# MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

## FACULTY OF ENGINEERING, APPLIED SCIENCES AND TECHNOLOGY

### DEPARTMENT: MINING AND MINERAL PROCESSING ENGINEERING

**MODULE: ROCK MECHANICS**

**CODE: ENGP 311**

**SESSIONAL EXAMINATIONS**
**DECEMBER 2023**

**DURATION: 3 HOURS**

**EXAMINER: J.MUCHEMWA**

INSTRUCTIONS

1. *Question 1 and 2 are **compulsory**, and choose any other three (3) questions from **section B***
2. *Show all working.*
3. *Start a new question on a fresh page*
4. *Total marks 100*
5. ***ADDITIONAL MATERIALS**: graph paper, list of formulae and calculator.*

## Question 1

(a) A tunnel is to be driven through a weathered quartz with the following geologic characters: A point load strength index of 4Mpa, RQD value of 65%, spacing between joints is 450mm, joints are slightly rough and have a separation of less than 1mm, walls are highly weathered, tunneling conditions are anticipated to be damp, the dominant joint sets dips at 30 degrees against the direction of the drive. Using data provided in **List of Tables** provided;

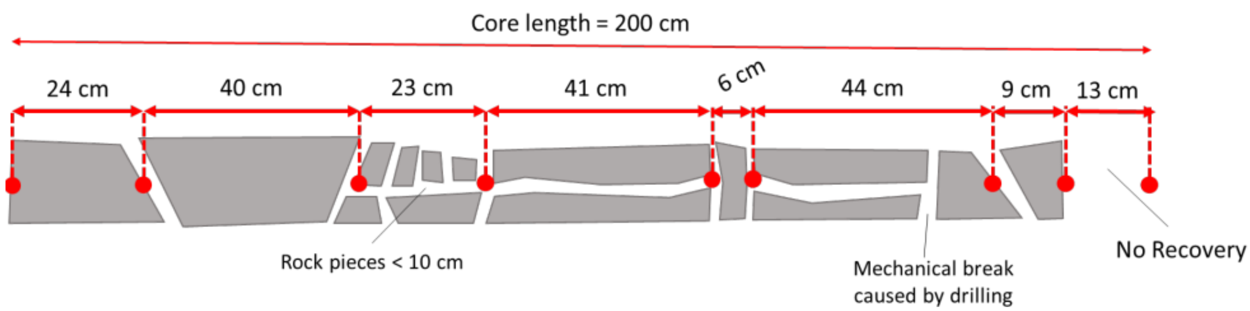
(i) Determine the RMR value for this rock mass. **[10]**

(ii) Recommend possible excavation method and support requirements for this tunnel. **[5]**

(b) Discuss limitations of any two primitive methods of rock mass classification systems used in mining. **[5]**

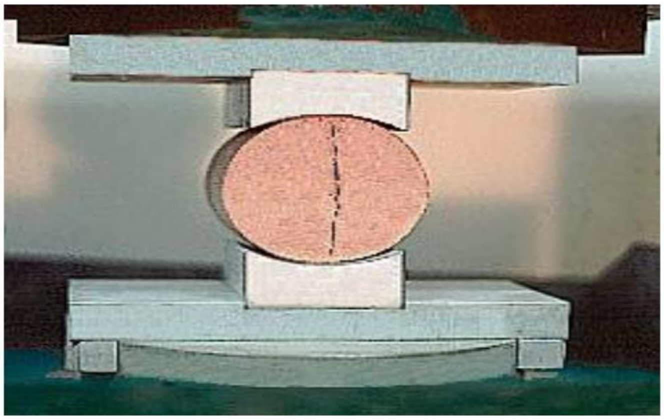
## Question 2

(a) A 200cm borehole log of a rock is illustrated below. Determine the RQD value for this rock sample. **[7]**




(b) You are the mine manager at an underground mine and you receive a call from mine captain that a massive fall of ground in North 3 section resulted in death of a jumbo operator who was drilling in a raise. A report of fall of ground needs to be compiled and presented to the Ministry of Mines. Briefly list the headings and describe the layout of your report. **[7]**

(c) Name and describe how the instrument shown below is used in testing strength of rocks in rock engineering. **[6]**



