Dr. Ir. A.C. Dieudonné

AESB2341
Rock Mechanics and Rock Engineering

2018 - 2019

Practice exam

Name	
Student number	
Exam completion time	
Signature	

— The duration of the exam is 3 hours.
— There are 4 questions. Each question carries 25 points.
— The exam document counts 6 pages, the answer book has 13 pages.
— Write your answers in the answer book, clearly identifying answers.
— Answer all questions.
— Indicate your name and student number on each page.
— Use readable hand writing. Non-readable hand-writing will not be graded.
— Do not use red pen or pencil.
— Good luck !

Question 1 (25 points)

In an experimental study of 1994, Martin and Chandler investigated the mechanical behaviour of Lac du Bonnet granite. Martin and Chandler performed triaxial tests under different confining stresses σ_3. They adopted the ISRM testing procedure, which includes recording the axial (ε_{axial}) and lateral ($\varepsilon_{lateral}$) strains in a sample as it is loaded. An example of axial stress versus axial and lateral strain curves for Lac du Bonnet granite in uniaxial compression is given in Figure 1.

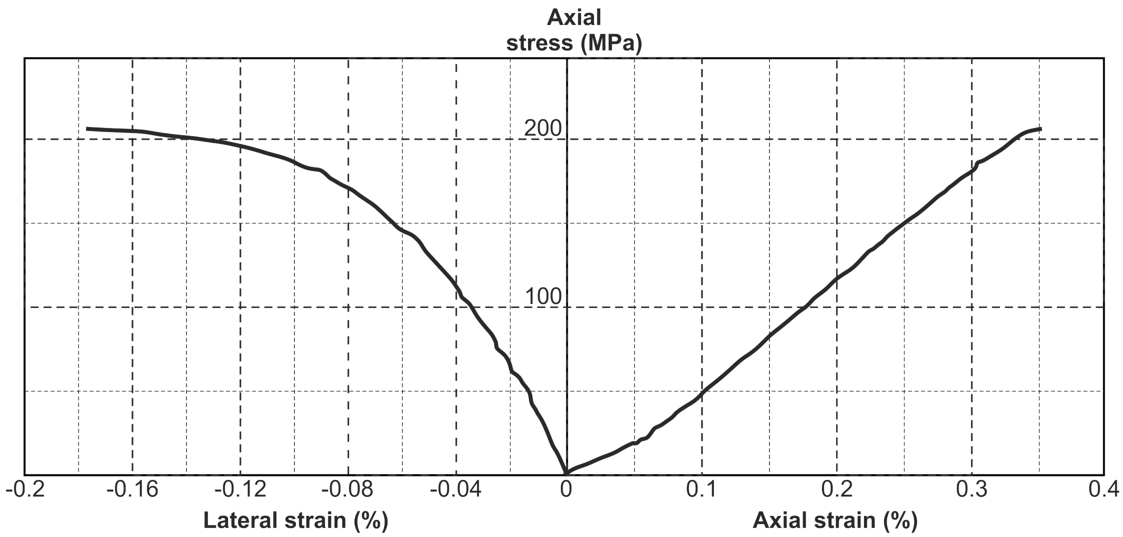

FIGURE 1 – Stress - strain diagram obtained from a single uniaxial compression test on Lac du Bonnet granite (Martin and Chandler, 1994).

a Describe the stress - strain curves of Lac du Bonnet granite in terms physical processes occurring in the sample. Be specific and refer to the above diagram, which you can annotate. [**7.5 points**]

b Determine Young's modulus and Poisson's ratio of Lac du Bonnet granite. [**3 points**]

c Determine the uniaxial compressive strength of Lac du Bonnet granite. [**1.5 point**]

d Which class of material does the of Lac du Bonnet granite belong to ? [**1 point**]

e After failure, Martin and Chandler took a picture of the sample. They recorded that the specimen failed along a single fracture. Which information does the picture showed in Figure 2 give about the strength of Lac du Bonnet granite ? Give a qualitative and quantitative answer. [**3 points**]

