Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS **PAPER 3.2:** SOFT ROCK TABULAR MINING **SUBJECT CODE: COMRMC** **DATE: 06 OCTOBER 2022** **TIME**: **14H30 TO 17H30**	**EXAMINER:** N KHATHI **MODERATOR:** M MAZIBUKO **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 4

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. MULTIPLE CHOICE QUESTIONS

Choose the correct answer:

1.1 The suggested new shallow depth pillar design guidelines for Witbank Coalfields are as follows:

a) Pillar width-to-height (w/h) ratio > 2.2; Areal percentage extraction (e%) $< 75\%$; Bord width > 6.5m; Pillar width ≥ 6.6m; Safety factor ≥ 2.0.
b) Pillar width-to-height (w/h) ratio ≥ 2.1; Areal percentage extraction (e%) $> 75\%$; Bord width $= 6.5$m; Pillar width < 7.0m; Safety factor ≥ 2.2.
c) Pillar width-to-height (w/h) ratio ≥ 2.2; Areal percentage extraction (e%) $\leq 75\%$; Bord width ≤ 6.5m; Pillar width ≥ 6.5m; Safety factor ≥ 2.1.
d) Pillar width-to-height (w/h) ratio ≥ 2.2; Areal percentage extraction (e%) $\leq 75\%$; Bord width ≤ 6.5m; Pillar width ≥ 6.5m; Safety factor ≥ 2.0. (2)

1.2 Rock Mass Quality (Q-value) is determined using the following mathematical relationship:

a) $Q = \frac{RQD}{J_r} \times \frac{J_n}{J_a} \times \frac{J_w}{SRF}$

b) $Q = \frac{RQD}{J_r} \times \frac{J_n}{J_a} \times \frac{SRF}{J_w}$

c) $Q = \frac{RQD}{J_n} \times \frac{J_r}{SRF} \times \frac{J_a}{J_w}$ (2)

d) $Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$

1.3 On determining strength of laminae using Impact Splitting test; the individual roof rating for each unit is determined using the following relationship:

a) $Rating = 4 \times f_s;\ f_s \leq 5$ and $Rating = 2 \times f_s + 10;\ f_s \leq 5$

b) $Rating = 4 \times f_s;\ f_s \leq 5$ and $Rating = 2 \times f_s + 10;\ f_s > 5$

c) $Rating = 4 \times f_s;\ f_s > 5$ and $Rating = 2 \times f_s + 10;\ f_s \leq 5$

d) $Rating = 4 \times f_s;\ f <_s 5$ and $Rating = 2 \times f_s + 10;\ f_s \geq 5$ (2)

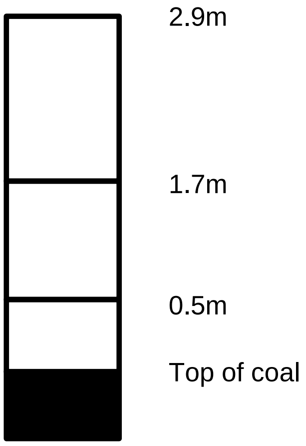
1.4 The reason for installing roofbolts closest to pillar sides, prior to installing those [roofbolts] in the centre of the roadway is because: a) It is easier to install roofbolts close to pillar sides first. b) The greatest sliding takes place in the centre of the roadway; not at the edges of the roadway. c) Roofbolts at edges are the most valuable roofbolts to be installed since the greatest amount of sliding takes place at the edges of the roadway, and not in the centre. d) It is most practical and cost saving to install roofbolts at edges as the Roofbolting machine will always be positioned close-by pillar sides at every cycle of roofbolt installation.	(2)
1.5 Some of the characteristics for Full Column Resin “FCR” (slow and fast combination) roofbolts include: a) Active, stiff, good resistance to corrosion. b) Active, soft, medium resistance to corrosion. c) Passive, stiff, good resistance to corrosion. d) Active, stiffish, poor resistance to corrosion.	(2)
1.6 Stretching of roofbolts spacing can have two major serious consequences, which are: a) Roofbolts will be subjected to high horizontal stresses and shear failure of roofbolts will be experienced. b) Roofbolts may be overloaded and fail. Failure will be initiated above the roofbolt horizon and will result in massive roof failures. c) The beam may be weak and fail. It will be impossible to tension roofbolts on installation. d) Laminations between roofbolts can sag and break. Anchor may be overloaded and fail.	(2)
1.7 Squat pillar formula is used when: a) Mining depth to floor exceeds 100m. b) Pillar width-to-height ratio is greater than 5. c) Pillar width is greater or equal to 6.5m. d) Mining height is less than 2.5m.	(2)