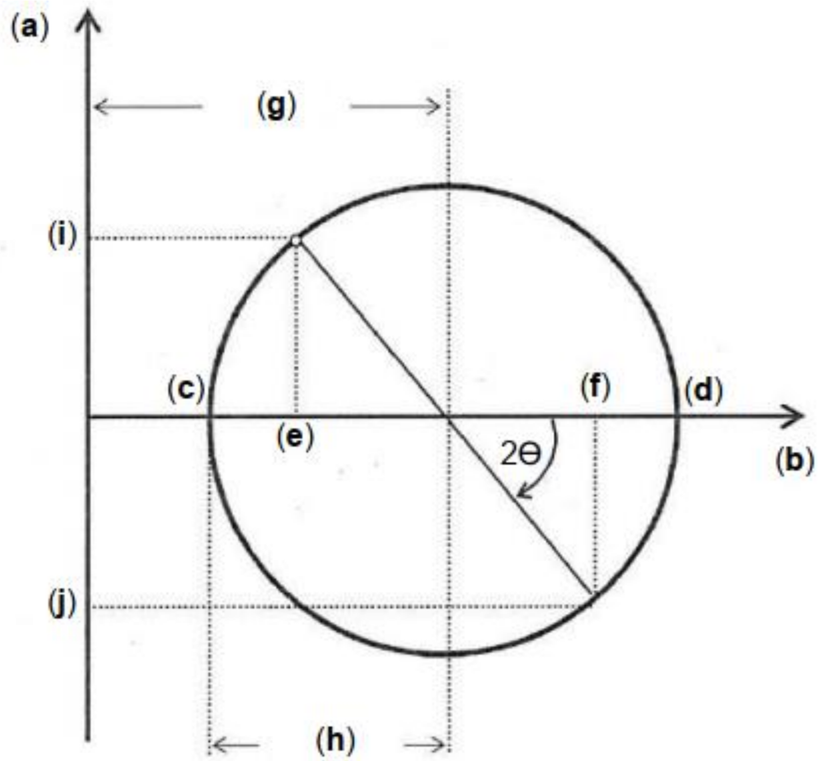
## SECTION B

Answer any **<u>three</u>** questions from this section

**<u>Question 3</u>**

(a) Given the Mohr's circle of strain below. Name the annotations (a) to (j).

**[10]**




(b) Readings from a rectangular strain rosette are given below:

- $\boldsymbol{\varepsilon}_0 = 8\mu$
- $\boldsymbol{\varepsilon}_{45} = 11\mu$
- $\boldsymbol{\varepsilon}_{90} = -15\mu$

(i) Calculate the magnitude and direction of principal strains and illustrate your results as per Mohr's circle. **[10]**

## <u>Question 4</u>

The Mohr-Coulomb failure envelope of a rock specimen is described by the following relationship: $\boldsymbol{\tau}^2 = \{27{,}58(\sigma + 2{,}07)\}$Mpa.

(a) Plot the failure envelope for this rock. **[10]**

(b) Determine which of the following state of stresses results in the failure of the specimen:

Case 1: $\boldsymbol{\sigma}_1 = 10.5$Mpa and $\boldsymbol{\sigma}_3 = -5$Mpa

Case 2: $\boldsymbol{\sigma}_1 = 26$ Mpa and $\boldsymbol{\sigma}_3 = -2$ Mpa

Case 3: $\boldsymbol{\sigma}_1 = 43$ Mpa and $\boldsymbol{\sigma}_3 = -1.5$ Mpa **[10]**

**<u>Question 5</u>**

**(a)** The table below lists a number of support types used in underground mines. State which support type is active and which is passive at the time of initial installation. Also classify them in terms of what conditions they best operate in? **[10]**

| Support unit | Active/ Passive | Dynamic/Static conditions |
|---|---|---|
| End-anchor bolts | | |
| Tin cans | | |
| Shepherd crooks | | |
| Pre-stressed mat packs | | |
| Crush pillar | | |
| shotcrete | | |
| Wire mesh and lace | | |
| Cemented backfill | | |
| Timber sets | | |
| Grouted ripple bar | | |

(b) Define the difference between a seismic event and a rock burst? **[2]**

(c) What 4 parameters can be obtained instantly from a seismic monitoring system when a seismic event occurs? **[4]**

(d) Briefly describe how do you shotcrete a mined out zone in underground mines. **[6]**

## **Question 6**

You are appointed the long-wall superintended at a coal mine where there have been 100 reported incidents for slope failures resulting in injuries to personnel and mechanical damages to mine equipment.

