Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS **RMC PAPER 3.1**: HARD ROCK TABULAR **SUBJECT CODE:** COMRMC **EXAMINATION DATE:** 12 MAY 2022 **TIME**: 14:30 – 17:30	**EXAMINER:** KB LE BRON **MODERATOR:** P. COUTO **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 4

THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. Answer **ALL** the questions **legibly** in English and **in the suggested table format**.
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.

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 and other smart devices e.g. Smartwatches are **NOT** allowed in the examination room.

QUESTION 1.

1.1 Only write down True or False for each of the following statements:

A. Creep deformation commonly occurs between layers of mat packs.
B. Support in conventionally mined stopes extracting tabular ore bodies at shallow depths, should have high initial stiffness.
C. The VCR has a lower closure rate than the Vaal Reef at the same depth below surface.
D. Scattered mining is practised when the rock mass is highly faulted.
E. In longwall mining, the follow-behind footwall tunnels are generally developed greater than 50 m below the reef.
F. Bord and pillar layouts are generally employed in ultra-deep mines.
G. Reef drives are considered to have a lower rock fall risk than strike gullies, and therefore require less stringent support compared to ASGs.
H. Stabilising pillars are only required in deep mines.
I. The UG1 and UG2 has been extensively mined due to their PGM content.
J. High horizontal stresses within the Bushveld Complex prevents all potentially loose rocks from dislodging.

(10)

1.2 A vertical ventilation shaft is required to a depth of 821 m below surface, for an existing mine, currently producing 200kT of ore per month through the equipped main shaft (the capacity of the equipped vertical shaft is 220kT). The ventilation engineer has calculated that the final shaft diameter should be 6.5 m in order to provide the necessary ventilation for the planned mining. The exploration drill hole grid spacing is 200 m x 200 m, and the planned location of the ventilation hole is approximately in the centre between 4 exploration holes. The oriented core from these 4 holes, have been geologically and geotechnically logged. The excavation is planned to be raise bored and will be unsupported. You, as the appointed rock engineer, has been asked to review and assess the stability of the 6.5 m diameter vertical shaft.

A. Briefly list:
   i. The main requirements to successfully drill the raisebored shaft.
   ii. The main risk/s associated with raiseboring? (5)

B. Is there alternative method to raiseboring? How would this method differ from raiseboring in terms of impact on current shaft availability? (2)

C. (i) Recommend an alternative excavation layout / design (to the 6.5 m diameter vertical shaft), which would ensure that the ventilation engineer's requirements are still met with your proposed design?
   (ii) Justify your answer. (4)

(10)

1.3 Describe typical rock related hazards for the following scenarios:

A. Mining of the VCR at a depth of 3-4 km below surface. (4)

B. Describe typical risk reduction measures to limit the associated rock related risk. (4)

C. How would mining of the Carbon Leader at 700 m below the VCR, impact mining on the VCR? Explain (2)

(10)

[30]

QUESTION 2.

2.1 A platinum mine is planning to extract the Merensky reef at a depth of 1300 m below surface using a bord and pillar layout, and you have been requested to assess the geotechnical risk associated with the planned mining and to advise the management on the way forward.

Assume the following:

- Depth of the Merensky ore body below the ground elevation is 700 m
- The k-value is 45 MPa
- Current bord dimensions are 10 m on dip and 10 m on strike
- Current pillar dimensions are 8 m x 8 m
- The dip of Merensky reef is less than 10 degrees
- The best cut mining height is 2 m

2.1.1 Draw a schematic/section/diagram showing the main chrome and platinum bearing orebodies within the Bushveld Igneous Complex. Ensure they follow the correct sequence. (5)

2.1.2 Why do we not use a safety factor of 1 as a criterion to design stable pillars? (5)

2.1.3 Calculate the shear stress component for a 1 kg block on a sliding surface dipping at 45 degrees. Show all calculations / schematics. (5)

2.1.4 Will a pillar on the Merensky reef dipping at 0° behave the same as when it is dipping at 45°? Explain. (5)

2.1.5 Calculate the pillar strength using the Hedley – Grant formula, the pillar stress and safety factor, for the scenario above.

(6)

2.1.6 Will the pillar system be stable? Explain.

(4)

[30]

QUESTION 3.

3.1 Match column A to what you believe is the most suitable application in column B (drilling).

Number	*A*	*B*
3.1.1	Pilot hole (400 mm diameter) drilled from surface	Tunnel face drilling
3.1.2	PQ hole	Drop raise
3.1.3	1 m diameter Up-hole	Raiseboring
3.1.4	165 mm diameter hole	Blind Bore Slot
3.1.5	V-cut	Core drilling

(2½)

3.2 Match column A to what you believe is the most suitable in column B (monitoring).

Number	*A*	*B*
3.2.1	CSIRO Cell Strain Gauge	Stress measurement
3.2.2	Packer test	Bed separation in roof
3.2.3	“Flat jack”	Borehole breakout
3.2.4	Borehole Extensometer	Overcoring method
3.2.5	Borehole Camera	Hydraulic fracturing

(2½)

