CHAMBER OF MINES OF SOUTH AFRICA

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS PAPER 1 : THEORY **SUBJECT CODE:** COMRMC1 **EXAMINATION DATE:** 10 OCTOBER 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 five 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 - (BEAM THEORY)

1.1 Sketch three different types of elastic beams, indicating on each the maximum compressive, tensile and shear stresses. (12)

1.2 Sketch a simple Voussoir beam, indicating the maximum compressive and shear stresses. (3)

1.3 List three potential modes of failure of a Voussoir beam. (3)

1.4 What are the fundamental assumptions governing Voussoir beams? (2)

[20]

QUESTION 2 - (ROCK MASS CLASSIFICATION)

2.1 List and describe the five parameters of the original Geomechanics Classification system (RMR). (5)

2.2 What adjustments are made to the Geomechanics Classification to obtain an overall rock mass description? (2)

2.3 List and briefly discuss the modifications required to the Geomechanics Classification to calculate MRMR, according to Laubscher and Taylor? (9)

2.4 Estimate the in situ Hoek-Brown ‘m’ and ‘s’ parameters suitable for underground mining of a rock mass that has a Barton’s Q value of 25 and internal friction angle of 53°. (4)

[20]

QUESTION 3 - (ROCK PROPERTIES)

3.1 Sketch stress-strain graphs of typical triaxial compression tests, illustrating the effect of increased confinement on rock strength and failure behaviour. (5)

3.2 Two rock samples were subjected to triaxial compression testing. The samples failed at the following stresses:

Test 1: σ_1 = 600 MPa σ_3 = 100 MPa

Test 2: σ_1 = 900 MPa σ_3 = 200 MPa

i) Draw the Mohr circles that represent these two tests. (2)

ii) Determine the cohesion and internal friction angle using your drawing. Assume Mohr-Coulomb failure. (2)

3.3 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)

3.4 Study the table of typical elastic constants and strength properties of different rock types below. Discuss the difference in rock behaviour expected of these rock types in laboratory testing in terms of axial and radial deformation, triaxial strength and shear strength. (6)

Rock Type	**E (GPa)**	**v**	**σ_c (MPa)**	**C_o (MPa)**	**φ_i°**
Quartzite	70	0.23	220	45	35
Pyroxenite	100	0.3	120	20	50
Sandstone	30	0.1	70	20	30
Granite	60	0.2	220	30	55

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QUESTION 4 - (STRESS IN ROCK)

4.1 The virgin or primitive state of stress is a function of several influencing factors. List and describe at least four of these factors. (4)

4.2 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. Sketch the expected shape of break-out (sockets) around shotholes for $k = 0.5$, $k = 1$ and $k = 1.5$. (3)

4.3 Use the Kirsch equations to calculate the tangential stress in terms of the vertical virgin stress (q) at mid-height on the periphery of a circular tunnel for each of the scenarios listed in Question 4.2 above. Which k-ratio should result in the least stress damage to the sidewalls of the tunnel? (8)

4.4 Calculate the k-ratio that will result in tangential stress of zero at the crown of the tunnel. (5)

[20]

QUESTION 5 - (STRESS AND STRAIN)

5.1 The 2D virgin stress tensor measured at a depth of 1788 m below surface is given by:

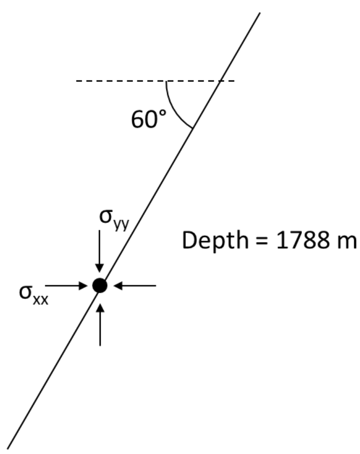
$$\begin{pmatrix} \sigma_{xx} & \tau_{xy} \\ \tau_{yx} & \sigma_{yy} \end{pmatrix} = \begin{pmatrix} 40 & -8.66 \\ -8.66 & 50 \end{pmatrix}$$

Calculate:

i) the average overburden density (1)

ii) the k-ratio (2)

5.2 Calculate and plot the normal and shear stresses acting on a 60° dipping fault as depicted below, when subjected to the virgin stresses listed in Question 5.1. (5)



5.3 Calculate the magnitude and direction of the major principal stress of the stress state given in Question 5.1 above. (6)

5.4 A wooden table has four identical legs, each 900 mm long with 90 mm diameter. The axial elastic modulus of wood is 4 GPa. Assuming that the legs do not break, calculate the shortening of each leg when a mass of 10 tonnes is placed on the table. Assume that the mass is distributed evenly on the four legs. (6)

[20]

TOTAL MARKS: [100]

FORMULAE SHEET

1. $m_i = 2(\beta_o - 1)$
2. F = mg
3. $q_v = \rho g h$
4. $\beta_o = \frac{(1+\sin\varphi_i)}{(1-\sin\varphi_i)}$
5. RMR = 9 ln Q + 44
6. $\mu = tan\varphi_i$
7. $\mathbf{s} = \mathbf{e}^{\frac{(\mathbf{RMR}-\mathbf{100})}{\mathbf{9}}}$
8. $\mathbf{m} = \mathbf{m_i}\,\mathbf{e}^{\frac{(\mathbf{RMR}-\mathbf{100})}{\mathbf{28}}}$
9. $k = \frac{v}{1-v}$
10. $G = \frac{E}{2(1+v)}$
11. W = ½ σε
12. ε = Δℓ / L
13. E = σ/ε
14. $\varepsilon_r = -v\varepsilon_a$
15. $\varepsilon_3 = \frac{1}{E}[\sigma_3 - v(\sigma_1 + \sigma_2)]$
16. $\sigma_n = \sigma_1 cos^2\theta + \sigma_2 sin^2\theta$
17. $\tau_{nm} = -\frac{1}{2}(\sigma_1 - \sigma_2)sin2\theta$
18. $\tau_n = c + \mu\sigma_n$
19. $\sigma_1 = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}\sqrt{}\left[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2\right]$
20. $\sigma_2 = \frac{1}{2}(\sigma_x + \sigma_y) - \frac{1}{2}\sqrt{}\left[(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2\right]$
21. $\theta = \frac{1}{2}arc\tan\left[2\tau_{xy}/(\sigma_x - \sigma_y)\right]$
22. $\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_2)$
23. $\sigma_{x\prime} = \sigma_x cos^2\theta + 2\tau_{xy}\sin\theta\cos\theta + \sigma_y sin^2\theta$
24. $\sigma_{y\prime} = \sigma_x sin^2\theta - 2\tau_{xy}\sin\theta\cos\theta + \sigma_y cos^2\theta$
25. $\tau_{x\prime y\prime} = \frac{1}{2}(\sigma_y - \sigma_x)\sin 2\theta + \tau_{xy}\cos 2\theta$
26. $\sigma_{\theta\theta} = \frac{1}{2}q(1+k)\left(1+\frac{R^2}{r^2}\right) + \frac{1}{2}q(1-k)\left(1+\frac{3R^4}{r^4}\right)\cos 2\theta$