MINERALS COUNCIL
SOUTH AFRICA

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS 3.2 (COAL) **SUBJECT CODE:** COMRMC3.2 **EXAMINATION DATE:** 05 November 2020 **TIME:** 14h30 – 17h30	**EXAMINER:** W. Mahne **MODERATOR:** L. Prinsloo **TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES: 12 (Including cover page)

SPECIAL REQUIREMENTS:

1. **Answer *ALL* questions and read these requirements**
2. References other than those provided are not permitted. **Formulas are found on page 9-12**
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

You are appointed as the Project Rock Engineer for a new green fields opencast mine. The following information is available:

- Shallow mine with 7 m overburden and two seams 3m apart.

Utilization potential:

- Contract with ESKOM Power Station to buy unwashed coal (no beneficiation process necessary) at a negotiated price.
- The power station is ±50 km from this area and transport in the form of coal trucks on existed roads is to be utilized.

Labour:

- Local people (with mining experience – this area is close to existing coal mining on the Highveldt) will be employed.
- The local community will be supported by buying or contracting services from local Black Economic Empowerment Companies.

Assume the following:

- No surface streams or rivers are present
- Situated on the Highveld in Mpumalanga
- Fault system: N-S
- Top seam 0.6m thick = Quality: Bituminous Low quality
- Parting: 3 m thick = Competent/massive sandstone
- Bottom seam: 2.5 m thick = Quality: Export coal
- Overburden: 1m thick = Laminated sandstone/Siltstone
- Topsoil: 0.6m thick
- Size of deposit: 17 700 million tonnes
- Coal quality = Power Station Utilizable:
    - CV: 25 MJ/kg
    - Volatile matter: >20%
    - Sulphur: >1%
    - Minimum ash deformation point of 1200º C

Most of these “assumptions” were obtained from the geological model / report.

A minimum of 4 cored boreholes per 100 ha (approximately 500 m spacing) were drilled. Depth of the boreholes were at least 20 m deep.

1.1 Explain what you need before you can give inputs into the design of this mine. Consider:

- General information that would play a role in the successful mining of the coal.
- Reserves
- Geology
- Mining license
- Rock & soil properties
- Integration between departments required

(12)

1.2 What mining method & associated equipment would you consider?

(3)

1.3 Explain what lay-out & mining sequence you would recommend, touching upon negotiating surface structures in the area as well?

(10)

[25]

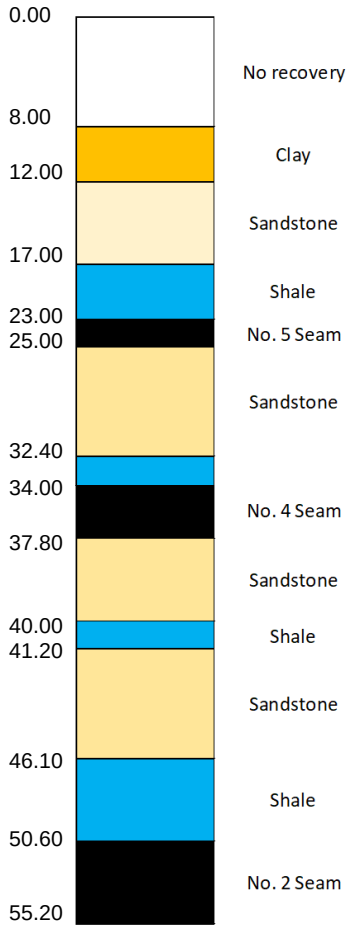
QUESTION 2

You are the Rock Engineer at Shonalanga Colliery, a mine located in the Witbank Coalfields. The full No. 4 seam is being extracted, through the bord-and-pillar mining method, at a Mining Height of 3.8 m. The coal seam in the area is overlain by a 1.6 m-thick layer of laminated shale, which is located below a 1.0 m-thick sandstone layer. The standard bord width for the mine is 7.2 m.

The number 2 seam was mined in the early 60's. The primary mining height at the time of mining was 2.5 m. Subsequently top coaling was done in a portion of the mine to extract the full seam height.

From the mine plan the following mining parameters were measured:

- Centres 13 m x 13 m
- Bord Width 6.5 m



2.1 Use the van der Merwe 2013 Overlap Reduction methodology to assess the stability of the 2 seam workings.

(10)

2.2 Determine what the affect the scaling would have on the Safety Factor of the pillars in the areas where coaling was done and give appropriate recommendations for the mining of the 4 seam.

(9)

2.3 Supply the planning department mining parameters for the mining of the 4 seam for the primary development and the production panels

(6)

[25]

QUESTION 3

You are also required to do a support design for the colliery mentioned in Question 2. From a neighbouring operation the following fallout thicknesses (m) were obtained.

