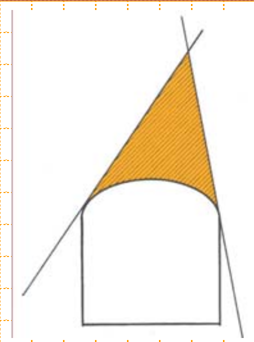


EOSC433:

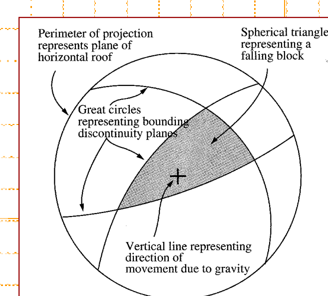
Geotechnical Engineering Practice & Design

Supplementary Notes: Wedge Volume Calculation

Kinematic Analysis – Underground Wedges

The minimum requirement to define a potential wedge is four non-parallel planes; the excavation periphery forms one of these planes. On a hemispherical projection, these blocks may be identified as spherical triangles where the plane of projection represents the excavation surface.

If a tetrahedral block/wedge exists, there are three kinematic possibilities to be examined: the block falls from the roof; the block slides (either along the line of maximum dip of a discontinuity, or along the line of intersection of two discontinuities); or the block is stable.



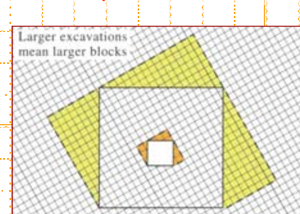
Hudson & Harrison (1997)

Geometrical Analysis of Maximum Wedge Volume

Once a series of joint sets have been identified as having wedge forming potential, several questions arise :

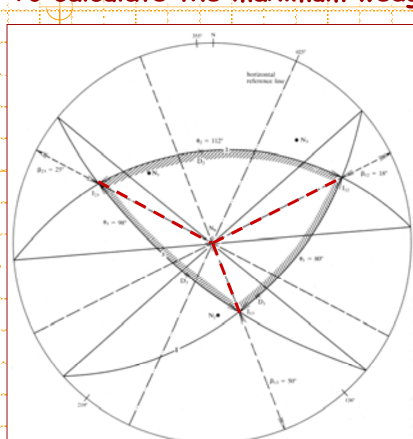
- in the case of a falling wedge, how much support will be required to hold it in place (what kind of loads on the added support can be expected, how dense will the bolting pattern have to be, etc.);
- in the case of a sliding wedge, do the shear stresses exceed the shear strength along the sliding surface, i.e. that provided by friction and sometimes cohesion (in the form of intact rock bridges or mineralized infilling), and if so, how much support will be required to stabilize the block, how dense will the bolting pattern have to be, etc..

In both cases, the volume/weight of the maximum wedge that may form is required. This can be determined through further geometrical constructions.



Geometrical Analysis of Maximum Wedge Volume

To calculate the maximum wedge volume:



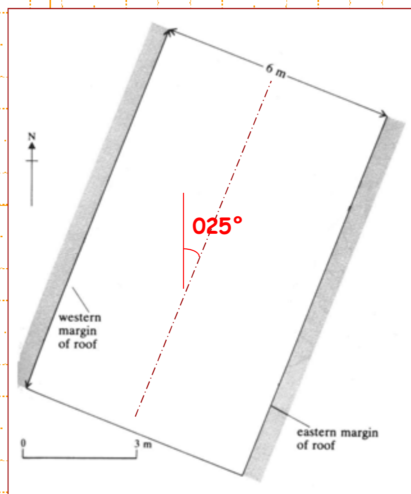
Priest (1985)

1) Identify the joint planes/great circles on the stereonet plot that form the wedge. In this example, the three persistent, planar discontinuity sets have dip directions/dips of: (1) 138/51, (2) 355/40, (3) 219/67.

   Together, these joints are known to form wedges within the horizontal, planar roof of an excavation in sedimentary rock.

   The stereonet construction is finished by drawing lines passing through the corners of the spherical triangle and centre of the stereonet.

Maximum Wedge Volume



2) On a separate sheet of paper, construct a scaled plan view, where the width of the window represents the width of the excavation. As such, the analysis will consider the largest block that could be released from the excavation roof.

   In this particular example, the roof is rectangular in shape, is 6 m wide, and has it's long axis orientated at an azimuth of 025°.

