Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA - CERTIFICATE IN ROCK MECHANICS 3.2 (COAL) **SUBJECT CODE: COMRMC3.2**	**EXAMINER:** W. Mahne **MODERATOR:** L. Prinsloo
EXAMINATION DATE: 9 MAY 2019 **TIME:** 14:30 – 17:30	**TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES: 11 (Including cover page)

SPECIAL REQUIREMENTS:

1. **Answer *ALL* questions and read these requirements**
2. References other than those provided are not permitted.
3. Hand-held electronic calculators may be used.
4. Put 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.

5. **Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).**
6. Show all calculations on which your answers are based.
7. Illustrate your answers by sketches of diagrams wherever possible.
8. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.
9. Answers must be given to **an accuracy that is typical of practical conditions**.
10. In presenting answers, candidates are encouraged to use **tabulations** and **diagrams** or answers must be written in **bullet** points – **No long paragraphs**.
11. Cell phones are **NOT** allowed in the examination room

QUESTION 1

1.1 Appreciation of typical rock strengths obtain through rock testing is important. When looking at values used in literature or lab reports, what must be taken into account before using the values in your modelling or statistical analysis?

(10)

1.2 Give a summary of the factors that contribute to the final unit rating value of the CMRR:

(5)

[15]

QUESTION 2

Colliery A, where you are the appointed Rock Engineer, has decided to re-open an old rehabilitated Open cast mining area to mine the deeper coal reserves by means of underground mining. A box-cut and portals as means of entry to the planned underground workings need to be designed. The shaft position that has been decided on, will allow for the decline of the box-cut to intersect the line were the old High wall (East – West orientation) meets the rehabilitated zone. All the undermining applications & environmental legalities are in place. Below, please find a bore hole log representative of the lithology at the box-hole position.

You will be mining the 4 seam of which the top part is generally of a lower quality.

In-situ stress measurements at Colliery A have established that the major stress direction has a north-south orientation with a magnitude of approximately 4 MPa. The sedimentary strata are generally characterized by a low regional slope of ± 1-degree in a south-easterly direction. The regional slope is influenced locally by geological features such as Dolerite dykes and sills, rolls as well as differential compaction effects over prominent high areas in the Pre-Karoo Paleo-topography.

Prominent Dolerite dykes with a general ENE-WSW-strike and varying thickness are developed over the region and numerous other thinner dykes also occur throughout. Prominent structures such as faulting and jointing have approximately the same sub-regional strike as the major dykes mentioned and therefore present a prominent weak structural direction.

The contract with the company that will do the work have been negotiated, the will start in October 2019 and first coal must be mined by 1 March 2020.

BOREHOLE SECTION

DEPTH	WIDTH	RECORD OF STRATA
	17.70	SOIL
17.70	0.00	Base of Soft Overburden
	2.87	SANDSTONE, cream, Fine to medium grained, massive, micaceous, Highly_Weathered
20.57	0.00	Base of Weathering
	2.06	SANDSTONE, cream, Fine to medium grained, massive, micaceous, Slightly weathered
22.63	0.00	Base of Hard Weathering
29.78	7.15	SANDSTONE/SILTSTONE, cream, Fine to medium grained, massive, micaceous, interbedded 60% sandstone 40% siltstone.
30.07	0.29	SILTSTONE, grey, Fine_Grained, massive, micaceous
30.52	0.45	SANDSTONE/SILTSTONE, cream, Fine to medium grained, massive, micaceous, interbedded 50% sandstone 50% siltstone.
30.66	0.14	SANDSTONE/SILTSTONE, grey, Fine_Grained, massive, micaceous
30.72	0.06	SANDSTONE, cream, Fine to medium grained, massive, micaceous
30.83	0.11	SANDSTONE/SILTSTONE, grey, Fine to medium grained, massive, micaceous
37.52	6.69	SANDSTONE, cream, Fine to medium grained, massive, micaceous, interbedded Interbedded siltstone 20%.
39.57	2.05	SANDSTONE/SILTSTONE, grey, Fine to medium grained, massive, micaceous, interbedded 50% siltstone 50% sandstone.
39.61	0.04	SANDSTONE, cream, Medium_Grained, massive, micaceous Conglomeratic sandstone.
39.77	0.16	COAL, No. 4 Top Seam
43.92	4.15	COAL, No. 4 Main Seam
44.64	0.72	SHALE/SILTSTONE, black, Fine_Grained, massive, micaceous, interbedded 80% shale 20% siltstone.
44.94	0.30	SANDSTONE/SILTSTONE, grey, Fine_Grained, massive, micaceous, interbedded 50% sandstone 50% siltstone.
45.47	0.53	SHALE/SILTSTONE, black, Fine_Grained, massive, micaceous, interbedded 80% shale 20% siltstone.
45.64	0.17	SANDSTONE/SILTSTONE, grey, Fine to medium grained, massive, micaceous, interbedded 50% sandstone 50% siltstone.
47.56	1.92	SANDSTONE, cream, Coarse_to_Medium_Grained, massive, micaceous
48.91	1.35	SANDSTONE/SILTSTONE, grey, Fine to medium grained, massive, micaceous, interbedded 50 / 50.
56.38	7.47	SANDSTONE, cream, Medium_Grained, massive, micaceous, interbedded Interbedded siltstone 20%.

