Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS 3.2 (COAL) **SUBJECT CODE:** COMRMC3.2 **EXAMINATION DATE:** 13 MAY 2021 **TIME:** 14:30 – 17:30 (3 HOURS)	**EXAMINER:** W. Mahne **MODERATOR:** L. Prinsloo **TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES: 10

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 and other smart devices e.g. smart-watches are **NOT** allowed in the examination room

QUESTION 1

1.1 As a Rock Engineer working on an underground operation, you are required to provide a service that not only ensures the safety of the personnel working on the operation, but you are also required to provide recommendations that is cost effective.

Any design must be made on sound design principles.

Due to changes taking place in the coal industry w.r.t. reduced coal price and rise in production and labour cost you are required to re-evaluate the current support design methodology on the operation.

Describe a sound, approved design methodology that is industry accepted.

(10)

1.2 To start any project, the following information is necessary:

- Reserves: Abundance, distribution and complexity of deposit
- Resources: Financial, labour and market
- Financing plays an important part to obtain, explore and finally exploit any reserves and in order to apply for financial or investor aid a comprehensive report must be available. Such a report should include some of the following headings:
  - Resource and reserve calculation and reporting
  - Calculation of resources and reserves
  - Evaluation methods and procedures
  - Geological drilling
  - Sampling
  - Computer processing and deposit modelling
  - Processing
  - Geotechnical aspects
  - Geohydrology
  - Environmental aspects
  - Governmental legislation
  - Economic assessment
  - Phase 1 Geological study
  - Phase 2: Conceptual economic study
  - Phase 3: Pre-feasibility study

- Phase 4: Feasibility study
- Phase 5: Operational phase

The basis of this report is a Geological Investigation to obtain a Geological Model. This Geological Model which will assist in the feasibility studies (market, utilization potential, life of mine etc.), the Application for Prospecting Right and Mining Licence (which include a detailed financing plan, social and labour plan, Mining Work Programme, Environmental Management Plan (incl. Closure objectives & Closure Plan) and Pollution Control and Waste Management) and the actual design, lay-out and mining method to be utilized, should consist of high level, good quality, reliable and dynamic information. This information must be verifiable.

Such an integrated investigation will provide details on the Geometry, palaeo-topographical features, structural geological features, such as the headings below. In bullet formation, provide examples of what details can be investigated under each heading ($^1/_2$ mark per example):

1.2.1 Geomorphology (3)

1.2.2.Structural geology ($2^1/_2$)