1.8 Violent pillar failure occurs when: a) Force required to fail the overburden < Force required to fail pillars; therefore, the overburden material fails prior to pillar failure. b) Force required to fail the overburden > Force required to fail pillars; therefore, pillars will fail prior to overburden failure. c) External energy required to deform pillars is required in the system. d) The post peak modulus of pillars is positive.	(2)
1.9 In multiple seam mining at depths to floor greater than 40m, barrier pillars are superimposed when: a) Parting distance > 1.5 times the pillar centre distance. b) Parting thickness > 0.75 times the pillar centre distance. c) Parting thickness < 0.75 times the pillar centre distance. d) Parting thickness < 1.5 times the pillar centre distance.	(2)
1.10 Maximum expected subsidence in the case of pillar system failure for mining depth to floor less than 80m is calculated as: a) $S_m = 0.8 \times h_e$. b) $S_m = 0.5 \times h_e$. c) $S_m = 0.1 \times h_e$. d) $S_m = 0.5 \times h_e$ to $S_m = 0.1 \times h_e$.	(2)
	[20]

QUESTION 2. ROCK MASS CLASSIFICATION

A geological borehole was logged and the lithology of the immediate roof above the coal seam was tested using an impact splitter. The depths of the rated units (measured from the top of the coal seam as shown in the sketch below) were 0.5m, 1,7m and 2.9m above the coal seam; and their individual roof ratings were 15, 40 and 5; respectively. 2.1 Determine the thickness of the units. 2.2 Determine the mean unit height above the roof. 2.3 Determine the weighted roof rating. 2.4 Using Tables in Appendix 1, estimate the maximum cut-out distance and the acceptable bord-width.	 (3) (6) (6) (5)

Summarized log:



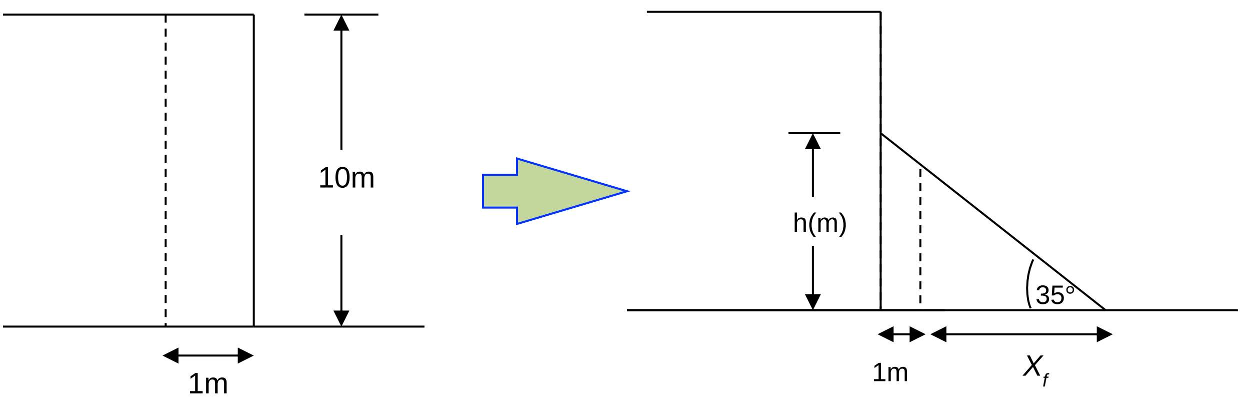
Populate the following table:

Depth (m)	**Thickness, t (m)**	**Unit Rating (R)**	**Mean unit height, h (m)**	**Weighted roof rating, Rw**
2.9m		5		
1.7m		40		
0.5m		15		
			Final roof rating	

[20]

QUESTION 3. HIGHWALL FAILURE ANALYSIS

A vertical crack was mapped striking parallel to the vertical highwall of 20m height. The distance between the crack and the slope face was 1m. Assuming the worst-case scenario that all the material defined by the vertical column will fail; calculate the following:



3.1 Volume of failed material if the bulking factor was 1.25. 3.2 The position of the catch berm to effectively contain failed material (X_f). 3.3 Comment on the effectiveness of the catch berm.	(5) (10) (5)
	[20]

