CHAMBER OF MINES OF SOUTH AFRICA

I

EXAMINATION PAPER

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

NUMBER OF PAGES: 12 (Including cover page)

SPECIAL REQUIREMENTS:

1. **Answer <u>ALL FIVE</u> 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. **<u>Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).</u>**
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 **<u>an accuracy that is typical of practical conditions</u>**.
10. In presenting answers, candidates are encouraged to use **<u>tabulations</u>** and **<u>diagrams</u>** or answers must be written in **<u>bullet</u>** points – **<u>No long paragraphs</u>**.
11. Cell phones are **NOT** allowed in the examination room

QUESTION 1

You are the appointed Rock Engineer at a mine in the Witbank Coalfields area. A new block of ground is planned to be mined adjacent to an area that are currently being mined. The number 4 seam will be mined.

- Depth of mining (Section) ranges from ≈ 17 m to ≈ 80 m.
- The immediate roof of the seam consists of laminated shales.
- The number 2 seam was mined out in the mid 60's at a mining height of approximately 2.5 m.
- Interburden between the Number 2 and 4 seams is on average 30 m.

Use a solid design methodology when doing the design for the mining of this block of ground.

Make reasonable assumptions where necessary. Clearly state up front all assumptions made.

In the area where the borehole (Appendix 1) information was obtained from for the Number 4 seam the following must be done:

a. Calculate the mining parameters of the Number 2 seam if a Factor of Safety of approximately 1.6 was maintained. Average bord widths at the time of mining was 6.5 m.

For various parameters used in the exam.

Section	SF Calc S&M VdM FCT	Seam	C1	C2	W1	W2	h (m)	H (m)	b (m)		W:H	SF
Q 1a	S&M	4	16.0	16.0	8.8	8.8	3.7	57.5	7.2	cm	2.4	2.03
Q 1a	S&M	2	16.0	15.0	9.5	8.5	2.5	90.0	6.5	db	3.4	1.60
Q 1a	S&M	2	18.0	18.0	11.5	11.5	2.5	116.5	6.5	db	4.6	1.69
Q 1a	S&M	2	13.0	13.0	6.5	6.5	2.5	60.0	6.5	db	2.6	1.54
Q 1a	S&M	2	12.5	12.5	6.0	6.0	2.5	50.7	6.5	db	2.4	1.62
Q 1a	S&M	2	17.5	17.5	11.0	11.0	2.5	113.7	6.5	db	4.4	1.64

[3]

b. Using the Van der Merwe 2013 Overlap Reduction Methodology do a pillar design for the long-term excavations as well as the production panels for the area where the borehole information was obtained. Take into account that stooping will be planned for the Number 4 seam.

Stooping

Overlap reduction formula (Deducted 3 marks for not using the correct formula

Deducted 1 mark for not doing the CM adjustment.

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

$$Load = 0.025\ \frac{C_1C_2}{w_1w_2}$$

Section	SF Calc S&M VdM FCT	Seam	C1	C2	W1	W2	h (m)	H (m)	b (m)		W:H	SF
Q 1b	VdM	4	15.5	15.5	9.0	9.0	3.7	57.5	6.5	db	2.4	1.99
Q 1b	VdM	4	14.5	15.5	8.0	9.0	3.7	57.5	6.5	db	2.4	1.77
Q 1b	VdM 2013	4	15.5	15.5	9.0	9.0	3.7	57.5	6.5	cm	2.4	2.11
Q 1b	VdM 2013	4	14.4	14.4	7.9	7.9	3.7	57.5	6.5	db	2.1	1.61

c. Give the criteria for the NEVID stooping method.

SF > 1.8

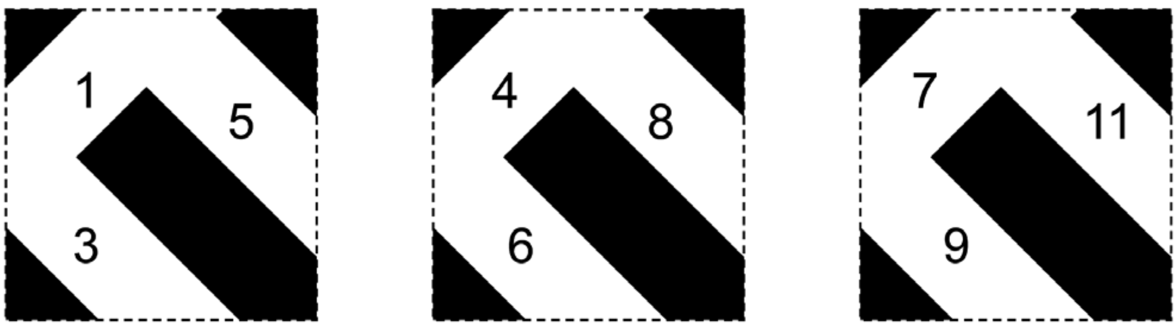
Snook SF ≈ 0.8

Bleeder roads to be left for ventilation purposes

Stopper pillars to control goaf

[3]

