CHAMBER OF MINES OF SOUTH AFRICA

SYLLABUS AND REFERENCES FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS AND COAL MINING OPTIONS

Note: References are provided for each section of the syllabus. These references provide the basic framework to study for the certificate. Some topics are not fully covered in the references, especially with regard to mining practice. It is therefore necessary to read papers in the Journal of the SAIMM, proceedings of the Mine Managers' Association, SA Colliery Managers' Association, SIMRAC research reports and SANGORM publications to supplement your knowledge.

1. PART 1 - THEORY

1.1 Applied mechanics

1.1.1 Terms and definitions

- Define the following terms, giving units where applicable:
  Modulus of elasticity, shear modulus, bulk modulus, Poisson's ratio, potential energy, kinetic energy, elastic strain energy, isotropy, homogeneity, dilation, volumetric strain.
- Explain each of the following terms:
  Spalling, slabbing, induced fractures, burst fractures, joint, fault, slip, dyke, bedding plane, lamination, cleavage surface, comminution, striations, slicken side, seismic event, rockburst, strain burst, convergence, closure, dip, strike, anticline and sycline folds, erosion channel, foliation, geological unconformity.

1.1.2 Stress and strain components

- Illustrate the complete state of stress at a point indicating the positive sense of normal and shear stresses.
- Calculate principal stresses from stress components in two dimensions.
- Calculate normal and shear components of stress on a plane at any orientation in a two dimensional stress field given either the principal stresses or stress components in the x-y directions.
- Calculate principal strains from strain components in two dimensions.
- Calculate strain components in any orientation given the principal strains or the strain components in the x-y directions.
- Make use of the Mohr-circle representation of stresses in two dimensions to determine principal stresses or stress components along a plane.
- Describe the shear and normal stresses induced in a simply supported beam, cantilever beam and a built in beam under their own weight, note the positions of maximum tension, compression and shear.

UNISA
UNIVERSITY OF SOUTH AFRICA

Examination Paper • Eksamenvraestel

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA CERT. IN ROCK MECHANICS – PAPER 1	**EXAMINER:** M HANDLEY
SUBJECT CODE: COMRME	**MODERATOR:** J KLOKOW
EXAMINATION DATE: 24 October 2005	**TOTAL MARKS: [100]**
TIME: 09h00 - 12h00	**PASS MARK: 60%**

NUMBER OF PAGES: 7

SPECIAL REQUIREMENTS:

1. **ANSWER *ALL FOUR* QUESTIONS.**
2. References other than those provided may not be used.
3. Hand-held electronic calculators may be used.
4. 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.**
5. Write on one side of the paper only.
6. Show all calculations on which you base your answers.
7. In answering these questions, take full advantage wherever necessary of your practical experience as well as of the data given.
8. Graph paper is available from the invigilator.
9. A list of formulae and any other essential charts and tables will be issued at the time of the examination.

ROCK MECHANICS PAPER 1 (COAL AND METALLIFEROUS OPTIONS)

QUESTION 1

1.1 Illustrate the complete state of stress at a point in three dimensions using positive components and the Rock Mechanics Sign Convention. Name all the stress components.

(9)

1.2 Show *quantitatively* why the stress tensor must be symmetric in static conditions (i.e. $\sigma_{xy} = \sigma_{yx}$; $\sigma_{yz} = \sigma_{zy}$; $\sigma_{zx} = \sigma_{xz}$)

(6)

1.3 Illustrate the normal and shear stresses that will develop in a horizontal cantilever beam as a result of its own weight at:
a) the beam root (where it emerges from the vertical wall);
b) midway between the beam root and its end;
c) show the position of the neutral line in the beam.

(6)

1.4 Explain the concept of plane strain using principal strains. Calculate the symbolic values of the principal stresses necessary for a plane strain condition using the equations of elasticity.

(4)

TOTAL: 25 MARKS

QUESTION 2

A series of triaxial tests in the laboratory yielded the following results from five samples of one rock type:

Table 1: Triaxial Strength Results

Sample Number	Confining Stress, MPa	Peak Stress, MPa
1	5.0	30.0
2	9.5	70.0
3	15.0	101.0
4	20.0	120.0
5	30.0	170.0

Use the data and the graph paper provided to determine the following rock parameters:

2.1 Uniaxial compressive strength **(2)**

2.2 Cohesion **(6)**

2.3 Angle of internal friction. **(6)**

2.4 Comment on the relationship between σ_1 and σ_3. **(3)**

2.5 A numerical model estimates the following stress states at two critical points in the same rock type underground:

Point 1: σ_1 = 100 MPa, σ_3 = 20 MPa;
Point 2: σ_1 = 80 MPa, σ_3 = 10 MPa.
Comment on whether you would expect the rock to fail at each point or not, using the data you have been given. **(4)**