3.3 Match column A to what you believe is the most suitable in column B (laboratory test specimen and behaviour).

Number	*A*	*B*
3.3.1	Shallow dipping joints	Axial Splitting
3.3.2	Intact rock	Uncontrollable post-peak behaviour
3.3.3	Vertical joints	Anisotropic behaviour
3.3.4	Fine grained, homogeneous, brittle rocks	Post-peak behaviour
3.3.5	Servo-controlled testing machine	Continuous and isotropic

(2½)

3.4 Match column A to what you believe is the most suitable in column B (reef type and commonly associated behaviour).

Number	*A*	*B*
3.4.1	Strain (face) bursts	LG6/LG6A
3.4.2	High convergence rates	MG2
3.4.3	Low convergence rates	Merensky reef
3.4.4	Pillar bursts	Carbon Leader
3.4.5	Back-breaks	Ventersdorp Contact Reef

(2½)

3.5 Define the following:

3.5.1 Geophone

3.5.2 Reef

3.5.3 Aquifer

3.5.4 Seismic moment

3.5.5 Directional drilling

(5)

3.6 Which tools would you employ to define the following:

3.6.1 Core orientation line

3.6.2 Orientation and location in 3D space of a drill hole

3.6.3 Orientation of geological structures within a borehole

3.6.4 Water pressure in a borehole

3.6.5 Displacement within a borehole

(5)

[20]

QUESTION 4.

4.1 Multiple choice:

4.1.1 The s-wave travels through Quartzite rock at velocities of up to:

a) 6500 m/s
b) 5500 m/s
c) 4500 m/s
d) 3500 m/s

4.1.2 MAP3D is capable of modelling:

a) Elastic behaviour of rock masses
b) Explicit fault slip
c) Rock mass failure
d) All of the above

4.1.3 Quartzite rock may be:

a) Massive
b) Jointed
c) Bedded
d) All of the above

4.1.4 FLAC3D is able to simulate:

a) Inelastic behaviour of rock masses
b) Strain softening
c) Backfill
d) All of the above

4.1.5 What is considered to be a stable shape for a tunnel in ultra-deep mines, assuming continuous and isotropic rock mass conditions?

a) Curved roof
b) Square roof
c) Rectangular roof
d) Gothic arch roof

4.1.6 The p-wave travels through Quartzite rock at velocities of up to:

a) 6500 m/s
b) 5500 m/s
c) 4500 m/s
d) 3500 m/s

4.1.7 A surface wave along a highly fractured tunnel at great depth will exhibit the following:

a) Higher wave amplitude compared to body waves
b) Lower wave amplitude compared to body waves
c) Higher velocities compared to body waves
d) None of the above

4.1.8 Peak particle velocity (PPV) is related to the:

a) Amplitude of the wave
b) Velocity of the wave
c) Frequency of the wave
d) Wavelength

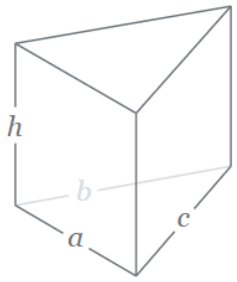
4.1.9 The Bushveld Complex is:

a) largest igneous intrusion within the earth’s crust
b) approximately 2 million years old
c) is well known for its gold deposits
d) All of the above

4.1.10 Calculate the volume of a borehole with a 50 mm diameter and a 250 m depth measured from collar:

a) 0.0049
b) 0.049
c) 0.49
d) 4.9

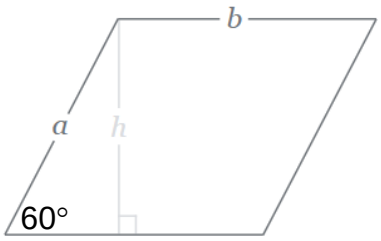
4.1.11 Calculate the volume of a tri-angular wedge in the roof of a tunnel with dimensions: h=1 m; a=1 m; b=1 m; c=1 m;



$$V = \frac{1}{4} h \sqrt{-a^4+2(a\,b)^2+2(a\,c)^2-b^4+2(b\,c)^2-c^4}$$

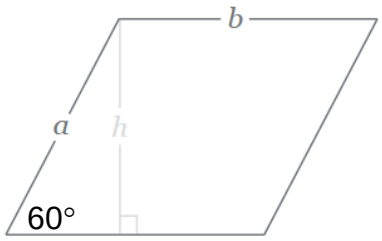
a) 0.0866 m^3
b) 0.0433 m^3
c) 0.433 m^3
d) 0.866 m^3

