CHAMBER OF MINES OF SOUTH AFRICA

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN STRATA CONTROL – METALLIFEROUS **SUBJECT CODE: COMCSC** **EXAMINATION DATE:** **TIME**: 14:30 – 17:30	**EXAMINER:** Y. JOOSTE **MODERATOR:** D.A. ARNOLD. **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES:

THIS ISNOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. Answer **all questions**. Answer the questions **legibly** in English.
2. Write your **ID 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.

3. Show all calculations **and check calculations on which the answers are based.**
4. Hand-held electronic calculators may be used for calculations. Reference notes may not be programmed into calculators.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. **Final answers** must be given to an accuracy which is typical of practical conditions, However be careful not to use too few decimal places during your calculations, as rounding errors may result in incorrect answers

   NB Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used. (even if the calculated value is correct).
8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.

QUESTION 1 – DEFINITIONS

Define the following terms and where applicable give the symbol and units used:

1.1 **Weight:** Weight of a body is a measure of the gravitational force acting on the body at a particular location. Unit = Newton

1.2 **Force:** An action (vector quantity) that tries to change the state of movement, the rate of movement or the direction of movement of a body.
Units = Newton (N)
Formula: F = m x a

1.3 **Triaxial compression:** The state of a body under the influence of compressive stress being applied in three directions.

1.4 **Shear stress:** Shear stress is the stress acting parallel to the strata or a plane tending to cause shear movement when the shear stress exceeds certain inherent shear strength of the rock
Symbol = τ (Tau)
Units = Pascal

1.5 **Safety factor:** The relation between the unit strength and the applied stress (if the unit strength is more than the stress the unit will be stable and if the stress is more than the unit strength, the unit will fail.)

1.6 **Rock mass:** Rock as it occurs in situ, including its discontinuities.

1.7 **Intact rock:** Usually a sample of rock. Rocks which contains no fractures, neither geological nor stress related.

1.8 **Abutment**: The areas of un-mined rock at the edges of mining excavations that may carry elevated loads resulting from re-distribution of stress.

1.9 **Active support**: Any support that on installation exerts a force onto the rock walls.

1.10 **Accelerometer**: A ground motion sensor that measures acceleration

Interpret **[20]**

QUESTION 2 – ROCK MASS CLASSIFICATIONS

2.1 Various Rock Mass Rating systems are available to classify the rock mass. List the name of the classification system as well as the parameters of each of the two rock mass rating methods:

- RMR
- Q

The following six parameters are used to classify a rock mass using the *RMR* system: (Bieniawski)

1) Uniaxial compressive strength of rock material.

2) Rock Quality Designation *(RQ*D).

3) Spacing of discontinuities.

4) Condition of discontinuities.

5) Groundwater conditions.

6) Orientation of discontinuities.

RQD is the Rock Quality Designation (Barton)

J n is the joint set number

J r is the joint roughness number

J a is the joint alteration number

J w is the joint water reduction factor

SRF is the stress reduction factor

(13)

2.2 Calculate the rockmass quality by conducting a rock mass rating using the Q metod. Motivate your reason for each value chosen used in the rock mass rating? Attached is a rock mass rating form.

A borehole intersected an intensely jointed zone at approximately 900m below surface.The zone is some 60m in length and 190 joints have been recorded from the core. There appear to be two distinct joint sets, dipping at roughly 30 and 70 degrees respectively. Traces of serpentinite filling, varying from 0-3mm are visible in the joint planes. Area seems to be damp. There also appears to be a 1.2m thick lamprohyre dyke running through the middle of this zone, at an angle of 45 degrees.

RQD = 115 – (3.3 X (190 joints / 60m))

=115-10.45

=104.55

Jn (4-6) = 2 joint sets and possibly one random due to dyke having joints associated with it.

Jr (1-2.5) = Any motivated answer as no dta was given in the questionnaire.

Ja (2-4) = Serpentinite filling 0-3mm thick

Jw (0.66) = Damp

SRF (2.5) = One dyke less than 1.2m thick.

Now Q can be calculated.

Q = (RQD/Jn) x (Jr/Ja) x (Jw/SRF)

Q = (104.55 / 6) x (2.5 / 2.5) x (1 / 2.5)

Q = 23.42 X 1 X 0.4

Q = 9.36 (estimated)

(9)

2.3 Why is Rock mass Classification systems important for a Rock Engineer?

(3)

During the feasibility and preliminary design stages of a project, when very little detailed information on the rock mass and its stress and hydrologic characteristics is available, the use of a rock mass classification scheme can be of considerable benefit. At its simplest, this may involve using the classification scheme as a checklist to ensure that all relevant information has been considered. At the other end of the spectrum, one or more rock mass classification schemes can be used to build up a picture of the composition and characteristics of a rock mass to provide initial estimates of support requirements, and to provide estimates of the strength and deformation properties of the rock mass.

