UNISA university of south africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS: PAPER 2	**EXAMINER:** LJ SCHEEPERS
SUBJECT CODE: COMRME	**MODERATOR:** J LUCAS
EXAMINATION DATE: OCT 2011	**TOTAL MARKS:** [100] **PASS MARK:** 60%
TIME: 9:00 – 12:00	

NUMBER OF PAGES: 12

SPECIAL REQUIREMENTS:

1. **<u>ALL</u> candidates to answer Question 1**

   Candidates to answer <u>all three</u> Questions
2. References other than those provided are not permitted.
3. Hand-held electronic calculators may be used.
4. Write 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. **<u>Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).</u>**
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.

QUESTION 1 (25 points)

You are part of a feasibility Study team for GM mining company in South Africa. Site 1 is near Witbank, Site 2 is near Rustenburg and Site 3 is near Carletonville.

Multiple Choice Questions (10 points)

1.1 Which resources are you most likely to find at site 1

a) Platinum b) Coal
c) Gold d) Kryptonite (1)

1.2 Which resources are you most likely to find at site 2

a) Platinum b) Coal
c) Gold d) Kryptonite (1)

1.3 Which resources are you most likely to find at site 3

a) Platinum b) Coal
c) Gold d) Kryptonite (1)

1.4 Which is the most likely rock type you will find at site 1

a) Sedimentary b) Igneous
c) Metamorphic d) Kryptonite (1)

1.5 Which is the most likely rock type you will find at site 2

a) Sedimentary b) Igneous
c) Metamorphic d) Kryptonite (1)

1.6 Which is the most likely rock type you will find at site 3

a) Sedimentary b) Igneous
c) Metamorphic d) Kryptonite (1)

1.7 Which depth category is likely to be more descriptive of site 1

a)	Deep	b)	Shallow	
c)	Intermediate	d)	Open pit	(1)

1.8 Which depth category is likely to be more descriptive of site 2

a)	Deep	b)	Shallow	
c)	Intermediate	d)	Open pit	(1)

1.9 Which depth category is likely to be more descriptive of site 3

a)	Deep	b)	Shallow	
c)	Intermediate	d)	Open pit	(1)

1.10 Choose the most likely origin of the resource likely found at site 2

a)	Organic material	b)	Inland see	
c)	Sill-like intrusions	d)	Kimberlite	(1)

Question 1 continue (15 points)

1.11 List what geotechnical information you would gather to be used for design in your feasibility study (5)

From drilling - A stratigraphic sequence column

RQD

Rockmass strength properties for each important stratgraphic rock layer through lab UCM tests on drill core

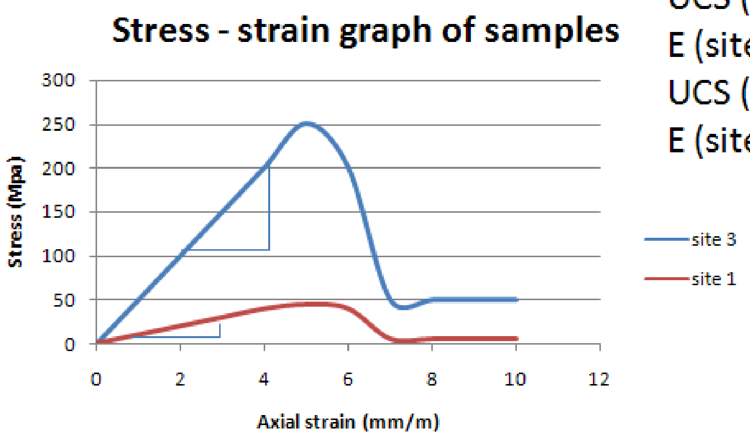
Rockmass rating from drill core – number of joints, dip and strength properties of joints

Joints strength tests on identified important joints

Geo-hydrological information

Major geological features that may influence stability

1.12 Draw the load deformation graphs of a rock sample from the reef from site 1 and from site 3 on the same graph. Assume likely values and make the differences clear (5)