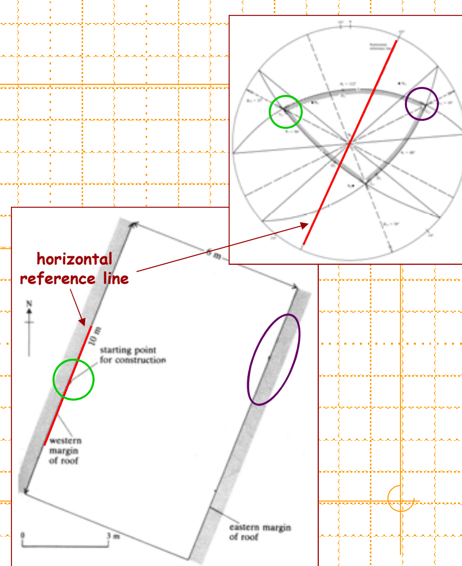
   Given that the great circle representing the horizontal plane through the tunnel coincides with that of the stereonet projection, it is convenient to construct the window aligned parallel to the tunnel axis.

Maximum Wedge Volume

3) On the scaled window, mark an arbitrary horizontal reference line and starting point. For example, about halfway along the western margin of the roof.

   Inspection of the spherical triangle in the stereonet plot suggests that the corner of the face triangle formed by planes 2 and 3 will touch the western margin of the roof, and the corner formed by planes 1 and 2 will touch the eastern margin when the largest possible tetrahedral block is considered.

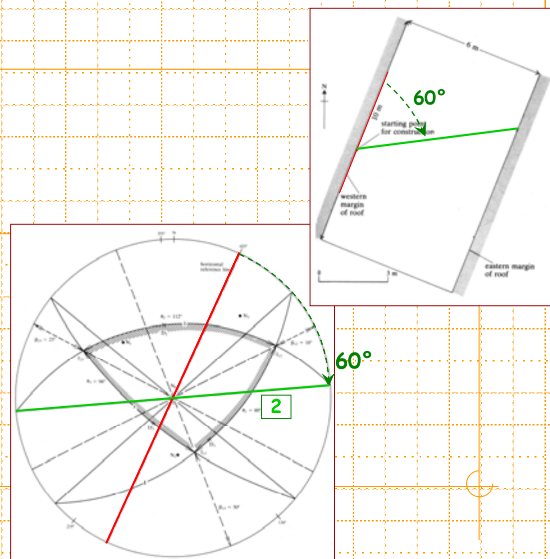
   As such, the arbitrary reference point can represent the corner of the face triangle formed by planes 2 and 3.



Maximum Wedge Volume

4) The lines associated with planes 2 and 3 can now be added to the window construction by counting off the angles between the horizontal reference line on the stereonet plot (at 025°) and the diametral lines for planes 2 and 3 (striking at 085° and 129°, respectively).

These angles can then be transferred to the window construction and measured off relative to the starting point and reference line along the western margin of the roof.



Maximum Wedge Volume

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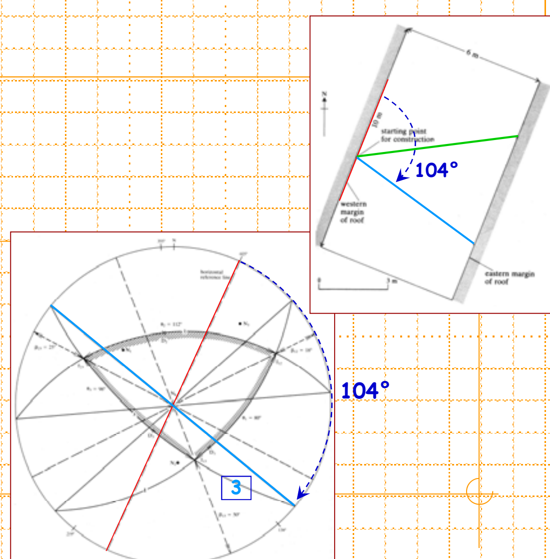
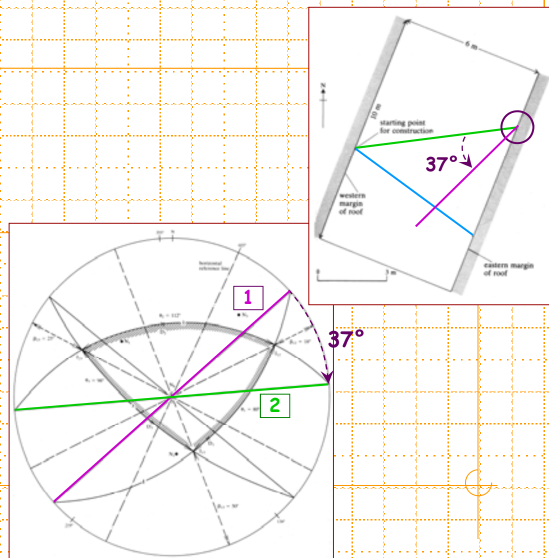


