G#7

CHAMBER OF MINES SERVICES (PROPRIETARY) LIMITED

15 July 1997

ROCK ENGINEERING CIRCULAR NO. 20/97 (INFORMATORY)

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CERTIFICATE IN ROCK MECHANICS - MAY 1997

Please find copies of examination papers for the Certificate in Rock Mechanics which were written in May 1997, together with suggested answers and examiners' comments.

S BRUNGER
MANAGER : EXAMINATION ADMINISTRATION

Enclosure:

Exeirc/Grmcirc

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS & COAL OPTIONS

PART 1 - THEORY 12 May 1997

EXAMINER: Mr GS Esterhuizen

MODERATOR: Mr KR Noble

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

ANSWER ALL QUESTIONS

A pass mark is 60 per cent.

References are not permitted.

Hand-held electronic calculators may be used. (No pre-programming.)

Put your examination number of 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.

Write on one side of the paper only.

Show all calculations on which your answers are based.

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

Unless stated otherwise, assume the density of quartzite is 2 700 kg/m^3, the Poisson ratio is 0,2 and the modulus of elasticity is 72 GPa.

PART 1 - THEORY

QUESTION 1

Intact rock strength

(a) A number of compression tests were carried out on 50 mm diameter samples of quartzite.
The results were as follows (results in MPa):

Test:	1	2	3	4	5	6	7	8	9
σ_3	0	0	0	5	5	5	10	10	20
σ_1	180	183	175	201	198	207	231	244	269

Make use of the graph paper to plot the test results and to determine the uniaxial compressive strength of the rock, the friction angle and the cohesion. The equations on the attached page may be of assistance.

10 marks

(b) You have determined that the above rock tends to split by extension fracturing when the extension strain (negative strain) is greater than $-0{,}03 \times 10^{-3}$. Determine the minimum strain for test No. 6 in the above table, and comment on whether the specimen may have failed owing to the extension strain. The intact rock has an elastic modulus of 52 GPa and a Poisson's ratio of 0,22.

5 marks

(c) Which of the following failure criteria should provide the best representation of the rock strength in the above case: Coulomb criterion or Hoek-Brown criterion? Motivate your answer.

5 marks

TOTAL 20 marks

PART 1 - THEORY

QUESTION 2

Jointed rock and rock mass behaviour

(a) When creating excavations in jointed rock it is always recommended that the support be installed as close as possible to the advancing face. Refer to the behaviour of joints under shear to justify this practice.

5 marks

(b) The dilation caused by joints when they shear can have a stabilising effect. Explain with the aid of a sketch how this dilation may assist in improving the stability of an excavation in jointed rock.

5 marks

(c) Make use of the attached classification table to classify a rock mass for which the following data are known:
The rock mass contains one well developed joint set which dips at 70° to the South. A few randomly oriented joints have been observed. A tunnel will be developed from East to West through this rock mass.
Intact rock uniaxial compressive strength: 162 MPa.
Rock Quality designation: 88%
Joint spacing: 1,5 to 2 m
Joint condition: Slightly rough with infilling of 1 to 2 mm
Groundwater: Dry
Make use of the classification parameters to calculate the uniaxial compressive strength of the rock mass using the Hoek-Brown criterion. The m-value for intact rock was found to be 12,5 based on triaxial strength tests. Comment on the validity of the strength which you have just calculated. The equations on the attached page may be useful.

10 marks

TOTAL 20 marks

PART 1 - THEORY

QUESTION 3

Stresses in the earth and monitoring

(a) Determine the horizontal component of the tectonic stress if the following stresses were measured at a depth of 500 m in norite:
Horizontal stress 22 MPa in all directions
Vertical stress 15,7 MPa
The norite rocks have an elastic modulus of 88 GPa, a Poisson's ratio of 0,25 and a density of 3 200 kg/m^3. Assume g = 9,81 m/s^2.
5 marks

(b) The measurement of stress in rock is a task which must be carried out with great care. Name and discuss three factors which may cause inaccurate stress measurement results when using a triaxial strain gauge.
6 marks

(c) You have been given the task of monitoring a vertical shaft whilst mining is taking place in the vicinity of the shaft. It is not expected that the shaft will be damaged, but as a cautionary measure, the management would like to know whether there are any risks to safety and equipment during the mining operation which will take approximately 18 months to complete. What would you monitor, what type of instruments would you use and what monitoring programme would you recommend?
9 marks

TOTAL 20 marks

PAPER 1 - THEORY

QUESTION 4

Analytical and numerical models

(a) A vertical shaft with a diameter of 6 m has been excavated by a boring machine. It is intended to drill vertical ore passes close to this shaft. You have told the mine design staff that the ore passes should be at least 20 m away from the shaft. However, they are reluctant to abide by your recommendation and want to place the ore passes 10 m away from the shaft (skin to skin) as shown in figure 4.1. Make use of the equations for the stresses around circular excavations to demonstrate that your recommendation is valid.

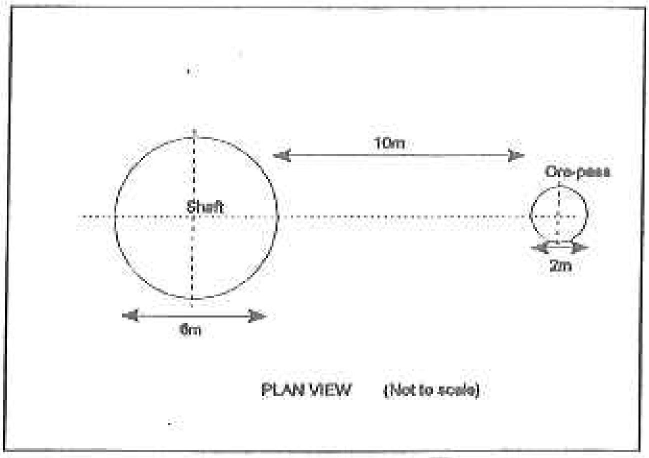


Figure 4.1 Plan view of proposed shaft and ore-pass

The following data are available. Horizontal k-ratio = 1 (Hydrostatic), horizontal stress = 50 MPa, estimated large scale strength of rock = 140 MPa. The formula for maximum tangential stress at boundary of circular excavation is on the attached page.

The proposed layout is as shown in figure 4.1
The equations for stresses at a point in the rock mass near a circular excavation for a hydrostatic stress field are on the attached page.

q is the field stress, *r* is the radius of the excavation and *R* is the radial distance to the point of interest.

10 marks

(b) Assume that the stresses at the proposed ore pass position are high enough to cause rock failure. Sketch the approximate location and type of failure of the surrounding rock that can be expected, and also explain why this failure would have more serious consequences in the ore pass than in a tunnel for example.

5 marks

(c) You intend to model the above shaft and ore pass using a two-dimensional elastic numerical model. State briefly the shortcomings of such a model and also state how the extent of potential failure around the excavations can be determined using the elastic model.

5 marks

TOTAL 20 marks

QUESTION 5

The following stresses were computed at a point 1 m into the sidewall of a tunnel, using a two dimensional stress analysis program:
$\sigma_x = 4$ MPa, $\sigma_y = 192$ MPa, $\tau_{xy} = 44$ MPa.
The x-axis is horizontal. The program assumes plane strain conditions. The rock properties are as follows:
$E = 65$ GPa, $\nu = 0{,}18$

(a) Determine the out of plane stress and determine whether this stress is the minimum principal stress.

7 marks

(b) Calculate the strength of the rock at the above point and determine whether it will fail if the following data are available for the Coulomb failure criterion:
cohesion = 12 MPa, friction angle = 32°. Indicate the orientation of the Coulomb failure plane relative to the excavation sidewall.

3 marks

TOTAL 10 marks

ROCK MECHANICS PART 1 Theory MAY 1997

Q1 a) Plot of results should show $\phi \simeq 35-40°$

and $c \simeq 35$ MPa

the equation $\sigma_c = \dfrac{2c\cos\phi}{1-\sin\phi} = \dfrac{2 \cdot 35\cos 40°}{1-\sin 40°} = 150$ MPa.

b) ε_3 for test no 6 :

In triaxial test $\sigma_2 = \sigma_3$ N.B. 3D situation!

$$\varepsilon_3 = \frac{1}{E}\left(\sigma_3 - \nu(\sigma_1 + \sigma_2)\right)$$

$$= \frac{1}{52000}\left(5 - 0{,}22(207+5)\right)$$

$$= -0{,}8 \times 10^{-3}$$

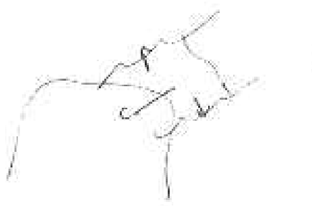
Yes: likely to have failed in extension

c) Hoek Brown - because Coulomb assumes rock fail in shear - this is not the case if specimens fail by splitting. H & B criterion does not assume a failure mechanism, but merely attempts to fit the actual results.

