

Assignment 3

(Due: 27 February, 2020 by 17:00)

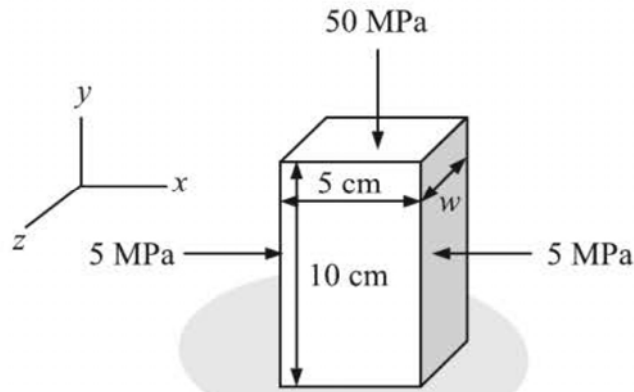
- Q1.** A tunnel is proposed to be excavated 150 m below ground surface in a granite rock mass containing 3 joint sets. The dip of the dominant joint set is 50° , average RQD is 74%, average joint spacing is 0.24 m, joint surfaces are generally stepped and rough, tightly closed and unweathered with occasional stains. The joint surfaces observed in exploratory excavations are wet but not dripping, average rock material UCS is 160 MPa and no abnormal *in-situ* stress is expected (i.e., assume that vertical stress is the major principal stress).
- (a). Estimate the **RMR** value with due consideration of the adjustment for discontinuity orientation if the tunnel is **driven with the dip of the dominant joint set**.
 - (b). In the same location, if the tunnel is **driven parallel to the strike of the dominant joint set**, what would be the **RMR** value?
 - (c). Using the RMR from part a), determine the **stand-up time** and propose appropriate **tunneling support measures** if the tunnel span is 15 m.
- Q2.** A rock mass has three joint sets, each spaced at 17 cm. The joints are rough and the joint profile is almost planar. The joint surfaces of critical joints are slightly altered with sandy clay coatings. The rock mass is moist only. Laboratory tests on core samples of intact rock gave an average uniaxial compressive strength of 255 MPa. The principal stress directions are approximately vertical and horizontal and the magnitude of the horizontal principal stress is approximately 1.7 times that of the vertical principal stress. The plan is to excavate a road tunnel of 8 m diameter at a depth of 200 m perpendicular to the strike and against the dip of the main joint set dipping at 22° . Assume a unit weight of 25 kN/m^3 for the rock mass and estimate the **RMR, Q and GSI**. Using the **Q-index**, propose appropriate **tunneling support measures** (taking $\text{ESR}=1.0$).

Hint: use the volumetric joint count, J_v to estimate the RQD.

Q3. Consider a rock sample with dimensions and load conditions as shown in the figure below and determine the **2-D strain tensor** ($\varepsilon_x, \varepsilon_y, \varepsilon_z, \gamma_{xy}$), the **out-of-plane normal stress** (σ_z) and the **volumetric strain** ($\varepsilon_{vol.}$) for the following two cases:

- (a). $w = 1$ cm (assume **plane stress** loading);
- (b). $w = 100$ cm (assume **plane strain** loading).

Assume E and ν of rock are **10 GPa** and **0.25**, respectively.



Q4. Seven specimens were prepared from a core recovered from a potential reservoir site. All specimens were tested in a triaxial cell under dry conditions, at various confining stresses. The axial stress at failure was measured for each specimen and the results are summarized below.