(a) Describe the possible factors which might have contributed to failures of these high walls. **[5]**

(b) With aid of diagrams, describe the possible modes in which these failures were occurring. **[10]**

(c) It is suggested by a hired geotechnical consultant company that the mine should try "smooth wall blasting" to avoid recurrence of this incident.

   i. Explain what you understand by term "smooth wall blasting"? **[3]**

   ii. What other methods of your choice, besides smooth wall blasting do you suggest to control high wall slope failures? **[2]**

# LIST OF FORMULAE

## TABLE 1:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **A. CLASSIFICATION PARAMETERS AND THEIR RATINGS** | | | | | | | | | |
| | Parameter | | Range of values | | | | | | |
| **1** | Strength of intact rock material | Point-load strength index | >10 MPa | 4 - 10 MPa | 2 - 4 MPa | 1 - 2 MPa | For this low range - uniaxial compressive test is preferred | | |
| | | Uniaxial comp. strength | >250 MPa | 100 - 250 MPa | 50 - 100 MPa | 25 - 50 MPa | 5 - 25 MPa | 1 - 5 MPa | < 1 MPa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| **2** | Drill core Quality *RQD* | | 90% - 100% | 75% - 90% | 50% - 75% | 25% - 50% | < 25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| **3** | Spacing of discontinuities | | > 2 m | 0.6 - 2 . m | 200 - 600 mm | 60 - 200 mm | < 60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| **4** | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation < 1 mm Slightly weathered walls | Slightly rough surfaces Separation < 1 mm Highly weathered walls | Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation > 5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| **5** | Groundwater | Inflow per 10 m length (l/m) | None tunnel | < 10 | 10 - 25 | 25 - 125 | > 125 | | |
| | | (Joint water press)/ (Major principal V) | 0 | < 0.1 | 0.1, - 0.2 | 0.2 - 0.5 | > 0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| **B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS** (See F) | | | | | | | | | |
| Strike and dip orientations | | | Very favorable | Favorable | Fair | Unfavorable | Very Unfavorable | | |
| Ratings | | Tunnels & mines | 0 | -2 | -5 | -10 | -12 | | |
| | | Foundations | 0 | -2 | -7 | -15 | -25 | | |
| | | Slopes | 0 | -5 | -25 | -50 | | | |
| **C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS** | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Rating | 100- 81 | 80-61 | 60- 41 | 40-21 | < 21 |
| Class number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |
| **D. MEANING OF ROCK CLASSES** | | | | | |
| Class number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | > 400 | 300 - 400 | 200 - 300 | 100 - 200 | < 100 |
| Friction angle of rock mass (deg) | > 45 | 35 - 45 | 25 - 35 | 15 - 25 | < 15 |
| **E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions** | | | | | |
| Discontinuity length (persistence)<br>Rating | < 1 m<br>6 | 1 - 3 m<br>4 | 3 - 10 m<br>2 | 10 - 20 m<br>1 | > 20 m<br>0 |
| Separation (aperture)<br>Rating | None<br>6 | < 0.1 mm<br>5 | 0.1 - 1.0 mm<br>4 | 1 - 5 mm<br>1 | > 5 mm<br>0 |
| Roughness<br>Rating | Very rough<br>6 | Rough<br>5 | Slightly rough<br>3 | Smooth<br>1 | Slickensided<br>0 |
| Infilling (gouge)<br>Rating | None<br>6 | Hard filling < 5 mm<br>4 | Hard filling > 5 mm<br>2 | Soft filling < 5 mm<br>2 | Soft filling > 5 mm<br>0 |
| Weathering<br>Ratings | Unweathered<br>6 | Slightly weathered<br>5 | Moderately weathered<br>3 | Highly weathered<br>1 | Decomposed<br>0 |