Q2 a) Joint strength τ reaches peak after small displacement

If blocks allowed to move shear strength destroyed and becomes less stable. Early support will assist in keeping shear strength in pre-peak range & preserve peak strength

b) In ug excavation when joint starts to move dilation occurs due to roughness, if



dilation forces increase normal stress on shearing planes $\Rightarrow$ increases shear resistan

2

c) Rock classification using RMR

UCS: 162 ———— 12
RQD: 88 % ———— 17
Joint Sp: 1,5 - 2 ———— 25
Join Cond: SR fill 1-2mm ———— 12
GW: Dry ———— 10

Total: 76

Individual ratings may differ based on personal interpretat

$m_i = 12,5$ given

Adjustment unfav -

UCS if $\sigma_3 = 0$

$\Rightarrow \sigma_c = UCS \times \sqrt{s}$

$= 42,7 MPa.$

$s = e^{\left(\frac{RMR - 100}{9}\right)}$

$= 0,06948$

$m = m_i e^{\left(\frac{RMR - 100}{24}\right)}$

$= 4,599$

Strength is only valid for large rock sample where side dimension is say 10x joint spacing (ie 10-20 m block)

Q3 a) $q = \rho g h = 3200 \times 9,81 \times 500 = 15,7 MPa.$

Poisson effect $\sigma_h = \frac{\nu}{1-\nu} \sigma_v = \frac{0,25}{0,75} \sigma_v = 5,2 MI$

$\Rightarrow$ Tectonic effect $22 - 5,2 = 16,8 MPa$ Horiz

b) 1) Grain size of rock (eg quartz pebbles in conglomerate) local effects may override strain measurements

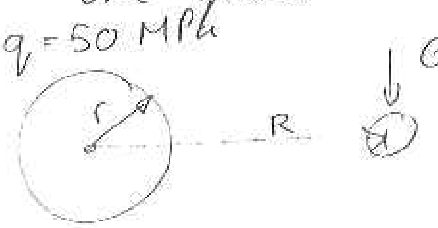
2) Poor contact between strain gauge & rock surface - difficulty in using glue down a small hole

3) Incorrect orientation of strain gauges - difficulty in working in small hole

4) Local fractures in rock - small scale discontinuities will affect small scale measurements.

3(c) Main cause of damage is differential strain which may damage steelwork / lining. Need to measure vertical & horizontal displacement
- Install pegs for survey to measure vertical
- Need accurate steel tape extensometer
- Institute logging system during shaft exams to note changes in steelwork / buckling / cracks in concrete lining
- Programme - weekly inspections during shaft exam + measurement of pegs - plot and present graphically.
- Borescope to see behind lining (9)
- Seismic monitoring to see if potential damage near shaft - active structures etc

Q4 a) Calc effect of shaft on stress field at ore pass



$R = 3 + 10 + 1 = 14\text{m}$

$r = 3$

$$\sigma_\theta = q\left(1 + \frac{r^2}{R^2}\right)$$

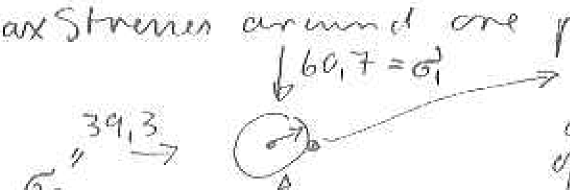
$$= 50\left(1 + \frac{3}{14}\right)$$

$$= 60{,}7 \text{ MPa}$$

$$\sigma_r = 50\left(1 - \frac{3}{14}\right)$$

$$= 39{,}3 \text{ MPa}$$

Max Stresses around ore pass:



σ_{max} at side of o/p. $= 3\sigma_1 - \sigma_3$

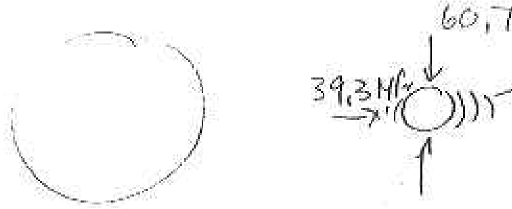
$= 3 . 60{,}7 - 39{,}3$

$= 142{,}6 \text{ MPa}$

If no shaft effect max stress at ore pass will be: $\sigma_{max} = 3 . 50 - 50 = 100 \text{ MPa}$ (10

$\Rightarrow$ Shaft causes 42,6 increase in stress

4b)



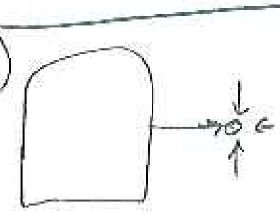
fracturing will be in form of dog earing here

More scraling in ore pass because ore tipped will remove fractured rock & cause further fracturing to continue - could carry on till ore pass holes into shaft! (5)

4c) Elastic model does not model failure, assumes rock is continuous, etc. Will not take into account already failed material. Failure extent can be estimated using say H & Brown criterion and apply it at "benchmark" points in surrounding rock. (5)

Question 5

a)



$\sigma_x = 4$
$\sigma_y = 192$
$\tau_{xy} = 44$

First calc out of plane stress:

$$\varepsilon_z = 0 = \frac{1}{E}\left(\sigma_z - \nu(\sigma_x + \sigma_y)\right) \text{Ho}$$

$$\Rightarrow \sigma_z = \nu(\sigma_x + \sigma_y) = \underline{35,3 \text{ MPa}}$$

This is a principal stress.

Determine principal stresses in 2D plane.

$\sigma_1 = \frac{1}{2}$ ... not really required

$$\sigma_2 = \tfrac{1}{2}(\sigma_x + \sigma_y) - \tfrac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}$$

$$= \tfrac{1}{2}(196) - \tfrac{1}{2}\left(\sqrt{188^2 + 4(44)^2}\right)$$

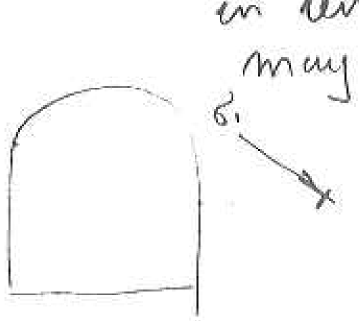
$$= 98 - 103,8$$

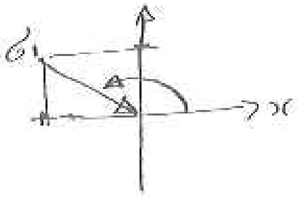
$$= \underline{-5,78 \text{ MPa}}$$

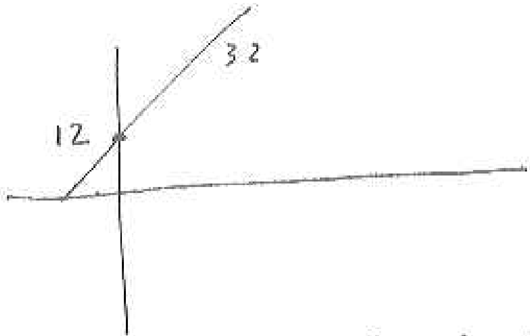
$\Rightarrow \sigma_z$ is not minimum principal stress!

5b) Calc strength:

Rock will fail in tension or may shear:







Angle of θ_1 relative to x-axis:

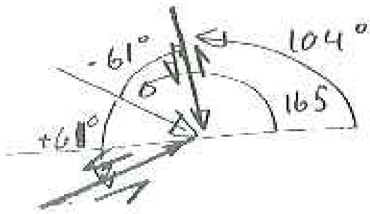
$$\theta_1 = \frac{1}{2}\arctan\frac{2\tau_{xy}}{(\sigma_x - \sigma_y)}$$

$$= \frac{1}{2}\arctan\left(\frac{88}{-188}\right)$$

$= 25°$ (2nd quard)

ie $= 165°$

Shear plane is $45° + \phi/2$ from this orientation: ie $45 + 16 = 61°$



Two shear planes at 104° and 226° from horizontal

PAPER 1

EXAMINERS COMMENTS

QUESTION 1 Nobody used 3D Hooke equation!

QUESTION 2 Quite well answered

QUESTION 3 —"—

QUESTION 4 Only two candidates got this one!

QUESTION 5 Second part poorly answered.

QUESTION 6

QUESTION 7

QUESTION 8

QUESTION 9

QUESTION 10

GENERAL

SIGNATURE

CSIR GEOMECHANICS CLASSIFICATION OF JOINTED ROCK MASSES

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	PARAMETER		RANGES OF VALUES						
1	Strength of intact rock material	Point load strength index	> 8 MPa	4-8 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial compressive strength	> 200 MPa	100-200 MPa	50-100 MPa	25-50 MPa	10-25 MPa	3-10 MPa	1-3 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90%-100%	75%-90%	50%-75%	25%-50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of joints		> 3m	1-3m	0.3-1m	50-300 mm	< 50 mm		
	Rating		30	25	20	10	5		
4	Condition of joints		Very rough surfaces Not continuous No separation Hard joint wall rock	Slightly rough surfaces Separation < 1 mm Hard joint wall rock	Slightly rough surfaces Separation < 1 mm Soft joint wall rock	Slickensided surfaces or Gouge < 5 mm thick or Joints open 1-5mm Continuous joints	Soft gouge > 5mm thick or Joints open > 5mm Continuous joints		
	Rating		25	20	12	6	0		
5	Ground water	Inflow per 10m tunnel length	None		< 25 litres/min	25-125 litres/min	> 125 litres/min		
		Ratio joint water pressure / major principal stress	OR 0		OR 0.0-0.2	OR 0.2-0.5	OR > 0.5		
		General conditions	OR Completely dry		OR Moist only (interstitial water)	OR Water under moderate pressure	OR Severe water problems		
	Rating		10		7	4	0		

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

Strike and dip orientations of joints		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100—81	80—61	60—41	40—21	< 20
Class No	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK MASS CLASSES

Class No	I	II	III	IV	V
Average stand-up time	10 years for 5m span	6 months for 4 m span	1 week for 3 m span	5 hours for 1.5 m span	10 min. for 0.5 m span
Cohesion of the rock mass	> 300 kPa	200-300 kPa	150-200 kPa	100-150 kPa	< 100 kPa
Friction angle of the rock mass	> 45°	40°-45°	35°-40°	30°-35°	< 30°

