



MINERALS COUNCIL
SOUTH AFRICA

EXAMINATION PAPER
METALLIFEROUS option

SUBJECT: MINERALS COUNCIL OF SOUTH AFRICA – CERTIFICATE IN STRATA CONTROL – METALLIFEROUS SUBJECT CODE: COMCSCM EXAMINATION DATE: 03 NOVEMBER 2020 TIME: 14:30 – 17:30	EXAMINER: JC VAN ZYL MODERATOR: J ESTERHUYSE TOTAL MARKS: [100] PASS MARK: (60%)
NUMBER OF PAGES: 7	
THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED Formulas are given on page 6 and 7 of this questionnaire SPECIAL REQUIREMENTS: 1. All candidates must complete Questions 1 to 4 . 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 (minimum 2) during your calculations, as rounding errors may result in incorrect answers. NB: Ensure that the correct unit of measure (SI units) 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.	

1 Question 1 – General: (25 marks)

1.1 Indicate if the following statements are, True or False (10)

- 1.1.1 Boreholes drilled in high stress intact rock exhibit immediate spalling or dog-earing.
- 1.1.2 Diurnal distributions of seismic data show a pronounced peak in seismicity just before the blast occurs.
- 1.1.3 Since closure rates in shallow environments are low and horizontal clamping are absent, stiff local support is required to control the hangingwall.
- 1.1.4 Sequential grid mining involves a grid of pre-development with breast mining up to dip pillars left intact.
- 1.1.5 Wherever possible, tunnels should pass closely above or below pillars and abutments to ensure minimal damage as a result of high stresses.
- 1.1.6 Cave mining is a term used to describe the practice of supporting only the immediate working area of advancing panels and allowing the unsupported back area to collapse in a controlled fashion.
- 1.1.7 Stopping is considered steep when the dip of the strata is equal or greater than 35 degrees.
- 1.1.8 Depth of fracturing ahead of the stope face is directly related to the ERR.
- 1.1.9 Ride is the differential oblique movement between the hangingwall and footwall and is affected by factors such as reef dip.
- 1.1.10 Overstopping is an effective method of protecting off reef excavations from the effects of mining induced stress changes.

1.2 In each case, write down the correct answer. It is not required to show your calculations. Partial marks may be allocated if calculations are shown. (15)

1.2.1 (2)

What is the volume of timber contained in a 55 cm x 55 cm mat pack installed in a stoping width of 1.2m?

- a)** 3.63 m³ **b)** 0.363 m³ **c)** 0.0363 m³ **d)** 0.00363 m³ **e)** none of the above

1.2.2 (2)

If the timber material (in question 1.2.1) has a density of 0.700 t/m³, what is the mass of the pack?

- a)** 0.254 t **b)** 0.254 kg **c)** 2.54 kg **d)** 0.254 kg **e)** none of the above

1.2.3 (2)

How many packs (in question 1.2.1) could theoretically be transported on a truck with a 20t bearing capacity?

- a)** 7.87 **b)** 800 **c)** 78.7 **d)** 787 **e)** none of the above

1.2.4 (3)

A perfectly square shaped haulage (developed on strike) on a gold mine, is 3.5m wide. Calculate the area of wire mesh per meter of tunnel length that is required to support the tunnel if it extends to within 1m of the footwall.

- a)** 16 m² **b)** 1.6 m² **c)** 4.25 m² **d)** 8.5 m² **e)** none of the above

1.2.5 (2)

If the virgin stress is 30 MPa and the induced stress is 10 MPa, the new field stress in MPa is:

- a)** 20 **b)** -20 **c)** -10 **d)** 40 **e)** none of the above

1.2.6 (2)

The capacity of a tendon is 450 MPa. The demand on the tendon is 150 MPa. Therefore, the factor of safety is:

- a)** 30 **b)** 0.3 **c)** 1.6 **d)** 3 **e)** none of the above

1.2.7 (2)

The recommended design for the width to height ratio of crush/yield pillars is:

