# CHAMBER OF MINES OF SOUTH AFRICA

## WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

## COAL OPTION

PART 2 - APPLICATIONS 11 November 1997

EXAMINER: Mr C Oldroyd

MODERATOR: Dr B Madden

Maximum time allowed 3 hours (09:00 - 12:00)

**ANSWER ALL QUESTIONS**

A pass mark is 60 per cent.

**EXAMINATION INSTRUCTIONS**

1. References are not permitted.

2. Hand-held electronic calculators may be used. **(NO PRE-PROGRAMMING).**

3. Put your examination 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.

4. Write in ink on one side of the paper only.

5. Show all calculations on which your answers are based.

6. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.

7. Graph paper is available from the invigilator.

## PART 2 - APPLICATIONS - COAL OPTION

### QUESTION 1

a) What do you understand by the term *contact shear strength* when applied to resin roofbolting? How would you determine the contact shear strength? Indicate the methodology used.

4 marks

b) How is the maximum tensile stress in the roof related to bord width? Give a comparative example.

2 marks

c) How is the maximum tensile stress related to beam thickness? Give a comparative example.

2 marks

d) Should steel tendon roof support in collieries be stiff or yielding? Support your answer.

2 marks

e) Give three examples of active and passive support used on collieries.

3 marks

f) Pillar failure can be either controlled or uncontrolled. By means of sketches describe each type.

2 marks

Name some of the factors which influence:

(i) System stiffness
(ii) Pillar stiffness during failure

2 marks

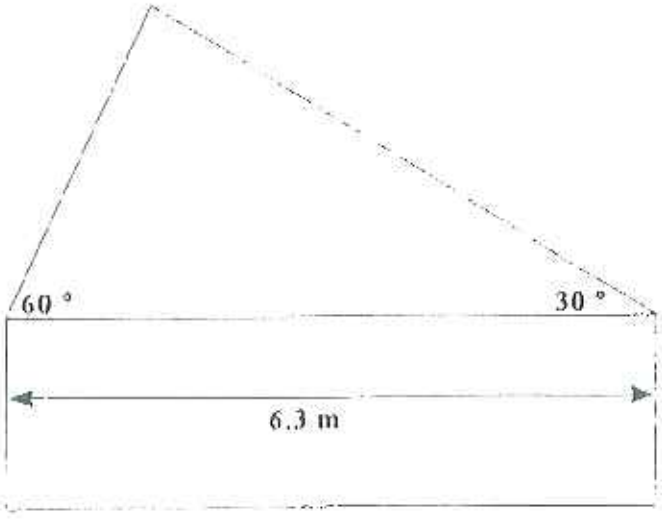
## PART 2 - APPLICATIONS - COAL OPTION

### QUESTION 1 (Cont.)

g) A 6,3 m wide roadway is bordered by a 60° slip on the left hand side which runs parallel to the road. On the right hand side there is a slip which dips at 30° which also runs parallel to the bord. The roof material is coal.

Recommend a support system consisting of point anchored resin bolts. Support your answer with calculations and relevant assumptions.

