CHAMBER OF MINES OF SOUTH AFRICA

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS PAPER 1 : THEORY **SUBJECT CODE:** COMRMC1 **EXAMINATION DATE: 11 OCTOBER 2016** **TIME**: 14:30 – 17:30	**EXAMINER:** WM BESTER **MODERATOR:** H YILMAZ **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 6

THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. Answer **all four questions**. Answer the questions **legibly** in English.
2. Write your **ID Number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.

NB: Your name **must not** appear on any answer book or loose sheets.

3. Show all calculations **and check calculations on which the answers are based.**
4. **Only non-programmable basic scientific calculators** may be used for calculations.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. **Final answers** must be given to an accuracy which is typical of practical conditions, However be careful not to use too few decimal places during your calculations, as rounding errors may result in incorrect answers

NB: Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used even if the calculated value is correct.

8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

1.1 Sketch and explain the complete stress-strain graph for rock in uniaxial compression, indicating the following:

i. Radial strain
ii. Volumetric strain
iii. Brittle-ductile transition
iv. Residual strength
v. Hysteresis in the post peak region (15)

1.2 A circular pillar is located at a depth of 1,500 m below surface. The overburden density is 2.8 tonne/m^3. If the percentage extraction around the pillar is 72.5%, calculate the average vertical stress on the pillar. (3)

1.3 The pillar discussed in Question 1.2 consists of three different horizontal rock layers. All three layers have the same Poisson's ratio (v = 0.3). The Young's modulus of the top layer is 100 GPa, middle layer is 70 GPa and bottom layer is 130 GPa. Calculate the vertical compressive strain of each layer in the pillar, assuming no horizontal stresses within the pillar and the vertical stresses are uniformly distributed. (3)

1.4 Calculate the radial strain of each layer. What would you observe underground? (4)

[25]

QUESTION 2

2.1 Barton's Q (Tunnelling Quality Index) is evaluated by the formula:

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

Describe the meaning of each of the six variables in the Q-Index formula and describe their influence on tunnel stability. (12)

2.2 Calculate the RQD of a 4.95 m core run where all the joints intersected by the borehole are spaced exactly 11 cm apart. What would the RQD have been if all the joints were spaced 9 cm apart? Discuss. (3)

2.3 Which strength criterion is commonly used when assessing the strength of in-situ rock that is transected by many closely-spaced joint sets at multiple angles? Discuss the limitations of this criterion. (5)

2.4 Barton and Choubey developed the following equation to calculate shear strength on a plane:

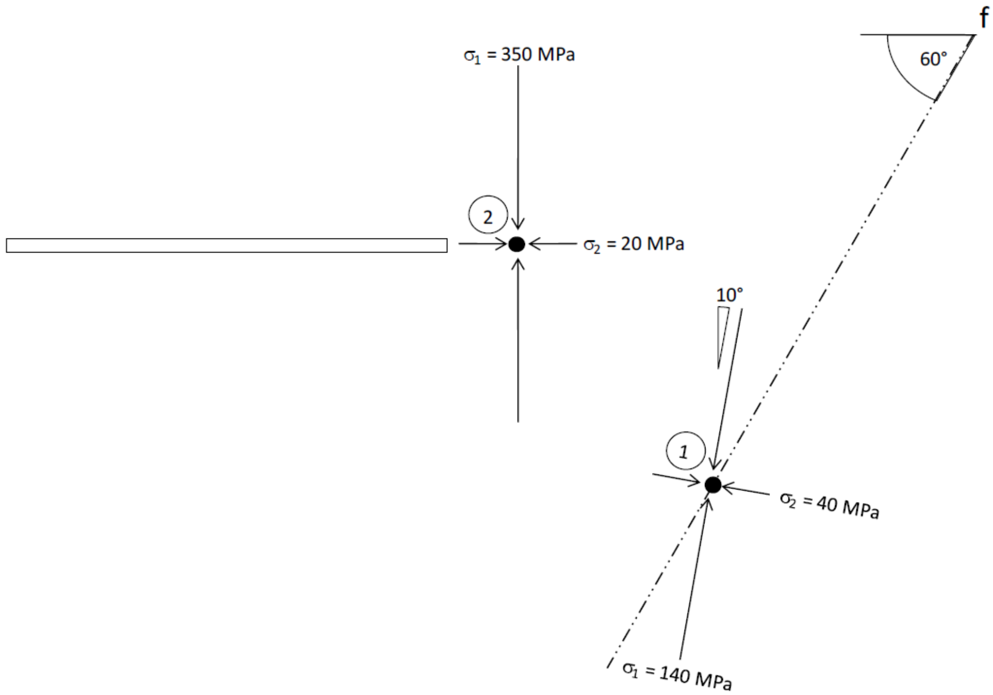
$$\tau = \sigma_n \times \tan\left\{\varphi_b + JRC \times log_{10}\left({}^{JCS}/_{\sigma_n}\right)\right\}$$