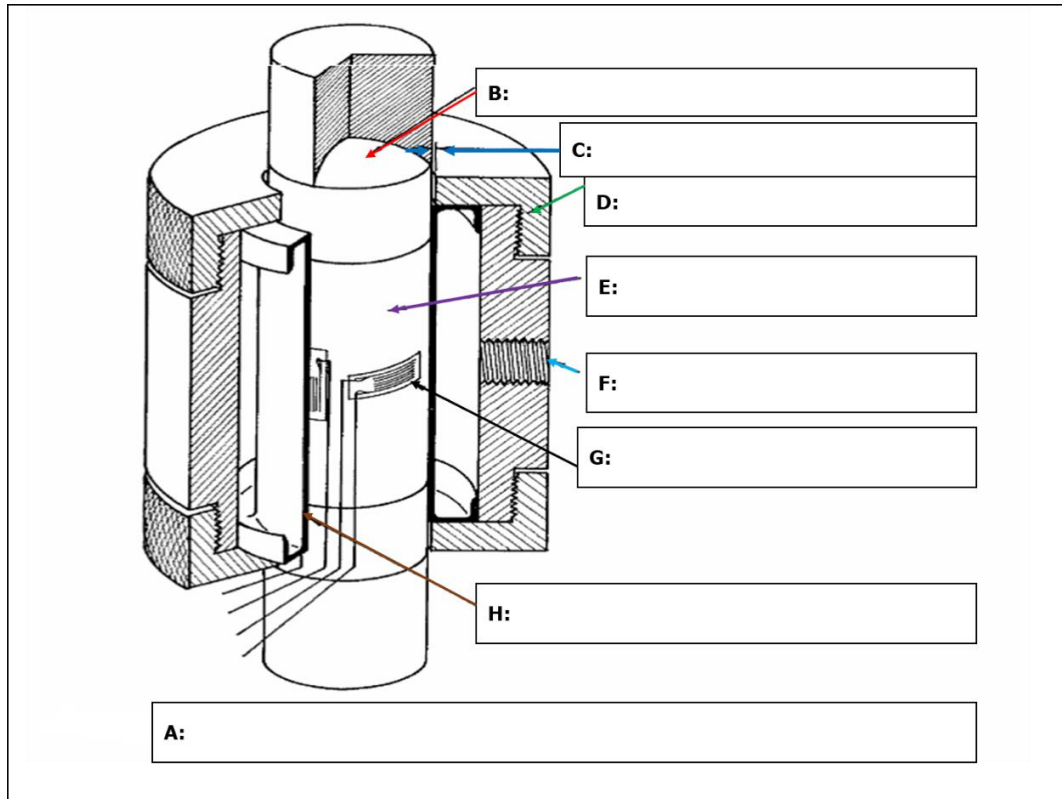
- a)** >3 **b)** <3 **c)** =3 **d)** >30 **e)** none of the above

2 Question 2: Definitions (20 marks)

- 2.2 Homogeneity (1)
- 2.3 Poisson ratio (2)
- 2.4 Shear modulus/modulus of rigidity (3)
- 2.5 Bulk Modulus (3)
- 2.6 Potential Energy (3)
- 2.7 Kinetic energy (2)
- 2.8 Slabbing (1)
- 2.9 Yield (1)
- 2.10 Weight (2)
- 2.11 What is the weight of a block with mass 1000 kg? (2)

3 Question 3: Rock Strength (30 marks)

- 3.1 Explain the differences between a strength criterion and a constitutive relation (4)
- 3.2 Draw 4 graphs describing the following constitutive relation: (8)
 - 3.2.1 Linear elastic
 - 3.2.2 Non-Linear elastic
 - 3.2.3 Elasto plastic
 - 3.2.4 Pure plastic
- 3.3 Describe the Hoek-Brown criterion and provide the formula (4)
- 3.4 Provide the formula for determining rock strength and describe two shortcomings of the Hoek-Brown criterion (4)
- 3.5 Name three other strength criterion (3)
- 3.6 State the apparatus (A) and annotate the diagram depicted on the next page from B-H (7)