d. With the help of an annotated diagram explain the NEVID method of stooping, which would include the additional support requirements, the cutting sequence of the pillars and the sequence of pillar extraction.



Support requirements – length of units, spacing of units, monitoring, pillar support requirements, MRS

Sequence of pillar cutting

Sequence of panel mining, barrier pillars, Stopper pillars,

[9]

[25]

QUESTION 2

Fall of ground history is given in the table below for similar conditions encountered while mining the Number 4 seam in a different area. Geotechnical analysis indicated that the roof material would behave similar in the area to be mined. Dry drilling will be done.

When designing the support use acceptable values for the rockmass parameters, support systems etc. State all assumptions (all assumptions must be reasonable).

FOG Data							
4	2.4	0.3	0.2	0.5	2.5	0.3	1
1	0.25	0.5	0.2	0.8	0.5	0.6	0.3
0.05	0.25	0.3	0.4	0.3	0.7	2	1
0.06	0.1	0.5	0.35	0.3	1	1.5	
0.1	1	0.5	2	0.15	0.3	0.8	

a. State and justify the support design methodology will be used to support the roof of the underground mining operations. [2]

Although the idea was to use the data in Question 1, it was not specify in the question paper, therefore each student's questions was marked on the method they chose

b. State the design criteria for the support system. [5]

Safety factor to be used

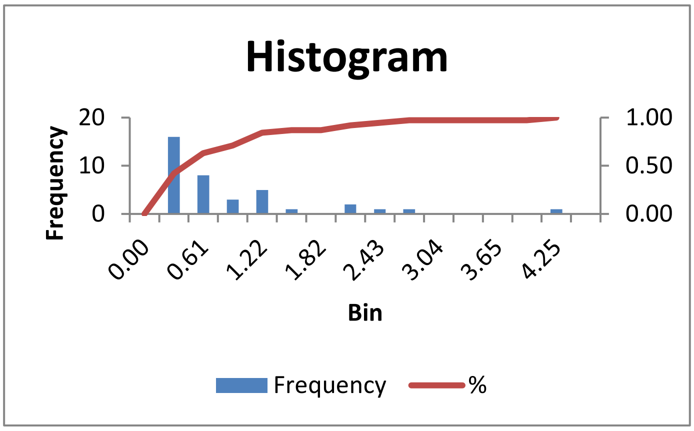
Resin requirements

Required hole size

Drilling method

Fallout thickness the design will cater for.

c. Design the support system for a 7.2 m bord width. [10]



0.00	0	0	0.00
0.30	16	16	0.42
0.61	8	24	0.63
0.91	3	27	0.71
1.22	5	32	0.84
1.52	1	33	0.87
1.82	0	33	0.87
2.13	2	35	0.92
2.43	1	36	0.95
2.73	1	37	0.97
3.04	0	37	0.97
3.34	0	37	0.97
3.65	0	37	0.97
3.95	0	37	0.97
4.25	1	38	1.00

Beam needs to support approximately 2.4 m of roof. – conservative would be the maximum fallout height of 4.3 m

Although the idea was to use the data in Question 1, it was not specify in the question paper, therefore each student's questions was marked on the method they chose and the calculations they did. The calculations would depend on the assumptions they made w.r.t. the height of the stable zone.

Sound basis of assumptions were required from the FOG data.

Marks were given for the analysis of the FOG data.

Calculations Correct formula used and ultimate design

If suspension was recommended – mention of additional support should be made.

Suspension could also be recommended from the experience in the Witbank Coal fields where shales are supported by means of suspension rather than beam building.

d. Describe and give examples of active and passive support used in the underground coal mining industry. [3]

e. For a bolt length determined above, complete the table below with the appropriate dimension for full column resin grouted roof bolts. Show all calculations and state all assumptions.