QUESTION 4. PILLAR DESIGN

A conventional drill and blast underground section is proposed at a depth to floor of 200m below surface. The Manager requested your input on whether 18.5m x 18.5m pillar centre distances with a mining height of 1.5m will yield a safe mining environment with minimum pillar safety factors (SF) of 1.6.	
4.1 Calculate pillar strength. 4.2 Calculate pillar load. 4.3 Will it be practical to achieve the Manager's request? What is the safety factor? 4.4 Calculate percentage extraction.	(7) (6) (4) (3)
	[20]

QUESTION 5. ROOF SUPPORT

If cable anchors with a strength of 0.25MN were to be installed into 36mm diameter holes to support 4m thick laminated shale/ mudstone; with shear resistance of the resin/ rock contact of 2MPa, design support following steps below:	
5.1 Calculate the load on the system if the density of the rock is 2 500 kg/m^3. 5.2 Calculate the required spacing of cable anchors. 5.3 Calculate the required length of cable anchors. 5.4 Comment on tensioning of cable anchors. 5.5 Define the following: 5.5.1 Active support and Passive support 5.5.2 Stiff support and Soft support	(3) (3) (5) (1) (4) (4)
	[20]

TOTAL MARKS = [100]

APPENDIX 1
IMPACT SPLITTING TABLES

Nominal core size	Approximate diameter (mm)	Chisel drop height (to nearest mm)
TNW	60.5	102
BQ	36.1	36
NQ	47.3	62
HQ	63.2	111

Unit rating	Rock class	Roof rating
<10	Very Poor	<39
11 – 17	Poor	40 – 69
18 – 27	Moderate	70 – 99
28 – 32	Good	100 – 129
>32	Very Good	>130

Swell index	Slake durability index	Description	Rating
<1	<14	Good	A
1 – 3	14 - 26	Moderate	B
3.1 – 15	26.1 - 36	Poor	C
>15	>36	Very poor	D

	Blocky – joints >1m apart	Very blocky – joints 0.5 to 1m apart	Disturbed – joints <0.5m apart
Rough joints	0.78	0.67	0.56
Smooth joints	0.67	0.56	0.50
Slickensided joints	0.56	0.46	0.39

Roof condition	Max. cut-out distance (m)	Bord width (m)	Typical systematic support			
			Type	Length (m)	Pattern	Distance between rows of bolts (m)
Excellent	>18	7	M16 point anchor	0.9 or 1.2	Spot bolting false roof	N/A
Very Good	>18	6.5 to 7	M16 point anchor	1.2	Spot bolting and 5 bolts per intersection only	N/A
Good	18	6 to 6.5	M16 point anchor	1.2 or 1.5	5 bolts per intersection and 2 per row in bords	2 to 2.5
Moderate	12	5.5 to 6	M16 or M20 full column resin	1.5 or 1.8	9 bolts per intersection and 3 per row in bords	1.5 to 2
Poor	6	5 to 5.5	M20 full column resin	1.8	16 bolts per intersection and 4 per row in bords. Steel straps may be necessary	1 to 1.5
Very Poor	<6	<5	Specialised support. e.g. 1.8m M20 full column resin bolts and /or cable anchors with steel straps. Cable trusses, cluster stick packs or shotcrete may also be required	≥1.8	As dictated by conditions. Typically 5 bolts per row with steel straps. Often 9 cables in intersections.	<1

Unit rating	Rock class	Roof rating
<9	Very Poor	<34
10 - 13	Poor	35 – 51
14 - 19	Moderate	52 – 75
20 - 28	Good	76 – 113
29 - 42	Very Good	114 – 167
>42	Excellent	>167

Rating	Description	Swell index	Slake durability index		
			Floor		Roof
			Continuous miner / Roadheader	Conventional drill and blast	
A	Good	<1	<5	<10	<2
B	Moderate	1 – 3	5 – 15	10 – 20	2 - 4
C	Poor	3.1 – 15	15.1 – 25	20.1 – 30	4.1 – 10
D	Very Poor	>15	>25	>30	>10

