EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA CERTIFICATE IN ROCK MECHANICS PAPER 1 – THEORY **SUBJECT CODE:** COMRME **EXAMINATION DATE:** 25 OCTOBER 2007 **TIME:** 9:00 – 12:00	**EXAMINER:** M HANDLEY **MODERATOR:** J KLOKOW **TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES: 7

SPECIAL REQUIREMENTS:

1. **Answer *ALL FOUR* questions**
2. References other than those provided are not permitted.
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 in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).**
6. Show all calculations on which your answers are based.
7. Illustrate your answers by sketches of diagrams wherever possible.
8. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.
9. Answers must be given to an accuracy that is typical of practical conditions unless stated otherwise.

A REMINDER THAT ONLY ANSWERS ON THE RIGHT HAND SIDE OF THE PAGE WILL BE MARKED. THE LEFT HAND PAGE IS FOR ROUGH CALCULATIONS AND WILL NOT BE MARKED!

QUESTION 1

a) Define plane strain. **(2)**

b) Define strain energy. **(2)**

(2)

c) Define principal strain. **(2)**

d) Describe the Mohr-Coulomb failure criterion. **(4)**

e) Explain strain softening. **(2)**

f) Five cylindrical samples of rock are tested in compression in a rock-testing machine under triaxial loading conditions. The first sample is tested uniaxially, and the uniaxial strength was found to be 200 MPa. The results from the other four tests with increasing compressive confinement are listed in the Table 1.1.

Table 1.1: Triaxial test Results

Confining Stress (MPa)	Peak Strength (MPa)
5	228
10	264
15	300
20	315

All samples showed brittle behaviour in the post-failure regime. Determine the Mohr-Coulomb parameters for the failure envelope of the rock. **(10)**

g) If one of the samples tested had Hoek-Brown m and s values of 15 and 1.0 respectively, what would the peak strength be if confinement were 20 MPa? How does this compare with the Mohr-Coulomb result?

(3)

TOTAL: 25 MARKS

QUESTION 2

The virgin state of stress in the Earth's crust is most simply described by two models, known as the uniaxial strain (complete lateral restraint) model and Heim's Rule, both of which assume that the vertical stress is purely the result of the overburden weight, and that the horizontal stresses are the result of processes that take place after the rock mass has formed.

2.1 Show, using a simple model that, on average, the vertical stress in the Earth's crust at any point must be equal to the overburden weight. **(5)**

2.2 Using the equations of elasticity, derive the relation between the vertical and horizontal stress given by the uniaxial strain model given below:

$$\sigma_{xx} = \sigma_{yy} = \frac{\nu}{1-\nu}\sigma_{zz},$$

where ν is the Poisson's ratio, σ_{zz} is the vertical stress, and $\sigma_{xx} = \sigma_{yy}$, the horizontal stresses. **(6)**

2.3 An erosional stress state model asserts the following:

where $k = \dfrac{90 + 0.017(h-5000)}{150 + 0.030(h-5000)}$, and h is depth below surface in metres.

Plot the horizontal and vertical stresses vs. depth on the graph paper provided from surface to 5000 m below surface, and comment on the major features of the stress profiles you obtain. **(9)**

2.4 Comment on the shortcomings of the erosional model given in 2.3 above.

(5)

TOTAL: 25 MARKS

QUESTION 3

A vertical production shaft on a platinum mine is raise-bored in an excellent quality rockmass from 1600 m b.s. to surface at 3 m diameter. It is then reamed downwards to 10 m diameter, and lined with monolithic reinforced concrete rings 250 mm thick, with a 50 mm thick backing layer of porous concrete between the ring and the rockmass. Because the rockmass quality is excellent, only spot bolting is employed as a primary support before the concrete rings are installed.

The shaft intersects the Merensky Reef dipping at 5° to the east at 1500 m. In order to shorten the sinking-equipping cycle and to build up production on the Merensky Reef horizon as soon as possible, you as the rock mechanics practitioner recommend that a 300 by 300 m pillar be left on the Merensky Reef to protect the shaft.

This means that a life-of-shaft monitoring programme must be implemented in order to assess the effects of stress build-up in the shaft pillar on the shaft barrel. The survey department therefore installs a series of benchmark pegs in rings of four and set 10 m apart vertically in the shaft.

They are anchored in the rock and protrude through the concrete lining, so that they are visible in the shaft for measurement by Invar tapes and extensometers. The benchmark layout and peg naming convention is shown below.

