Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS **PAPER 2:** BASIC ROCK MECHANICS PRACTICE **SUBJECT CODE: COMRMC** **DATE: 04 OCTOBER 2023** **TIME**: **14H30 TO 17H30**	**EXAMINER:** FP MOSIANE **MODERATOR:** S DURAPRAJ **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 9

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. GENERAL MULTIPLE CHOICE

1.1 Slate is an example of a/an:				
A. Sedimentary rock	B. Igneous rock	C. Metamorphic rock	D. Igneous rock subjected to extreme temperature	(1)
1.2 What type of an explosive is “Anfex”				
A. Ammonium Nitrate	B. Water based gels	C. Water based emulsion	D. Nitro-glycerine based	(1)
1.3 The incomplete recovery of strain during unloading due to energy consumption is defined as:				
A. Radial straining	B. Brittle-ductile transition	C. Strain softening	D. Hysteresis	(1)
1.4 During the course of mining, methane (CH4) may be intersected. At what minimum %, when mixed with air does methane explode?				
A. 2-3%	B. 3-4%	C. 5-15%	D. >15%	(1)
1.5 What type of numerical modelling code is FLAC?				
A. Finite element code	B. Boundary element code	C. Finite difference code	D. Hybrid element code	(1)
1.6 If the gold (sampling value) called for at a mine is 250kg/month and the plant recovered 200kg of gold, what is the Mine Call Factor? The Plant Manager reported a 5% residue on the gold achieved				
A. 80%	B. 76%	C. 84%	D. 85%	(2)
1.7 Assume a shale layer that is 0.8m thick, overlain by a thick quartzite beam is supported with 200mm diameter resin bolts. The hole diameter is 26mm, the yield strength of the steel is 480MPa and the density of the shale is 2480kg/m^3. Calculate the yield load of the roof bolt?				
A. 192 kN	B. 150.8 kN	C. 81 kN	D. 324.5 kN	(2)
1.8 With reference to question 1.7 above, determine the minimum support density required to support the shale layer?				

A. 0.10 bolt/m^2	B. 0.06 bolt/m^2	C. 0.24 bolt/m^2	D. 0.129 bolt/m^2	(2)
1.8 According to Jager and Ryder, what is the typical ERR(MJ/m^2) for deep level operations (depth range 2250-3500m), in the absence of regional support?				
A. 40-80	B. >80	C. <8	D. 8-40	(1)
1.9 In geologically undisturbed sediments and rock masses originating from a molten state, the value of k is expected to be 1 (one). This is known as:				
A. K- ratio	B. Poisson's ratio	C. Heim's rule	D. Tectonic stress	(1)
1.10 A change in deformation with time at a constant stress is known as:				
A. Anisotropic behaviour	B. Creep	C. Strain rate	D. Isotropic behaviour	(1)
1.11 What is the standard compression rate recommended for testing of support units for static conditions in a press?				
A. 300mm/min	B. 3m/sec	C. 30mm/min	D. 3mm/min	(1)
1.12 Quartzite is formed by:				
A. Dynamic Metamorphism	B. Thermal Metamorphism	C. Hydro Metamorphism	D. Dynamothermal Metamorphism	(1)
1.13 Calculate the effective pillar width for a pillar measuring 7mx4m				
A. 5m	B. 6m	C. 4m	D. 3m	(2)
1.14 Determine the modulus of rigidity of the material if the Young's Modulus is 100 GPa and the Poisson's ratio is 0.25 ($E = G(2(1+ v))$)				
A. 60	B. 40	C. 250	D. 100	(2)
				[20]

