CHAMBER OF MINES OF SOUTH AFRICA

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS PAPER 1 : THEORY **SUBJECT CODE:** COMRMC **EXAMINATION DATE: 9 MAY 2017** **TIME**: 14:30 – 17:30	**EXAMINER:** WM BESTER **MODERATOR:** H YILMAZ **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 7

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 idealised stress-strain graphs, indicating loading and unloading paths, for the following materials:

i. Linear elastic
ii. Non-linear elastic
iii. Perfectly plastic
iv. Elasto-plastic
v. Elasto-plastic with strain hardening (15)

1.2 A mine pole (180 mm diameter) has an axial elastic modulus of 4 GPa. Calculate the mass that will compress the mine pole by 0.1% when loaded axially. (6)

1.3 The modulus of rigidity, also called shear modulus, indicates the resistance to deflection due to shear stresses. Calculate the modulus of rigidity (assuming a Poisson's ratio of 0.33) of the mine pole discussed in Question 1.2. (2)

1.4 Calculate the strain energy density of the mine pole discussed in Question 1.2. (2)

[25]

QUESTION 2

2.1 List and describe the six parameters used to classify a rock mass using Bieniawski's RMR_{89} system. (6)

2.2 List the five rock mass classes as defined by their RMR value ranges. (5)

2.3 The two most widely used rock mass classifications are Bieniawski's RMR and Barton's Q. Discuss the similarities and differences between RMR and Q. (8)

2.4 Define and discuss homogeneity, isotropy and continuity of rock masses, and the implications thereof for elastic theory assumptions. (6)

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QUESTION 3

The following state of stress is given: $\begin{pmatrix} -5 & -26 \\ -26 & 25 \end{pmatrix}$ kPa

3.1 Calculate the magnitude of the principal stresses. (4)

3.2 Calculate the direction of the major principal stress. (6)

3.3 Calculate the maximum shear stress. (2)

3.4 Sketch the Mohr's circle representation of the stress state provided in matrix form. Indicate principal stresses, maximum shear stress and principal directions on the circle. (10)

3.5 Sketch simple Mohr circles for the following cases: (3)

i) Uniaxial compression

ii) Uniaxial tension

iii) Pure shear

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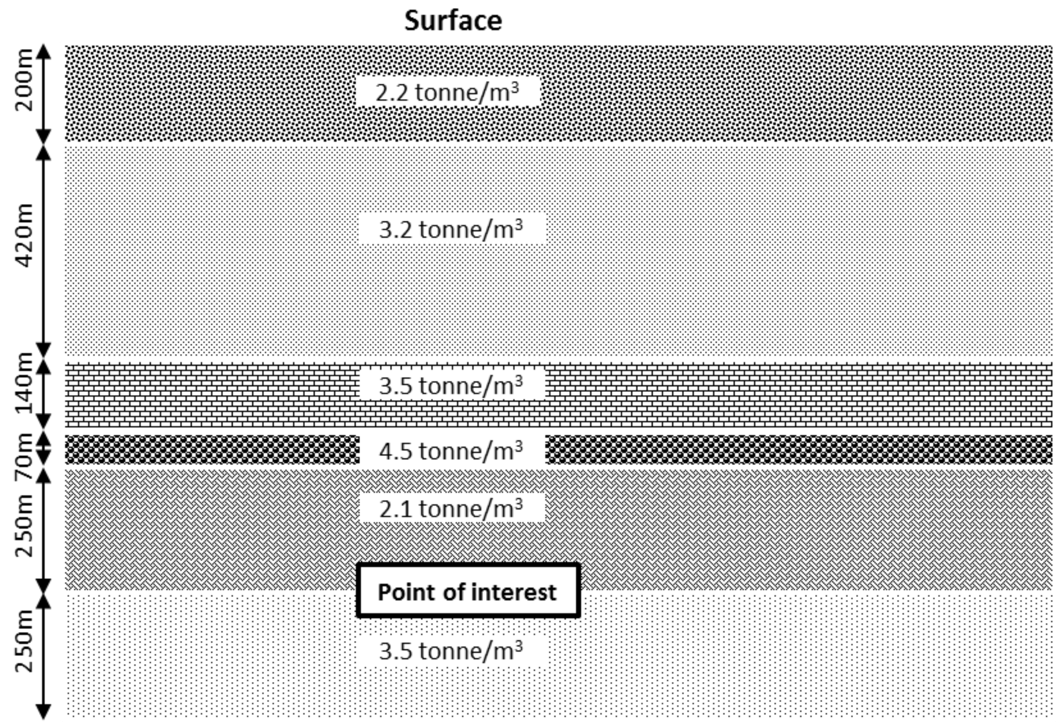
QUESTION 4