0.35	0.55	0.83	0.45	0.25	0.25
0.20	2.80	0.20	0.84	0.50	0.70
0.55	0.50	0.37	0.36	0.40	
0.30	0.43	0.25	0.40	0.15	
0.23	0.64	1.00	0.65	0.35	
0.82	0.70	2.20	0.45	0.40	

The following additional information is provided:

- Roofbolters on the operation are capable of applying a pre-tension of 50kN to the bolt installations.
- The load obtained in Short Encapsulation Pull Tests (SEPT) conducted in similar roof composition was 150kN.
- Bolts are 20 mm diameter and constructed of S-grade steel.

Make use of reasonable, industry-acceptable values in the calculations.

3.1 From the Fall of Ground data provided, calculate the 95% Fall-out Thickness (FOT).

(5)

3.2 State which support design technique you will use and justify your answer.

(1)

3.3 Calculate the support resistance criterion for the 95% FOT.

(4)

3.4 Making use of the 95% FOT calculated above, design a resin bolt support system to be used at the operation. Ensure that all of the necessary support design checks are done (integrity of competent layer, bolt spacing to prevent failure between bolts, etc.). Clearly state all criteria and assumptions.

(14)

3.5 The above design will cater for 95% of the fallout thicknesses. What system would you put in place to account for the 5% not covered in the support design.

(1)

[25]

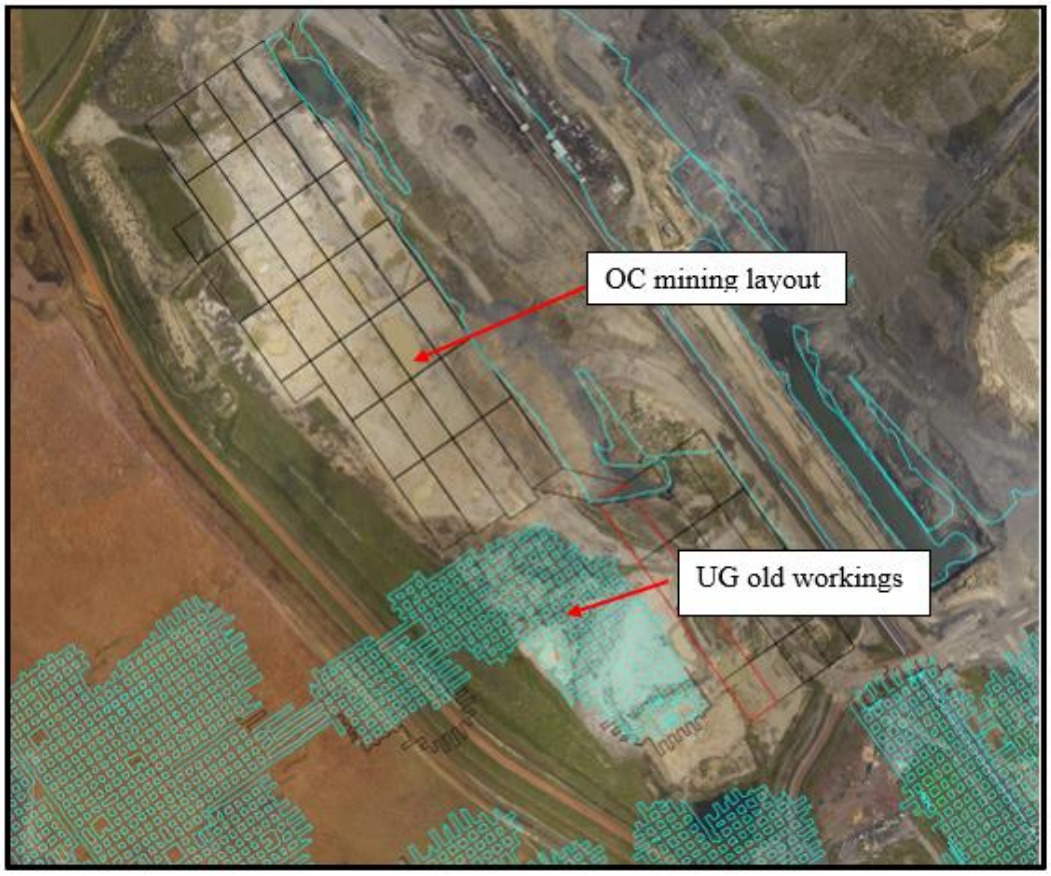
QUESTION 4

You are the appointed Rock engineer at Pagamiza Mine. The General Manager requested you to analyze the feasibility and geotechnical risks involved in mining an underground barrier pillar with strip mine methodology. The underground mining was done >5 years ago.

Strip mining sequence:

- Pre-strip top-soil
- Drill and blast pre-split
- Drill and blast overburden
- Remove overburden with Dragline
- Drill and blast coal
- Load and haul coal

The height of the planned spoils has been calculated to be worst case 30m with a density of material of 2000kg/m^3.