Average rock / soil property results of the different lithological units in Colliery A mining area.

Rock / Soil Type	Elastic Modulus (GPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Compressive Strength (MPa)
Sandstone	13	5	15	75
Shale	15	5	7	75
Siltstone	1	6	8	70
Gritstone	13	5	15	75
Coal	5	5	8	25
Mudstone	7	5	8	40
Dolerite	100	14	20	190
Loose sandy soil (Extrudes from fingers)	0.4	0	16	0.0019
Firm sandy soil (Easy to mould& sticks to hand)	0.4	0	16	0.0376
Firm sandy soil with silt & clay (Moulds with moderate pressure)	0.5	0	17	0.1921
Firm silt & clay soil	0.5	0	18	0.3842
Hard, competent soil (Does not mould by hand)	0.4	0	15	0.7684

Mine A falls in a Summer rainfall zone – Mean annual rainfall (mm) measured

Year	**Colliery A**
2010	**783**
2011	**576**
2012	**608**
2013	**391**
2014	**1042**
2015	**613**
2016	**1184**
2017	**555**
2018	**907.5**

2.1 Discuss a basic design for the box-cut, including the bench configuration, taking into consideration the rehabilitated & unmined zones. No calculations need to be shown, but assumptions w.r.t to safety factors, angles & bench designs must be motivated.

Give an annotated section that can be used for modelling of the slopes.

(10)

2.2 Do a basic support design for the different zones in the box-cut, from overburden down to coal seam floor. Keep in mind that the adits / portals will be in use for at least 17 years. No calculations have to be shown, but safe working strategies & assumptions need to be motivated.

(7)

2.3 Discuss a basic support design for the portals (brows) including the portals pillars (no calculations necessary)

(8)

2.4 When planning underground portals in an existing High wall, what are the important factors to assess?

(5)

[30]

QUESTION 3

3.1 A support assessment for the potential future mining area at a depth of around 105m below surface to the top of the coal seam has been requested by the Technical Services Manager. Two distinct geotechnical areas have been identified with the following information:

- Area A, has a 95% fall out thickness of around 0.54m - consisting of a weak mudstone layer overlying the coal seam,
- Area B, has a 95% fall out thickness of around 1.15m - consisting of a shale layer overlying the coal seam,

- In both areas the mudstone and the shale layers are overlain by a thick competent sandstone unit.

Using the following:

- Roofbolt diameter : 20mm,
- Borehole diameter : 26mm,
- Roofbolt Yield Strength : 170kN,
- Contact Shear Strength : 3.5MPa,
- Design Bord Width : 7.2m,
- Mining Height : minimum 3.8m

Calculate and provide the support requirements for both geotechnical areas?
State all other assumptions made during this assessment.

(10)

[10]

QUESTION 4

4.1 A continuous 10.0 m wide barrier pillar, at a depth of 150m divides two goafed areas, with a goaf angle of 21° on either side. Calculate the average pillar stress/m^2 of the barrier pillar. State any assumptions.

(5)

4.2 There is a 3 m thick coal seam at a roof depth of 153 m. It is recommended to have 6.5 m bords. In order to achieve a factor of safety of 1.6, what pillar width would be required?

(6)

4.3 A FCT will be used to mine a 9 road, 4 seam, production panel at an average depth of 55 m below surface. The following needs to be taken into account:

- Thickness of the 4 seam is 3.5 m and the full seam will be mined.
- Optimal angle that the FCT can operate is 70°.

4.3.1 State all assumptions.

4.3.2 Show all calculations and Issue a design for the panel.

(9)

[20]

QUESTION 5

Sketch, describe, explain and discuss the different methods of rib pillar mining:

5.1 Wongawilli system.

5.2 The Munmorrah system.

5.3 The old Ben method.

[15]

QUESTION 6

Discuss the following points with regards to the phenomena of sinkholes and subsidence in a coal mining environment:

6.1 Physical signs

6.2 Appearance / profile

6.3 Failure mechanism

6.4 Risk to surface

6.5 Mitigation there-of

6.6 Rate of failure

[10]

[100]

Equation Sheet

Candidates may find some of the following equations useful, although other equations may also be used.

