the dimension of the wedge height of the wedge its base dimension to get its volume.

(Refer Slide Time: 09:32)

Structurally controlled failure: sidewall failures

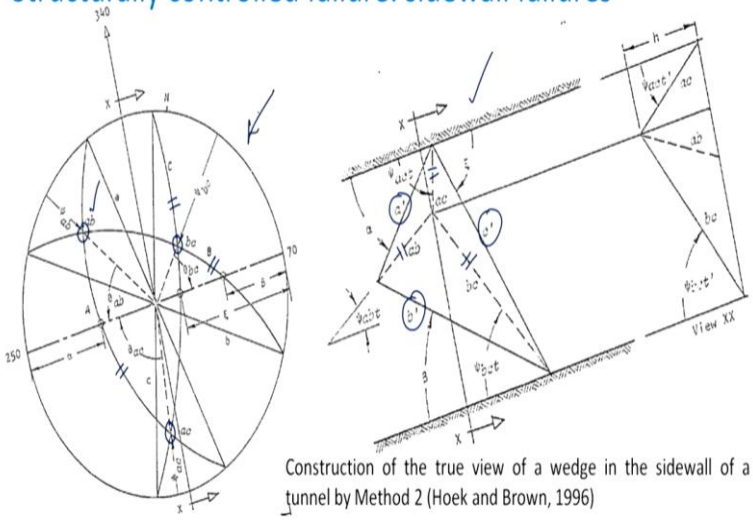
Method 2

* Traces a, b, & c of the joints in the sidewall of the tunnel are found by determining the apparent dips, α, β, & ξ of the planes A, B, & C in a vertical plane parallel to tunnel axis

So, in this case traces a, b and c of the joints in the side wall of the tunnel, these are found by determining their apparent dips which are represented by α, β, and ψ for the planes a, b and c respectively. In a vertical plane that is parallel to tunnel axis, so here this is what is a difference that we will consider the vertical plane, which is parallel to tunnel axis.

(Refer Slide Time: 10:06)

Structurally controlled failure: sidewall failures

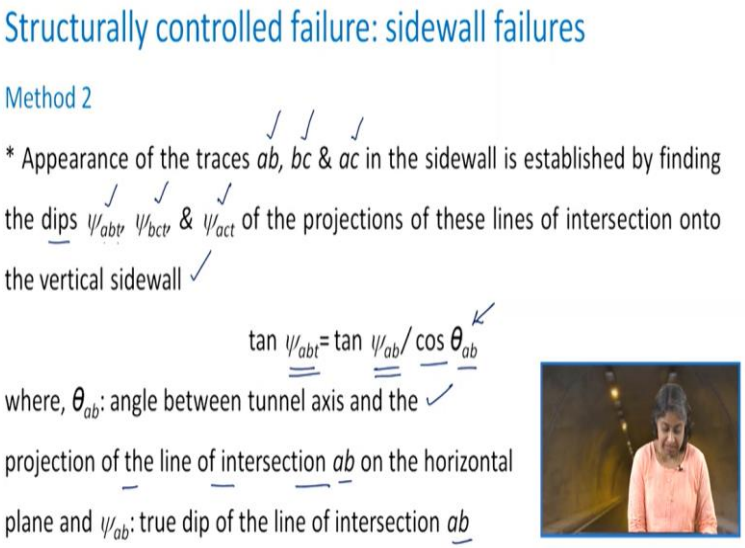


Construction of the true view of a wedge in the sidewall of a tunnel by Method 2 (Hoek and Brown, 1996)

Take a look here, that how this looks like. So, we have the great circle a, great circle b, and great circle c which represent the 3 discontinuity which will form the wedge in the side wall, causing the side wall failure. So, here in the similar way as we have been doing earlier you see the intersection of these great circles a and b this is the point that is represented by ab this is bc this is represented here and ac is here.