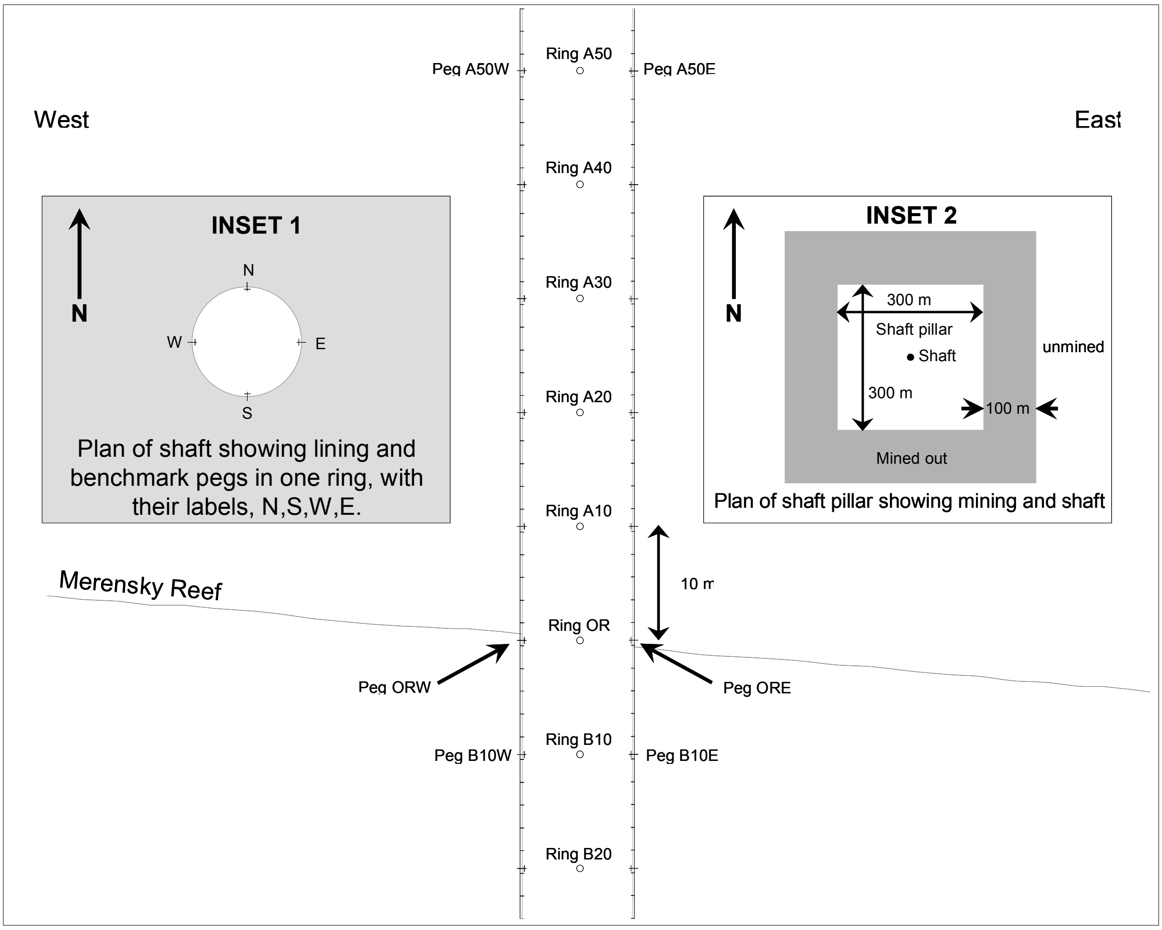

Figure 3.1: Section through shaft at the Merensky Reef intersection

The rockmass has a Young's Modulus of 50 GPa, and a Poisson's Ratio of 0.25, and you assume it is isotropic and homogeneous for analysis purposes.

3.1 Do you expect the shaft lining to have any influence on mining induced displacements in the rockmass? Give reasons for your answer. **(3)**

3.2 From the inception of mining to the formation of the shaft pillar (see Inset 2 in Figure 3.1 for mining details), the vertical distance between Ring A10 and Ring B10 has diminished by 13 mm. At the same time, the horizontal distance between pegs ORN and ORS, as well as that between ORE and ORW have diminished by 1.5 mm.

You have been told that the radial displacements inside a circular hole in a flat plate loaded at its boundaries at infinity are given by:

$$u_r = \frac{-a^2}{2Gr}\left[\frac{\sigma_1+\sigma_2}{2} - \frac{\sigma_1-\sigma_2}{2}\left\{2(1-2\nu)+\frac{a^2}{r^2}\right\}\cos 2\theta\right]$$

$$u_\theta = \frac{-a^2}{2Gr}\left[\frac{\sigma_1-\sigma_2}{2}\left\{2(1-2\nu)+\frac{a^2}{r^2}\right\}\sin 2\theta\right]$$

In the equations above, u_r and u_θ are the radial and tangential displacements respectively, a is the radius of the circular hole, and r is the radial distance from the centre of the hole. All the other variables represent the usual quantities.

Calculate the horizontal and vertical stress changes in the pillar 100 m from the shaft centreline. Clearly indicate your assumptions and your reasoning behind your calculations. **(12)**

3.3 Calculate the change in radial and tangential horizontal stress at the rockmass-shaft lining interface, <u>after the formation of the pillar</u> if the virgin stress is given by the relationship in 2.3. **(4)**

3.4 Use tributary area theory to estimate the total vertical stress in the shaft pillar if the ground on all sides of the pillar has been mined to a distance of 100 m from the shaft pillar boundaries (see Inset 2 in Figure 3.1). Comment on the comparison between this result and the total vertical pillar stress obtained from Question 3.2 above. **(6)**

TOTAL: 25 MARKS

<u>QUESTION 4</u>

A fault striking north-south and dipping 60° to the West is to be tested for stability using water injection. Rock stress measurements of the stress tensor close to the fault yield the following results (assume the rock mechanics sign convention, and that the stress components are expressed in terms of the standard mine coordinate system):

4.1 If the vertical stress component is equal to the overburden weight, at what depth was the measurement made? (Assume ρ = 2700 kg/m^3, and $g=9.81m/s^2$). **(2)**

4.2 What water pressure will be just enough to force the fault open? **(5)**

4.3 If the fault has a cohesion of 4 MPa and a friction angle of 15°, what water pressure is sufficient to cause it to slip? **(10)**

4.4 If all the other shear stress components currently zero in matrix above, were actually non-zero, would this have had any effect on the normal stress acting on the fault? Give reasons for your answer. **(4)**

4.5 Using a diagram, and your results from 1.3, indicate which way you expect the fault to slip. **(4)**

TOTAL: 25 MARKS

EXAM TOTAL: 100 MARKS