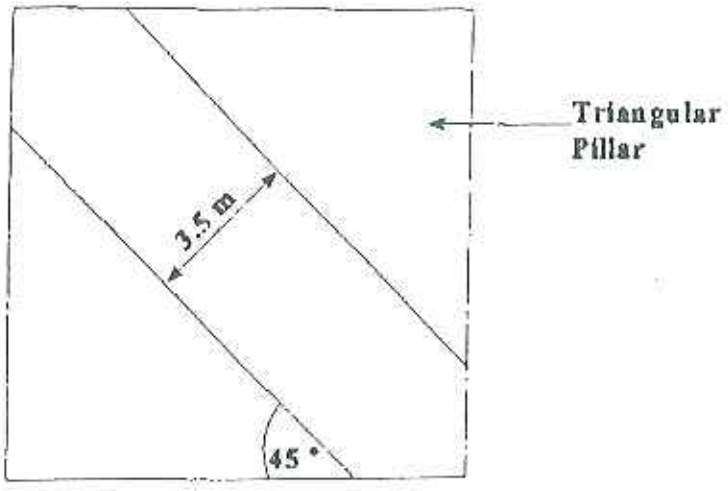
8 marks



## PART 2 - APPLICATIONS - COAL OPTION

### QUESTION 1 (Cont.)

g) i) Calculate the safety factor of the triangular shaped pillars shown in the sketch below which were formed during a retreat splitting operation. The mining height is 4 m, pillar centres 18 m and depth below surface to floor is 40 m. The initial bord width is 6 m. Assume a diagonal cut width of 3,5 m.




4 marks

g) ii) If the triangular pillars were replaced by circular pillars, having a radius of 2,79 m, calculate the pillar safety factor.

4 marks

TOTAL 33 marks

## PART 2 - APPLICATIONS - COAL OPTION

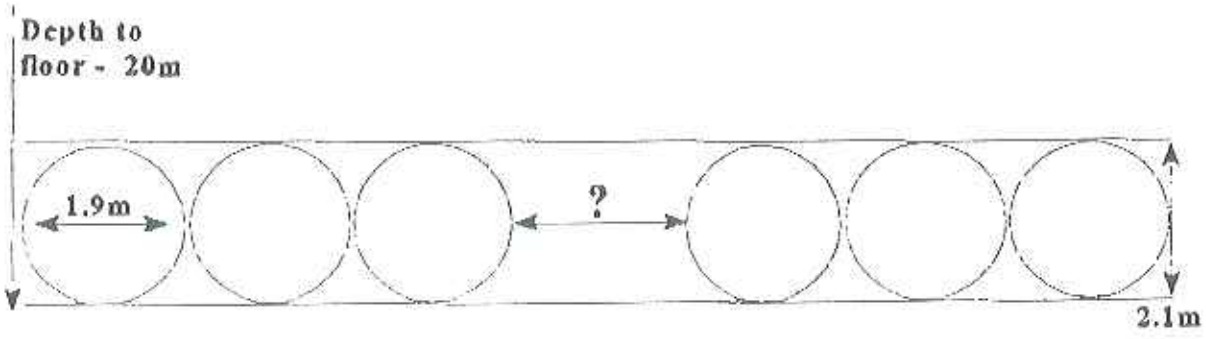
### QUESTION 2

a) Auger mining has once again commenced on South African collieries. From a rock engineering perspective briefly comment on the advantages and disadvantages of the method.

4 marks

b) An auger creating a hole diameter of 1,9 m is to be used to extract a portion of the number 5 seam. Assuming three holes are spaced close together (0,2 m skin to skin), calculate the required pillar width to achieve a safety factor of 1,6. The depth to the floor of the seam is 20 m. The pattern of mining is to be carried out over a long distance. Do not use the continuous miner adjustment. Do not apply the shallow depth mining criteria.

9 marks




Note the assumptions you have made.

c) Calculate the volumetric extraction of the seam.

2 marks

TOTAL 15 marks

## PART 2 - APPLICATIONS - COAL OPTION

### QUESTION 3

Hereford Colliery developed the B seam with conventional drill and blast methods to the following geometry:

| | | | |
|---|---|---|---|
| - | Pillar centres | = | 25,5 m |
| - | Pillar width | = | 20 m |
| - | Bord width | = | 5,5 m |
| - | Mined height | = | 3,2 m |
| - | Depth to floor | = | 200 m |
| - | Safety factor | = | 1,63 |
| - | % extraction | = | 38,5 |

The A seam, which overlies the B seam, is located at a depth (to floor of seam) of 181,8 m, is 2 m thick and of good quality. The parting between the A and B seams consists predominantly of competent sandstone with occasional thin (<100 mm) bands of carbonaceous material.

The colliery owners wish to increase the extraction of the A seam over that which was obtained in the B seam. Continuous miners and shuttle cars will be employed in the development of the A seam.