1. Bolt ϴ	Hole Diameter mm				Hole length	Resin Capsule ϴ	Required. Length of Resin Capsule
	Collar	Mid	Back	Average			
18mm	25.3	25.0	24.7	25.0			
20mm	26.4	25.2	25.0	25.3			

[5]

[25]

QUESTION 3

Longwall mining is considered at a depth of approximately 200 m below surface.

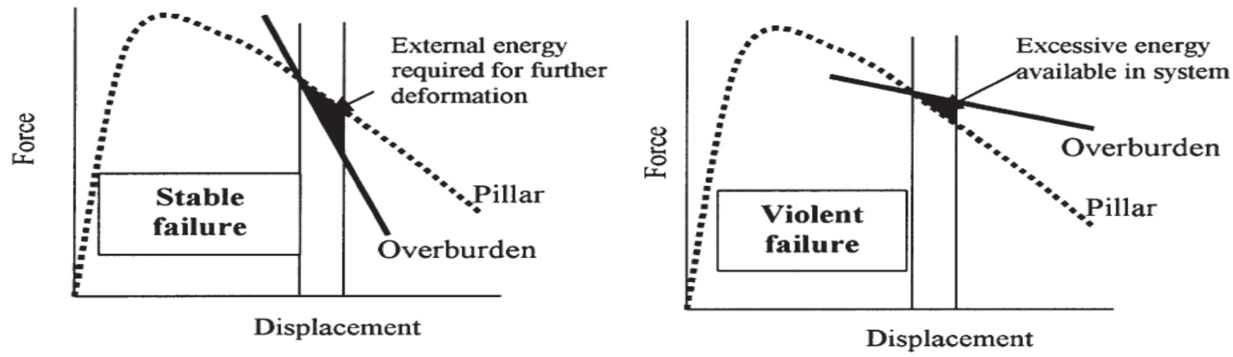
a. Give a brief discussion on the factors that you need to consider during the design of a Longwall panel.

Geology – dykes, discontinuities, soft floor, roof conditions – incl, competent layers that may cause you to have to initiate the first goaf, roof skin layers – slabbing on and in front of chocks, face breaks. Undulating seam height Stress – regionally & locally – stress pinchpoints/concentrations / basic principle stress direction.

Size / shape of Tail & Maingate pillars – design must be stable during operations, but must yield over time to ensure that no unmined solid areas are left in-situ – stress concentrations, as well as surface damage.

[10]

b. Explain on the hand of the bottom diagrams the failure mechanism within the face roof area of a Longwall face during stationary and very slow movement of the shearer. Assume the goaf is approximately 5m from the rear of the chock line.



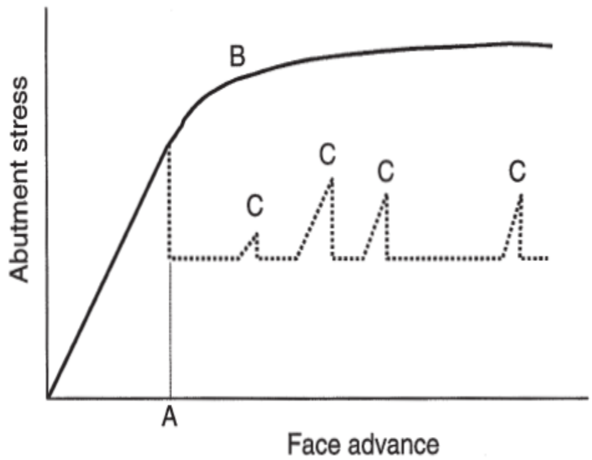
Goaf formation – under normal cutting conditions, the roof breaks in small portions and follows the cycle of cutting. If the goaf hangs up or the shearer is stationary, the goaf fails in a single mass –usually violent.

Stationary Longwall may lead to face breaks: Often face breaks are preceded by unplanned stoppages of more than a day (Van der Merwe & Madden (2002).

- Probable explanation for this phenomena is that during a prolonged standing time, the temporary high stress zone which causes the micro-fractures to form, remains in the same zone for long enough time to cause the fractures to increase in size, become active.
- This, in turn, leads to instability.
- Rock failure is time dependent – to minimise damage and uncontrolled failure, is to "move" through the rock mass as quickly as possible.
- When a Longwall face remains stationary, this instability occurs and when mining resumes the rock has already been damaged.
- The face basically mines into pre-existing fractures and face breaks might be imminent.