UCS (site 3) = 250 MPa
E (site 3) = 50 Gpa
UCS (site 1) = 45 MPa
E (site 1) = 10 GPa

1.13 List the important considerations for preparing a rock sample for testing in a laboratory (5)

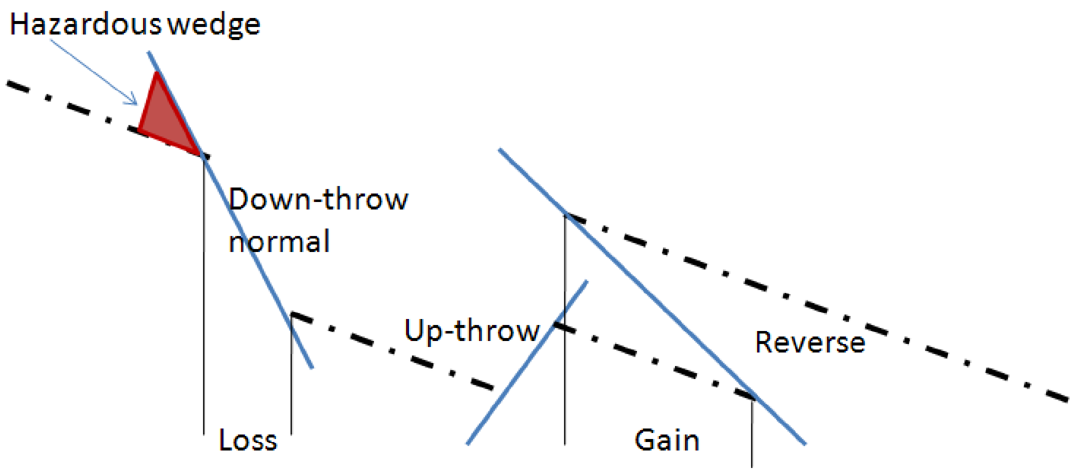
Prepared from standard core samples, slender (w:h of 0.5 to 0.3), coal to w:h of 1. Ends need to be parallel. Axial loading normal to bedding. Ends smooth to reduce friction

[25]

QUESTION 2 (50 points)

You are the shaft rock engineer at Ritzburg Gold mine. Your orebody is equally distributed on 2 reefs. The RC1 reef ranges from 200m to 500m below surface. The RC2 reef ranges from 3000m to 5000m below surface. Both reefs dip at 20° to the East and are superimposed (on top of each other). Both reefs are 2m thick with the grade distributed evenly through the reef package. The reef is displaced by a series of NW to SE trending faults and stiff dykes.

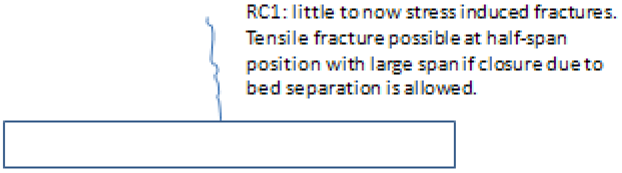
2.1 Draw a West-East section through an area on the mine that will make the terms up-throw fault, down-throw fault, reverse fault and normal fault clear. (5)