**F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING****

| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis | |
|---|---|---|---|
| Drive with dip - Dip 45 – $90^0$ | Drive with dip - Dip 20 – $45^0$ | Dip 45 – $90^0$ | Dip 20 – $45^0$ |
| Very favorable | Favorable | Very unfavorable | Fair |
| Drive against dip - Dip 45-$90^0$ | Drive against dip - Dip 20-$45^0$ | Dip 0-20 - Irrespective of strike | |
| Fair | Unfavorable | Fair | |

| Rock mass class | Excavation | Rock bolts (20 mm diameter, fully grouted) | Shotcrete | Steel sets |
|---|---|---|---|---|
| I - Very good rock<br>*RMR*: 81-100 | Full face,<br>3 m advance. | Generally no support required except spot bolting. | | |
| II - Good rock<br>*RMR*: 61-80 | Full face ,<br>1-1.5 m advance. Complete support 20 m from face. | Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh. | 50 mm in crown where required. | None. |
| III - Fair rock<br>*RMR*: 41-60 | Top heading and bench<br>1.5-3 m advance in top heading.<br>Commence support after each blast.<br>Complete support 10 m from face. | Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown. | 50-100 mm in crown and 30 mm in sides. | None. |
| IV - Poor rock<br>*RMR*: 21-40 | Top heading and bench<br>1.0-1.5 m advance in top heading.<br>Install support concurrently with excavation, 10 m from face. | Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh. | 100-150 mm in crown and 100 mm in sides. | Light to medium ribs spaced 1.5 m where required. |
| V – Very poor rock<br>*RMR*: < 20 | Multiple drifts 0.5-1.5 m advance in top heading.<br>Install support concurrently with excavation. Shotcrete as soon as possible after blasting. | Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert. | 150-200 mm in crown, 150mm in sides, and 50 mm on face. | Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required.<br>Close invert. |

# APPENDIX B

$$\tan 2\theta = \frac{\gamma_{xy}}{(\varepsilon_x - \varepsilon_y)} \qquad \tan 2\theta = \frac{2\tau_{xy}}{(\sigma_x - \sigma_y)}$$

$$\varepsilon_1 = \frac{1}{2}\left(\varepsilon_x + \varepsilon_y\right) + \frac{1}{2}\sqrt{\left(\varepsilon_x - \varepsilon_y\right)^2 + \gamma_{xy}{}^2} \qquad \sigma_1 = \frac{1}{2}\left(\sigma_x + \sigma_y\right) + \frac{1}{2}\sqrt{\left(\sigma_x - \sigma_y\right)^2 + 4\tau_{xy}{}^2}$$

$$\varepsilon_2 = \frac{1}{2}\left(\varepsilon_x + \varepsilon_y\right) - \frac{1}{2}\sqrt{\left(\varepsilon_x - \varepsilon_y\right)^2 + \gamma_{xy}{}^2} \qquad \sigma_2 = \frac{1}{2}\left(\sigma_x + \sigma_y\right) - \frac{1}{2}\sqrt{\left(\sigma_x - \sigma_y\right)^2 + 4\tau_{xy}{}^2}$$

$$\varepsilon_n = \varepsilon_1 \sin^2\theta + \varepsilon_2 \cos^2\theta \qquad \sigma_n = \sigma_1 \sin^2\theta + \sigma_2 \cos^2\theta$$

$$\varepsilon_n = \frac{1}{2}\left(\varepsilon_x + \varepsilon_y\right) + \frac{1}{2}\left(\varepsilon_x - \varepsilon_y\right)\cos 2\theta \qquad \sigma_n = \frac{1}{2}\left(\sigma_x + \sigma_y\right) + \frac{1}{2}\left(\sigma_x - \sigma_y\right)\cos 2\theta$$

$$\gamma_{nm} = -(\varepsilon_1 - \varepsilon_2)\sin 2\theta \qquad \tau_{xy} = -\frac{1}{2}(\sigma_1 - \sigma_2)\sin 2\theta$$

$$\gamma_{max} = \sqrt{\left(\varepsilon_x - \varepsilon_y\right)^2 + \gamma_{xy}{}^2} \qquad \tau_{max} = \sqrt{\left(\sigma_x - \sigma_y\right)^2 + 4\tau_{xy}{}^2}$$

$$\sigma_n = \sigma_x \cos^2 \theta + 2\tau_{xy} \sin \theta \cos \theta + \sigma_y \sin^2 \theta$$

$$\tau_{nm} = \frac{1}{2}\left(\sigma_y - \sigma_x\right) \sin 2\theta + \tau_{xy} \cos 2\theta$$

$$q = \rho g h \qquad \sigma_v = q \qquad \sigma_h = kq \quad k = \frac{v}{1-v} \quad P = \frac{\sigma_v}{(1-e)}$$

$$RQD = 115 - 3.3 J_v$$

$$RQD = (Total\ length\ of\ core \geq 100mm)/(Length\ of core\ run)$$

# END OF EXAM