4.1 In situ stresses determine the confinement imposed on the rock mass. Describe the impact of low, medium and high stress on stability of the rock mass. (6)

4.2 The vertical virgin stress in a stratified rock mass can be estimated using the formula: $\boldsymbol{q_v = \sum_{i=1}^{n} \rho_i g h_i}$

Use this formula to calculate the vertical virgin stress at a point of interest 1,080 m below surface for the hypothetical scenario sketched below. (3)



4.3 The database of in situ stress measurements carried out in Southern Africa lists horizontal stress components in deep level mines ranging between 0.3 and 1.5 times the vertical stress component. Calculate the horizontal stress component at the point of interest in Question 4.2, using:

i) Heim's rule

ii) Rigid confinement theory (assume Poisson's ratio is 0.3)

iii) The database average $\boldsymbol{k}$ value of 0.6

iv) The database best fit linear regression line: $\boldsymbol{q_h = 10 + 0.01h}$ (4)

4.4 Describe and explain at least two specific situations in hard rock mines where abnormal virgin stresses can be anticipated. (2)

4.5 In some of the shallow coal mines of South Africa, the measured horizontal virgin stress values range from 0.1 to 0.4 times the vertical stress component. Provide a probable reason for these low ***k*** values. (1)

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

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

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

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

Calculate the radial, tangential and shear stresses above the crown of a 6 m diameter circular tunnel at a distance of 25 cm into the solid from the skin of the tunnel. The virgin vertical stress component (q) is 20 MPa. The virgin horizontal stress components are: $q_{H1} = 2q_{H2} = 2q$

i) The tunnel is aligned with q_{H2}

ii) The tunnel is aligned with q_{H1} (8)

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TOTAL MARKS: [100]

FORMULAE SHEET

1. $l_c = \dfrac{s_m G}{2(1-\nu)q}$

2. $q = \rho g H$

3. $e = 1 - \dfrac{w_1 w_2}{C_1 C_2}$

4. $RCF = \dfrac{3\sigma_1 - \sigma_3}{F\sigma_c}$

5. $\mu = tan\varphi$

6. $k = \frac{\upsilon}{1-\upsilon}$

7. $G = \frac{E}{2(1+\upsilon)}$

8. W = ½ σε

9. ε = Δℓ / L

10. E = σ/ε

11. $\varepsilon_r = -\upsilon\varepsilon_a$

12. $\varepsilon_3 = \frac{1}{E}[\sigma_3 - \upsilon(\sigma_1 + \sigma_2)]$

13. $\sigma_n = \sigma_1 cos^2\theta + \sigma_2 sin^2\theta$

14. $\tau_{nm} = -\frac{1}{2}(\sigma_1 - \sigma_2)sin2\theta$

15. $\tau_n = c + \mu\sigma_n$

16. $\sigma_1 = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}\sqrt{}\left[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2\right]$

17. $\sigma_2 = \frac{1}{2}(\sigma_x + \sigma_y) - \frac{1}{2}\sqrt{}\left[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2\right]$

18. $\theta = \frac{1}{2}arc\tan\left[2\tau_{xy}/(\sigma_x - \sigma_y)\right]$

19. $\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_2)$

20. $\sigma_{x'} = \sigma_x cos^2\theta + 2\tau_{xy}\sin\theta\cos\theta + \sigma_y sin^2\theta$

21. $\sigma_{y'} = \sigma_x sin^2\theta - 2\tau_{xy}\sin\theta\cos\theta + \sigma_y cos^2\theta$

22. $\tau_{x'y'} = \frac{1}{2}(\sigma_y - \sigma_x)\sin 2\theta + \tau_{xy}\cos 2\theta$