Lab Practical - Wedge Analysis of Underground Excavations

Part A – By Hand

1. Based on a discontinuity line survey, three joint sets were identified as having the potential to form a wedge in the roof of a 5 m-wide tunnel opening. The three persistent, planar discontinuity sets have dip directions/dips of: (1) 028/54°, (2) 165/70°, and (3) 305/64°. The north-south tunnel is excavated in a strong limestone with a unit weight of 24 kN/m^3. Calculate the volume of the largest wedge that can be expected. ***Show your work and record the calculated wedge volume on your exercise answer sheet!***

Part B – Computer Aided

1. Repeat the analysis you performed above using the RocScience program UNWEDGE, and compare the volumes calculated by hand and using UNWEDGE. ***Record the calculated wedge volume on your exercise answer sheet!***

   Note: If you have not used this program before, follow the simple instructions below to get started:
   Go to Start > All Programs > RocScience > Unwedge
   On the sidebar, click "Add Opening" and enter the vertex values on the lower right hand corner.
   Example: 0,0 (press enter) and do the same for the other vertices. Type 'c' to close the opening.
   Go to Analysis > Project Settings, set the units to "Metric, stress as MPa", click OK.
   Go to Analysis > Input Data:
   Under the General tab, enter the desired tunnel axil orientation, design Factor of Safety and unit weight.
   Under the Joint Orientations tab, enter the dip and dip orientations of the discontinuities
   Under the Joint Properties tab, enter the shear strength properties of the discontinuities
   Click Apply and OK.
   You will now notice the wedge information on the sidebar.
   To view the wedges formed, click the "3D Wedge View" icon on the toolbar.

2. Assuming that the strengths for all three joint sets are the same (cohesive = 0 MPa, friction = 40°), calculate the factor of safety for the wedge and briefly discuss the result. ***Record your answer on the exercise answer sheet!***

3. Now assume that the joints aren't fully persistent and that intact rock bridges provide an equivalent tensile strength of 0.01 MPa for the joints. Re-calculate the factor of safety for the wedge. ***Record your answer on the exercise answer sheet!***

4. Open the '*Support*' menu and select the '*Add Bolt Pattern*' tool (If you do not see that option, under Support, click "Switch to Perimeter Support Designer"). Note the maximum apex height of the wedge. Specify a bolt length of 2 m, with an in-plane spacing of 2 m and an out of plane spacing of 3 m. Implement the pattern along the tunnel roof only, such that the bolts are approximately 0.5 m from either of the two walls. Go to Support > Bolt Properties, use the default bolt strength properties (0.1 MN for all). Re-calculate the factor of safety and compare to the value you get if the tensile strength from the intact rock bridges can't be depended on due to the uncertainty of their presence or not. ***Record your answers on the exercise answer sheet!***

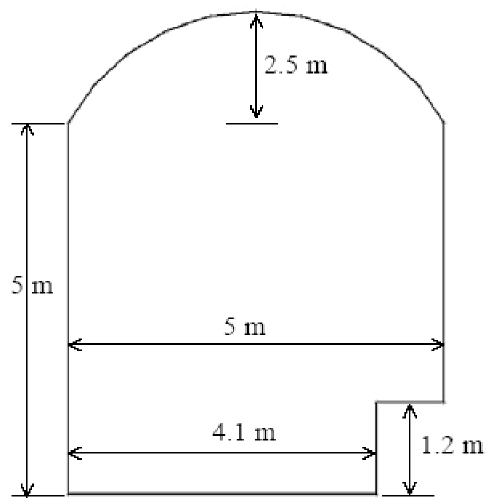
5. The tunnel in question is a mine drift, for which a factor of safety of 1.5 is required. In a comparison of support costs, a decision is required whether to go with an option of smaller diameter bolts with a lower yield strength, or a bolting pattern that uses fewer bolts.

   a) Assuming the absence of rock bridges, modify the bolt properties to determine the lowest tensile capacity (MN) for the given bolt pattern used above.

   b) With the above bolt pattern 12 bolts are required for every 10 m length of tunnel. Assuming that the strength properties for the bolts are the same as those originally given (i.e. tensile capacity = 0.1 MN), derive a bolting pattern that uses the fewest bolts per 10 m tunnel interval.

   Record your answers on the exercise answer sheet!

Part C – Influence of Stresses on Wedges



1. Start a new analysis and add an '*opening section*' with the dimensions specified in the figure to the right. The trend and plunge of the tunnel axis are both 0°.

2. Three primary joint sets have been mapped:

   Joint Set #1 (dip/dip direction) = 60°/030°
   Joint Set #2 (dip/dip direction) = 60°/150°
   Joint Set #3 (dip/dip direction) = 60°/270°

   All three joint sets have the same properties: c = 0.1 MPa, ϕ = 30°, and zero tensile strength. The rock mass is assumed to have a unit weight of 26 KN/m^3.

3. Comment on the maximum wedges that form and note those that may be problematic (e.g. volume in m^3, factor of safety, etc.). ***Record your answers on the exercise answer sheet!***

4. In situ stress measurements have been made providing the data shown to the right. If these *in situ* stresses are taken into account, how do they affect the calculated Factor of Safety for any roof wedges? Hint: Explore the '*Field stress*' option under the '*Analysis*' menu. ***Record your answers on the exercise answer sheet!***

Principal Stress	Magnitude (MPa)	Orientation	
		Trend	Plunge
σ_1	20	5°	85°
σ_2	15	185°	5°
σ_3	7	95°	0°