Without employing secondary or total extraction methods, or any form of filling the B seam workings, determine, by employing industry accepted design methods, the best method of increasing the extraction of the A seam.

Clearly document your methodology and show all calculations.

TOTAL **20 marks**

## PART 2 - APPLICATIONS - COAL OPTION

### QUESTION 4

A section is carrying out bord and pillar mining with a Joy continuous miner and is equipped with a Rham roofbolting machine fitted with on-board hydraulic temporary support jacks. Point anchored rebar 1,5 m long is being installed anchoring in sandy shale.

Because this roof horizon slabs readily when exposed a 0,5 m or thicker coal beam is left in the roof.

Carry out a risk assessment on the entire roofbolting operation using the following format:

| Potential Risk/Hazard | Rating, i.e. High/Medium/Low | Controls/Remedial Action |
|---|---|---|
| | | |
| | | |
| | | |

TOTAL **20 marks**

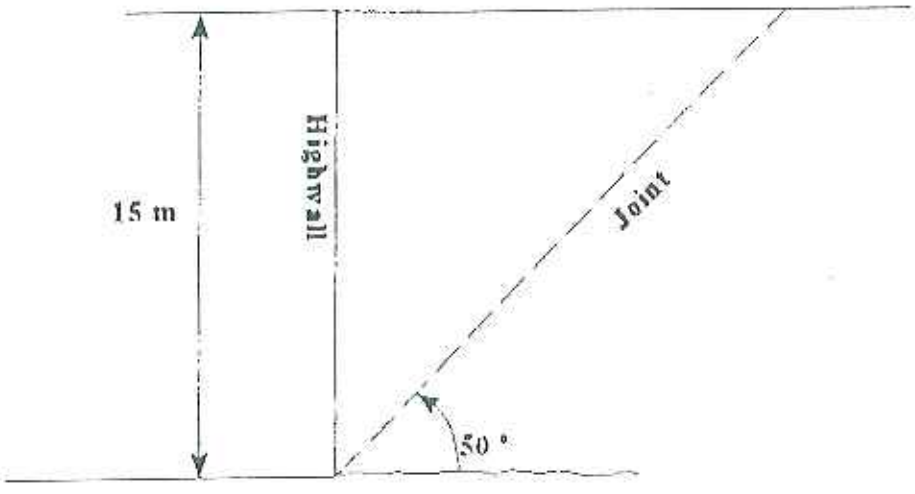
## PART 2 - APPLICATIONS - COAL OPTION

### QUESTION 5

a) A joint exists in a vertical highwall face as illustrated below. The joint surface strikes parallel to the highwall face. Given the information below, calculate the safety factor against sliding taking place on the joint surface.

| | | |
|---|---|---|
| Density of rock (ρ) | = | 2 600 kg/m³ |
| Friction angle of joint surface (Φ) | = | 30° |
| Cohesion of joint surface (c) | = | 0 kPa |
| Gravitational acceleration (g) | = | 9,81 m/s² |

4 marks




b) Briefly describe the following terms with respect to slope stability: (Use sketches where necessary)

(i) Plane failure
(ii) Wedge failure
(iii) Circular failure
(iv) Toppling failure

4 marks

c) Calculate the horizontal force (F) required to stabilise the wedge in (a) above with a safety factor of 1.5.

4 marks

TOTAL 12 marks

1 2 (c) [illegible] Nov 99

## ANSWERS :

### QUESTION 1

1a i) B = 6m
t = 0.3m
SG = 2.5

$$\sigma_T = \frac{\rho g L^2}{2t}$$

$$\sigma_T = \frac{2500 \times 9.8 \times (6)^2 \times 10^{-6}}{2\ (0.3)}$$

$$= 1.47 \text{ MPa} \qquad (1)$$

1a (ii)

$$\sigma_T = \frac{2500 \times 9.8 \times (5)^2 \times 10^{-6}}{2\ (0.1)}$$

$$= 3.063 \text{ MPa} \qquad (1)$$

Roof is stable in the first case. Stable in the second. (1)
Gas pressure 1.47 MPa from first case.