1.2.3 Local geology ($2^1/_2$)

1.2.4 Rock and soil properties (2)

1.2.5 Load Deformation properties (1)

1.2.6 Seam distribution and thicknesses ($^1/_2$)

1.2.7 Geohydrology: ($^1/_2$)

1.2.8 Mining Equipment ($^1/_2$)

1.2.9 Monitoring system ($^1/_2$)

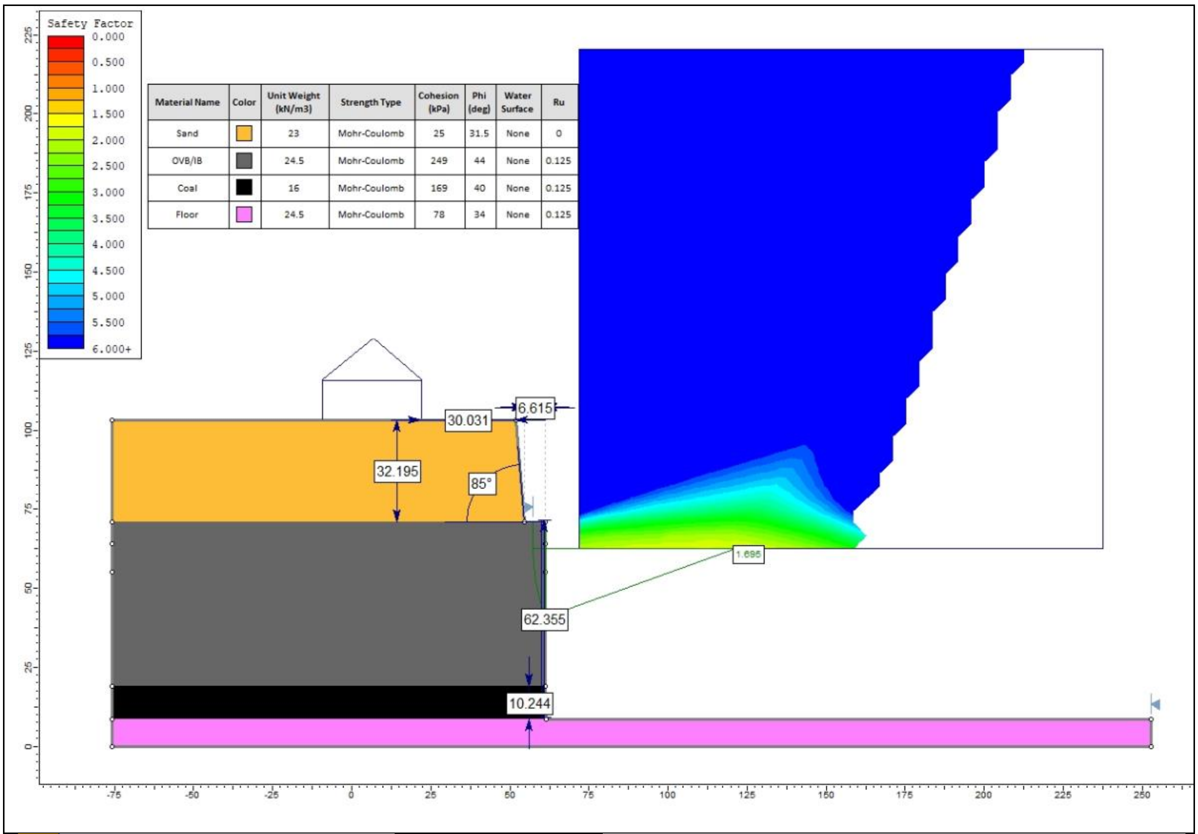
1.2.10 What will have an impact on the quality & level of the information in such a report? (2)

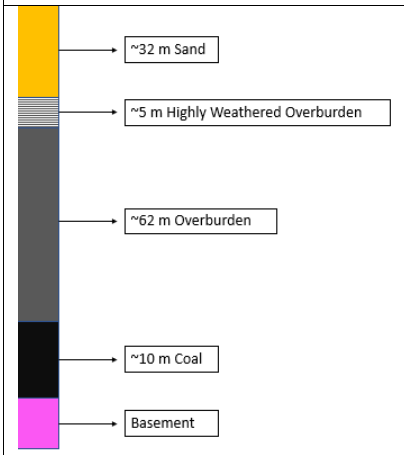
[25]

QUESTION 2

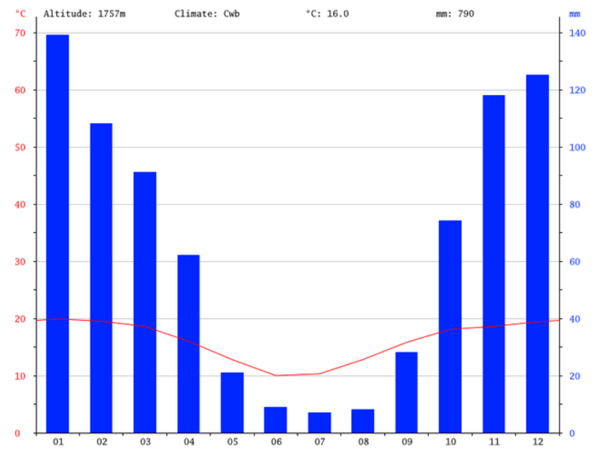
2.1 Briefly discuss the different modelling analysis techniques and their application. (Note: Do not name different software packages, explain the analysis techniques using bullet points. LEM vs FEM vs FDM etc.) (8)

2.2 The model below was drawn in Slide 6.0 for a permanent slope at a high wall portal. The borehole log in figure 2 indicates the lithology at the portal. Figure 3 indicates the monthly rainfall and temperatures in the area.