The following information is available:

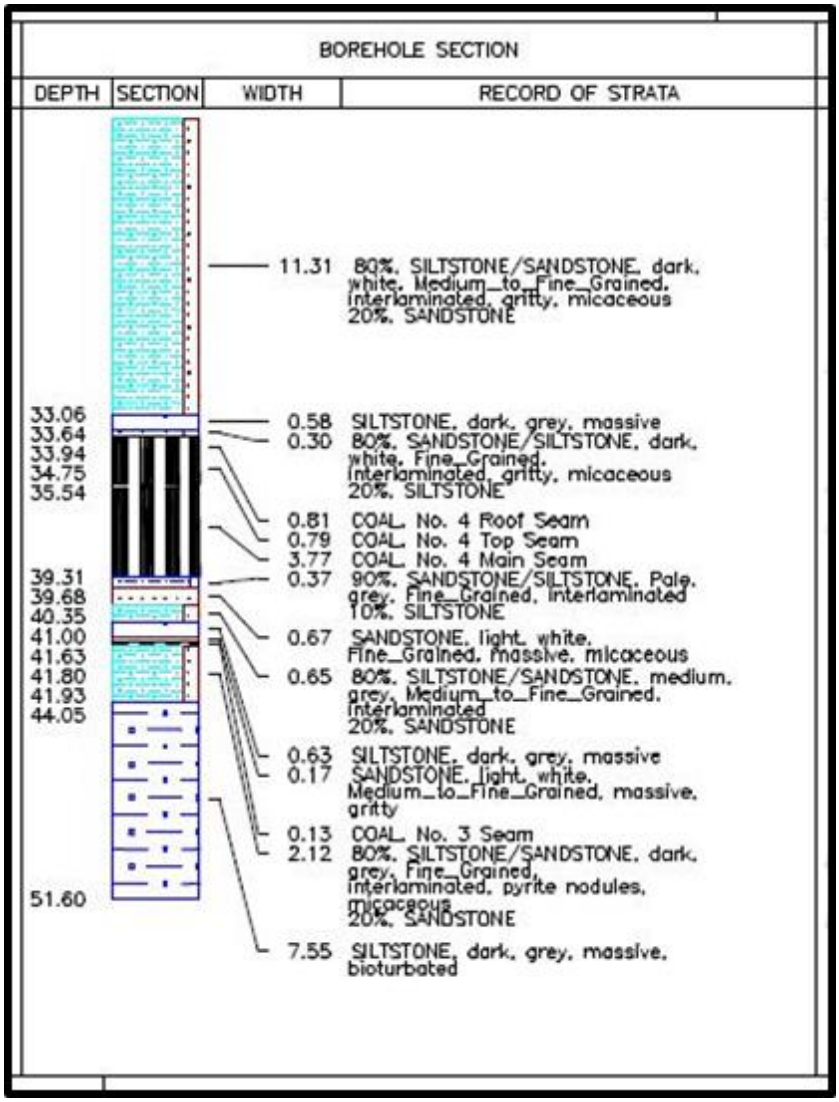
The height of the planned spoils has been calculated to be worst case 30m with a density of material of 2000kg/m³.

The actual offsets by the Survey Department was taken to determine the average centers The increase in height and load created by the spoil material and the actual pillar dimensions underground where then used to determine the decrease in the Factor of Safety once the spoils were to be placed on top of the pillars.

FoS Calc	Centres	Pillar width (m)	Mining height (m)	Depth to floor (m)	Method
S&M	14.5	7.3	4	30	CM
VdM 2013	14.5	7.3	4	30	CM
Dump height (m)	**Density (kg/m³)**	**w:h**	**FoS**	**PoS VdM 2013**	**PLI 2013**
30	2000	1.8	1.63		
30	2000	1.8	1.21	97.01%	1441

Rock Type	Cohesion (kPa)			Friction Angle (deg)			Ru	Density (kg/m³)		
	Mean	Std Dev	CoV	Mean	Std Dev	CoV		Mean	Std Dev	CoV
Spoils	30	8	0.27	40.5	8.1	0.2	0.125	2000	500	0.25
Coal	120	30	0.25	30	8	0.27	0.125	1600	400	0.25
Hards	480	120	0.25	35	9	0.26	0.125	2000		
Sand	10	2.5	0.25	31	8	0.26	0.125	1900		
Softs/weathered rock	31	8	0.26	30	8	0.27	0.125	2480		

Minimum beam thickness (m)	Bord widths (m)
1.84	7.2
2.04	8
2.3	9
2.81	11
3.58	14



4.1 Discuss the impact the planned Safety Factor and the actual Safety factor over time, as well as the width to height ratio will have on the pillar stability.

(5)

4.2 Discuss the potential for encountering sinkholes & subsidence.

(5)

4.3 Discuss the typical controls that you would put in place to ensure overall stability.

(5)

4.4 Discuss the typical High - & Low wall failure mechanisms expected and provide the associated controls when mining this area.

(10)

[25]

[100]

Equation Sheet

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

Pillars

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

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

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

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

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

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

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

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

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

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

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

$$Load = \frac{\left[.025(H - T) + .03T\right]C_1C_2}{w_1w_2}$$

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

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

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

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

$$S_{\min} = 0.4$$

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

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

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

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

$$\sigma_t = \frac{fq_c s^2}{2t^2}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$S = t_l d\theta$$

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

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

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

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

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

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

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