$$\sigma^T = 1.47 + \frac{700\ 000\ (6)^2}{2\ (0.3)}$$

$$= 42 \text{ MPa} \qquad (1)$$

Drill gas bleeder holes / support lower roof (2)

**Total (6)**

1b Pillar centres on lower seam = 20m pillar width = 14
$\Delta$ w = 0.3 (2)

Pillar centres on upper seam = 20m due to multiple seam contrasts (3)

(-2) if multiple seam constraint not seen

in this question the depth was given differently, i.e. 109m pillar width for 109m = 12.23m, plus 6m for bord width = 18.23. 19m centre.

1c SG of floor and 2,5

i) Contamination roof = 2.5 x 0.3 = 0.75
Contamination floor = 0.5 x 0.5 x 2.5 = 0.625
Product 2.0 x 1.6 = 3.2

$$\% \text{ Contamination} = \frac{0.75 + 0.625}{3.3}$$

= 42.3% (30.05%)

*(Answer also accepted if done by total weight)*

ii) Contamination floor = 2.5 x 5 x 5 = 0.625

$$\% \text{ Contamination} = \frac{0.625}{3.2}$$

= 19.5% (16.45%)

Yields Coal 70% of 3,2 = 2.24

i) Total Yield $\frac{2.24}{4.58}$ = 48.9% *(different by weight)* (1)

ii) Totals $\frac{2.24}{3.825}$ = 58.6% *(different by weight)* (1)

Pillar Punching/Increased height (2)

Roof support, to minimise contamination, must be installed close to the face and will reduce productivity. Fairly dense support needed. (1)

Low bearing pressure equipment (½)
Minimise tramming/possibly continuous haulage (1)
Minimise water usage (½)
Slake durability (½)
Swelling tests (½)

1d

1. Safety factor 1.6 to 1.7 a little low (2)
2. Pillars adjacent to goaf mined 20 years ago weakened and fractured (2)
3. Check surface for subsidence/goaf to surface (2)
4. Full goaf not developed (1)
5. Monitor (1)
6. Weakened pillars will have snooks which cannot support the roof (1)
7. Cannot stoop with broken breaker and finger lines (1)

1e

i) Dump at 20m
Equivalent strata thickness at S.G. 1.6 = 12.8m
at S.G. 1.3 = 10.4m (1)

Effective depth below surface 35.4 to 37.8m (½)
Pillar centres for S.F 1.7 = (5.33 + 6.4) say 12m (2)
$\Delta w$ = 0.3 (½)
B = 6.4m (½)

ii)

| | |
|---|---|
| w:h > 2 | Not satisfied |
| w > 5 | Shallow guidelines satisfied |
| % c < 75% | |
| Safety Factor > 1.7 | |

(2)

Possible sinkhole development/dump stability/pollution effects (3)

## QUESTION 2

| Potential Hazard | Possible Controls | Potential Problems | Additional Action/ Information Needed | Rating |
|---|---|---|---|---|
| 1. Roof Slabbing<br><br>(7 Points) | 1. Bolted during development.<br><br>2. Barring down.<br><br>3. Install fingerlines.<br><br>4. Canopies for operator.<br><br>5. Cable handler to stand well back<br><br>6. Speed of extraction. Do not leave partially extracted pillars | 1. Slips not bolted. Bolts ineffective. Safety factor of support system for suspension of 0.6m sandy shale = 1.4. If 0.2m upper coal added safety factor only 1.<br><br>2. Slabs not identified<br><br>3. Poorly installed.<br><br>4. Poorly designed.<br><br>6. Machine breakdowns. | 1. Check efficiency of original support. Random pull tests. Check support of slips.<br><br>2. General roof conditions. Delimination of coal roof.<br><br>4. Check specifications.<br><br>6. Check availability records for CM. | High |
| 2. People going into the goaf<br><br>(2 Points) | 1. Breakerlines. | 1. Knocked out. Installed in wrong place. | 1. Investigate timber/ roofbolt breakerlines. | Medium |
| 3. Airblast caused by goaf hanging up and then failing<br><br>(2 Points) | 1. Leave snooks as small as possible. | 1. Large snooks due to high stresses and geological discontinuities. | 1. Map panel to identify slips. | Medium |
| 4. Large slabs falling from pillar sides and striking people.<br><br>(2 Points) | 1. Barring down. | 1. Constantly needed. Slabs not identified | 1. Assess pillar conditions. | Medium |