FORMULA SHEET

PILLAR DESIGN

$$L_p = \frac{25HC_1C_2}{w_1w_2}$$

$$L_p = \frac{[25(H-T)+30T]\times C_1C_2}{w_1w_2}$$

$$L_p = \frac{25HC_1C_2}{\left(C_1-\frac{B}{sin\alpha}\right)\times\left(C_2-\frac{B}{sin\alpha}\right)}$$

$$\sigma_p = 7.2\frac{w^{0.46}}{h^{0.66}}$$

$$\sigma_p = 4\,300\left(0.64+0.36\frac{w}{h}\right)$$

$$\sigma_p = 180\frac{w^{2.46}}{HC^2h^{0.66}}$$

$$w_{ep} = \frac{2w_1w_2sin\alpha}{w_1+w_2}$$

$$\sigma_p = 3\,500\frac{w}{h}$$

$$\sigma_p = k\frac{R_o^b}{V^a}\left\{\frac{b}{\varepsilon}\left[\left(\frac{R}{R_o}\right)^{\varepsilon}-1\right]+1\right\}$$

$$w = C - \frac{B}{sin\alpha}$$

$$w_e = \frac{4A}{c}$$

$$SF = 288\frac{w^{2.46}}{HC^2h^{0.66}}$$

$$SF = 140\frac{w^3}{hH(w+B)^2}$$

$$\eta = \eta_o\left(1+\frac{2\Delta w_o}{w}\right)^{2.46}$$

$$SF = 288\frac{w^{2.46}}{HC^2h^{0.66}}\times\left(1+\frac{2\Delta w_o}{w}\right)^{2.46}$$

$$SF = 140\frac{w^3}{hH(w+B)^2}\left(1+\frac{2\Delta w_o}{w}\right)^{2.46}$$

$$SF' = SF\left(\frac{h}{h+\Delta h}\right)^{0.66}$$

$$SF' = SF\left(\frac{h}{h+\Delta h}\right)$$

$$SF'' = SF\left(\frac{w-\Delta w}{w}\right)^{2.46}$$

$$SF'' = SF\left(\frac{w-\Delta w}{w}\right)^{3}$$

$$R = m\left[\frac{h}{T}\right]^x$$

$$T_L = \left[\frac{d}{mh^x}\right]^{\frac{1}{1-x}}$$

$$d_c = w - [0.00714S_mHhC^2]^{0.333}$$

Values of *m* and *x*:		
	***m* - Value**	***x* - Value**
Vaal Basin, Klip River & South Rand	1.3888	0.804
Witbank No. 2 and No. 4 seams	0.1624	0.8135
South African squat pillar strength:		
Constants, a and b	0.0667 and 0.5933, respectively	
Rate of strength increase	2.5	

ROOF SUPPORT

$$\sigma_{nj} = \frac{\gamma L^2}{2t}$$

$$\sigma_j = \frac{3\gamma L^2}{t}$$

$$\eta = \frac{qL^4}{32Et_b^4}$$

$$S_b = \sqrt{\frac{2t_{ave}\sigma_t}{n_q\gamma F}}$$

$$\sigma_t = \frac{\gamma L^2F}{2t}$$

$$\sigma = \frac{qL^2}{2t^2}$$

$$\tau_d = \frac{3qLF}{4t_m}$$

$$\tau_r = c + \sigma_e\tan\phi$$

$$\sigma_e = \frac{F_b}{S_b^2} - q$$

$$\sigma_s = \frac{4F_b}{\pi d_s^2}$$

$$F_b = S_b^2\times\left(\frac{0.75qLF}{t_m\tan\phi}+q\right)$$

$$l_a = \frac{\gamma S_b^2t_{lam}}{\pi d\tau}$$

$$l_a = \frac{F_m}{\pi d_h\tau}$$

$$l_{frc} = \frac{d_h^2-d_s^2}{d_c^2}\times l_a$$

$$l_{src} = \frac{d_h^2-d_s^2}{d_c^2}\times t_m$$

$$S_m = \sqrt{\frac{P}{F\gamma t_{lam}}}$$

$$\tau = \frac{P}{\pi dl_r}$$

$$s_f = d_b\sqrt{\frac{\pi\sigma_b}{4F\gamma t_{lam}}}$$

$$R_w = R\times 2\times(2-h)\times t$$

$$W = \rho gFh_f$$

$$W = \gamma h_fFL$$

$$S_b = \frac{\pi d_hl_b\tau_r}{W}$$

$$s_l = \sqrt{\frac{R}{W}}$$

$$l_b = t_{lam}\left[1+\frac{\gamma S_b^2}{\pi d\tau}\right]$$

$$n = S_f\frac{\rho gt}{P_f}$$

$CSF = \frac{Strength}{\sigma_x}$ $\gamma_m = 0.0025\frac{D-T}{D} + 0.03\frac{T}{D}$ $-\frac{E_p}{E} = 0.23\left[\frac{5}{\left(\frac{w}{h}\right)} - 1\right]$