TABLE 6 - THE EFFECT OF JOINT STRIKE AND DIP ORIENTATIONS IN TUNNELLING

Strike perpendicular to tunnel axis				Strike parallel to tunnel axis		Dip 0°-20° irrespective of strike
Drive with dip		Drive against dip				
Dip 45°-90°	Dip 20°-45°	Dip 45°-90°	Dip 20°-45°	Dip 45°-90°	Dip 20°-45°	
Very favourable	Favourable	Fair	Unfavourable	Very unfavourable	Fair	Unfavourable

$$\tan\psi = \frac{1 + \sin\phi}{1 - \sin\phi}$$

$$\sigma_c = \frac{2c\cos\phi}{1 - \sin\phi}$$

$$\frac{m}{m_i} = e^{\left(\frac{RMR - 100}{24}\right)}$$

$$s = e^{\left(\frac{RMR - 100}{9}\right)}$$

$$\sigma_1 = \sigma_3 + (m\sigma_c\sigma_3 + s\sigma_c^2)^{\frac{1}{2}}$$

$$\sigma_{max} = 3\sigma_1 - \sigma_3$$

$$\sigma_r = q\left(1 - \frac{r^2}{R^2}\right)$$

$$\sigma_\theta = q\left(1 + \frac{r^2}{R^2}\right)$$

$$\tau_{r\theta} = 0$$

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS OPTION

PART 2 - APPLICATIONS 13 May 1997

EXAMINER: Mr WJ de Maar

MODERATOR: Mr M Roberts

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

ANSWER ALL QUESTIONS

A pass mark for this paper is 60 per cent.

References are not permitted.

Hand-held electronic calculators may be used. (No pre-programming).

Put your examination number of 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.

Write on one side of the paper only.

Show all calculations on which your answers are based.

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

Graph paper is available from the invigilator.

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 1

(a) Caving is used selectively in certain narrow tabular deposits with considerable success.

i) Describe the caving method commonly used and its associated support. 4 marks

ii) What rock conditions promote caving? 2 marks

iii) What rock mechanics benefits are derived from caving? 3 marks

iv) What practical problems are encountered in cave mining? 3 marks

(b) The management of a gold mine is considering the introduction of face support at a maximum distance of 2 m from the face after the blast. The flat-dipping tabular orebody is at a depth of 2 000 m below surface. The average stoping width is 1,5 m.

As the mine's rock mechanics officer you have been asked to give recommendations. What aspects should you consider in designing stope support, keeping the guidelines for Codes of Practice for support in mind? 13 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 2

(a) A 75° dipping fault was intersected during the development of a 10 m high hoist chamber in quartzitic rock. The fault runs parallel to one of the sidewalls, daylighting 1 m above the floor of the hoist chamber. There is a smooth horizontal bedding plane 1 m from the top of the hoist chamber. Tests on the fault plane gave a cohesion of 1,5 kN and an angle of friction of 40°.

i) Calculate the minimum additional restraining force necessary to stop the wedge from sliding into the hoist chamber. 3 marks

ii) What is the safety factor for the wedge on the fault plane? What safety factor is regarded as acceptable? 3 marks

iii) Give an excavation and support sequence for the hoist chamber. 4 marks

(b) Strike stabilising pillars have been introduced on a number of deep level gold mines. Critically discuss the implementation of strike stabilising pillars taking examples from the mining industry. 10 marks

(c) i) Calculate the Rock Wall Condition Factor (RCF) for the following parameters:

$\sigma_1 = 40$ MPa $\sigma_3 = 20$ MPa $\sigma_c = 70$ MPa and F = 1,0

3 marks

ii) What in your opinion should the recommendation be according to the calculated RCF? 2 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 3

(a) In an elastic medium the convergence of an underground parallel-sided panel is given by

$$Sz = \frac{2(1-v)\,q}{G} \sqrt{l^2 - x^2}$$

where
v = Poisson's ratio
G = Modulus of rigidity
q = vertical stress
l = half span of panel
x = distance from panel centre
Sz = elastic convergence

Calculate the elastic convergence 20 m from the face of a panel 580 m wide at a depth of 3 100 m below surface. The stoping width is 1,5 m. The modulus of rigidity is 60 GPa and Poisson's ratio is 0,2. 4 marks

(b) A horizontal circular tunnel is bored in quartzite at a depth of 2 800 m below surface. The relative density of the overlying strata is 2,7. The horizontal to vertical stress component is half (k = 0,5).

i) From your practical experience where would you expect fractures to be located and to what depth around the tunnel? Discuss the support requirements for this bord tunnel. 5 marks

ii) Sketch the complete state of stress of the surface of the tunnel. 2 marks

(c) The stability of pillars depends on the pillar itself and the surrounding strata.

i) What are the criteria which determine the stability of a pillar and the surrounding strata? 4 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 3 (Cont.)

ii) Sketch a load deformation curve of a typical yield pillar with a width to height ratio of 2, and name the various stages of the load deformation curve. 3 marks

iii) Indicate with simple sketches what is meant by controlled and uncontrolled pillar failure. 3 marks

(d) Describe what a control pillar is and what purpose it serves. 2 marks

(e) What is pre-splitting and why is it used? 2 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 4

(a) The attached plan shows a portion of the "Lucky" Gold Mine. The mine has unpay zones, structural disturbances and high seismicity. A scattered mining method is employed.
Haulages are pre-developed and are situated 25 m below the reef plane. The stoping width is 1 m.

(i) Discuss whether the scattered mining method is appropriate. Give reasons for your answer. 2 marks

(ii) Discuss the location of haulages below the reef plane. What alternative can you suggest? 2 marks

(iii) How would you extract the block of ground below the dyke between the A6 and A7 connections? 2 marks

(b) Pre-conditioning is presently researched in deep level gold mines.

i) Discuss the rock mechanics principles that are involved. 3 marks

ii) Briefly describe the two different methods of pre-conditioning of a stope face. 3 marks

iii) What is the outcome in stopes where pre-conditioning is on trial? 3 marks

(c) A seismic event occurred ahead of a stope face at depth. Damage to the area consisted of large falls of ground in the stope face over approximately 15 m of the length of the panel, and to a height of approximately 1,2 m. The rock in the stope face showed fragmentation of, on average, 3 cm to 5 cm over most of the area, with one large block which fell out on a joint plane-bedding plane combination. The event was located on the mine's seismic system.

i) Give a list of typical parameters which can be obtained from the seismic system. 4 marks

PART 2 - APPLICATIONS - METALLIFEROUS

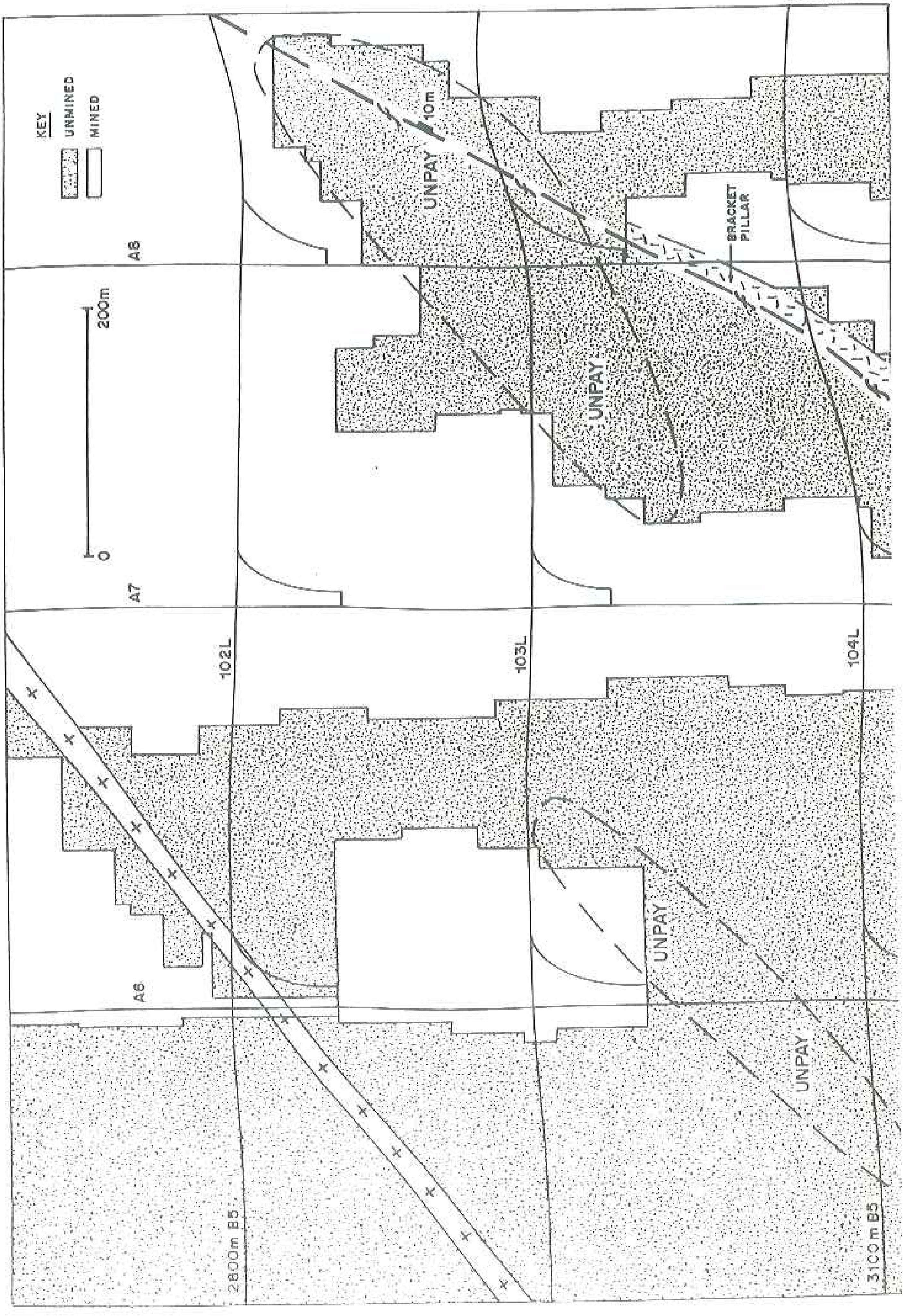
QUESTION 4 (Cont.)

ii) Explain the significance of the various parameters and how the information can be used to improve the mining layout and support design in order to reduce the damage as a result of seismicity.