| Potential Hazard | Possible Controls | Potential Problems | Additional Action/ Information Needed | Rating |
|---|---|---|---|---|
| 5. Goaf overruns Breakerline<br><br>(6 Points) | 1. Safety factor = 1.85 Pillar stiffness. Fenders ± 5m should be reasonably stiff.<br>2. Breakerlines<br>3. Mining sequence | 1. Wide boards. Excessive spalling subsequent to development.<br>2. Must be re-set if knocked out.<br>3. Incorrect extraction sequence. | 1. Assess pillar conditions. Check for spalling (reduced pillar width)<br>3. Map panel. Look for anything which may affect sequencing | Medium |
| 6. Methane build-up in goaf.<br><br>(2 Points) | 1. Ventilation.<br>2. Methane in upper coal band drained by roofbolt holes.<br>3. Monitoring. | 1. Methane flushing in from goaf.<br>2. Presence of methane in sandstone.<br>3. Unknown triggers of ignitions during goafing | | High |
| 7. Roof slabbing due to poor orientation of stooping line with discontinuities.<br><br>(2 Points) | 1. Panel to be mapped.<br>2. 45° stooping line with NE-SW direction. | | 1. Check if slips follow rough line of faults shown on the survey plan. | Medium |
| 8. People injured by F.O.G. while reparing CM in face<br><br>(2 Points) | 1. High degree of maintenance especially tramming.<br>2. Temporary support. | 1. Poor maintenance<br>2. Insufficient/too short. | 1. Check CM availability records.<br>2. Check availability of temporary support. | Medium |

A fair degree of latitude will be tolerated.

QUESTION 3

a) 1) Calculate effective pillar width $= \frac{4A}{C}$

Bord width: $B = \frac{6.5}{\sin 60°}$
$= 7.5m$ -½

Pillar widths: $W_1 = 22 - 7.5 = 14.5$
$W_2 = 20 - 7.5 = 12.5$ -½

Area paralellagram: $A = W_1 \perp h$
$\therefore A = 14.5 * 12.5 * \sin 60° \ (\perp h = W_2 \sin 60°)$
$= 156.84\ m^2$ -½

Circumference: $C = 2(W_1) + 2(W_2)$
$= 2(14.5) + 2(12.5)$
$= 54m$ -½

Effective width: $W_{Eff} = \frac{4A}{C}$
$= \frac{4(156.96)}{54}$
$= 11.62m$ -1

2. Check w:h ratio: Smallest dimension = $W_2$ = 12.5m
w:h = 6.25 -1

Thus the squat pillar formula applies.

3. Calculate SF: $\sigma_s = \frac{18708}{V^{0.0667}} \left\{ 0.2373 \left[ \left( \frac{R}{5} \right)^{2.5} - 1 \right] + 1 \right\}$

Volume: $V = A * h$
$= 156.97 * 2$
$= 313.94\ m^3$ - ½

Strength: Thus $\sigma_s = \frac{18708}{313.94^{0.0667}} \left\{ 0,2373 \left[ \left( \frac{625}{5} \right)^{2.5} - 1 \right] + 1 \right\}$
$= 15\ 004.09$ kPa -1

Load: Original Area $= 22 * 20 * \sin 60°$
$= 381.05 m^2$ -½

Load $= 25H \left( \frac{\text{Original Area}}{\text{Pillar Area}} \right)$
$= 8\ 321.37$ -1

$SF = \frac{\text{Strength}}{\text{Load}}$
$= \frac{15\ 004.09}{8\ 321.37}$
$= 1.80$ -1

**Total (8)**

b) i) Large spans across intersections
ii) Acute corners will fail
iii) Mining off line a problem
iv) Facilitate continuous haulage
v) Facilitate large solid drum continuous mines (5)

QUESTION 4

1/. Determine what mining methods may be employed ie,.
Stooping
Top Coaling **(1)**

2/. Determine whether safety factor of initial workings will permit safe secondary extraction.