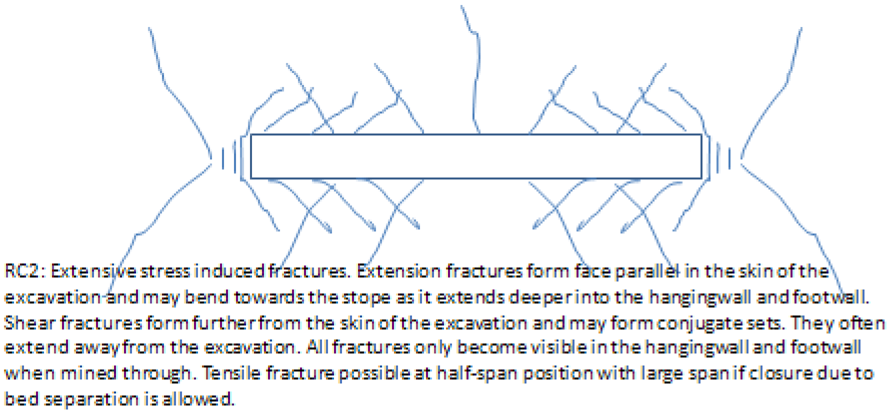


2.2 List and describe the hazards associated with the faults mentioned in 2.1 for the RC1 and the RC2 (5)

The wedge formed between the reef and the up-throw side of the fault plane is formed when the reef is mined against the fault because the fault plane act as a parting plane with low cohesion. This wedge is unstable under gravity in shallow (RC1) mining conditions. In deep (RC2) mining conditions these wedges may also become unstable but are often less of a problem from a gravity fall of ground perspective due to high clamping forces. The fault planes however often become hazardous from a seismicity perspective as high stress levels at depth and stress changes due to mining in the vicinity of the faults may induce shear stress on the fault plane or reduce normal stress on the fault plane (reduced clamping) that may result in slip on the fault plane; i.e. large seismic events.

2.3 Draw and annotate the drawing the likely fracture pattern around a stope in RC1 and in RC2 that will make the difference clear (5)





2.4 Design a room and pillar mining strategy for the RC1. Show all assumptions you make. Use common rules of thumb to make decisions on mining spans and use a Hedley & Grant formula to calculate the pillar width. Do the calculation for 200m below surface only. Assume no joints or other structures in your pillars. (10)

Determine the span between pillars required for the mining process. This is mostly a mining decision. However the stability of the mining spans is inversely proportional to the span. In typical mines in the Rustenburg area, spans in excess of 6m may become unstable. I therefore assume a span of 6m to be sufficient for the mining process and I assume that a sufficient support strategy will be implemented to make this mining span stable.

To determine pillars size I assume a sufficiently large mining area that regional abutments can be ignored. I also assume that no surface subsidence is allowed and that pillars must be stable for a very long time. I therefore assume a factor of safety (FOS) of 2.0. I don't have joint information and therefore assume no joints and good rockmass rating. I also assume that the major geological features will be avoided or a different mining strategy will be used. I therefore design for the ground between faults and do not include the impacts of faults on the pillar design. I assume that the hangingwall strata, reef and footwall all have similar UCS of 200MPa. I choose the Hedley and Grant design formula to determine pillars size:

$\sigma s = K \cdot w^{0.5} * h^{-0.75}$, where;

σs is the pillar strength (MPa);

K is the strength of a cubic metre of rock;

w is the pillar width (m);

h is the pillar height (m).

Methods described in literature for selection of K vary from K equals the UCS to K equals one-third of UCS according to Kersten (1984). I assume K = 1/3 UCS. Therefore,

$\sigma s = 0.33*200* w^{0.5} * 2^{-0.75}$

$\sigma s = 39.64*w^{0.5}$

$APS = A_1 *h*\rho*g/A_2$, where A_1 is tributary load area and A_2 is area of pillar

$APS = (w+6)^2 *0.2*3*10/w^2$

$APS = (w+6)^2 *6/w^2$

$FOS = \sigma s/APS = 2$

Therefore look for a w that will satisfy the formula

$39.64*w^{0.5}/ (w+6)^2 *6/w^2 = 2$

Testing with w = 4 will show FOS = 2.11

My board and pillar design is therefore 4m square pillars spaced at 10m centres to allow 6m boards between pillars.