4 Question 4: Support (25 marks)

- 4.1 You are a newly appointed Strata Control Officer on an intermediate depth mine. Your Rock Engineer has requested you to do a preliminary analytical assessment of a planned vertical raisebore ore pass. Determine the radial and tangential stress components on the edge of the excavation as well as for **points at a depth into the sidewall** from the edge of the excavation equal to 1.5 x excavation diameter and 3 x excavation diameter. The theta angle is 0°

The excavation will be developed to a diameter of 5.0m within a competent rockmass having an overburden density of 3 ton/m^3 . The mining depth is 1000m below surface. Assume the vertical stress is equal to the overburden and the horizontal stress is 44.145 MPa. Tabulate your final answers. (17)

- 4.2 Plot the profile of the of the Radial and Tangential stresses calculated in 4.1 above on the graph paper provided. Ensure the label your plot. (6)
- 4.3 What conclusion can you draw from the results? (1)
- 4.4 Should a second 5m diameter orepass be excavated, What distance apart would you recommend between two excavations? (1)

Formulas:

$$Q = \frac{RQD}{J_n} \frac{J_r}{J_a} \frac{J_w}{SRF} \quad RMR = 9 \log_e Q + 44$$

$$\sigma_1 = \sigma_3 + \sigma_{ci} \left(m_b \frac{\sigma_3}{\sigma_{ci}} + s \right)^a \quad \sigma_1 = \sigma_3 + \sigma_{ci} \sqrt{m_b \frac{\sigma_3}{\sigma_{ci}} + 1}$$

$$GSI > 25 \quad GSI = RMR_{76} \quad GSI = RMR_{89} - 5$$

$$GSI < 25 \quad Q' = \frac{RQD}{J_n} \frac{J_r}{J_a} \quad GSI = 9 \log_e Q' + 44$$

$$m_b = m_i \exp\left(\frac{GSI - 100}{28}\right) \quad RQD = 115 - 3.3 \times Jv$$

$$GSI > 25 \quad s = \exp\left(\frac{GSI - 100}{9}\right) \quad a = \frac{1}{2} \quad \sigma_1 = \sigma_3 + \sigma_{ci} \sqrt{m_b \frac{\sigma_3}{\sigma_{ci}} + s}$$

$$\sigma_{im} = \frac{\sigma_{ci}}{2} \left(m_b - \sqrt{m_b^2 + 4s} \right) \quad \sigma_{cm} = \sigma_{ci} \sqrt{s}$$

$$GSI < 25 \quad s = 0 \quad a = 0.65 - \frac{GSI}{200} \quad \sigma_1 = \sigma_3 + \sigma_{ci} \left(m_b \frac{\sigma_3}{\sigma_{ci}} \right)^{0.65 - \frac{GSI}{200}}$$

$$\sigma_{im} = 0 \quad \sigma_{cm} = 0$$

$$\sigma_{ci} > 100 \text{ MPa} \quad E_m \text{ (GPa)} = 10^{\left(\frac{GSI-10}{40}\right)}$$

$$\sigma_{ci} < 100 \text{ MPa} \quad E_m \text{ (GPa)} = \sqrt{\frac{\sigma_{ci} \text{ (MPa)}}{100 \text{ (MPa)}}} 10^{\left(\frac{GSI-10}{40}\right)}$$

$$\tau = \sigma_n \tan \left[\phi_a + JRC \log_{10} \left(\frac{JCS}{\sigma_n} \right) \right] \quad A = \frac{\pi D^2}{4}$$