6 marks

TOTAL 25 marks

Question 4A


KEY
UNMINED
MINED
200m
0
A8
A7
A6
102L
103L
104L
2800m B5
3100m B5
10m
UNPAY
UNPAY
UNPAY
UNPAY
BRACKET PILLAR

Rm mgt P2
May 199

QUESTION 1 - ANSWERS

a)

i)

- weak hangingwall is collapsed 6 - 7m behind the face
- timber sticks and hydraulic props on the face
- hangingwall slot is blasted 10 - 12m behind the face to induce the cave
- timber sticks must be blasted out behind the 3 rows of hydraulic props
- continuous and rapid face advance

ii)

- geology and highly laminated hangingwall strata
- shear movement along bedding planes in the hangingwall
- "plastic" flow of the hangingwall

iii)

- stope support strategy to cater for weak ground condition
- decrease of stress levels on the face
- decrease in level of seismicity
- decrease of stress damage on the face
- more competent hangingwall conditions in the face area

iv)

- the effectiveness of installed support
- containment of blast damage to the hangingwall
- lack of continuous and rapid face advance causing cave overruns and strata control problems on the face
- cave hangups causing increased stress damage on the face and ahead of the face
- very competent hangingwall strata

b) The answer should broadly consider aspects related to the guidelines for Codes of Practice for Support

- 5 year history of rock related accidents
- determine the degree of risk for rockfalls and rockbursts
- determine the specific geological, mining method, people and external hazards
- define strategies to manage the risk
- the strategy to include measures to avoid failures, the overall mining method and sequencing to be followed
- the stope and gully support system design to include: energy absorption capacity of support members (depends on rockburst conditions), spacing of support members, support resistance required by the hangingwall, areal coverage of the support member and the anticipated stope closure.

RM P2 (M) May 1997

QUESTION 2 - ANSWERS

a) (i) Disturbing force parallel to the fault plane

W = density x volume = 231,12kN per metre

D = W Sin 75° = 217,18kN

Resisting forces perpendicular to the fault plane

R = cA + Wcos75° tan 40°

R = 1,5 + 5,0 = 51,69kN

Minimum additional resisting force required is 217,18 - 51,69 = 165,49kN

(ii) Safety Factor is $\frac{\text{Resisting force}}{\text{Disturbing force}} = \frac{51,69}{217,18}$

SF = 0,238

A safety factor of 1,5 is regarded as acceptable.

(iii) Mining the top cut first and supporting the hanging wall of the top cut. Then progressing downwards taking 3 cuts in total.

b) Strike Stabilising Pillars (SSP)

- Each stabilising pillar and each underground situation is unique
- Western Deep Levels is the only mine where SSP have proved to be unstable (foundation failure - back area seismicity)
- All other deep level mines employing SSP's have derived benefits
- Pillars at Western Deep Levels appear to bear greater load than other mines at the same depth
- Pillar punching at Western Deep Levels (elastic displacements)
- Average pillar stress not to exceed 600 MPa or 2 x σ_c
- Geological structures should be included in SSP to increase extraction ratios
- SSP impose the disadvantages of mining inflexibility and back area pillar seismicity
- SSP with leads and lags of longwalls on either side result in enhanced levels of seismicity
- Average pillar stress, energy release rate, extraction ratio and width to height ratio are used for strike stability pillar design. These criteria are inadequate as pillars are composed of failed and intact rock.
- SSP usually have a width to height ratio in excess of 20
- Extraction ratio of 85% at 2000m depth to 65% at 4000m depth
- Backfill should complement strike stabilising pillars below 2000m depth.

c) (i) RCF $= \frac{3\sigma_1 - \sigma_3}{F\,\sigma_c} = \frac{120 - 20}{1,0 \times 70} = \frac{100}{70} = 1,4$

(ii) The level of support must be increased.

RM P2 (mel)

QUESTION 3 - ANSWERS

a) $\frac{2(1-0,2)}{60\ 000}$ x 83,7 $\sqrt{290^2 - 270^2}$

= 0,236m

b) (i)

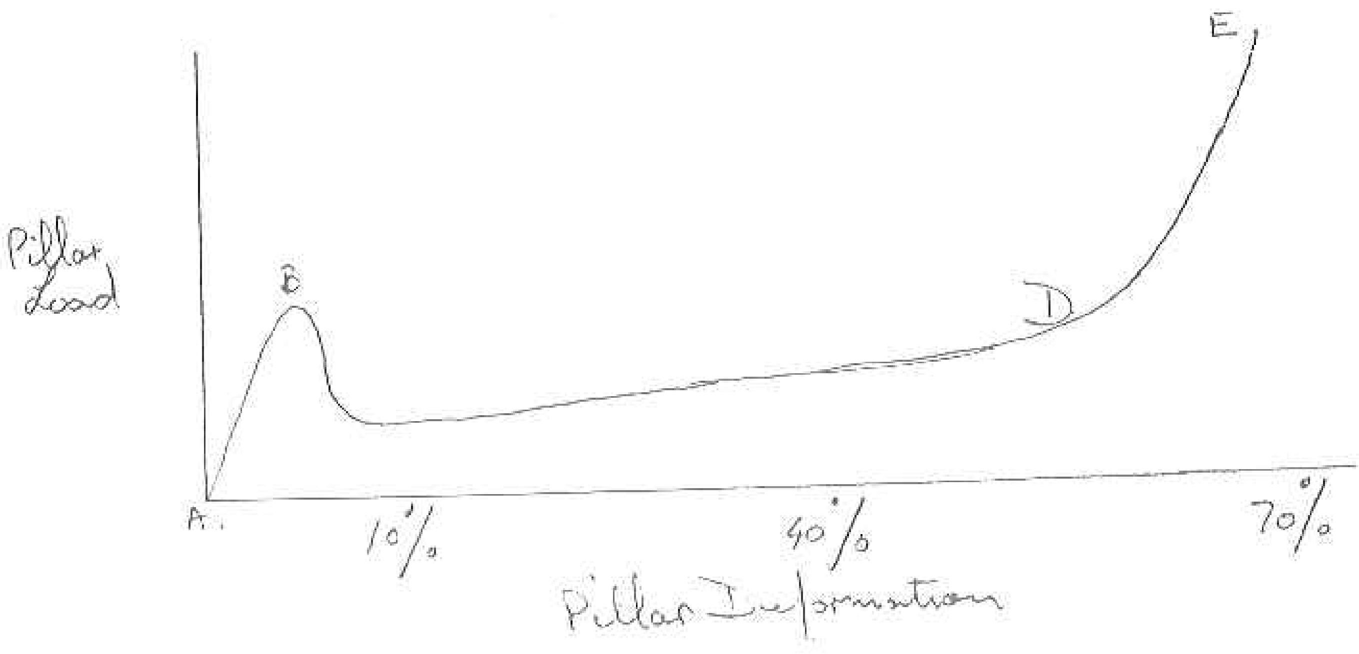
- In the sidewall of the circular tunnel
- Fractures should be slightly curved and parallel to the sidewall of the tunnel
- The fractures extend horizontally to approximately one diameter of the tunnel

(ii) The hangingwall stress drops to approximately 0,5 times the vertical stress and the sidewall stress increases to approximately 2,5 times the vertical stress.

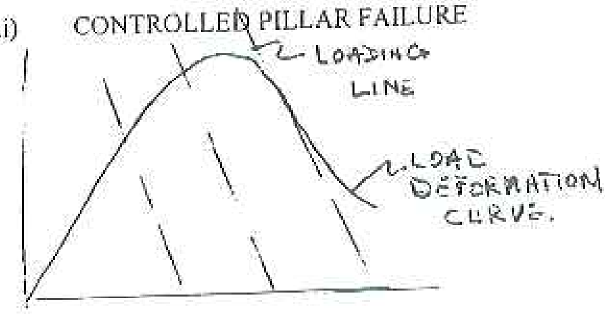
c) (i)

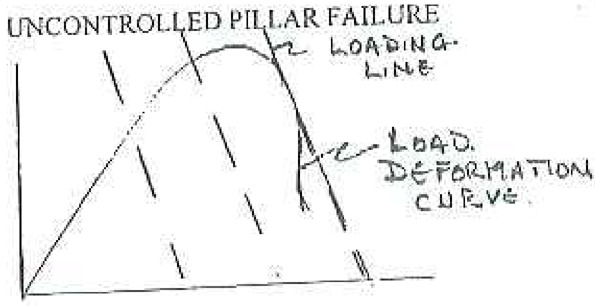
- Material of which the pillar is composed
- The width to height ratio of the pillar
- Discontinuities within the pillar and surrounding strata
- The stiffness of the surrounding strata
- The size of the pillar
- The load on the pillar

(ii) AB - Pre-peak
BC - Post peak
CD - Residual Strength
DE - Strain Hardening



(iii)





d)

- Control pillars have w:h ratio in excess of 10
- Control pillars are indestructible
- Used for compartmentalization in shallow mines
- Final line against regional collapse
- Resists surface subsidence

e)

- Pre-splitting involves the creation of a smooth stable face after the blast by drilling holes along the boundary line of the final face
- Holes are lightly charged
- Pre-split holes are fired and connect with cracks prior to the main blast

QUESTION 4 - ANSWERS

(a)

(i) The circumstances dictate that a scattered mining technique is used or possibly sequential mining. The partial extraction of the orebody needs a number of attaking points. To some degree partial extraction assists with minimising ERR and ESS. Leaving strategic pillars between connections will keep stress concentration levels down.