2.6 Comment on the failure model implied by the data, and on the failure mode you would expect underground for the stresses given in 2.5 above. **(4)**

TOTAL: 25 MARKS

QUESTION 3

A horizontal borehole is drilled on strike 2200 m below surface to measure the 2D in-situ stress state in the vertical plane perpendicular to the borehole axis, for a strike haulage that is in the planning stages. The strata dip at 30° from left to right when viewed down the borehole. The corrected strain reliefs obtained, using the rock mechanics sign convention, were as follows:

ε_{xx} (horizontal) = 0.000525
ε_{xy} = 0.000303
ε_{yy} (vertical) = 0.000875

3.1 Compute the vertical and horizontal stresses a tunnel would be subjected to if it were developed along strike with the borehole as its centreline, assuming E = 60 GPa, v = 0.2, ρ = 3058 kg/m^3, and g = 9.81 m/s^2.

(6)

3.2 Given the rock density, is the vertical stress calculated from the strain reliefs reasonable or not? Give reasons for your answer, and show your calculations.

(4)

3.3 Calculate the principal stresses, the principal strains, their directions, and illustrate these in a small diagram. Comment on their relationship with the strata.

(10)

3.4 If the planned tunnel is to be 1 km long, would you expect it to be subjected to the same virgin stress state along its entire length? Justify your answer, giving 5 reasons in support of it.

(5)

TOTAL: 25 MARKS

QUESTION 4

A coal mine is to be established in coal-bearing strata overlying a pre-existing gold mine. Because the coal is low quality, management seeks to use any existing gold mine infrastructure, such as shafts, etc. for access to the coal. There are several inclined, sub-incline shafts and one vertical shaft with a circular cross-section on the property. Management is considering using the vertical shaft as the main access to the mine for personnel, and as a downcast ventilation shaft. The gold shaft pillar, formed 40 years ago, was never mined because it is relatively low grade. The shaft with the gold reef pillar appear in the plan and section two pages below. In order to minimise stress on the coal face, management has decided to leave a circular coal pillar above the gold pillar. The size of the pillar and its position was determined by numerical modelling, and you can assume the average increase in vertical stress in the proposed coal pillar is 33% above virgin stress because of the gold reef pillar.

The horizontal virgin stress before gold mining took place at the coal seam elevation is estimated to be equal to the overburden weight in all directions, and the numerical modelling shows that it remains essentially unchanged by the gold mining and the proposed coal mining. Once the coal pillar has been formed, and the coal mining (presently planned to be longwall mining) reaches a span approximately equal to depth on all sides of the coal pillar, the vertical stress in the coal pillar is expected to be double the vertical stress currently estimated from the numerical modelling.

The old vertical shaft has been inspected and is currently in relatively good condition, with no observed failure in the rocks enclosing the coal seam, or the coal seam itself, although the supports installed fifty or more years ago are in poor condition. The supports are rockbolts only above and below the coal, and rockbolts with wire mesh and lacing together with shotcrete in the coal seam. Assume the vertical virgin stress in the coal-bearing strata is equal to the overburden weight, and is given by $\sigma_v = 0.025h$ MPa where h is the depth below surface in metres.

4.1 Calculate the virgin stress conditions in the coal seam shaft pillar before the gold mining, the stress conditions after the gold mining, and after the coal mining.

(6)

4.2 What are the tangential and radial stresses in the shaft barrel at coal seam elevation after gold mining, and after coal mining? Show your calculations and tabulate your results under the headings σ_{rr}, $\sigma_{\theta\theta}$, and σ_{zz} for each of the rock types listed in the table below.

(6)

4.3 Do you expect shaft sidewall failure in the sandstone or the mudstone near the coal seam or in the coal seam itself if the strata parameters are

as given in the table below? Tabulate your results under the rock types, and estimate failure potential in the shaft sidewall after gold mining (before coal mining) and after coal mining. Show your calculations and explain any anomalous results.