We join it with the center and that is how we get the traces, so, we come to this view which is the vertical projection, which is the vertical plane parallel to the tunnel axis. So, here you see that we get a prime, b prime, and, c prime and see, how these lines are parallel to the strike of these great circles, and according to that we draw the lines parallel to ab, ac and bc to the corresponding lines here in the stereographic projection.

(Refer Slide Time: 11:37)

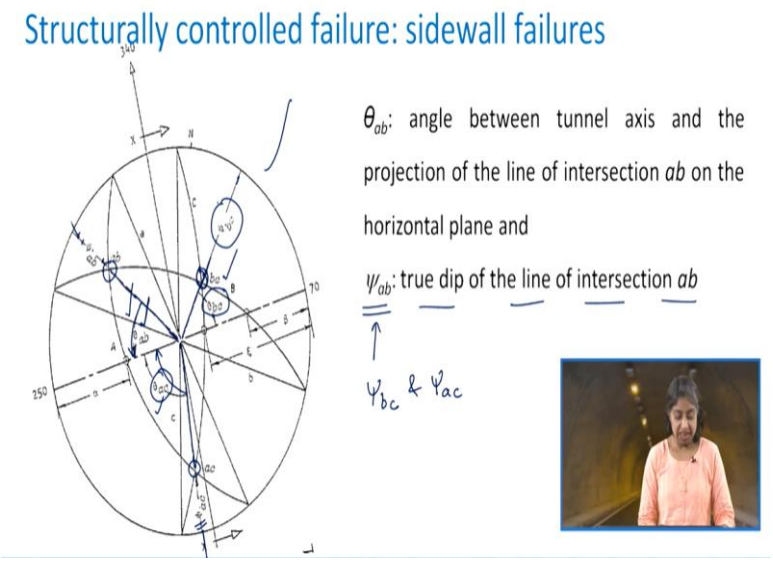


Now, the appearance of the traces ab, bc, and ac in the sidewall is established by finding the dips ψ_{abt} then ψ_{bct} and ψ_{act} of the projection of these lines of intersection onto the vertical sidewall. And use this expression that is

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

Now let us try to understand what are these angles. So, this θ_{ab} is the angle between the tunnel axis and the projection of the line of the intersection ab on the horizontal plane. And ψ_{ab} is the true dip of the line of intersection ab, let us take a look that how this appears in the stereographic projection.

(Refer Slide Time: 12:43)



So, you see that this is the intersection line the trace and the projection of this on the horizontal plane. So, we are considering the plane that is vertical to the tunnel axis. So, you see that it is projection is going to be this angle and that is what I am calling as θ_{ab}. Similarly, here you have this line as ac, and when I project it on this so this angle is going to be θ_{ac}. In the similar manner here, we have bc this is the point, and you take its projection this is what is going to be θ_{bc}.

So, according to this stereographic projection once side, draw the discontinuity in terms of their respective great circles we can always find out all these angles. So, this, ab is known θ_{ac} and θ_{bc} is now known to me. Now, this ψ_{ab} is the true dip of the angle of intersection ab, now how can we determine this?

So, take a look here this is ab so what we do is, in this direction only, I measure that, how many, number of divisions are there, so directly from there I can determine ψ_{ab}. And similarly, I can get ψ_{bc}, and also ψ_{ac}, see here this is ac and in this line along this line only I count the number of you know division. So, when you have the proper stereo plot here so that way the complete hemisphere is divided into some vertical and the horizontal great circle.

So, from there you will be able to obtain this ψ_{ac} and similarly, here you can see that this is what is bc trace and if we measure in this direction then we can find out the true dip of the line of intersection bc.