$$\begin{aligned}\varepsilon_{xx} &= \frac{1}{E} \{ \sigma_{xx} - \nu(\sigma_{yy} + \sigma_{zz}) \} & \gamma_{xy} &= \frac{1}{G} \tau_{xy} & \varepsilon_{xy} &= \frac{1}{2G} \tau_{xy} & G &= \frac{E}{2(1+\nu)} \\ \varepsilon_{yy} &= \frac{1}{E} \{ \sigma_{yy} - \nu(\sigma_{xx} + \sigma_{zz}) \} & \gamma_{yz} &= \frac{1}{G} \tau_{yz} & \varepsilon_{yz} &= \frac{1}{2G} \tau_{yz} & K &= \frac{E}{3(1-2\nu)} \\ \varepsilon_{zz} &= \frac{1}{E} \{ \sigma_{zz} - \nu(\sigma_{xx} + \sigma_{yy}) \} & \gamma_{zx} &= \frac{1}{G} \tau_{zx} & \varepsilon_{zx} &= \frac{1}{2G} \tau_{zx}\end{aligned}$$

$$\begin{aligned}\sigma_{xx} &= \lambda\Delta + 2G\varepsilon_{xx} & \tau_{xy} &= G\gamma_{xy} & \tau_{xy} &= 2G\varepsilon_{xy} & \Delta &= \varepsilon_{xx} + \varepsilon_{yy} + \varepsilon_{zz} \\ \sigma_{yy} &= \lambda\Delta + 2G\varepsilon_{yy} & \tau_{yz} &= G\gamma_{yz} & \tau_{yz} &= 2G\varepsilon_{yz} & \lambda &= \frac{E\nu}{(1+\nu)(1-2\nu)} \\ \sigma_{zz} &= \lambda\Delta + 2G\varepsilon_{zz} & \tau_{zx} &= G\gamma_{zx} & \tau_{zx} &= 2G\varepsilon_{zx}\end{aligned}$$

$$\begin{aligned}\sigma_{zz} &= 0 & \varepsilon_{zz} &= -\frac{\nu}{E}(\sigma_{xx} + \sigma_{yy}) \\ \varepsilon_{xx} &= \frac{1}{E}(\sigma_{xx} - \nu\sigma_{yy}) & \gamma_{xy} &= \frac{1}{G}\tau_{xy} & \sigma_{xx} &= \frac{E}{1-\nu^2}(\varepsilon_{xx} + \nu\varepsilon_{yy}) & \tau_{xy} &= G\gamma_{xy} \\ \varepsilon_{yy} &= \frac{1}{E}(\sigma_{yy} - \nu\sigma_{xx}) & \sigma_{yy} &= \frac{E}{1-\nu^2}(\varepsilon_{yy} + \nu\varepsilon_{xx})\end{aligned}$$

$$\begin{aligned}\varepsilon_{zz} &= 0 & \sigma_{zz} &= \nu(\sigma_{xx} + \sigma_{yy}) & Pe &= mgh \\ \varepsilon_{xx} &= \frac{1}{E} \left\{ (1-\nu^2)\sigma_{xx} - \nu(1+\nu)\sigma_{yy} \right\} & Ke &= 1/2mv^2 \\ \varepsilon_{yy} &= \frac{1}{E} \left\{ (1-\nu^2)\sigma_{yy} - \nu(1+\nu)\sigma_{xx} \right\}\end{aligned}$$

$$q = \rho gH \quad \sigma_v = q \quad \sigma_h = kq$$

$$\begin{aligned}\sigma_{rr} &= \frac{1}{2}q(1+k) \left(1 - \frac{R^2}{r^2} \right) - \frac{1}{2}q(1-k) \left(1 - \frac{4R^2}{r^2} + \frac{3R^4}{r^4} \right) \cos 2\theta \\ \sigma_{\theta\theta} &= \frac{1}{2}q(1+k) \left(1 + \frac{R^2}{r^2} \right) + \frac{1}{2}q(1-k) \left(1 + \frac{3R^4}{r^4} \right) \cos 2\theta \\ \tau_{r\theta} &= \frac{1}{2}q(1-k) \left(1 + \frac{2R^2}{r^2} - \frac{3R^4}{r^4} \right) \sin 2\theta\end{aligned}$$