[5]

c. Explain on the hand of the following diagrams the failure mechanism during a Longwall goafing process.



Conceptual curves of stress as a function of face advance. The solid line indicates the situation where the overburden remains intact and the broken line indicates the stress levels for an overburden that fails when the face advance is equal to "A".

During the process of Longwall mining, additional load is distributed to the solid, un-goafed face area.(Abutment)

This causes micro fractures to develop in the immediate roof and face area.
These micro fractures follow the same pattern as the stress trajectories – it thus follows the direction of extraction.
In the case of Longwalling, it thus follows the path of the shearer – thus micro-fractures will develop from both directions.
The second set criss-crosses the first set.

Under normal circumstances, these micro-fractures assist with the goafing process, but during long standing time, such as with break downs, these criss-crossing fractures may cause face breaks

[5]

[20]

QUESTION 4

An opencast colliery wishes to increase extraction of a 4.0m thick coal seam by highwall mining methods. It can be assumed that the final cut is approximately 1.0km long.

As the appointed Rock Engineer, prepare a design document that could safely extract a depth of 300m of coal.

The answer must be presented in bullet point format

a. Compare and contrast the benefits of Augur Mining vs Plunge Mining

Auger Disadvantages:

1. Diminishing power with increased depth. (restricted to about 130 m penetration)

2. Augers suffers from increasing coal size degradation with depth,

3. Fixed cutting height that diminish the percentage of coal recovered. (extract 30% to 40% of the coal to that
depth).

4. No ability to negotiate dips and rolls in the seam because of the rigid structure of the auger flights.

5. Low production rate

Highwall mining Advantages:

1. Greater depth of penetration with almost constant power (305 m penetration)

2. No coal size degrading with increase mining depth,

3. Variable cutting height using adjustable continuous miner cutting head (0.75m – 3.05m), extracting 60% to 80% of available coal.

4. Negotiate dips and rolls in the seam because of non-rigid structure of the push beams.

5. High production rate (80 000 – 120 000 ton / month) 6. Mine seam dips of +5 degree to -12 degree

[4]

b. Discuss how the highwall should be prepared for highwall mining

Highwall conditions

- Competent coal.
- Competent immediate overburden.
- If overburden is not competent, coal may be left as roof.
- Coal seams dipping from -12 to + 5 degrees.
- Relative flat seams, no faults
- Coal seams thicker than 80cm.

[2]

c. The width of the cutter drum selected is 3.5m wide. Provide a proposed design for a highwall mining layout that is both productive and stable.

Formula's were not given so every paper will be marked on the insight of the candidate into the Highwall mining.

Web and barrier pillars

- Web pillars ensure support of OB
- Barrier pillars prevent cascading collapse
- Barrier pillar typically every 10 to 20 drives
- Calculation method to be approved by local Mine Safety Authorities

Web pillar strength

$S_P = S_I$ [0.64 + 0.54 W / H]

Where: Sp = web or barrier pillar strength

S_I = in situ coal strength

W = web or barrier pillar width

H = mining height

Web pillar stress

$S_{WP} = S_V (W_{WP} + W_E) / W_{WP}$

Where: SV = in situ vertical stress

W_{WP} = web pillar width

W_E = highwall miner hole width

SF_{WP} = web pillar strength / web pillar stress (S_{WP})

If the number of web pillars in a panel is selected as "N", then the panel width is given by

$W_{PN} = N (W_{WP} + W_E) + W_E$

Neglecting the stress carried by the web pillars (i.e. assuming that they have all failed), the average vertical stress on a barrier pillar is

$S_{BP} = S_V (W_{PN} + W_{BP}) / W_{BP}$

Where: W_{PN} = panel width

W_{BP} = barrier pillar width

Similarly, the stability factor for barrier pillars against strength failure is simply

SF_{BP} = barrier pillar strength / barrier pillar stress (S_{BP})

[14]

[20]

QUESTION 5

The following questions are pertaining to the designing and mining of an opencast strip mining operation:

a. State and explain the different mining criteria used in the design and mining of the operation with regards to single and multiple bench, spoils, slopes, virgin and previously mined ground etc. What would be considered under different circumstances?

[6]

b. Give a brief explanation of the different failure mechanisms, their contributing factors, consequences, monitoring and remedial actions.