It is important to understand that the use of a rock mass classification scheme does not (and cannot) replace some of the more elaborate design procedures. However, the use of these design procedures requires access to relatively detailed information on in situ stresses, rock mass properties and planned excavation sequence, none of which may be available at an early stage in the project. As this information becomes available, the use of the rock mass classification schemes should be updated and used in conjunction with site-specific analyses.

[25]

QUESTION 3 – STRESSES

3.1 You are working on a narrow tabular mine at an average depth of 1950m below surface. You noticed a horizontally drilled hole in the sidewall of an excavation. The hole is 4cm in diameter and shows signs of spaling on the sidewalls of the hole.

Make use of the analytical equations below to calculate the radial and tangential stress on the sidewalls of the hole. The K-ratio on your mine is 0.5 and the overburden density is 2750kg/m3

$$\sigma_{rr} = \frac{p}{2}\left[(1+K)\left(1-\frac{a^2}{r^2}\right)-(1-K)\left(1-4\frac{a^2}{r^2}+\frac{3a^4}{r^4}\right)\cos 2\theta\right]$$

$$\sigma_{\theta\theta} = \frac{p}{2}\left[(1+K)\left(1+\frac{a^2}{r^2}\right)+(1-K)\left(1+\frac{3a^4}{r^4}\right)\cos 2\theta\right]$$

$$\sigma_{r\theta} = \frac{p}{2}\left[(1-K)\left(1+\frac{2a^2}{r^2}-\frac{3a^4}{r^4}\right)\sin 2\theta\right]$$

I allocated marks as follows as only 2 candidates could do the maths:

1½ points if they could determine that r = 2cm thus 0.02m

1½ points if they could calculate virgin stress and obtained a value of 53Mpa

The 2 marks for all three equations if they substituted the correct values into the equations.

(9)

3.2 Describe the type of fracturing one can expect around ore-passes in highly stressed ground, the resulting ore-pass shape and extent of fracturing.

In deep mines, very severe spalling and self-mining problems have manifested in operational ore passes, particularly when traversing weak rock formations. The extent of the magnitude of the stresses acting on the orepass in the X and Y directions would influence the mode of failure of these openings. Fracturing in the minor stress direction tends to extend further into the rock mass and lesser in the intermediate direction. The extent of fracturing again would be dependant on the rock strength and the magnitude of the stress field. When unsupported, such spalling taking place on an orepass could cause the rock at the perimeter to fail, extending further and further into the solid, as lesser confinement is available in the failed zone. Tipping ore into these passes would aggravate the extend of failure, due to the tipped rock breaking off the damaged outer shell of the orepass, causing the fracture zone to extend even further. Dog earing and the formation of the shape relative to the principle stresses. (4)

3.3 How is virgin stress calculated? (2)

depth, gravity and density

[20]

QUESTION 4 – MINING

4.1 Mining method selection is important to ensure that the orebody is extracted safely. What factors must be considered when selecting a mining method?

- Geometry of the deposit and the physical characteristics of the deposit and wall rock.
- Method adaptable to irregular ore limits, yielding good recovery and minimal dilution.
- Deposit strike length and dip.
- Consistency of the ore body width.
- The dimensions and regularity of deposit.
- The geomechanical properties of the wall rocks and ore.
- Nature of the grade distribution.
- Hydrogeology. (5)

4.2 List the differences between sequential grid mining and longwall mining.

Sequential grid

- Multiple raises develop and mined simultaneously
- Difficult to ventilate
- Long scraper distance
- Dip pillar layout
- Smaller spans
- Multiple Predevelopment of raises
- Geology known due to development in advance
- Development develop in higher stress
- More pillars can be left behind
- Grade can changes from low to high

Longwall

- One raise mined
- Easier to ventilate
- Strike pillar layout
- Large spans
- Pillars should not be left behind
- Development developed in destress areas
- Mostly higher uniform grade distribution

(6)

4.3 The depth of mining places a central role when decisions need to be made with regards to mining method and support strategies. Redraw the table below on your answer sheet and complete to indicate the difference in the parameters as the depth below surface increase.

Parameter	Shallow	Intermediate	Deep
Typical depth (m)	<1000	1000-2250	2250-3000
Typical ERR (MJ/m^2)	<8	8-40	40-80
Vertical virgin stress (MPa)	<25	25-60	60-95
Stress fracturing (intensity)	Little/none	Moderate	Deep
Stope closure(mm/m advance)	Low <10	Moderate(10-30)	High (30-60)
Influence of geology on h/w stability	Strong	Moderate	Moderate
Rockburst hazard	Minimal	Mod - severe	Severe

(11)

[20]

QUESTION 5 – SUPPORT

5.1 Explain the purpose of primary and secondary support in tunnels.

(4)

Primary support caters for the short-term rockmass condition. This will usually upgraded with the installation of a secondary support system to cater for the long-term rockmass environment (stress changes; seismicity; deformation). At this stage the function of the primary support is sometimes discounted, the primary support can be integrated with the secondary support to comprise the final support system.