Define and describe each of the four parameters required as input. What significance is there with an increasing σ_n? (5)

[25]

QUESTION 3

The two dimensional principal stress state at two points in a homogeneous rockmass are shown below:



3.1 Define the following (make use of sketches if required): (10)

i. Normal stress

ii. Shear stress

iii. Homogeneous rockmass

iv. Lithostatic stress conditions

v. Principal stress

3.2 If the fault has a friction angle of 30° and cohesion of 1.0 MPa, comment on its stability at Point 1. Show all calculations. (10)

3.3 What out-of-plane stress (σ_3) is required at Point 2 to satisfy the plain strain assumption? (Assume v = 0.3) (5)

[25]

QUESTION 4

Given the Kirsch equations below for the stresses around a circular opening:

$$\sigma_{rr} = \frac{1}{2}q(1+k)\left(1-\frac{R^2}{r^2}\right) - \frac{1}{2}q(1-k)\left(1-\frac{4R^2}{r^2}+\frac{3R^4}{r^4}\right)\cos 2\theta$$

$$\sigma_{\theta\theta} = \frac{1}{2}q(1+k)\left(1+\frac{R^2}{r^2}\right) + \frac{1}{2}q(1-k)\left(1+\frac{3R^4}{r^4}\right)\cos 2\theta$$

$$\tau_{r\theta} = \frac{1}{2}q(1-k)\left(1+\frac{2R^2}{r^2}-\frac{3R^4}{r^4}\right)\sin 2\theta$$

4.1 The input parameters for the calculation include k, q, R, r and Θ. Define and show these five input parameters on a sketch. (5)

4.2 Calculate the stresses anywhere around the periphery of the excavation for lithostatic loading. (3)

4.3 Calculate the distance into the solid where the radial stress is 90% of the virgin stress for lithostatic loading. (4)

4.4 For biaxial loading with k = 0.25, calculate the peripheral stresses on the side and top of a tunnel. (4)

4.5 For biaxial loading with k = 2.0, calculate the peripheral stresses on the side and top of a tunnel. (4)

4.6 Discuss the practical implications of your results calculated in Questions 4.4 and 4.5 above. (5)

[25]

TOTAL MARKS: [100]

FORMULAE SHEET

1. Total Energy = ½ m v^2 + mgh
2. $s_z = \frac{2(1-\nu)q}{G}\sqrt{l^2 - x^2}$
3. $l_c = \frac{s_m G}{2(1-\nu)q}$
4. $q = \rho g H$
5. $e = 1 - \frac{w_1 w_2}{C_1 C_2}$
6. $ERR = \frac{\Delta U_m}{\Delta A} = \frac{\pi(1-\nu)lq^2}{2G}$
7. $\nu_p = \sqrt{\frac{\lambda + 2G}{\rho}}$ $\qquad$ $\nu_s = \sqrt{\frac{G}{\rho}}$
8. $RCF = \frac{3\sigma_1 - \sigma_3}{F\sigma_c}$
9. $RQD = \frac{\sum lenght\ of\ core\ pieces > 10cm}{total\ lenght\ of\ core}\ x\ 100$
10. $\mu = tan\varphi$
11. G = $\frac{E}{2(1+v)}$
12. APS = $q_v/(1-e)$
13. $\varepsilon = \Delta\ell / L$
14. $E = \sigma/\varepsilon$
15. $\varepsilon_r = -v\varepsilon_a$
16. $\varepsilon_3 = \frac{1}{E}[\sigma_3 - v(\sigma_1 + \sigma_2)]$
17. $\sigma_n = \sigma_1 cos^2\theta + \sigma_2 sin^2\theta$
18. $\tau_{nm} = -\frac{1}{2}(\sigma_1 - \sigma_2)sin2\theta$
19. $\tau_n = c + \mu\sigma_n$
20. $\varepsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)]$
21. $\varepsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)]$
22. $\varepsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)]$