$OSF = \frac{\sigma_{tr}-\sigma_{to}}{\sigma_{tr}}$ $PSF = f_s - 1$ $\sigma_L = \frac{0.025H\times F}{1-e}$

$F = 0.99 \times (1-e^{\alpha})^{\beta}$ $\alpha = 2.2 + \frac{1.4L}{H}$ $\beta = \frac{0.667}{1+\frac{L}{H}} + 0.0067 \times \left(\frac{4E_r}{E_c} - 1.5\right)$

$H_m = 40 \times \sigma_p \times (1-e)$ $dh = \frac{h\Delta\sigma_p}{E_c}$ $\Delta\sigma_p = \sigma_p - 0.025 \times H$

$E_{cp} = \frac{0.56\times w_e}{h} - 2.293$ $\lambda = 1.861 \times \left(\frac{w}{h}\right)^{-0.931}$ $\lambda = 1.033 \times \left(\frac{w}{h}\right)^{-1.159}$

$-\frac{E_p}{E} = 0.23 \times \left[\frac{5}{\left(\frac{w}{h}\right)} - 1\right]$ $E_p > 0$ or $\frac{0.562\times w}{h} - 2.293 > 0$ $\lambda = \frac{EA}{h}$

$F_{xi} = \frac{3q}{2} \times \left({}^{1}/_{2} \times \frac{a_h^2}{a_x} - {}^{1}/_{3} \times a_h + {}^{1}/_{12}\, a_x\right)$ $F_{xm} = 3.5 \times \frac{w^3}{h}$

$\sigma_{si} = \frac{q}{3Bt} \times \left(\frac{a_h^2}{2} + \frac{a_x^2}{4} - a_h a_x\right)$ $\sigma_{sf} = -\frac{3\times a_h^2 \times q}{Bt}$

$L_C = 2H \times tan\phi$ $L_c = 2T\sqrt{k_s + \frac{B}{D} + 2(H-D) \times tan\phi}$ $\beta = \frac{1.53}{\gamma_m} - 0.8$

$\lambda_m = 1.861\left(\frac{w}{h}\right)^{-0.931}$ $\lambda_m = 1.033\left(\frac{w}{h}\right)^{-1.159}$ $E_p = \frac{0.562w}{h} - 2.293$

SUBSIDENCE

$\sigma_t = \gamma\frac{b^2}{2t}$ $\sigma_t = \frac{(\gamma_s t_s + \gamma_u t_u)\times b^2}{2t_s^2}$ $\tau_s = \frac{3\times(\gamma_s t_s + \gamma_u t_u)\times b}{4t_s}$

$B = \frac{(hb^2 + 2bh^2 cot\alpha) + \frac{\pi b^2 z}{2}}{\frac{\pi b^2 z}{2}}$ $z = \frac{2(hb^2 + 2bh^2 cot\alpha)}{(B-1)\times\pi b^2}$ $c = h\ cot\alpha$

$w_1 = -\frac{c}{B} + \sqrt{w^2 - \frac{c^2}{B^2}\left(\frac{4B}{3} - 1\right)}$ $\sigma = \frac{3FB_1}{2B_2 t^2}$ $S_m = 0.39\left(\frac{W}{H}\right)^{0.32}$

$S_m = 0.8h_e$ $S_m = 0.1h_e$ $T_m = 21.6S_m + 7$

$\varepsilon_{m+} = 4.2S_m + 1.7$ $\varepsilon_{m-} = -9.1S_m - 2.8$ $L_C = 2H \times tan\phi$

$L_c = 2T\sqrt{k_s + \frac{B}{D} + 2(H-D) \times tan\phi}$ $\beta = \frac{1.53}{\gamma_m} - 0.8$

$\gamma_m = 0.0025\frac{D-T}{D} + 0.03\frac{T}{D}$ $S_x = 0.5 \times S_m\left[tanh\left(\frac{6.996x}{W} - 1.609\right) + 1\right]$