f Propose a failure criterion of the form $\sigma_1 = a\sigma_3 + b$ for Lac du Bonnet granite. [**4 points**]

g What is the state of stress on the failure plane at failure ? [**4 points**]

h As part of its research program on the geological disposal of high-level radioactive waste, the Canadian Nuclear Fuel Waste Management Program has constructed an Underground Research Laboratory in the Lac du Bonnet batholith. High-level radioactive waste contains radionuclides which are strongly heat emitting. Heating arising from the canisters will induce significant temperature changes in the host formation. What effects is temperature likely to have on the mechanical behaviour of Lac du Bonnet granite ? [**1 point**]

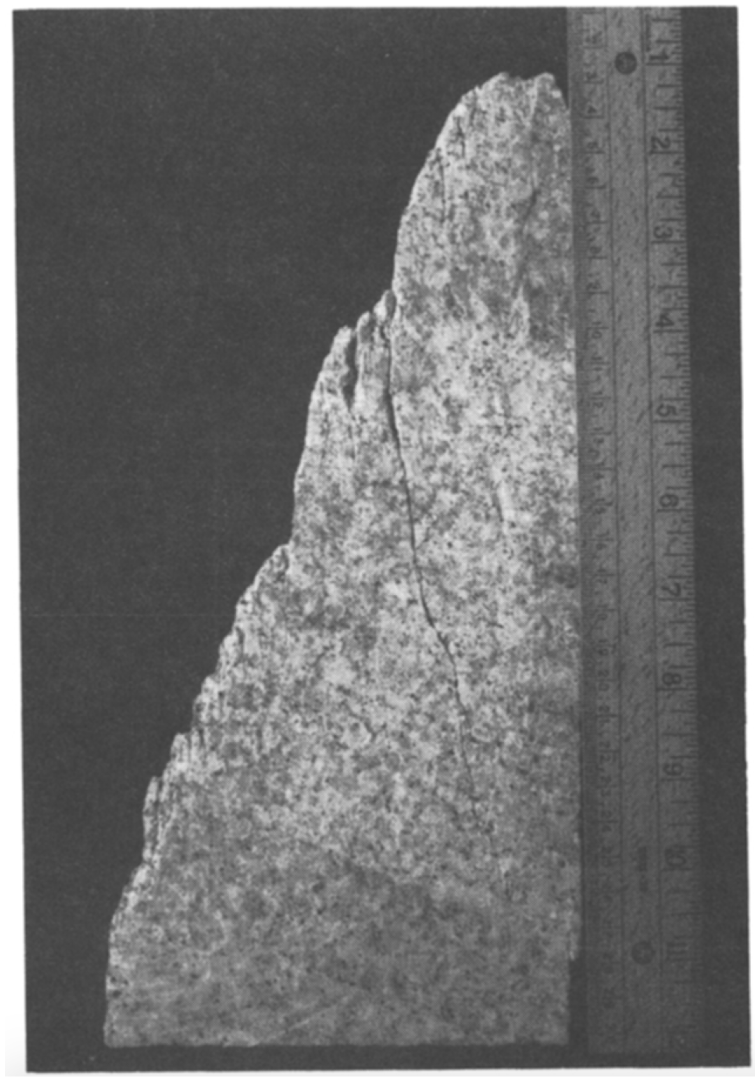

FIGURE 2 – Failed sample of Lac du Bonnet granite (Martin and Chandler, 1994). Units on the right of the ruler are cm.