5.2 List the difference between the following tendon support types:

5.2.1 End-anchor bolts

- Can be grouted
- Active support
- Corrosion limited when grouted
- More longer term support usually part of permanent support system

5.2.2 Friction bolts (4)

- Passive support – requires movement
- Corrion a problem
- Cannot be grouted with success
- Mainly use for primary support

5.3 Backfill is one of the most common support types used when extracting orebodies. Explain shortly how backfill may be used to provide local and regional support.

(8)

The ***local support*** benefit of backfill has been assessed in terms of its in situ influence on rock-related accidents and rockburst damage in the stope face area. This was done by comparing normalized accident rates for backfilled panels with equivalent rates for unfilled panels for given time periods at various mines. The result shows a correlation between high percentages of filling and reduced accident rates in backfill panels compared to unfilled panels. The converse was also shown whereby low backfilling percentages were associated with higher accident rates, and this persisted across different reef types.

Thus significant reductions in rockfall accident rate and rockburst damage are obtained in backfilled stopes compared to conventionally supported stopes when the percentage of area backfilled is high (60 - 70% of mined area). It is also important that backfill is kept close to the face (less than 6m), and good face area support is used between the backfill and the face.

The effectiveness of backfill as a ***regional support*** is commonly assessed in terms of limiting ERR, ESS and APS to acceptable levels and maximizing reef extraction. This beneficial regional support function is, however, only achieve if an appropriate percentage of good quality filling is carried out on a mine wide basis. Unlike pillars, backfill does not tie up valuable portions of reef and can be considered to have economic advantages in this regard. The *regional support* applications of backfill are:

- To limit the amount of elastic deformation of the rockmass affected by mining.
- To reduce the occurrence of seismic events by reducing ERR levels as well as the magnitude of shear stresses acting on planar geological structures.
- To reduce the stresses acting on stabilizing pillars to below that indicated by pillar failure criteria.
- To increase the percentage ore extraction by allowing greater spacing between stabilizing pillars and in general being able to leave fewer reef unmined in specific hazardous conditions.

5.4 When calculating the energy absorption capacity of support elements in a support layout the following equation is used.:

Energy absorption: $E = ½ mv^2 + mgh$

List the parameters in the above equation together with the unit of the parameter.

m = mass
g = gravitational pull
h = downward hang displacement.
v = velocity (3m/s) (4)

TOTAL MARKS: [100]

APPENDIX A

FORMULE SHEET

1. Total Energy = ½ m v^2 + mgh
2. $s_z = \frac{2(1-\nu)q}{G}\sqrt{l^2 - x^2}$
3. $l_c = \frac{s_m G}{2(1-\nu)q}$
4. $\sigma_s = 7.2\frac{R_0^{0.5933}}{V^{0.0667}}\left\{\frac{0.5933}{\varepsilon}\left[\left(\frac{R}{R_0}\right)^{\varepsilon} - 1\right] + 1\right\} MPa$
5. $e = 1 - \frac{w_1 w_2}{C_1 C_2}$
6. $ERR = \frac{\Delta U_m}{\Delta A} = \frac{\pi(1-\nu)lq^2}{2G}$
7. $\nu_p = \sqrt{\frac{\lambda + 2G}{\rho}}$ $\qquad \nu_s = \sqrt{\frac{G}{\rho}}$
8. $RCF = \frac{3\sigma_1 - \sigma_3}{F\sigma_c}$
9. $RQD = \frac{\sum lenght\ of\ core\ pieces > 10cm}{total\ lenght\ of\ core}\ x\ 100$
10. $\frac{h}{s} = \frac{1}{\sqrt{\frac{8h}{s} - 6}}$
11. Q = RQD/Jn x Jr/Ja x Jw/SRF

12. $G = \dfrac{E}{2(1+v)}$

13. $\tau = \sigma n \; tan(\text{Ø} + JRC\ 10 \log \tan(^{JCS}/\sigma n\ ))$

14. $APS = q_v/(1-e)$

15. $\varepsilon = \Delta\ell / L$

16. $E = \sigma/\varepsilon$

17. $\nu = \varepsilon_r / \varepsilon_a$

18. $Ps = K\, w^{0.46} \big/ h^{0.66}$

19. $Ps = K\, w^{0.5} \big/ h^{0.75}$

20. Salamon

$$FS = 288 \frac{w^{2.46}}{Hh^{0.66}(w+b)^2}$$

21. D Merwe

$$S = 3.5\left(\frac{w}{h}\right)(MPa) \quad L = \frac{25HC^2}{w^2}$$

22 Squat

$$\sigma_s = 7.2 \frac{R_0^{0.5933}}{V^{0.0667}} \{ \frac{0.5933}{\varepsilon} [(\frac{R}{R_o})^{\varepsilon} - 1] + 1 \} \quad L = \frac{25HC^2}{w^2}$$