Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS **PAPER 1:** THEORY **SUBJECT CODE: COMRMC** **EXAMINATION DATE: 4 OCTOBER 2022** **TIME**: **14H30 TO 17H30**	**EXAMINER:** SZ PETHÖ **MODERATOR:** O RAKUMAKOE **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 5

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

SPECIAL REQUIREMENTS:

1. **Answer All the 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. Hand-held electronic calculators may be used for calculations. **Reference notes may not be programmed into calculators.**
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) is 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 AND OTHER SMART DEVICES are **NOT** allowed in the examination room.

QUESTION 1.

Laboratory testing was carried out at on sandstone samples with a diameter of 42mm, and the following results were obtained at failure:

σ_3 (MPa)	Load (kN)
5	72.0
15	103.9
25	126.0
35	162.0
50	195.0

1.1 Calculate σ_1 for the above results.	(5)
1.2 Plot the Mohr circles and calculate the values for the cohesion (c) and the friction angle (φ).	(7)
1.3 Determine the UCS value of this rock specimen.	(3)
1.4 Determine the orientation of the most likely shear failure plane.	(3)
1.5 What is the load at failure when the confining pressure is 20MPa?	(2)
1.6 Illustrate the idealized constitutive models that describe the stress-strain relationships, by means of a simple sketch.	(5)

[25]

QUESTION 2.

<table>
<tr><td>An underground chamber is to be excavated in an intensely jointed sedimentary rock mass. Geological observations indicate that the quality of the rock mass can be characterised by a modified Q' value of 0.1. Laboratory tests showed that the mean uniaxial compressive and tensile strengths of the intact rock were 35MPa and 2.3MPa, respectively, and the Hoek-Brown constant m_i was 15.</td><td></td></tr>
<tr><td>2.1 Determine the equation for the Hoek-Brown failure criterion for both the intact rock and the rock mass?</td><td>(8)</td></tr>
<tr><td>2.2 In the $\boldsymbol{\sigma_3}$ stress range of -3MPa to 25MPa, plot the appropriate failure envelopes in the $\boldsymbol{\sigma_1 - \sigma_3}$ co-ordinate system for both the intact rock and the rock mass.

Note: For the purposes of plotting the failure envelopes, a minimum of five points should be used to adequately define the failure envelopes.</td><td>(6)</td></tr>
<tr><td>2.3 Calculate the rock mass deformation modulus.</td><td>(3)</td></tr>
<tr><td>2.4 If the following corresponding principal stresses are expected to be set up at various points in the rock mass

<table>
<tr><td></td><td>MPa</td><td>MPa</td><td>MPa</td></tr>
<tr><td>(a)</td><td>-5</td><td>5</td><td>10</td></tr>
<tr><td>(b)</td><td>30</td><td>10</td><td>15</td></tr>
<tr><td>(c)</td><td>40</td><td>20</td><td>22</td></tr>
</table>

Determine which of the three stress conditions will induce failure.</td><td>(3)</td></tr>
<tr><td>2.5 Describe and explain the limitations of using the Hoek-Brown failure criterion in Rock Engineering investigations.</td><td>(5)</td></tr>
</table>

[25]

QUESTION 3.

3.1 Explain Heim's law.	(3)
3.2 Explain the rigid confinement (lateral restraint theory).	(3)
3.3 Explain why stresses calculated using the above two methods may vary in reality.	(3)
3.4 Explain the k ratio, and how it varies for shallow to deep mining.	(3)
3.5 Explain the principle of the doorstopper strain cell.	(3)
3.6 Explain the use and assumptions of the Kirsch equations.	(3)
3.7 The Kirsch equations are indicated below: $\boldsymbol{\sigma}_{\boldsymbol{rr}} = \frac{1}{2}(q_h + q_v)(1 - t^2) + \mathrm{p}t^2 + \frac{1}{2}(q_h - q_v)\,(1 - 4t^2 + 3t^4)\cos 2\theta$ $\boldsymbol{\sigma}_{\boldsymbol{\theta\theta}} = \frac{1}{2}(q_h + q_v)(1 + t^2) - \mathrm{p}t^2 - \frac{1}{2}(q_h - q_v)\,(1 + 3t^4)\cos 2\theta$ $\boldsymbol{\tau}_{\boldsymbol{r\theta}} = -\frac{1}{2}(q_h - q_v)(1 + 2t^2 - 3t^4)\sin 2\theta$ Calculate the value of the maximum and the minimum tangential stress and the shear stress at these values, and where does it occur, stating all of your assumptions.	(7)

[25]

QUESTION 4.

4.1 Given the following stress matrix, calculate all of the strain components employing the 2D representation of Hooke's Law and the Modulus of Rigidity formulae? $\begin{pmatrix} 30 & 3 \\ 3 & 65 \end{pmatrix}$ Where the Poisson's ratio = 0.3, and the Young's Modulus = 60GPa	(5)
4.2 Using the answers calculated in Question 4.1, calculate the strain energy density that is stored at this point within the rock mass.	(3)
4.3 Calculate the magnitude and direction of the principal stresses for the stress state as described in Question 4.1 above.	(5)
4.4 Discuss the stages of creep and where creep is encountered in your mining practice.	(6)
4.5 Describe the three types of beams that can be encountered in an underground mining situation, such as in sedimentary (layered) strata.	(6)

[25]

Total Marks = [100]