Maximum Wedge Volume

5) The point where the line for plane 2 intersects the eastern margin of the roof in the window construction represents the corner of the face triangle formed by planes 1 and 2. Thus, the line for plane 1 can be added by measuring the angle between the two planes on the stereonet and transferring it to the window construction.

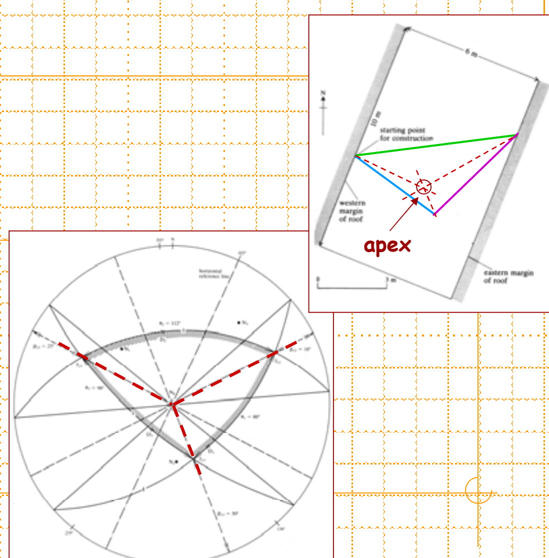
The outline/trace of the wedge on the tunnel roof is now complete.



Maximum Wedge Volume

6) The next step is to add the corner edges of the wedge to complete the 3-D trace of the tetrahedron in the window construction box.

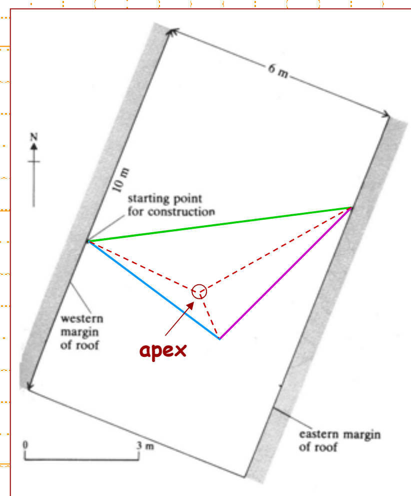
This can be done following a similar procedure by transferring the lines of intersection between the planes (i.e. I_{12}, I_{23}, I_{13}) and their measured angles from the stereonet to the window construction.



Maximum Wedge Volume

7) Since this construction can be completed graphically by overlaying the stereonet with the window construction, or geometrically by measuring the angles off the stereonet and transferring them onto the window construction, several checks can be made to find any errors that may have arisen.

The final step involving the finding of the location of the wedge's apex also gives a valuable check since the area of the triangle of error formed by these converging lines is a measure of any imprecision in the construction.



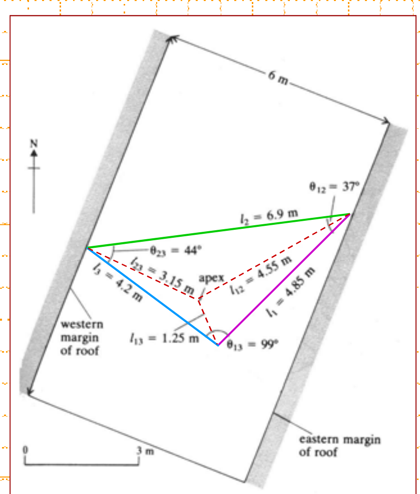
Priest (1985)

Maximum Wedge Volume

8) The dimensions of the face triangle appearing on the excavation surface can now be scaled off directly from the construction. It's area, A_f, can be found by taking any pair of adjacent sides and their included angles:

$$A_f = \tfrac{1}{2} l_1 l_2 \sin\theta_{12} = \tfrac{1}{2} l_2 l_3 \sin\theta_{23} = \tfrac{1}{2} l_1 l_3 \sin\theta_{13}$$

This gives a face area of 10.1 m^2.