QUESTION 2. INVESTIGATION AND EVALUATION

2.1 **List 5 parameters** that can be derived from recorded wave forms following a seismic event?	(5)
2.2 When installing seismic sensors (geophones) both underground and on surface, it is vitally important to ensure that certain aspects are done correctly to ensure that the information recorded following a seismic event is accurate. **Name 5 of these aspects?**	(5)
2.3 Most Rock Engineering models are Lagrangian and can be categorized into either differential or integral methods. The importance of this is to understand how any given technique can be best applied and how efficient it may be in solving any given problem. **Name 5 different modelling techniques that are typically used in numerical modelling packages used in the Rock Engineering discipline.**	(5)
2.4 When building a model to assess the various criteria that you are most interested in, there should be some **logical steps to follow in building up this model. Name 5 of these.**	(5)
	[20]

QUESTION 3. FUNDAMENTAL PRINCIPLES OF MINING LAYOUTS AND MINING LAYOUT DESIGN

Ore passes are special excavations that are a key component of a mine's production system. Failure or blockage of a pass can have a severe effect on production, and the clearing or rehabilitation of a pass can be a safety hazard. **3.1 List and discuss the important rock engineering related aspects that need to be considered in the planning and design of ore passes.**	(7)
The Rockwall Condition Factor (RCF) design criterion can be used to predict tunnel rockwall conditions and recommend suitable support. **3.2 Write down the formula and briefly explain what each variable represents.**	(3)
3.3 List and briefly discuss 5 aspects that should be considered when designing large excavations.	(10)
	[20]

QUESTION 4. ROCKMASS CLASSIFICATION

Barton's Q system, Bieniawski's RMR system and Laubscher's MRMR are three of the widely used Rockmass classification systems. **4.1 Compare and contrast these three rockmass classification systems and their respective applications.**	(9)
A development end at a shallow platinum mine has intersected poor ground and this has led to a reduction in the face advance per blast. A 60 m long exploration diamond drill hole has been drilled ahead of the face to gather information on expected ground conditions. The core has been orientated. You are required to analyse the orientated core recovered from the hole. You record a total of 380 joints in the core. There appear to be two distinct sets of strike joints, dipping at roughly 20 and 80 degrees respectively. While the one set is rough and undulating, the other is smooth, planar and slickensided. Traces of a non-softening filling, varying in thickness from 0 – 3 mm, and which has slightly altered the walls are visible in the joint planes. No water seems to be present. There also appears to be a 3.0-metre-thick weathered dyke running through the middle of this zone, at an angle of 45 degrees. **4.2 Calculate the rock mass quality based on the Q-system, using the tables provided in Appendix 1. Motivate the reason for each value chosen for use in the rock mass rating.**	(7)
4.3 Briefly **discuss** how **groundwater and poor blasting** can negatively impact slope **stability** and **explain what measures** can be put in place to ameliorate the problem.	(4)
	[20]

QUESTION 5. MINING SUPPORT AND MINING SUPPORT DESIGN

You are the newly appointed Rock Engineer at a shallow, bord and pillar operation. The Mining Manager has reported to you that the pillars in the roadways are showing signs of scaling and he is concerned. A factor of safety of 1.6 was used for the design. **5.1 As the Rock Engineer, identify and explain the possible reasons for this phenomenon.**	(7)
5.2 What corrective measures would you take to ensure the future stability of the roadways?	(4)
5.3 Discuss the principles of operation of a hydraulic prop?	(3)
5.4 Provide 3 advantages and 3 disadvantages of a hydraulic props as a support system.	(6)
	[20]

Total Marks = [100]