Question 2 (25 points)

A vertical shaft is to be excavated in the vicinity of clay-filled fault at 500 m depth. The diameter D of the shaft is 6 m. Figure 3 depicts the situation in the horizontal plane. The vertical stress at 500 m is caused by the weight of the overlying rock and the horizontal state of stress is isotropic. The average density of the overburden is 26 kN/m^3 and its Poisson's ratio has been measured equal to 0.35. The resistance to slip on the fault is purely cohesive, and of magnitude 1 MPa.

a Calculate the vertical and horizontal *in situ* stresses before excavation of the shaft. Consider the theory of elasticity and assume conditions of uniaxial strain in the vertical direction with zero lateral strain. [**4 points**]

b Develop a mathematical expression of the shear stress acting on the fault plane as a function of the angle θ between the normal stress acting on the fault plane σ_n and the radial stress σ_r, and of the distance between the shaft axis O and the fault $(L + R)$.
[**10 points**]

c Calculate the value of the angle θ at which the shear stress on the fault plane τ is maximum. [**5 points**]

d Calculate the minimum distance $L + R$ between the shaft axis O and the fault which is required to maintain the elastic stress distribution in the rock mass and avoid slippage along the fault. [**6 points**]

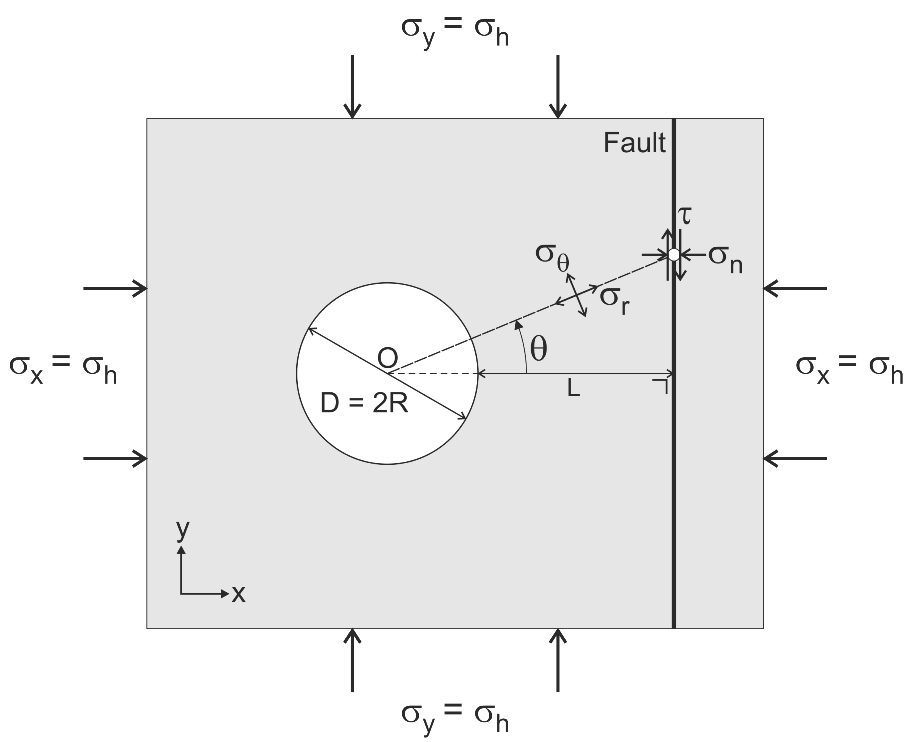

FIGURE 3 – Vertical shaft excavated in the vicinity of clay-filled fault at 500 m depth.

Question 3 (25 points)

a List 5 geometrical properties of discontinuities. [**5 points**]

b How does each of these geometrical properties of discontinuities affect the stability of surface excavations (slopes) ? Explain your answers. [**7.5 points**]

c Figure 4 shows the outcrop of a sedimentary formation near Phoenix, Arizona. Point at 3 geometrical properties of discontinuities in Figure 4 using arrows and label each of them. [**3 points**]

d Which type of slope failure occurred in the outcrop of Figure 4 ? [**1 point**]

e List the necessary kinematic conditions for this slope failure mechanism to be activated. Highlight two of these conditions on the picture or on a sketch. [**5 points**]

f What kind of support technique(s) could be implemented to avoid further failure of the slope ? Justify your answer. [**3.5 points**]

FIGURE 4 – Outcrop of a sedimentary formation near Phoenix, Arizona. The car gives the scale !