(ii) The pre-developed haulages are unlikely to cope with the high induced stress levels and extreme changes in stress. The orebody does not allow post developed haulages. Consideration should be given to:

- waste mining above haulages to destress them where unpay zones occur
- bolstering the support of haulages to cope with stress changes
- locating haulages deeper into the footwall

(iii) Put up a diagonal raise from the A6 to the A7 connection leaving a substantial bracket pillar on the dyke. History of mining north of the dyke indicates difficult mining conditions.

- Mine downdip from the diagonal.
- The sequencing of this block of ground must be confirmed by numerical modelling.
- As an alternative, A6 and A7 connections to be holed just below 102 level. The block of ground can be updipped leaving a substantial bracket pillar on the dyke. (Mining stops when conditions deteriorate).
- Numerical modelling should confirm the safest way of extracting the block of ground.

b)

(i)

- redistribution of stress away from the working face

- reducing the risk of a face burst
- lower stress ground is able to absorb more energy from distant seismic events
- strain energy release is facilitated by stable sliding of blocks past each other.

(ii) Perpendicular Holes

- short holes drilled perpendicular to the face.
- 3m long holes (38-42mm diameter) spaced 3m apart in the middle of the face.
- ANFO explosives is recommended
- one metre of stemming for hole consisting of clay, bentonite or sand

Parallel Holes

- face parallel holes drilled up to 5,5m from face
- holes are 89mm in diameter and extend the length of the face
- emulsion explosive is recommended
- crushed rock and clay stemming

(iii)

- reduction in the incidence of rockbursts
- the number of severe rockbursts were reduced
- increased drilling and charging up time
- increase in face advance
- improved hangingwall conditions

c)

(i)

- Location of seismic event
- Time of seismic event
- Magnitude of seismic event
- Seismic moment
- Radiated energy
- Source dimension
- Calculation of ESS

c)

(ii)

Location

- Displacement of rock in relation to mining geometry
- Locating "hot spots"
- Locating adverse structure
- Locating problematic mining layout
- Locating area for possible rescue operation

Time

- Frequency of events
- Related to mining activities.

Magnitude

- Relates to mechanism (crush or shear)
- Larger magnitude events produce more potential damage
- Adequacy of support (possible improvement)
- Charge stope layout and support
- Possible withdrawal of personnel

Moment

- The seismogram can indicate direction of movement (if discontinuity is identified).
- Also identifies area where instability occurred.
- Mining layout and support to be changed according to predicted seismicity.

Energy

- Seismogram indicates the potential energy of the event.
- Energy must be related to support resistance (may be changed)

Source

- Identifies the area from where this seismic event took place.
- Identifies potential area of concern. (geology or mining layout)
- Identifies mining and support measures that must be taken to minimise seismicity and damaging effects.

PAPER 2 (MET)

EXAMINERS COMMENTS

QUESTION 1 Disappointing answers, particularly the aspects that relate directly to the Codes of Practise!

QUESTION 2 Poorly answered It was surprising to see how few candidates knew anything about support design!

QUESTION 3 In general the question was well answered

QUESTION 4 Reasonably answered.

QUESTION 5

QUESTION 6

QUESTION 7

QUESTION 8

QUESTION 9

QUESTION 10

GENERAL

SIGNATURE

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

COAL OPTION

PART 2 - APPLICATIONS	13 May 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.

References are not permitted.

Hand-held electronic calculators may be used. (No pre-programming.)

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.

Write on one side of the paper only.

Show all calculations on which your answers are based.

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

Graph paper is available from the invigilator.

PART 2 - APPLICATIONS - COAL

QUESTION 1

(a) Calculate the maximum tensile stress in the following cases:

i) Bord = 6 m. Beam thickness = 0,3 m consisting of an impervious sandstone. 1 mark

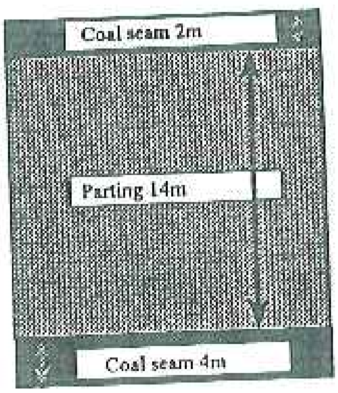
ii) Bord = 5 m. Beam thickness = 0,1 m consisting of an impervious sandstone 1 mark

If the compressive strength of an impervious sandstone is 40 MPa, comment on the stability of the roof in these two cases. 1 mark

If in the first case a gas pressure of 700 kPa is applied above this layer what would be the resulting tensile stress and what actions would you take if any? 3 marks

(b) A section through two mineable seams and the parting is shown below. Both seams will be mined by bord and pillar methods, the upper seam preceeding the lower. A minimum safety factor of 1,6 is to be achieved and a 6 m bord will be mined using a continuous miner. Calculate the required pillar centres for both seams.

Depth below surface 109 m

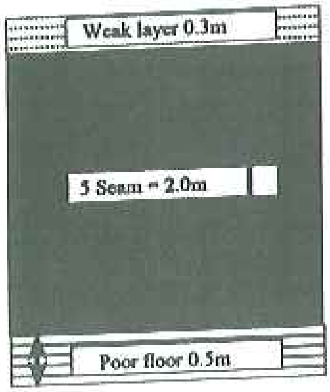


7 marks

PART 2 - APPLICATIONS - COAL

QUESTION 1 (Cont.)

(c) Stratigraphy around the seam



A seam is well known for having a very weak floor and sometimes a weak roof layer.
Calculate the percentage contamination by weight in the following cases:

i) The weak layer fails and half the poor floor contaminates the product.
ii) The weak layer does not fail and half of the poor floor contaminates the product.

2 marks

If the yield of the seam is 70% by weight, calculate the total yield in each of the cases.

2 marks

Very briefly comment on the following aspects in the above environment if the seam is to be mined with a continuous miner.

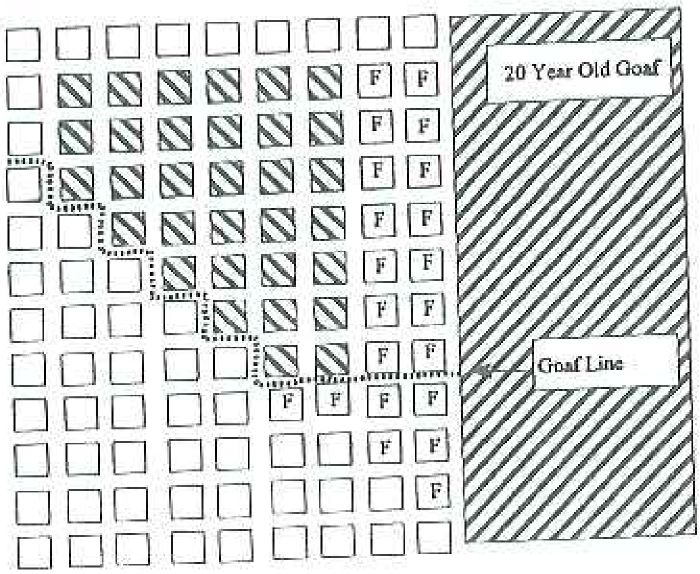
- Pillar design/Stability
- Roof support and how it might impact on mining
- Minimisation of floor contamination
- Geotechnical tests that may be conducted to predict floor behaviour.

6 marks

QUESTION 1 (Cont.)

(d) Pillars having 15 m centres mined on 6,5 m bords at a height of 2,3 m are being stooped at a depth of 84 m. The pillars were initially mined conventionally but are being stooped with a continuous miner. The extraction layout is as shown in the sketch below. Pillars marked with an F are failing in a controlled fashion. They have scaled, and timber breaker lines have failed. Inspection of the pillars, roof and floor does not reveal any obvious weaknesses. Briefly comment on the failures and what you might do to investigate the problem further. What problems may this pose for stooping?

10 marks



(e) A slurry dam is to be constructed above No. 2 seam reserves which lie 25 m below surface (top of the seam). A select horizon of 3,5 m thickness will be mined after the dam is constructed. Dam height will eventually be 20 m.

i. Calculate pillar centres required to achieve a safety factor of 1,7 if a continuous miner is to be used.

5 marks

ii Briefly comment on the design of the underground workings and its effect on the long term stability of the dam.

5 marks

TOTAL 43 marks

QUESTION 2

It is planned to carry out secondary extraction in a 4,3 m thick seam by stooping pillars with a Joy Continuous Miner (drum width 3,3 m). The following information was obtained from the survey department:

Cover depth (m)	120
Centres (m)	23 x 23
Bord width (m)	6,5
Mining height (m)	3,8 (from seam floor)

The panel in question was mined some 5 years ago by conventional drill and blast methods.

The seam is overlain by 0,6 m of highly laminated sandy shale with 4 m of massive, medium grained sandstone above. A complicating factor is the presence of an irregularly occurring thin coal band 0 to 0,2 m thick between the shale and massive sandstone. This coal band is known to carry methane.