Appendix 1

DESCRIPTION	VALUE	NOTES
1. ROCK QUALITY DESIGNATION	***RQD***	
A. Very poor	0 - 25	1. Where *RQD* is reported or measured as ≤ 10 (including 0),
B. Poor	25 - 50	a nominal value of 10 is used to evaluate *Q*.
C. Fair	50 - 75	
D. Good	75 - 90	2. *RQD* intervals of 5, i.e. 100, 95, 90 etc. are sufficiently
E. Excellent	90 - 100	accurate.
2. JOINT SET NUMBER	J_n	
A. Massive, no or few joints	0.5 - 1.0	
B. One joint set	2	
C. One joint set plus random	3	
D. Two joint sets	4	
E. Two joint sets plus random	6	
F. Three joint sets	9	1. For intersections use ($3.0 \times J_n$)
G. Three joint sets plus random	12	
H. Four or more joint sets, random, heavily jointed, 'sugar cube', etc.	15	2. For portals use ($2.0 \times J_n$)
J. Crushed rock, earthlike	20	
3. JOINT ROUGHNESS NUMBER	J_r	
a. Rock wall contact		
b. Rock wall contact before 10 cm shear		
A. Discontinuous joints	4	
B. Rough and irregular, undulating	3	
C. Smooth undulating	2	
D. Slickensided undulating	1.5	1. Add 1.0 if the mean spacing of the relevant joint set is
E. Rough or irregular, planar	1.5	greater than 3 m.
F. Smooth, planar	1.0	
G. Slickensided, planar	0.5	2. J_r = 0.5 can be used for planar, slickensided joints having
c. No rock wall contact when sheared		lineations, provided that the lineations are oriented for
H. Zones containing clay minerals thick enough to prevent rock wall contact	1.0 (nominal)	minimum strength.
J. Sandy, gravely or crushed zone thick enough to prevent rock wall contact	1.0 (nominal)	
4. JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)
a. Rock wall contact		
A. Tightly healed, hard, non-softening, impermeable filling	0.75	1. Values of ϕr, the residual friction angle, are intended as an approximate guide
B. Unaltered joint walls, surface staining only	1.0	25 - 35 — to the mineralogical properties of the
C. Slightly altered joint walls, non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	2.0	25 - 30 — alteration products, if present.
D. Silty-, or sandy-clay coatings, small clay-fraction (non-softening)	3.0	20 - 25
E. Softening or low-friction clay mineral coatings, i.e. kaolinite, mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1 - 2 mm or less)	4.0	8 - 16

4. JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)	
b. Rock wall contact before 10 cm shear			
F. Sandy particles, clay-free, disintegrating rock etc.	4.0	25 - 30	
G. Strongly over-consolidated, non-softening clay mineral fillings (continuous < 5 mm thick)	6.0	16 - 24	
H. Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick)	8.0	12 - 16	
J. Swelling clay fillings, i.e. montmorillonite, (continuous < 5 mm thick). Values of J_a depend on percent of swelling clay-size particles, and access to water.	8.0 - 12.0	6 - 12	
c. No rock wall contact when sheared			
K. Zones or bands of disintegrated or crushed	6.0		
L. rock and clay (see G, H and J for clay	8.0		
M. conditions)	8.0 - 12.0	6 - 24	
N. Zones or bands of silty- or sandy-clay, small clay fraction, non-softening	5.0		
O. Thick continuous zones or bands of clay	10.0 - 13.0		
P. & R. (see G.H and J for clay conditions)	6.0 - 24.0		
5. JOINT WATER REDUCTION	J_w	approx. water pressure (kgf/cm^2)	
A. Dry excavation or minor inflow i.e. < 5 l/m locally	1.0	< 1.0	
B. Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C. Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates; increase J_w if drainage installed.
D. Large inflow or high pressure	0.33	2.5 - 10.0	
E. Exceptionally high inflow or pressure at blasting, decaying with time	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered.
F. Exceptionally high inflow or pressure	0.1 - 0.05	> 10	
6. STRESS REDUCTION FACTOR		***SRF***	
a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated			
A. Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth)		10.0	1. Reduce these values of *SRF* by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation
B. Single weakness zones containing clay, or chemically dis-tegrated rock (excavation depth < 50 m)		5.0	
C. Single weakness zones containing clay, or chemically dis-tegrated rock (excavation depth > 50 m)		2.5	
D. Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)		7.5	
E. Single shear zone in competent rock (clay free). (depth of excavation < 50 m)		5.0	
F. Single shear zone in competent rock (clay free). (depth of excavation > 50 m)		2.5	
G. Loose open joints, heavily jointed or 'sugar cube', (any depth)		5.0	