Question 4 (25 points)

A potential rock fall hazard has developed on a 38 m high, near-vertical rock face located above a two-lane highway (Figure 5). The evidence of instability is a series of tension cracks that have opened as the result of down-slope movement on the sheet joints. For design purposes, the assemblage of rock blocks is assimilated to a large block as shown in Figure 6. Its dimensions are : $H = 18$ m, $\psi_p = 25°$, $\psi_f = 70°$ and $b = 10$ m.

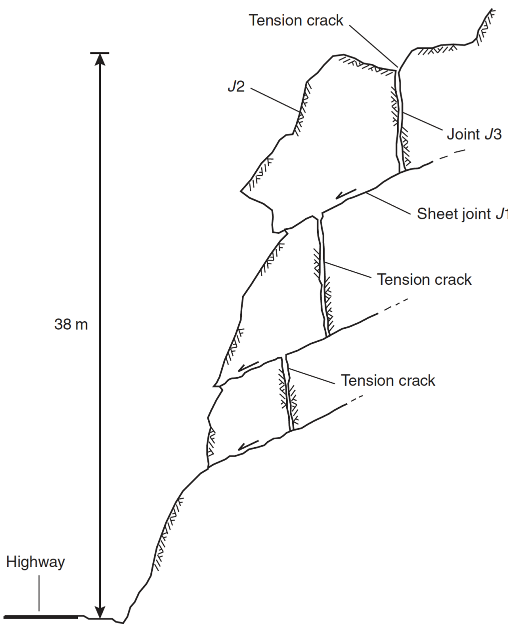

FIGURE 5 – Cross-section of the slope showing movement along sheet joints and location of tension cracks.

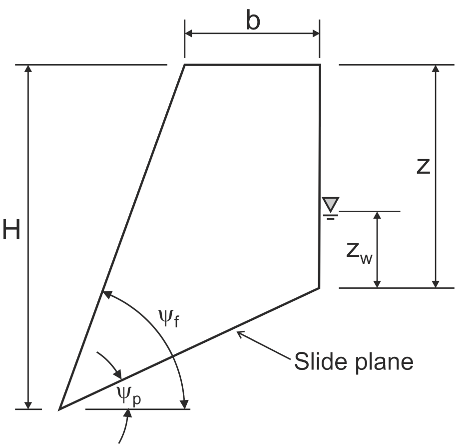

FIGURE 6 – Cross-section of block used in design to model the assemblage of rock blocks in the slope.

The rock unit weight γ_r is equal to 26 kN/m^3.The sheet joints are smooth, planar or slightly undulating, and there is generally no infilling apart from slight weathering of the surfaces. For these conditions where the joints have no infilling, the cohesion is zero and the shear strength comprises only friction. Direct shear tests on the sheet joints showed that the friction angle is equal to 36°.

The site is located in an area with high precipitation. It is assumed for design that water would accumulate in the tension crack to depth z_w, and that water forces would be generated both in the tension crack and along the sliding plane. Water enters the sliding surface along the base of the tension crack and seeps along the sliding surface, escaping at atmospheric pressure where the sliding surface daylights in the slope face.

- a List, label, represent and give the mathematical expression the forces acting on the block of Figure 6. [**8 points**]
- b Develop a mathematical expression of forces resisting failure along the slide plane. [**2 points**]
- c Develop a mathematical expression of forces driving failure along the slide plane. [**2 points**]
- d Give the mathematical expression and calculate the factor of safety against planar failure along the slide plane if the rock mass is dry. [**4 points**]
- e Is the dry rock mass stable or not ? [**1 point**]
- f Would removing the unstable rock by blasting improve the stability of the dry slope ? Argue. [**2 points**]
- g Calculate the factor of safety against planar failure along the slide plane if $z_w = 11$ m. Assume $\gamma_w = 10$ kN/m^3. [**5 points**]
- h Is the wet rock mass with $z_w = 11$ m stable or not ? [**1 point**]