Support during development consisted of 3 x 1,8 m long resin point anchored rebar roofbolts per row with 2 m between rows.

The panel is seven roads wide and is orientated in a North-South direction. A study of the 1:1 500 survey plans showed three small faults (0,1 m to 0,2 m throw) within the area of interest with a roughly North-West to South-East trend.

Fresh air will be restored to the area within the next month. However, the manager mining has requested you to carry out a preliminary risk assessment of the operation, prior to your visiting the panel with him.

Identify all major potential rock related hazards and itemise any steps that may be taken to control them.

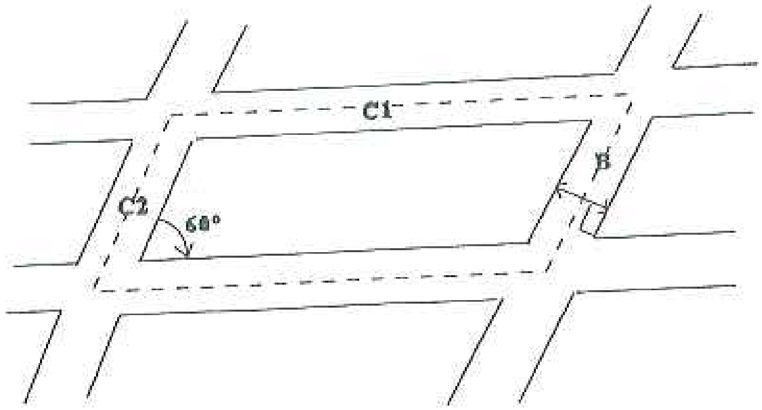
Where further information is required this must also be noted. For the sake of this exercise only rock related hazards/risks need to be considered and may be classified simply as high, medium or low. Your assessment should be presented in table form under the headings below:

Potential Rock related Hazard	Possible Controls	Potential Problems	Additional action/ information needed	Rating

TOTAL 25 marks

PART 2 - APPLICATIONS - COAL

QUESTION 3



(a) The pillar illustrated above has been mined by a continuous miner. Given the following information, calculate its safety factor.

Depth to floor	=	137 m
Mining height (h)	=	2 m
Centres (C1 x C2)	=	22 m by 20 m
Bord width (B)	=	6,5 m

8 marks

(b) Briefly comment on the rock mechanics considerations of the mining layout illustrated above.

6 marks

TOTAL 14 marks

PART 2 - APPLICATIONS - COAL

QUESTION 4

Management wish to maximise extraction in existing workings (apart from main development roadways) prior to developing the mine any further. Existing workings are well contained within barrier pillars and were developed from the floor of the Z seam by drill and blast methods to the following geometry. Bord width 6 m, Mining height 3 m, Pillar width 12 m and depth below surface to the floor of the Z seam 106 m. A generalised geological log of the area is depicted in Fig. 1. The surface is owned by the company and currently used for casual stock grazing. Assume that the maximum percentage extraction obtained by stooping a pillar is 60%, the SG of coal is 1,6 tonnes/m^3 and that no significant deterioration of the existing workings has occurred.

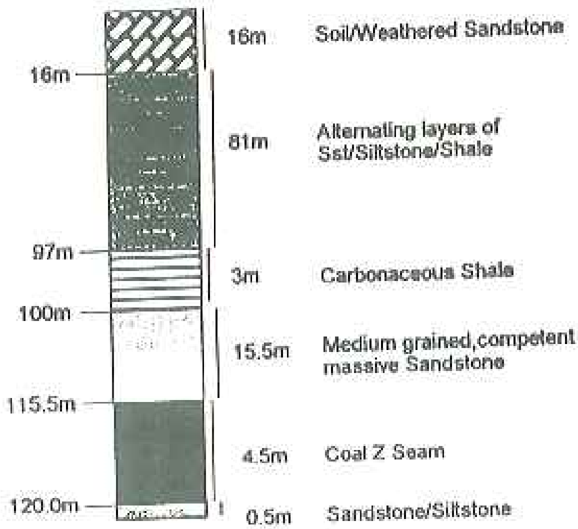


Fig 1 Generalised Geological Log

a) Assess the situation and recommend how best to maximise extraction of the existing workings. 8 marks

b) Motivate your choice of mining method. 4 marks

c) How would a total increase of 0,3 m to the bord width of the existing workings affect your choice of mining method. 4 marks

d) What effect will the 15,5 m thick, massive competent sandstone bed, directly overlying the Z seam have on your choice of mining method? 2 marks

TOTAL 18 marks

Dear Sylvia,

I have reviewed the six papers for the Coal Rock Mechanics examination and agree with the overall assessment by Mr C Oldroyd. While several candidates were given additional marks none obtained the required pass mark.

I reviewed the paper written in Afrikaans with Dr Hagan to ensure that the candidate received a fair review.

Only one candidate performed reasonably well, unfortunately just falling short of the required pass.

Question 1 was a combination of calculations and practical mining and was answered reasonably well by three candidates. As this question was worth 43 marks most time should have been spent on the question. However, it appeared that the candidates spent more time on this question at the detriment of the other questions and hence ran out of time.

Question 2 was a new type of question on rock engineering Risk Assessment. Only one candidate answered this well. Three candidates did not comply with the requested format, however, they were not penalized for this.

Question 3 required calculation and practical mining assessment. Only one candidate answered this question well.

Question 4 required calculation and practical mining assessment. One candidate answered this question very well and two others were reasonable.

The paper was challenging but fair, while additional marks were awarded in most cases I agree with the assessment of the examiner.

Yours Sincerely

Dr Bernard Madden

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS OPTION

PART 3 - GENERAL	14 May 1997
EXAMINER:	Mr CAF Sweet
MODERATOR:	Mr A Naismith

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

ANSWER ALL QUESTIONS

A pass mark for this paper is 60 per cent.

References are not permitted.

Hand-held electronic calculators may be used. (No pre-programming).

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.

Write on one side of the paper only.

Show all calculations on which your answers are based.

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

Graph paper is available from the invigilator.

PART 3 - GENERAL - METALLIFEROUS

NOTES FOR THE CANDIDATE

Read these notes carefully before you start answering the questions.

The problems are not always stated obviously in the questions. Part of your task is to determine from the question the precise nature of the problem. There are no "clear cut" answers. The questions demand that you draw on your formal, academic knowledge and on your experience. Also the questions require you to demonstrate your ability to think your way through a problem, much as you would have to in the real-life situation. You will disadvantage yourself if you work through the answers in a haphazard and unsystematic manner. You are more likely to gain the benefit of the doubt from the examiner and moderator if you approach the problem methodically than if you were to adopt an unstructured and sloppy approach.

Use large, clear, well labelled sketches when necessary. These will aid your thinking as well as make your answer clearer to the examiner and the moderator. Minute, poorly labelled and undimensioned sketches will not have the desired effect.

PART 3 - GENERAL - METALLIFEROUS

QUESTION 1

The following are the dimensions of a required pump chamber in Class 2 (using the CSIR System) ground at a depth of 1 300 meters. You are required to present to management your proposal of how to excavate this safely and efficiently. Your recommendations must include:

i.	Method of Mining	10 marks
ii.	Temporary Support	10 marks
iii	Permanent Support	10 marks
	TOTAL	30 marks

The excavation will be within the shaft pillar:

Length	:	60 m
Width	:	10 m
Height	:	7 m

QUESTION 2

This is a platinum mine on the UG2 horizon and you are the rock mechanics officer.

The proposal has been made to change the hole diameter from 32 mm to 45 mm and thereby reducing the number of holes required to be drilled in a stope. In addition, it is proposed that the hole length be increased to 1,6 m from the existing 1,35 m effective length. The stoping width is 1,6 m and there is a good footwall and hanging parting.

PART 3 - GENERAL - METALLIFEROUS

QUESTION 2 (Cont.)

Comment from a rock engineering viewpoint on:-

a) effect of change in hole diameter — 5 marks

b) effect of the change in hole length — 5 marks

c) change in drilling efficiencies — 5 marks

d) what would recommended explosives and initiation system be? — 5 marks

TOTAL 20 marks

PART 3 - GENERAL - METALLIFEROUS

QUESTION 3

You have recently been appointed been appointed the rock mechanics officer on a deep gold mine on the Far West Rand. You are required to review the stope support system in the stopes following a number of serious fall of ground incidents.

Your Code of Practice for combating rockfalls should list a number of variables that must be considered when evaluating a stope support system.

i) List and briefly discuss these variables
ii) Discuss briefly "Control of Rockfalls"
iii) Discuss briefly "Reduction of Rockburst Damage"

TOTAL 30 marks

QUESTION 4

You are the rock mechanics officer on a large, shallow metal mine, that has numerous faults, mining method is breast mining with scrapers. There is a thin parting occurring from 0,2 m to 0,4 m in the hanging wall which is considered to be very weak.

The stoping width is 1,25 m
Dip 20°
Panel length 35 meters
Pillars are provided at the top of the panels and are 4 x 4 m with 2 metre holings.

The mine has a major productivity drive on and one of the ways of getting better efficiencies is to reduce the workload and increase the number of blasts.

Sketch, discuss and motivate the temporary and permanent support you would apply giving spacing, density of support, dimensions and maximum distance from face after the blast.

Motivate the use of rock bolt support for this scenario.