Table of rock parameters

Rock Type	m	s	UCS (MPa)
Sandstone	7.5	0.1	60
Coal	3	0.1	20
Mudstone	5	0.01	40

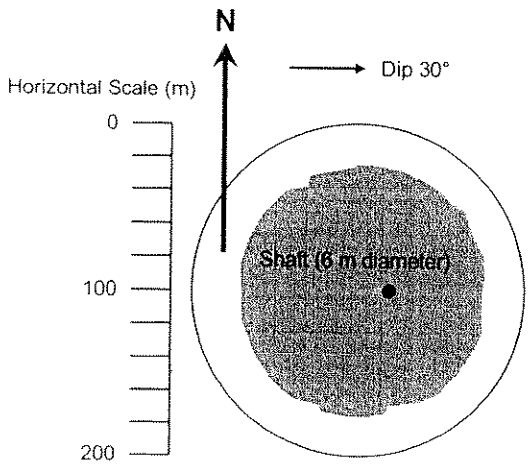
(10)

4.4 Using the model that mining induced fractures always lie in the plane defined by the maximum and intermediate principal stresses (i.e. perpendicular to the minor principal stress) show the expected fracture directions in the shaft sidewall near coal seam elevation.

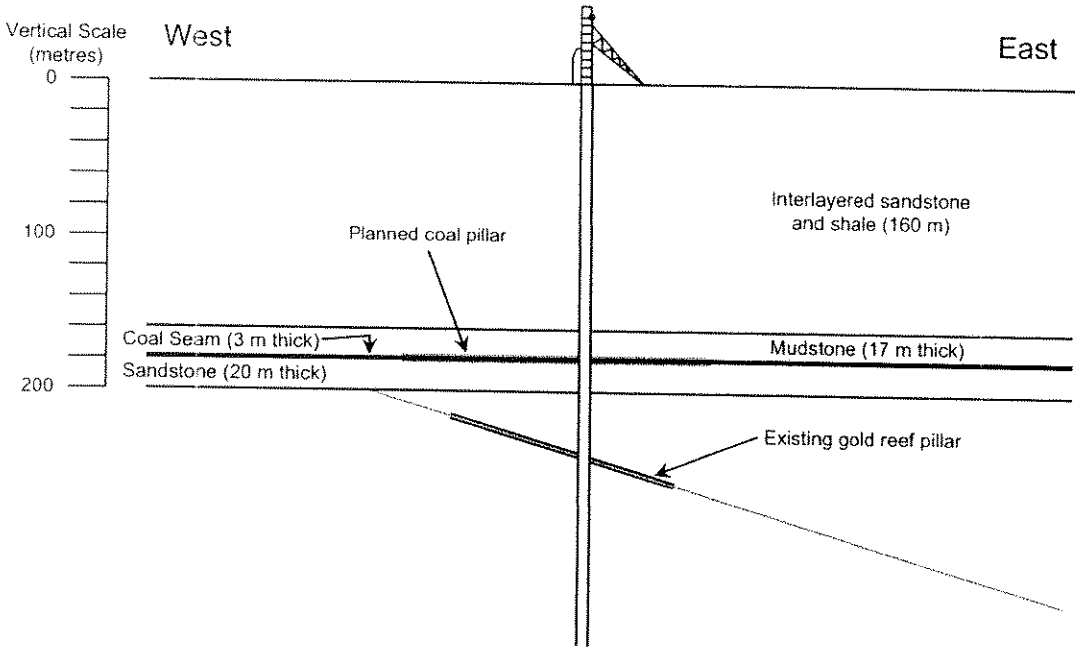
(3)

TOTAL: 25 MARKS

EXAM TOTAL: 100 MARKS



Plan of existing reef pillar (grey) showing shaft position and proposed coal pillar outline (black)



(f) There are offices of the Department of Minerals and Energy with Inspectors of Mines in the following towns:
- (i) Witbank
- (ii) Secunda
- (iii) Newcastle
- (iv) Ermelo

(g) The "Guidelines for the Compilation of a Mandatory Code of Practice to Prevent Roof Fall Accidents in Underground Coal Mines"
- (i) requires the formal appointment of a rock engineer at any mine where the Principal Inspector deems it necessary
- (ii) was not drawn up with the participation of labour representatives
- (iii) empowers safety representatives to stop production in a section where dangerous roof or pillar conditions are evident
- (iv) requires annual underground inspections of all underground coal mines by a rock engineer

(h) Coal measure rocks can be regarded as
- (i) isotropic in one direction
- (ii) modified sedimentary rock
- (iii) brittle ductile
- (iv) brittle elasto-plastic

(i) The constant "7.176" in the Salamon-Munro formula for the strength of coal pillars is
- (i) the strength of a 1-metre cube of coal
- (ii) an under estimation of the strength of coal
- (iii) a statistical number
- (iv) valid for all coal in South Africa

(j) The term "Stiff Roof Support System" is used to describe a system where
- (i) 600 MPa yield strength steel is used
- (ii) the maximum annulus is 4 mm
- (iii) full column resin is used
- (iv) roof movement is restricted to the minimum

20 marks

TOTAL MARKS: [100]