Specimen	1	2	3	4	5	6	7
σ_{1f} (MPa)	155.3	171.2	187.3	201.4	215.6	227.2	240.8
σ_{3f} (MPa)	2.5	4.2	5.9	7.6	9.3	11.0	12.8

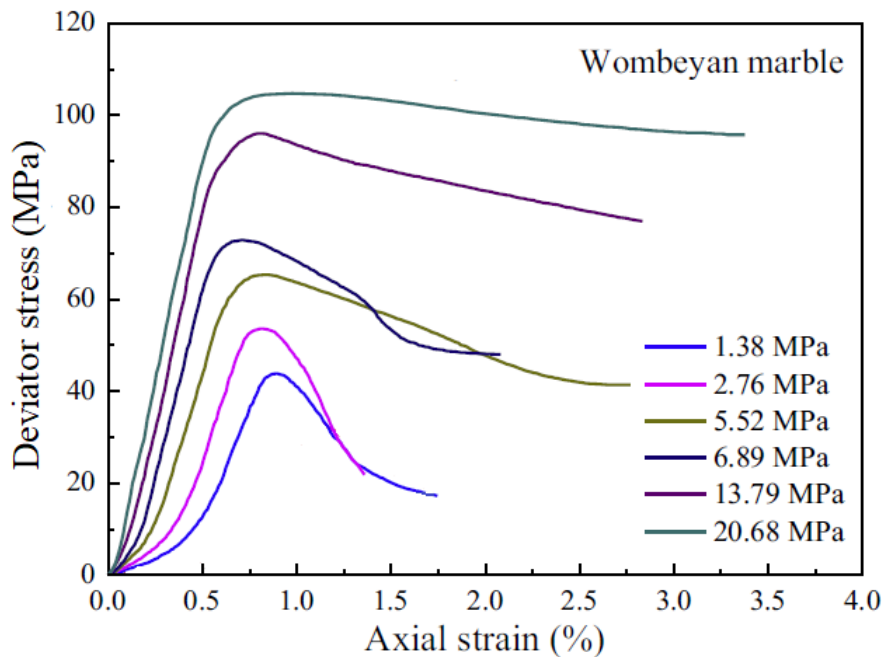
- Plot the Mohr-Coulomb failure envelope** in σ_1 - σ_3 space and **estimate the intact rock strength parameters** (unconfined compressive strength, cohesion and internal angle of friction);
- Determine the **intact rock strength parameters** m_i and σ_{ci} from a plot of $(\sigma_1 - \sigma_3)^2$ vs σ_3 and plot the theoretical Hoek-Brown failure envelope in σ_1 - σ_3 space.
- You are requested to test two additional core samples of the same rock under confining stress levels of **8 MPa and 15 MPa**, respectively. At what **levels of applied axial stress** would you ideally expect these intact core specimens to fail?
- For similar intact rock material, unconfined, it is anticipated that a momentary axial stress of **260 MPa** will be applied. What **confining stress** must be applied to this specimen, prior to axial loading, to just prevent failure from occurring at this level of applied axial stress?

The *in-situ* stress state at the reservoir site was measured to be: $\sigma_1 = 25$ MPa and $\sigma_3 = 5.6$ MPa. Answer the following questions:

- Is the rock mass at the site **stable**? **Show calculations** to support your answer.
- The pore water pressure, u at the site will be raised by the construction of the reservoir. What **value of u** will cause failure of the rock mass *in-situ*? Assume $\phi = \phi'$ and $c = c'$ and that the rock mass obeys the Terzaghi's effective stress principle.

Hint: Use the Hoek-Brown failure criterion to answer parts (c) and (d), and Mohr-Coulomb failure criterion to answer parts (e) and (f).

- Q5.** The results from triaxial testing on marble core samples at varying confining stresses are summarized in the figure below. Assume dry conditions, and
- plot the **peak and residual Mohr-Coulomb (M-C) failure envelopes** (on the same plot) in σ_1 - σ_3 space;
 - estimate the **M-C peak and residual rock strength parameters** (cohesion and internal angle of friction);
 - using the **M-C peak** strength parameters, estimate the **uniaxial compressive strength**, the **direct tensile strength** and the **indirect tensile strength** of this rock;
 - determine the Hoek-Brown (**H-B**) **intact rock strength parameters** m_i , σ_{ci} and σ_{ti} from a plot of $(\sigma_{1,peak} - \sigma_3)^2$ vs σ_3 and plot the theoretical **peak H-B failure envelope** in σ_1 - σ_3 space.



Source: Peng et al. (2015) with modifications