2.5 Design a support strategy for the RC1 List the design approach, support type and spacing and possible additional measures. (5)

The pillars are designed to support the overburden, so the support in the boards between pillars are based on beam theory with the aim of building a stable beam between pillars. The tendon length is designed to protrude through the tensile zone between pillars and as a rule of thumb a length of 0.5 times the span can be used. The diagonal span between pillars is calculated to be sqrt 2 * 6 = 8.5m. Therefore tendon length to be minimum 4.25m. Spacing between tendons can be influenced by a number of factors, but good ground conditions are assumed and therefore spacing based on half tendon length. Therfore the support design is 4.5m long pre-stressed mechanical cable anchors spaced 2m apart on a square pattern

2.6 Design a mining strategy for the RC2. Calculate the virgin stress tensor at 4km deep assuming a k-ratio of 0.5. List the most obvious geotechnical hazards associated and your strategies to deal with these hazards. (10)

Ulta high stress – $\sigma_z = \rho gh = 3*10*4 = 120$MPa, $\sigma_x = \sigma_y = 60$MPa

Hazards: high closure rate and seismicity – limit spans, leave regional stability pillars, install backfill. Install yielding support in the face area.

Extensive fracturing – install face support with increased area coverage and tendon support in gullies.

Unstable access ways – de-stress access ways or place sufficiently far from mining abutments

Large seismic events on faults and dykes – leave bracket pillars, approach at 35°.

Sequential grid mining strategy with 180m spans and 30m dip pillars with access haulages 100m in footwall and extensive support in crosscuts every 210m

Mini-longwall mining with follow-on development. Longwall spans limited to 180m with 40m strike stability pillars

2.7 Design a support strategy for the RC2. List the design approach, support type and spacing and possible additional measures. (5)

Consider fall-out height from accident analysis. Pre-stressed yielding elongates in the face with headboards, elongates spaced 1.5m apart and maximum 3m from the face. Backfill within 5m of the face, more than 70% area filled. To go to 5000m spans may have to be reduced further (less than 180m) or/and backfill stiffness increased (superfill).

2.8 Design a monitoring program for the RC1. List the monitoring objectives and monitoring equipment required. (5)

Possible instabilities to be monitored is related to large blocks of ground becoming unstable under gravity as well as support effectiveness. Also possible pillar failures. Monitoring equipment to be used includes extensiometers to monitor bed-separation, closure stations to monitor possible onset of back break or accelerated closure. Tell-tales in access ways to warn of possible large deformations. Tension indicators on anchors to monitor pre-stressing and smart cables to monitor rock deformation after installation of support. Borehole camera to monitor possible rockmass deformation on discontinuities or weak planes.

`

2.9 Design a monitoring program for the RC2. List the monitoring objectives and monitoring equipment required. (5)

Rockburst is the primary hazard and seismicity needs to be monitored to improve understanding of the rockmass response. Seismic system consists of geophones and or accelerometers in drilled holes underground to form a 3d network around active mining areas. Seismometers to record the geophone readings, cabling and modems to communicate over the seismic network and server and software to interpret readings.

[55]

QUESTION 3 (20 points)

3.1 List the long-term, medium-term and short-term Rock Engineering input required at Ritzburg Gold Mine. (5)

Long-term – COP and business plan (1 to 5 years), rules of the game, standards, procedures - updates annually
Medium –term – Business plan (6 months to 1 year), mining strategies, layouts, designs
Short-term – Monthly planning, strategy implementations, Monthly hazard assessment, accident investigations, strata control

3.2 List the parameters to be included in the monthly hazard assessment at Ritzburg mine. Highlight the differences in the hazard assessment between RC1 and RC2. (10)

RC1 – compliance to pillar size, pillar spacing, tendon support, stoping width, sequencing, faults exposed (possible wedge failure)
RC2 – compliance to overall mining face configuration, approach angles onto geological festures, inter panel lead/lags, stoping width

3.3 You are expected to investigate a fall of ground accident. List what you will be looking for in your investigation. (5)

General compliance to good mining practice. Identify mining practice that may lead to strata control issues.
Origen of fall and likely mechanism of failure
Compliance to support standards
Possible failure of the support system
Possible failure of support units

[20]