Ques.

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

COAL & METALLIFEROUS OPTIONS

PART 1: THEORY 9 November 1998

EXAMINER: K Noble

MODERATOR: G S Esterhuizen

Maximum time allowed 3 hours (09h00 - 12h00)

ANSWER ALL QUESTIONS

The pass mark for this paper is 60 percent.

EXAMINATION INSTRUCTIONS

1. References may not be used.
2. Hand-held electronic calculators may be used.
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 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.

QUESTION 1

A) Consider a thin, infinite, elastic plate uniformly stressed. Drill a circular hole of radius R in the plate. The distribution of stresses after the hole has been completed, for plane strain condition, is given by the equations:

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

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

$$\tau_{r\theta} = 0,\ \sigma_z = 2\nu p$$

Calculate the magnitudes of the stress and strain components at a point r = 1,5 R if p = 50 MPa and R = 1m. Also, determine the strain energy density at the same point. Take Young's modulus and Poisson's ratio to be 50 GPa and 0,25 respectively. **15 marks**

B)

(ii) For the following given state of stress, find the magnitude and directions of the principal stresses.

σ_x = 2,5 kPa

σ_y = 12,5 kPa

σ_{xy} = -13,0 kPa

(iii) Produce a clear annotated sketch that depicts the orientation of the principal stresses with respect to the x-y co-ordinate axis and the specified components of stress. The sketch needs not be to scale. **10 marks**

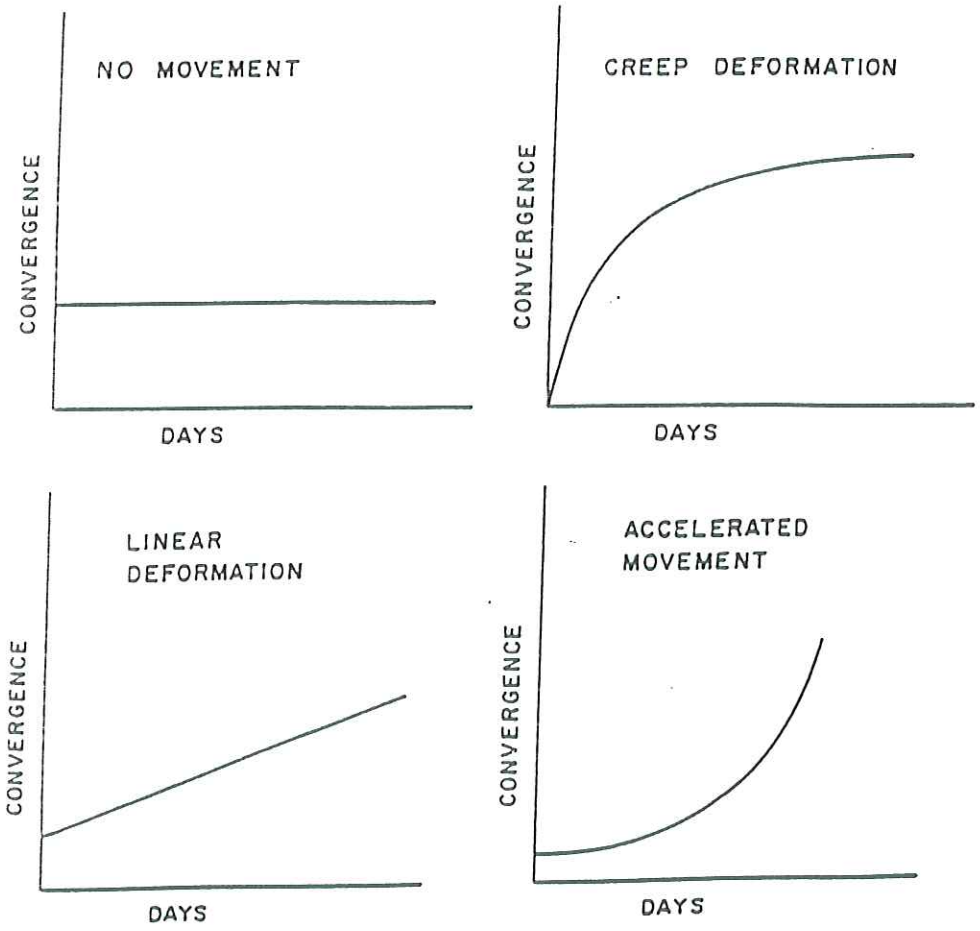
TOTAL: 25 MARKS

QUESTION 2

A) The physical strength and elastic properties of rocks are dependant on the rate of loading. The strength of rock under dynamic load is significantly higher than under static load (e.g. testing machine loading rate.) It is obvious that determination of the strength properties of rock dynamic loading is important, particularly in the case of an extraction where blasting and dynamic abutment stresses are present. Two methods of testing are used. Describe one of these methods and illustrate the results that you would expect. **10 marks**

B) Theoretically there are four possible types of ground movement as represented in the convergence curves below. The convergence is that of a stope.