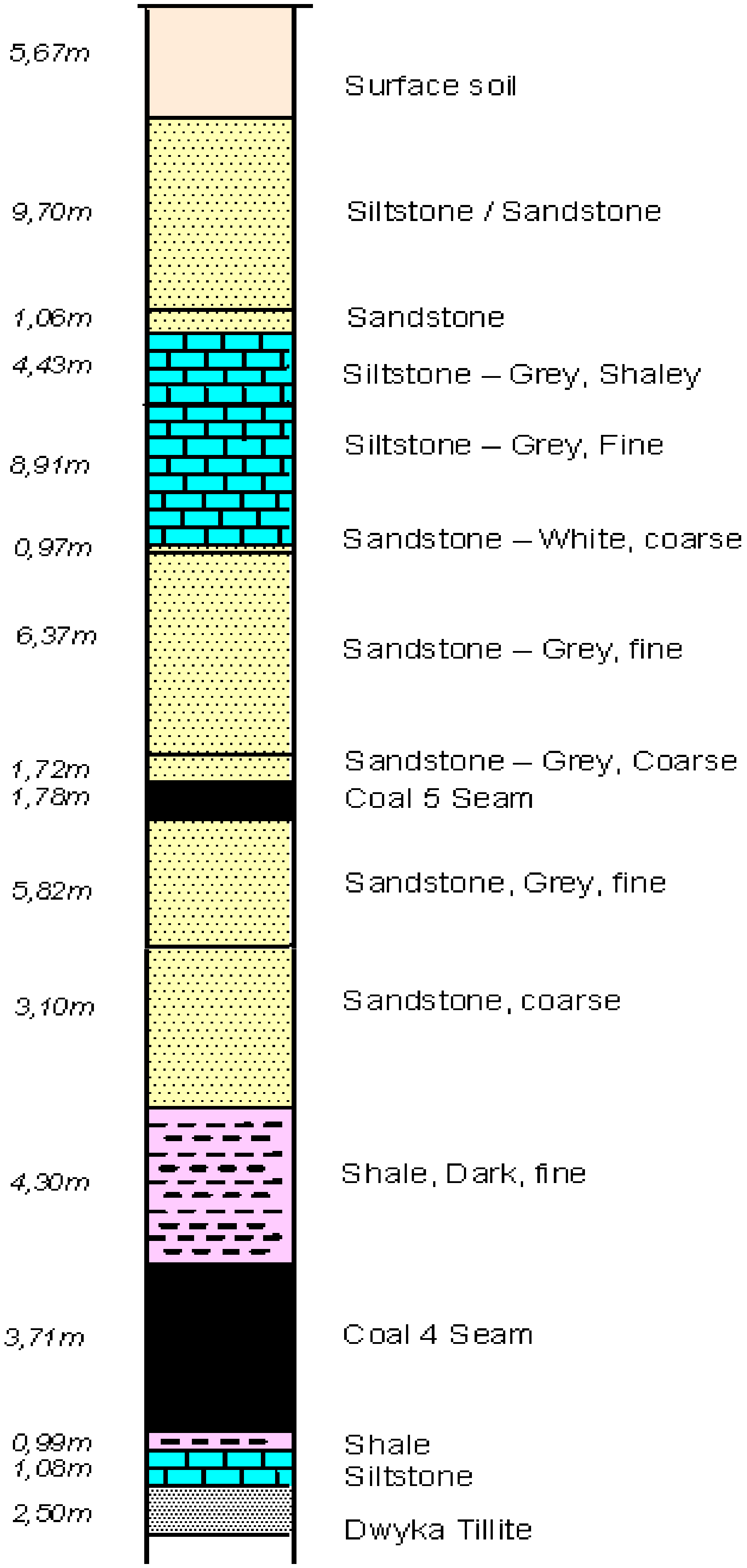
[4]

[10]