2.1 Calculate Safety Factor of existing workings.

$SF = Ps/Pl$ or $Sf = 288.w^{2.46}/H.h^{0.66}(w+B)^2$

$Ps = 7.2\ w^{0.46}/h^{0.66}$ $= (7.2)\ .12^{0.46}/3^{0.66}$ $=$ 10.93

$Pl = 0.025.H.C^2/w^2$ $= (0.025)\ .\ (106)\ .\ (18w^2)/12^2$ $=$ 5.96

$SF = Ps/Pl$ $= 10.93/5.96$ $=$ 1.83 **(2)**

Initial safety factor high enough for secondary extraction by Stooping as well as by Top Coaling. **(1)**

3/. Determine whether Top Coaling is feasible.

3.1 Calculate Safety Factor if Total seam mined (4.5 m)

$Ps = (7.2)\ .\ 12^{0.46}/4.5^{0.66}$ $=$ 8.37
$SF = 8.37/5.96$ $=$ 1.40 **(2)**

Safety factor is high enough to Top Coal provided that the operation is conducted on the **retreat.** **(2)**

4/. Calculate Tonnages produced by the two options.

4.1 Stooping

$12 \times 12 \times 3 \times 1.6 \times 0.6 =$ **414 tonnes** **(1)**

4.2 Top Coaling

$18^2 - 12^2 \times 1.5 \times 1.6$ = **432 tonnes** **(1)**

Both mining options produce similar tonnages. **Sub Total = 10**

5/. Select the Mining Option and Motivate the choice.

Top Coaling recommended.

5.1 Motivating Factors. (Examples)

5.1.1 Caving of the 15.5 m thick sandstone roof is likely to be difficult and redistribute load to the pillars causing a high stress environment should stooping be practised. (1)

5.1.2 Top Coaling can be conducted relatively safely with drill and blast methods where stooping, particularly in this environment, is best conducted with a continuous miner, i.e. Top Coaling allows a realistic choice of equipment. (1)

5.1.3 Top Coaling is a lower risk mining method than stooping, and will not damage the surface or the water table. (1)

5.1.4 Top Coaling can be, cheaper, more productive and easier to control than stooping. (1)

**Sub Total = 4**

6/. Determine the effect of a 0.3 m wider bord width in the existing workings.

6.1 Calculate the initial safety factor for the wider bord

$Ps = (7.2) . (11.5)^{0.46}/3^{0.66}$ = 10.81

$Pl = (0.025) . (106) . 18^2/11.5^2$ = 6.272

$Sf = 10.81/6.272$ = 1.72 (1)

Still high enough to allow secondary extraction to take place. (1)

6.2 Calculate the final safety factor for Top Coaling

$Ps = (7.2) (11.5)^{0.46}/(4.5)^{0.66}$ = 8.27

$Pl = (0.025) . (106) . 18^2/(11.5)^2$ = 6.272

$Sf = 8.27/6.272$ = 1.32 (1)

Final safety factor too low to allow Top Coaling to take place if 1.5 m of coal is mined. (1)

**Sub Total = (4)**

7. Describe what effect a 15.5 m thick sandstone will have on the mining method selected. (Very general)

7.1 Stooping

The sandstone is unlikely to break readily and will probably redistribute load onto the pillars in the face line making conditions very difficult.

Panel spans will need to be fairly wide (no need to determine them) and barrier pillars need to be extracted or softened, etc.

7.2 Top Coaling

No detrimental effect.

May result in little or no final support being required. Etc,.

**Sub Total = 2**

**Total = 20**