TOTAL 20 marks

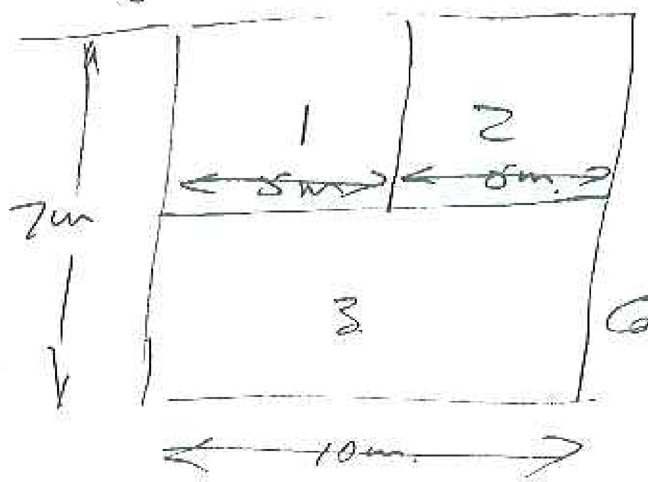
RM PAPER 3 (MET).

Q1.

The requirements were to
a) look at Rock mass rating Class 2 CSIR System and realise that it is "good" ground
b) Depth.

A number of methods would be acceptable.

preferred.



Could be 2 cuts on bottom.

1st Cut 10m ahead of 2nd.

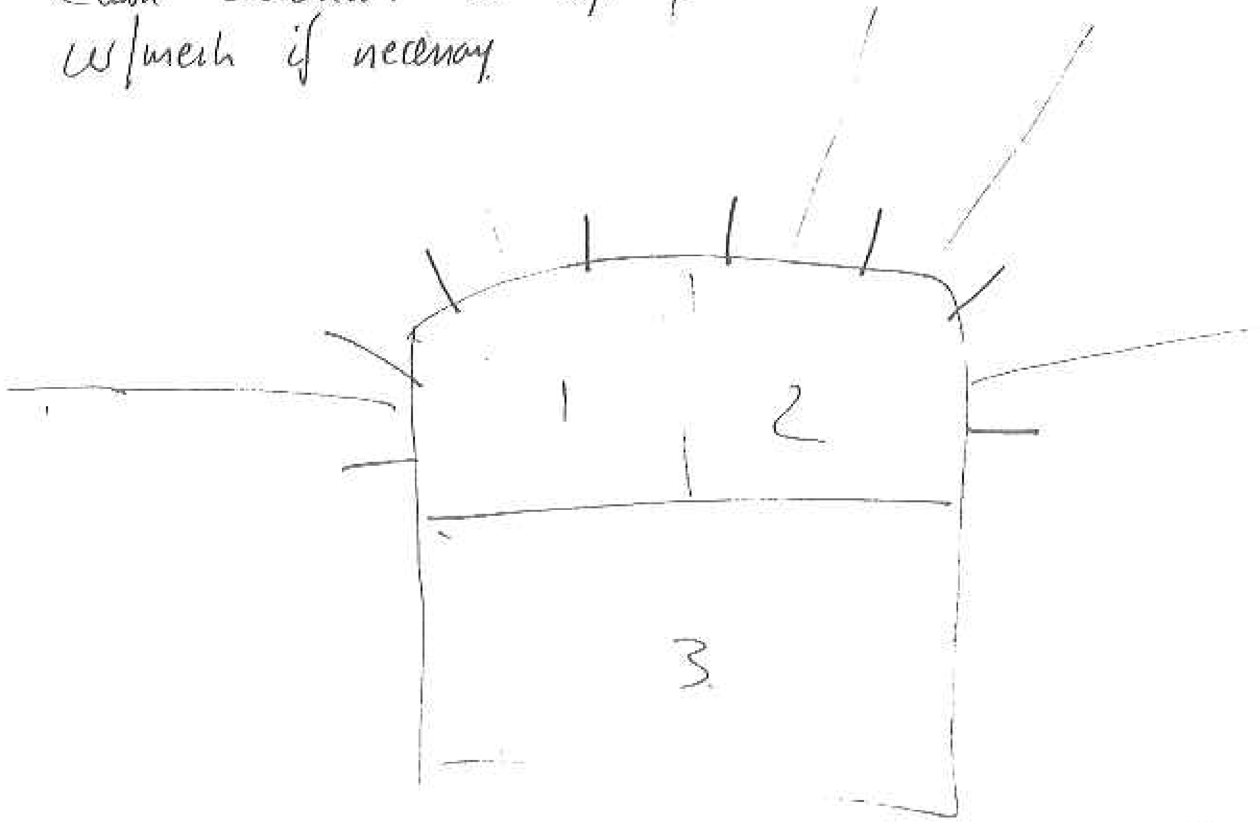
Top Cut taken out and supported Concurrently bottom Cut taken out
Smooth blast all perimeter holes except F/wall
Temp Support: Cantilever
- bolts (tem + perma) - installed close to face before
- w/mesh (temp) where necessary

Permanent. H/W. R/Bolts of appropriate length and spacing Carried 1st Cut not more than 4m from face after blast

Cable anchors of appropriate load with and spacing, tensioned, grouted not more than

6m behind second face (max)

S/walls bolted using 2-2,4m bolts of any type except
splitsets (long term required)
Cable anchors in top section.
W/mesh if necessary



take out 3rd cut and bolt sidewalls concurrently
when blasting complete W/mesh (optional) gunnite
min 50mm thick max 75mm.

Q2.

Primary requirement was to see that people thought the question through logically and gave reasonably acceptable answers, taking the time constraints into consideration

Amongst the matters requiring thought / discussion would be quantity of explosives and the charges associated taking into account the F/W e / Haw patterns

a) hole diameter - slower drilling
- more explosives / length
- better explosive characteristics of unfex used due to larger dia
- change spacing
- watch for drilling inaccuracies

b) hole length - more effective blast
- greater F/advance
- cannot support spacing
- change in amount of explosives
- drilling accuracy
- more effective use of stope team.

c Drilling Efficiency - time to drill larger dia
- time to drill longer holes
- less holes
- less collaring time
-

D. . Explosives - Anfex or emulsions
- Comment on why "stick" powder would be less effective.
- Nonel.
- Fuse & Igniter cord - slow

Q3.

Some of the points that needed to be addressed but an important aspect that was required was for the person to review stope support systems. List and discuss

(1) 1 Rock mass rating and/or Composition of H/W & F/W Rocks
2. Deformation Characteristics of the support units
3. Mining height
4. Stope closure rate
5 Stope closure during Rockbursts and the associated velocity of closure
6. Spacing of stope support units
7. Support resistance generated
8 Ability of system to absorb energy
9 Appropriate stiffness which will minimise damage to the area immediately surrounding the support unit.
10. Estimation of the rockfall support resistance Criteria for the mining horizon
11 Gully bolting / length / spacing etc
12. Construction of support not to endanger people.

(2) Control of Rockfalls

In order to Control rockfalls it is necessary to ana the fallout thickness to determine the support resistance criteria that would prevent rockfalls. The % fallout thick must be determined for a particular horizon and the support system must be capable of preventing at least ... of fallouts.

Earning

Training

inspections
audits
Commitment
Communication.

3 Reduction of Rockburst Damage

Using statistically determined block ejection thickness it is possible to calculate a minimum energy absorption requirement per square metre of stope hangingwall.

A support system must be capable of stabilising the stope H/W for 95% of the fallouts.

The velocity of ejection is assumed to be 3m/s unless verified by measurements.

Q4

Required a reasonable support layout considering

1) Shallow mine
2) S/width
3) panel length
4) Crush pillar

required regional pillar

roofbolting was a guide and would have been preferred regarding the hanging wall parting.

Stope support - temp - 2 rows mech props or sticks
support density - pre-stressed 5 to 6m^2/unit - Preferred
- not pre stressed 3 - 4m^2/unit

max support distance from face 6m. - this being the sticks

R/bolts should be drilled on a 2x2 or similar pattern, resin or end anchored preferably grouted. In not a necessity. no more than 1½ m from face before blast.

Can be answered in 1 page + drawing/sketch.

Do not want Packs, backfill Hydraulic props

PAPER 3 (MK)

EXAMINERS COMMENTS

QUESTION 1 Most people do not seem to know what Class 2 Ground (CSIR System) Refers to - many approaches were not useful

QUESTION 2 People seem to have difficulty coming to terms with imposed changes and did not reason changes through.

QUESTION 3 This question should all have scored high marks - people do not know or do not read relevant information.

QUESTION 4 People did not read question or are unable to understand anything different to what is on their minds - I do not

~~QUESTION 5~~ think people read their notes or can reason matters through logically

QUESTION 6

QUESTION 7

QUESTION 8

QUESTION 9

QUESTION 10

GENERAL Because of Exam time pressure persons who displayed that they thought the problem through and displayed that they were on the right track were given marks. People who went off on a tangent gained no extra marks and often lost because they wasted their own time.

SIGNATURE

C.H.F. Sweet

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

COAL OPTION

PART 3 - GENERAL	14 May 1997
EXAMINER:	Mr JC Viljoen
MODERATOR:	Mr WA Naismith

Maximum time allowed 2½ hours (09:00 - 11:30)

ANSWER ALL QUESTIONS

A pass mark for this paper is 60 per cent.

References are not permitted.

Hand-held electronic calculators may be used. (No pre-programming).

Put your examination number of 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.

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PART 3 - GENERAL COAL

QUESTION 1

You are employed on a colliery in the Witbank Coalfields. It is required to establish a connection between the No. 4 and No. 2 seams. The inter-seam parting is 18 m and both seams are mined-out on a bord and pillar lay out. The holing is required for the installation of a conveyor belt. The mining height in the No 4 seam is 2,8 m and that of the No. 2 seam is 4,5 m.

You need to advise mine management on the project. In your recommendations you need to substantiate your recommendation in detail (which could include schematic diagrams).