(i) Comment on the type of deformation described by these curves.
(ii) Comment on the probable level of stress under which each of these curves would occur.
(iii) Comment on the ground conditions in which you would expect these curves to apply.



15 marks

TOTAL: 25 MARKS

QUESTION 3

A) A tunnel is to be driven through slightly weathered granite with a dominant joint set dipping at 60° against the direction of the drive. Index testing and logging of diamond drilled core given typical Point-Load Strength Index values of 8 MPa and average RQD of 70%. The joints which are slightly rough and slightly weathered with a separation of <1mm are spaced at 300mm. There are three sets. Tunnelling conditions are expected to be wet. The tunnel is 10.0 m wide, 4 m high and 200.0 m below surface.

(i) Calculate the RMR value using the Geomechanics Classification System after Bieniawski (see Table 4.4)

(ii) What stability problems would you expect?

(iii) What blasting technique would you recommend? Elaborate fully.

(iv) What monitoring programme would you initiate to check on stability?

(v) What types of support would you consider to be appropriate and why? **20 marks**

B) Calculate the apparent cohesion of a joint surface at a normal stress of 2 MPa, using Barton's equation for joint strength. The following parameters are given:

Base friction angle	=	30°
Joint roughness coefficient	=	7
Joint wall strength	=	40 MPa

5 marks

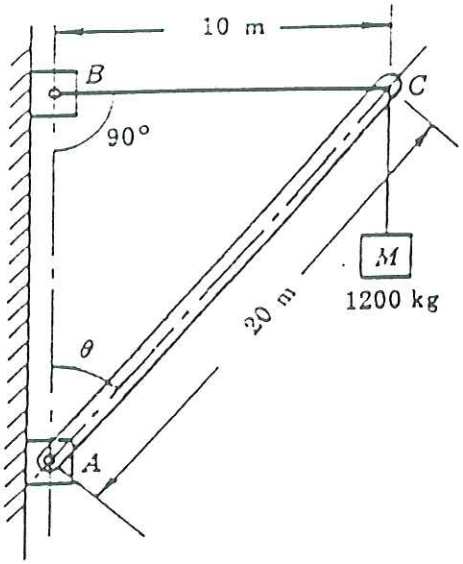
TOTAL: 25 MARKS

QUESTION 4

A) A boom, 20 m long, supports a load of 1 200 kg as shown below. The cable BC is horizontal and 10 m long.

(i) Calculate the forces in the cable and the boom.

(ii) Depict the situation using a force diagram.



10 marks

B) **Calculate** and **plot** the relationship between energy release rate and mining span for:

S_M = 0,75. Take H = 2 000m, ν = 0,2

G = 30 GPa and ρ = 2 700 kg/m^3

Use ℓ = 400, 500, 750, 1 000 and 1 250 respectively **15 marks**

TOTAL; 25 MARKS

TABLE 4.4: ROCK MASS RATING SYSTEM (AFTER BIENIAWSKI, 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS							
Parameter			Range of values				
1	Strength of intact rock material	Point-load strength index	>10 MPa	4-10 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive test is preferred
		Uniaxial comp. strength	>250 MPa	100-250 MPa	50-100 MPa	25-50 MPa	5-25 MPa | 1-5 MPa | <1 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 discontinuities		> 2 m	0.6-2 m	200-600 mm	60-200 mm	< 60 mm
	Rating		20	15	10	8	5
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous
	Rating		30	25	20	10	0
5	Ground water	Inflow per 10 m tunnel length (l/m)	None	< 10	10-25	25-125	> 125
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1-0.2	0.2-0.5	> 0.5
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing
	Rating		15	10	7	4	0

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)						
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS					
Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES					
Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300-400	200-300	100-200	< 100
Friction angle of rock mass (deg)	> 45	35-45	25-35	15-25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions					
Discontinuity length (persistence) Rating	< 1 m 6	1-3 m 4	3-10 m 2	10-20 m 1	> 20 m 0
Separation (aperture) Rating	None 6	< 0.1 mm 5	0.1-1.0 mm 4	1-5 mm 1	> 5 mm 0
Roughness Rating	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating	None 6	Hard filling < 5 mm 4	Hard filling > 5 mm 2	Soft filling < 5 mm 2	Soft filling > 5 mm 0
Weathering Ratings	Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**			
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip-Dip 45-90°	Drive with dip-Dip 20-45°	Dip 45-90°	Dip 20-45°
Very favourable	Favourable	Very favourable	Fair
Drive against dip-Dip 45-90°	Drive against dip-Dip 20-45°	Dip 0-20-Irrespective of strike*	
Fair	Unfavourable	Fair	

*Some conditions are mutually exclusive. For example, if infilling is present, the roughness of the surface will be over-shadowed by the influence of the gouge. In such cases use A.4 directly.

**Modified after Wickham et al. (1972).