Priest (1985)

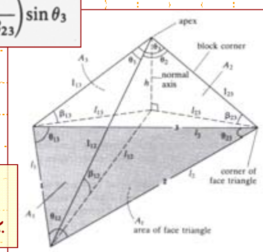
Maximum Wedge Volume

9) The areas of the three internal block surfaces can be found in a similar way from the edge lengths and appropriate internal angles:

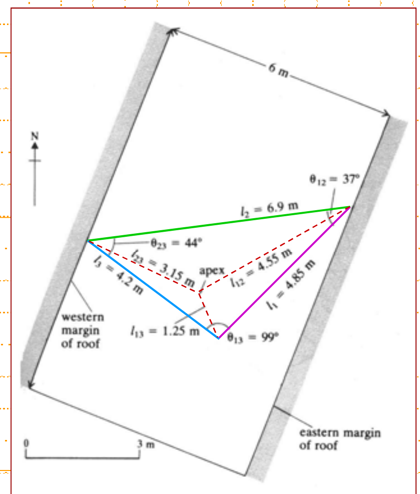
$$A_1 = \frac{1}{2}\left(\frac{l_{12}}{\cos\beta_{12}}\,\frac{l_{13}}{\cos\beta_{13}}\right)\sin\theta_1$$

$$A_2 = \frac{1}{2}\left(\frac{l_{12}}{\cos\beta_{12}}\,\frac{l_{23}}{\cos\beta_{23}}\right)\sin\theta_2$$

$$A_3 = \frac{1}{2}\left(\frac{l_{13}}{\cos\beta_{13}}\,\frac{l_{23}}{\cos\beta_{23}}\right)\sin\theta_3$$



... geometrical properties of a tetrahedral block.



Priest (1985)

Maximum Wedge Volume

10) To find the volume of the wedge, the wedge height and the face area are required. The face area, A_f, has already been found. The wedge height, h, is given by:

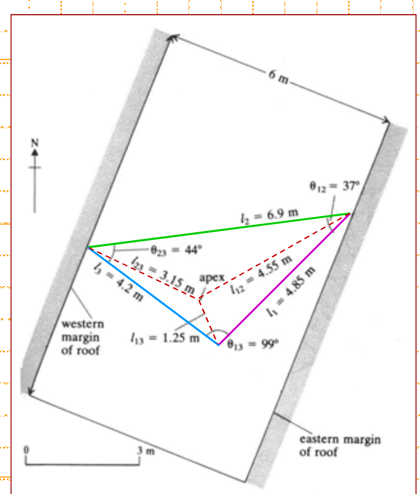
$$h = l_{12}\tan\beta_{12} = l_{23}\tan\beta_{23} = l_{13}\tan\beta_{13}$$

which for this example problem comes to 1.47 m.

The volume, V, of the tetrahedral block is then given as:

$$V = A_f h/3$$

resulting in a block volume of approximately 5 m^3.



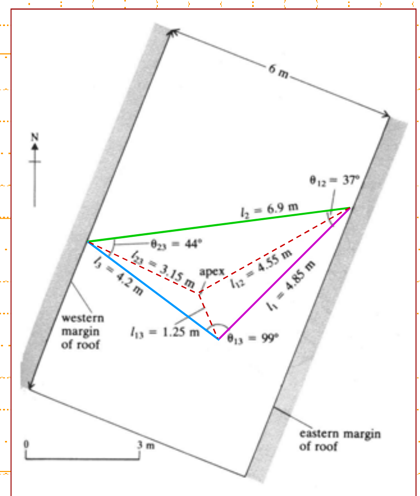
Priest (1985)

Maximum Wedge Volume

11) Now assuming a unit weight of 25 kN/m³ for sedimentary rock, the block would have a weight of approximately 124 kN.

By dividing this value through by the face area, it can be seen that a support pressure of only 12.3 kN/m², distributed over the face triangle, would be required to keep it in place.

This support pressure could, for example, be provided by rock bolts anchored beyond the block at a distance of 2 to 3 m above the excavation roof.



References

Hudson, JA & Harrison, JP (1997). Engineering Rock Mechanics – An Introduction to the Principles . Elsevier Science: Oxford.

Priest, SD (1985). Hemispherical Projection Methods in Rock Mechanics. George Allen & Unwin: London.