4.1.12 Solve for h in the parallelogram below if: a=2 m; b=5 m;



a) 1.73 m
b) 0.866 m
c) 8.66 m
d) 2 m

4.1.13 Calculate the area in the parallelogram below if: a=2 m; b=5 m;



a) 1.73 m^2
b) 0.866 m^2
c) 8.66 m^2
d) 2 m^2

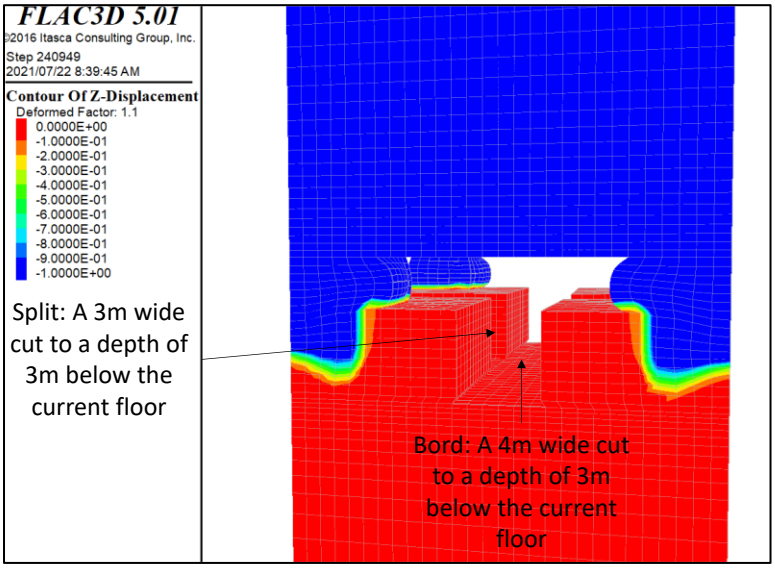
4.1.14 Extension fractures forming along the sides and above an advanced strike gully with no siding (at great depth) are:

a) Flat dipping
b) Steep dipping
c) Stable
d) Planar

4.1.15 The rock mass referred to as the Western Area Formation (WAF), found above the VCR is generally:

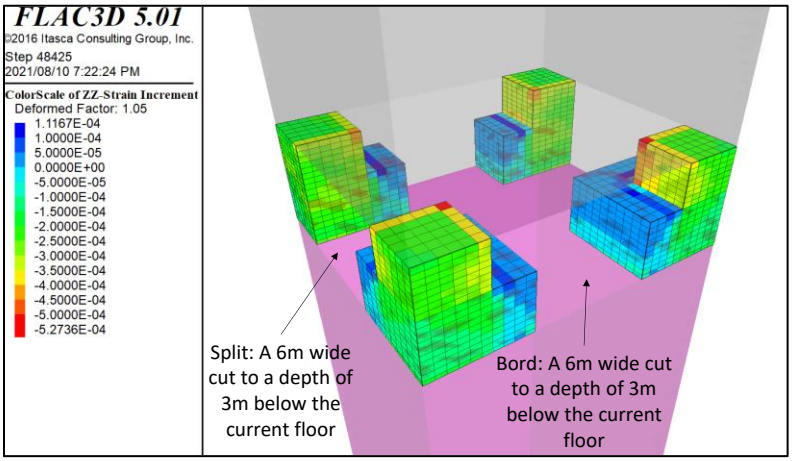
a) Strong with UCS > 250 MPa
b) Jointed and/or blocky
c) Continuous and Massive
d) Self-supporting

4.1.16 With reference to the layout below, is it?



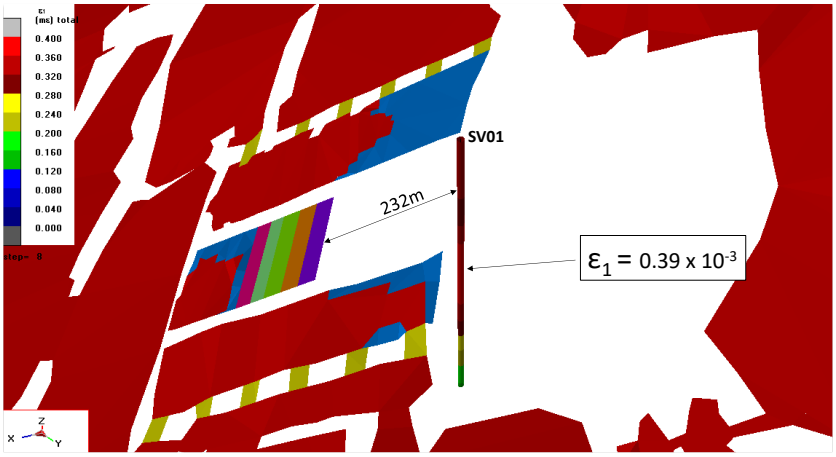
a) Stable
b) Unstable
c) Conditionally stable
d) None of the above

4.1.17 With reference to the layout below, are the pillars?



a) Stable
b) Unstable
c) Conditionally stable
d) None of the above

4.1.18 With reference to the layout below, is the vertical shaft?



a) Stable
b) Unstable
c) Conditionally stable
d) None of the above

4.1.19 To prevent scaling in an ore pass, the following typical support has successfully been implemented?

a) Tendons with mesh covered by a 100 mm thick layer of 70-90 MPa UCS andesite lava-based shotcrete
b) Tendons with TSL
c) Tendons only
d) None of the above

4.1.20 Kirsch equations may be applied to determine the horizontal middling between…?

e) Decline excavations with curved roofs
f) Decline excavations with square roof
g) Decline excavations with rectangular roof
h) None of the above

[20]