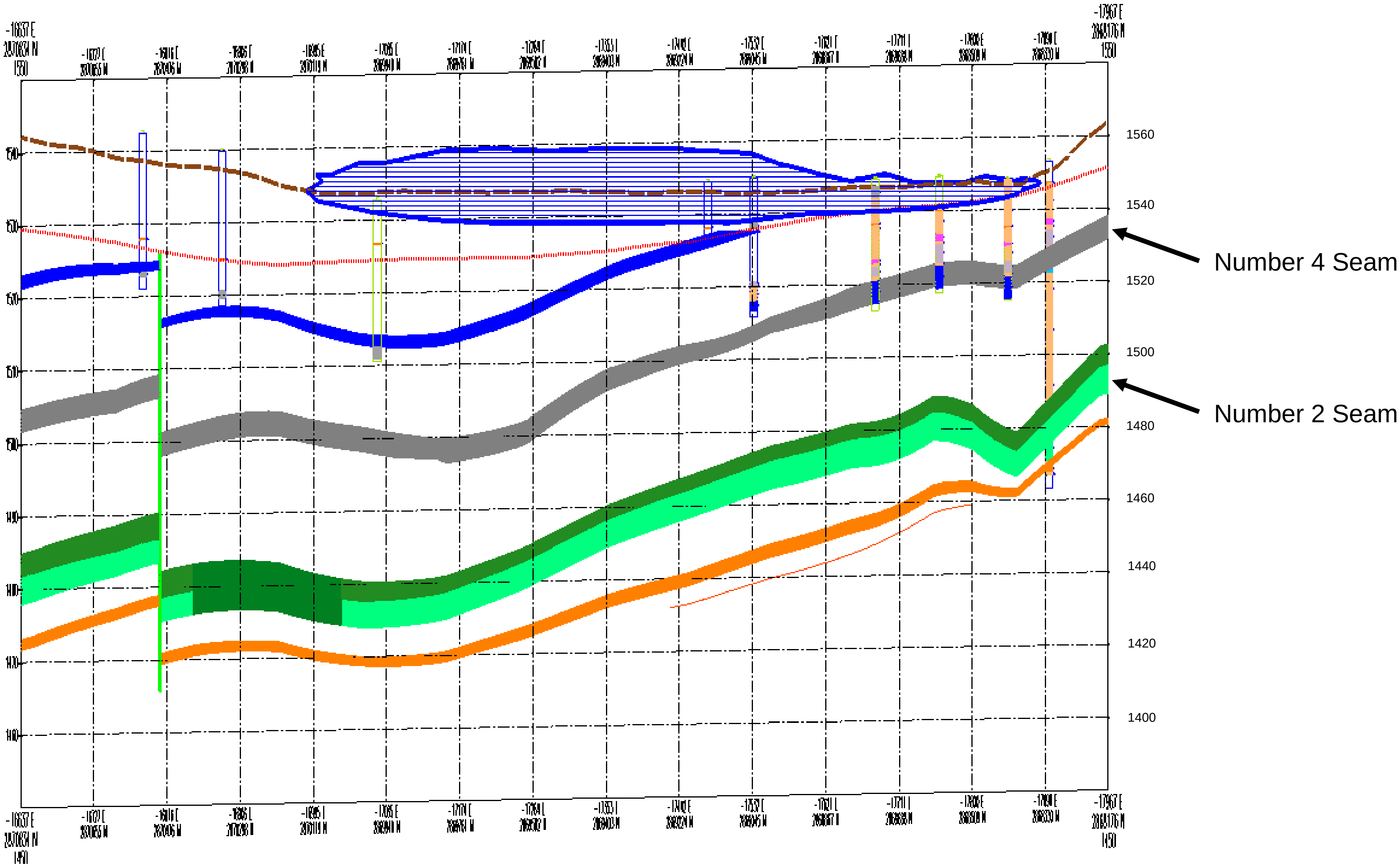
[100]

Appendix A

Borehole log of number 4 seam



Section Plan



Equation Sheet

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

Pillars

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$S_{\min} \;= 0.4$$

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

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

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

$$q = \rho g(t_{s} + t_{w})$$

$$\sigma_{t} = \frac{fq_{c}s^{2}}{2t^{2}}$$

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

$$q_{c} = q_{l} + \frac{q_{u}E_{l} - q_{l}E_{u}}{E_{l} + E_{u}}$$

$$l_{a} = \frac{\rho g s^{2} t_{w}}{\tau_{c}\pi d_{h}} + .05$$

$$\eta = \frac{SF\rho g t}{P_{d}}$$

$$\sigma_{ts} = \frac{4W_{b}}{\pi d_{b}^{2}}$$

$$l_{c} = \frac{l_{a}\left(d_{h}^{2} - d_{b}^{2}\right)}{\left(d_{h} - .002\right)}$$

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

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

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

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

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

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

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

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

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

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

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

$$S = t_l d\theta$$

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

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

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

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

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

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

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