(a) Compare all the merits of winzing or raising the inter-seam connection and motivate the recommended strategy. 5 marks

(b) Assume that the inter-seam connection is going to be raised, indicate the blasting and support strategy to be employed to establish a stabilised portal area. 10 marks

(c) To ensure the inter-seam connection holes into a stabilised environment, indicate the proactive preparatory work which needs to be implemented at the point of holing. 10 marks

TOTAL 25 marks

PART 3 - GENERAL COAL

QUESTION 2

The engineer needs to establish an underground workshop in the No. 5 seam horizon on one of the collieries situated in the Highveld Coalfield area. The area where the workshop is to be established has been mined-out on a bord and pillar layout. The workshop is to be sited in the main development having a cover depth of 60 m. The panel immediately adjacent to the proposed workshop has been stooped.

Considering the above facts, advise the engineer of all the factors to be considered (including health and safety) in the establishment of the workshop.

(a) Indicate the typical physical conditions which can be expected in this coalfield. In your answer, limit yourself to the strata conditions which are normally encountered.

10 marks

(b) Indicate to the engineer (with the required motivation) the requirements to be implemented to ensure the health and safety of personnel working in the workshop is ensured at all times. Your recommendations must include the establishment of the required excavations to work on equipment, specific support requirements and address the potential construction strategies the engineer might consider, as well as any other factors of importance. If specific monitoring requirements are to be implemented, these need to be indicated.

15 marks

TOTAL 25 marks

PART 3 - GENERAL COAL

QUESTION 3

The coal seam to be mined has inter-seam sandstone lenses and dolerite intrusions are common. The immediate roof consists of laminated shales about 2 m in thickness. The cover depth is in the order of 180 m and the seam thickness is 3,5 m.

With respect to the following mining methods to be employed, giving due consideration to the expected mining conditions, indicate the effect each will have on safety, health and working cost:

(a) Continuous miner and shuttlecars. 7½ marks

(b) Conventional mining employing coal cutters, gathering arm loaders and shuttlecars. 7½ marks

TOTAL 15 marks

QUESTION 4

Describe the following terms:

(a) Felsite

(b) Cleavage

(c) Devolatilisation

(d) Yield 5 marks

Indicate the influence that each of the above factors has on in-section productivity and working cost. 10 marks

TOTAL 15 marks

ROCK MECHANICS

PART 3

GENERAL: COAL (1997) - MODEL ANSWERS

QUESTION 1

Two options are available:

RAISING

ADVANTAGES	DISADVANTAGES
- Can be cleaned with scrapers.	- Face overhang a problem.
- Face preparation easy.	- Drilling updip requires effort.
- Water not to be pumped.	
- Drilling, cleaning can take place simultaneously.	
Cleaning of face easier with LHD's.	

5 marks

WINZING

ADVANTAGES	DISADVANTAGES
- Drilling requires less effort.	- Face preparation more difficult.
-	- Water logged face requires pumping.

From 1.1, the candidate should go for raising the connection. The following factors to be considered at establishment of portal in raise position.

- Conveyor belt curvature radius to be considered.
- Pre-split of roof to establish a solid face to establish the tunnel.
- Special support under the brow.
- Support of roof and pillars.
- Blasting strategy to maintain wedge portion of roof when development of tunnel commences.
- Support of wedge portion.
- Relevant/approximate dimensions to be provided (degrees, cross section, expected dimensions of brow, etc.)

10 marks

QUESTION 1 (Cont.)

Following from 1.1, the holing position can be established, ensuring the raise to hole in a pre-established, pre-supported solid face:

- Consider belt curvature, floor profile is established.
- Pillars and roof are supported.
- Lifting of floor takes place to establish a solid face.
- Face dimension needs to consider holing dimensions and brow (wedge) size.
- Will help if sides of decline is pre-split.
- Sidewall is supported.
- Holing position brow is pre-supported.
- Holing point inspected, logged to be clear of misfires.

10 marks

TOTAL <u>25 marks</u>

QUESTION 2

- Depending on the locality, the roof could be competent sandstones or laminated shales.
- The laminated shale roof is overlaid by a competent sandstone roof.
- The floor consists of a micaceous siltstone, which is friable and slakes when exposed to water.
- Floor heave does take place.
- Pillars are known to punch the floor.
- The coal seam itself is fairly competent.
- The seam thickness in general is thin (1,2 to 1,8 m).

10 marks

Two scenarios to be considered:

i) Shale roof.
ii) Competent sandstone roof.

QUESTION 2 (Cont.)

- **Shale Roof**

i) Shale roof to be blasted down to expose competent sandstone roof.

ii) Shale sides in roof to be bolted and meshing of brows must be considered.

iii) Blasting down shale roof will result in brows being established.
These to be supported with full column resin bolts.

iv) If shale is not blasted down in some areas, investigate quality of existing roof support.

v) In planning excavations, safety factor and w:h ratio must be considered and be sufficient.

vi) Scaling of pillars to be addressed by the wrapping of pillars and bolting. Special attention to be given to pillar corners.

vii) Floor heave is going to occur, to stabilise floors, it can be removed.

ix) Due to expected pressure on coal pillars (due to stooping), brick walls not to be built flash against coal pillars.
Provision to be made to inspect pillar movement.

x) Regular monitoring of pillars required which includes punching of floor. This could include measuring of roof/floor distance (closure).

xi) Lifting equipment not to be installed, suspended from the roof.

In the case of the competent sandstone roof, items (v) to (xi) must be considered. To gain height in the workshop it should be recommended that the roof is not to be blasted and that the floor is lifted.

15 marks

QUESTION 3

3.1 Continuous Miners

- Lenses in-seam causes high cutter pick consumption (increase cost), delay cutting rate (reduced production) and frictional heating remains a concern (ignite flammable gas). The silica dust generated while cutting affects health. Lenses damaging the cuter picks increase dust levels (coal dust explosion hazard and health hazard).

- Dolerite intrusions associated normally with slips (falls of roof, high support requirements, decreased yield) and flammable gas emissions (explosions).

- The shale roof will limit cutting distance and bord width. Requires systematic installation of support.

- The continuous miner cannot cut the dolerite, requires employment of drilling and blasting to negotiate dolerite. It limits pit room and reduces the available faces to be mined. Normally requires larger pillars to be mined to negotiate dolerite. This invariably results in poor ventilation conditions due to large centres.

3.2 Conventional Mining

- Position of lenses in face affects the cutting of the free face. Design of cutter determines influence on production.

- Drilling a problem due to lenses. Holes to be re-drilled not to intersect lenses.

- Blasting efficiency affected by lenses can cause large coal to be broken up by hand. Overhang of the coal face generally occurs.

- The dolerite intrusion associated slips, burnt coal same negative effect as tor continuous miners. Production more severely affected as a result of more coal faces required to maintain production.

- Shale roof limits bord width and installation of roofbolts to be installed systematically.

TOTAL 15 marks

QUESTION 4

4.1 Felsite

Reddish course crystalline material originating from the basement of the coal seam and of pre-korso origin.

4.2 Cleavage

Preferred planes of breakage of the coal seam caused by compaction of the coal seam.

4.3 Devolatilisation

Decrease in the volatile content of the coal seam as a result of an external geothermal heat source.

4.4 Yield

Ratio between the saleable coal and the run-of-mine coal.

QUESTION 4 (Cont.)

Felsite

- Productivity: Steep gradients, ridges caused by Felsite, affecting equipment movement. Caused thinning-out of coal seam in addition. Gradients, thinning-out affects section output.

- Working Cost: Reduced section output and increases cost.

Cleavage

- Productivity: Can enhance the cutting of coal. In instances, can affect the stability of pillars (causes propensity to scale).

- Working Cost: Improves cutting and reduces working cost. Larger pillars or scaling of pillars increase working cost.

Devolatilisation

- Productivity: Can cause poor mining conditions (roof) and weakening strength of coal.

- Working Cost: Increases support requirements and loss of saleable coal due to quality constraints.

Yield

- Productivity: The higher the yield, the better productivity measured in sales tons.

- Working Cost: Direct relationship between yield and working cost measured in sales tons.

TOTAL 15 marks

QUESTION 5

5.1 Inside of boundary, 15 m wide, measured at right angles in plane of roof formation. Opencast 9 m measured horizontally at right angles.

5.2 No person, other than shiftboss or official with higher rank, unless definite instruction received from ganger/miner in charge.

5.3 To be done by certificated miner or competent person specially trained or actual presence of miner/competent person. To be carefully examined and additional support to be installed or other precautions taken.

5.4 Be removed with permission in actual presence of miner/ganger.

5.5 Only be holder of blasting certificate.

TOTAL 10 marks

QUESTION 6

Terms of Reference.
Synopsis/Executive Summary.
List of Illustrations.
List of symbols/Glossary.
Introduction.
Materials to be Tested.
Methods.
Results.
Conclusions.
Recommendations.
List of References.
Bibliography.
Appendices.

TOTAL 10 marks

PAPER 3 (COAL)

EXAMINERS COMMENTS

QUESTION 1 Students not focussing on Rock eng. requirements - support haaw, deep roof etc.

QUESTION 2 Not aware of the real mtg environment. generally low room, shale roof, poor floors.

QUESTION 3 The critical issues to a rock eng. is not address (shale roof, dolerite intrusions, depth etc).

QUESTION 4 A fair understanding of terms, apart for 'felsite'

QUESTION 5

QUESTION 6

QUESTION 7

QUESTION 8

QUESTION 9

QUESTION 10

GENERAL Students do not analyse the consequences of the critical elements indicated in the question and systematicly analyse the effect on mining.

SIGNATURE [illegible]