Pillars

$$\sigma = 7{,}2\frac{w^{0{,}46}}{h^{0{,}66}}$$

$$\sigma = 5.47\frac{w^{0{,}8}}{h}$$

$$\sigma = 6.61\frac{w^{0{,}5}}{h^{0.7}}$$

$$\sigma = 4{,}3\left(0{,}64 + 0{,}36\frac{w}{h}\right)$$

$$\sigma = 3.5\frac{w}{h}$$

$$\sigma = k\frac{R_0^b}{V^a}\left\{\frac{b}{\varepsilon}\left[\left(\frac{R}{R_0}\right)^{\varepsilon} - 1\right] + 1\right\}$$

$$\sigma = \frac{.0786}{V^{0.0667}}\left\{R^{2.5} + 181.6\right\}$$

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

$$w = C - \frac{B}{Sin\alpha} \quad \text{m}$$

$$w_{ep} = \frac{2w_1 w_2 Sin\alpha}{w_1 + w_2} \quad \text{m}$$

$$SF_{cm} = SF\left(1 + \frac{0.6}{w}\right)^{2.46} \qquad SF_{cm} = SF\left(1 + \frac{0.6}{w}\right)^{3}$$

$$SF^{/} = SF\left(\frac{w - \Delta w}{w}\right)^{2.46} \qquad SF^{/} = SF\left(\frac{w - \Delta w}{w}\right)^{3}$$

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

$$Load = \frac{\left[.025(H - T) + .03T\right]C_1 C_2}{w_1 w_2}$$

$$Load_p = \frac{25HC_1C_2}{\left[C_1 - \frac{B}{Sin\alpha}\right]\left[C_2 - \frac{B}{Sin\alpha}\right]} \text{ kPa}$$

$$e\% = 100\left[\frac{h_m}{h_s}\left(1 - \frac{w^2}{C^2}\right)\right]\frac{W}{W+P}$$

$$E_{cp} = \frac{0{,}562w_e}{h} - 2{,}293$$

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

$$d = w - \left[0{,}00714S_{\min}HhC^2\right]^{0{,}333}$$

$$S_{\min} = 0.4$$

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

Region	m	x
Vaal Basin, Klip River and South Rand	1,3888	0,804
Witbank No 2 and 4 Seams	0,1624	0,8135
Witbank No 5 Seam	0,105	-0,3061

Roof Support

$$\sigma_t = \frac{qB^2}{2t^2}$$

$$q = \rho g(t_s + t_w)$$

$$\sigma_t = \frac{fq_cs^2}{2t^2}$$

$$s = 1.414t_{\min}\sqrt{\frac{\sigma_{tm}}{fq_c}}$$

$$q_c = q_l + \frac{q_uE_l - q_lE_u}{E_l + E_u}$$

$$l_a = \frac{\rho gs^2t_w}{\tau_c\pi d_h} + .05$$

$$\eta = \frac{SF\rho gt}{P_d}$$

$$\sigma_{ts} = \frac{4W_b}{\pi d_b^2}$$

$$l_c = \frac{l_a\left(d_h^2 - d_b^2\right)}{\left(d_h - .002\right)}$$

$$t_{sb} = \frac{fk\rho gB^2}{2\sigma_{tm}}$$

$$\tau_b = \frac{3k\rho gB}{4}$$

$$\tau = C_c + C_b + \frac{F_b}{s_b^2}\tan\phi$$

$$F_b = \frac{s}{\tan\phi}\left[\frac{3\rho gkBs}{4} - \sigma_r d_h\right]$$

$$F_T = F_b \rho gk t_{sb} s^2$$

$$l_a = \frac{F_T}{\pi d_h \tau_c}$$

$$\eta = \frac{\gamma B^4}{32Et^2}$$

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

$$\beta = \arctan\left(\frac{L/2}{\eta}\right) - \arctan\left(\frac{\eta}{L/2}\right)$$

$$R = \frac{L/2}{Cos\beta}$$

$$d\theta = \frac{\pi}{2} - \arctan\left(\frac{R - \eta - h_l}{L/2 - d}\right)$$

$$S = t_l d\theta$$

$$\sigma_r = \frac{\tau_l S_b}{d_b}$$

$$\varepsilon_r = \frac{\sigma_r}{E_r}$$

$$S_r = \varepsilon_r(d_h - d_b) + R_s$$

$$SSF = \frac{S}{S_r}$$

Subsidence

$$S_{m,he} = 0{,}39h\left(\frac{W}{H}\right)^{0{,}32}$$

$$S_{m,pf} = 0.1h_e$$

$$h_e = he$$

$$S_x = \frac{S_{max}}{2}\left[\tanh\left(\frac{7x}{W} - 1{,}645\right) + 1\right]$$

$$L_c = 2T\sqrt{k + \frac{\beta}{D}} + 2(H - D)\tan\theta$$

$$\beta = \frac{c - b\gamma d}{\gamma_m \tan\phi} - \frac{kl}{2}$$

$$\beta = \frac{1.53}{\gamma_m} - 0.8$$

$$\gamma_m = \gamma_s \frac{D - T}{D} + \gamma_d \frac{T}{D}$$

$$\gamma_m = 0.025\frac{D - T}{D} + 0.03\frac{T}{D}$$

$$T_m = 21.6S_m + 7$$

$$\varepsilon_{m+} = 4.2S_m + 1.7$$

$$\varepsilon_{m-} = -9.1S_m - 2.8$$

Physics

$$E_k = \frac{1}{2}mv^2$$

$$v_i = \sqrt{2gd}$$