DESCRIPTION	VALUE			NOTES
6. STRESS REDUCTION FACTOR			***SRF***	
b. Competent rock, rock stress problems				
	σ_c/σ_1	$\sigma_t\sigma_1$		2. For strongly anisotropic virgin stress field (if measured): when $5 \leq \sigma_1/\sigma_3 \leq 10$, reduce σ_c to $0.8\sigma_c$ and σ_t to $0.8\sigma_t$. When $\sigma_1/\sigma_3 > 10$, reduce σ_c and σ_t to $0.6\sigma_c$ and $0.6\sigma_t$, where σ_c = unconfined compressive strength, and σ_t = tensile strength (point load) and σ_1 and σ_3 are the major and minor principal stresses.
H. Low stress, near surface	> 200	> 13	2.5	
J. Medium stress	200 - 10	13 - 0.66	1.0	
K. High stress, very tight structure (usually favourable to stability, may be unfavourable to wall stability)	10 - 5	0.66 - 0.33	0.5 - 2	
L. Mild rockburst (massive rock)	5 - 2.5	0.33 - 0.16	5 - 10	
M. Heavy rockburst (massive rock)	< 2.5	< 0.16	10 - 20	3. Few case records available where depth of crown below surface is less than span width. Suggest *SRF* increase from 2.5 to 5 for such cases (see H).
c. Squeezing rock, plastic flow of incompetent rock under influence of high rock pressure				
N. Mild squeezing rock pressure			5 - 10	
O. Heavy squeezing rock pressure			10 - 20	
d. Swelling rock, chemical swelling activity depending on presence of water				
P. Mild swelling rock pressure			5 - 10	
R. Heavy swelling rock pressure			10 - 15	

ADDITIONAL NOTES ON THE USE OF THESE TABLES

When making estimates of the rock mass Quality (*Q*), the following guidelines should be followed in addition to the notes listed in the tables:

1. When borehole core is unavailable, *RQD* can be estimated from the number of joints per unit volume, in which the number of joints per metre for each joint set are added. A simple relationship can be used to convert this number to *RQD* for the case of clay free rock masses: $RQD = 115 - 3.3\,J_v$ (approx.), where J_v = total number of joints per m^3 ($0 < RQD < 100$ for $35 > J_v > 4.5$).
2. The parameter J_n representing the number of joint sets will often be affected by foliation, schistosity, slaty cleavage or bedding etc. If strongly developed, these parallel 'joints' should obviously be counted as a complete joint set. However, if there are few 'joints' visible, or if only occasional breaks in the core are due to these features, then it will be more appropriate to count them as 'random' joints when evaluating J_n.
3. The parameters J_r and J_a (representing shear strength) should be relevant to the weakest significant joint set or clay filled discontinuity in the given zone. However, if the joint set or discontinuity with the minimum value of J_r/J_a is favourably oriented for stability, then a second, less favourably oriented joint set or discontinuity may sometimes be more significant, and its higher value of J_r/J_a should be used when evaluating *Q*. The value of J_r/J_a should in fact relate to the surface most likely to allow failure to initiate.
4. When a rock mass contains clay, the factor *SRF* appropriate to loosening loads should be evaluated. In such cases the strength of the intact rock is of little interest. However, when jointing is minimal and clay is completely absent, the strength of the intact rock may become the weakest link, and the stability will then depend on the ratio rock-stress/rock-strength. A strongly anisotropic stress field is unfavourable for stability and is roughly accounted for as in note 2 in the table for stress reduction factor evaluation.
5. The compressive and tensile strengths (σ_c and σ_t) of the intact rock should be evaluated in the saturated condition if this is appropriate to the present and future in situ conditions. A very conservative estimate of the strength should be made for those rocks that deteriorate when exposed to moist or saturated conditions.