Borehole log at high wall portal.



Monthly rainfall and temperature graph.

2.2.1 Comment on the slope dimensions. (4)

2.2.2 Refer to the borehole log, indicate what failure modes you will typically expect in the different lithological units and propose controls to mitigate the risk. You can group units together if deemed appropriate (6)

2.2.3 What is the industry accepted criteria for Safety Factor and Probability of Stability for long term/ permanent slopes? (1)

2.2.4 Comment on the model, specifically refer to:

- Material Properties
- Infrastructure on the crest
- Safety Factor and Probability of Stability
- Slope Limits
- Search Grid
- Lithology

(6)

[25]

QUESTION 3

To maximise the ore-reserves and to increase the production rates your mine is looking at different mining methods.

For the increase in the production rates a Flexible Conveyor Train considered. The following information is available for the mining of the underground workings:

- The average depth to floor is 55 m.
- Coal seam is 3.8 m high (full seam will be mined).
- Fairly good roof conditions are expected and therefore a 7.2 m bord width is acceptable.

Opencast mining was done up to a point. From the highwall face there is approximately another 100 m of coal left between the face and the boundary of the mine. It is considered uneconomical to start an underground production section, with a portal from the highwall. Auger mining is considered. The depth of the 3.8 m thick seam is on average 22 m below surface.

(State all assumptions if required)

3.1 Design the underground workings to accommodate the Flexible Conveyor Train.

(10)

3.2 Compare the layout above with a normal production bord and pillar layout, using the Van der Merwe 2019 formulae. The panel must remain stable for a period of 500 years.

(10)

3.3 Give the optimal design for the mining from the highwall with the use of an Auger. Give recommendations on the size of the Auger required.

(5)

[25]

QUESTION 4

The mine where you are currently working has a major fault dividing the reserves into a Northern and Southern block. The thickness of the coal seam is ≈ 3.8 m in the Northern and 4.2 m in the Southern block. The seams are overlain by a highly laminated shale band of 0.54 m (Northern block) and 1.15 m (Southern block) in thickness.

Above the shales is a 6.0 to 8.0 m thick competent sandstone.

You are currently supporting the production panes with 1.8 m long full column resin bolts with 4 bolts in a row, with rows spaced 1.5 m apart.

Due to the abrasiveness of the sandstone you are requested to re-look at the support design.

(Use industry accepted lab values for the different rock types).

4.1 What impact will the abrasiveness of the sandstone have on production?

(1)

4.2 Calculate the safety factor of the current support system.

(6)

4.3 You are required to give the support requirements at a safety factor of 1.2 for the short-term production panels.

- Comment on the choice of safety factor.
- Briefly discuss the geotechnical domains that would influence the different support requirements.
- Give a support design for the different geotechnical domains identified.

(18)

[25]

[100]

Equation Sheet

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

Pillars

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

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

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

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

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

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

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

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

$$w_{ep} = \frac{2w_1 w_2 Sin\propto}{w_1 w_2}$$

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

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

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

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

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

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

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

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

$$S_{\min} = 0.4$$

$$C = w + \frac{B}{Sin\propto}$$

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

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

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

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

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

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

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

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

$$\eta = \frac{SF\rho g t}{P_d}$$

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

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

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

$$\tau_b = \frac{3k\rho g B}{4}$$

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

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

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

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

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

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

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

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

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

$$S = t_l d\theta$$

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

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

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

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

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

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

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