(Refer Slide Time: 15:26)

Structurally controlled failure: sidewall failures

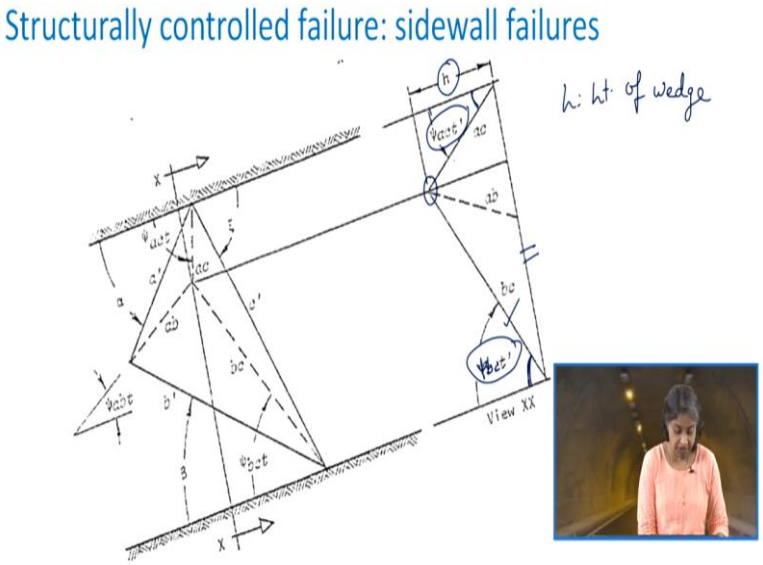
Method 2

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

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

So, similar way we can find out ψ_{abt} and ψ_{bct}, once we know θ_{bc} and θ_{ac} we can find this out. So, accordingly height h of the wedge can be obtained by determining the angles ψ_{bct}', and ψ_{act}' which represent the dips of the lines of intersection, as it is seen in a vertical line in right angle to the tunnel axis.

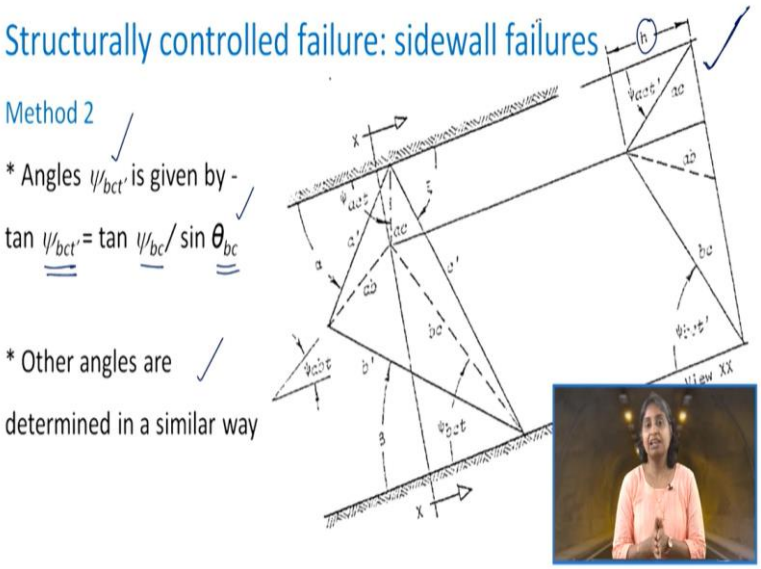
(Refer Slide Time: 16:01)



So, take a look here that how we can determine this, so you that this, what else your, ψ_{act}' and this is ψ_{bct}'. So, these can be determined so once these are known we know this base line and if you just draw 2 lines making an angle, respectively as ψ_{act}' and ψ_{bct}' here. Wherever these lines intersect that will represent the apex of that wedge, and its distance as shown here in this figure this will give you the height of the wedge.

So, once you know the height of the wedge and you know the base dimension, you can always find out that what is going to be the volume of the wedge.

(Refer Slide Time: 17:09)



So now this angle $\psi_{bct'}$, you can find out from this expression which is

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

This we saw with reference to first $\psi_{abt'}$ also. So, other angle can be determined in the similar way, so once we know this, we can complete the construction of this view, and from there we can determine the height of the wedge. So, this is how we can analyze the side wall failure in an underground excavation using this stereographic projection method.

So, in the next class we will be learning about the, elastic analysis of the circular tunnels, there we will see that how the analysis of the stresses and the analysis of displacement, they are carried out, thank you very much.