CHAMBER OF MINES OF SOUTH AFRICA

EXAMINATION PAPER MEMORANDUM

SUBJECT: CERTIFICATE IN ROCK MECHANICS PAPER 3.1 : HARD ROCK TABULAR **SUBJECT CODE:** COMRMC **EXAMINATION DATE:** OCTOBER 2015 **TIME**: 3 HRS	**EXAMINER:** B VAN DER KEVIE **MODERATOR:** WM BESTER **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES:

QUESTION 1 – MULTIPLE CHOICE

TICK THE CORRECT ANSWER ON THE ATTATCHED SHEET PROVIDED AND HAND IN WITH YOUR EXAM BOOK. ENSURE EXAM NUMBER IS ON THE SHEET.

1.1 Which **one** of the following statements is **correct ?**

a) Quartzite has an UCS of 160-220 KPa
b) The rock surrounding excavations are not in a state of uni-axial compression.
c) Tri-axial compressive tests are done to simulate the behaviour of the rock under confinement in the vicinity of underground openings.
d) Axial loading tests in a laboratory uses core with a length of 4-5 times its diameter.
e) a and b

(4)

1.2 Which **one** of the following 5 statements is **incorrect** ?

a) Sets of joints developed in response to major tectonic events and thus their occurrence can be expected over large areas.
b) In the Bushveld Complex, three sets of joints occur which are associated with tectonism, and further complex jointing is associated with "Potholes" on the reef horizon.
c) Joints are sensitive to minor deformation of the rock mass and shock loading due to mining activities, and unless adequately supported can cause large fall outs without warning.
d) Joints are geological discontinuities along which visible displacement has occurred.
e) a and c (4)

1.2 Which of the following statements is **correct** ?

a) In a shear strength testing of planar surfaces , each specimen is subjected to a stress parallel to the bedding plane, and the shear stress (τ) required to cause a displacement is measured.
b) Discontinuities may contain different infilling materials. The presence of such materials will influence the strength of discontinuities as well as its shear behaviour, depending on the characteristics of the infilling, such as the type of infilling and the thickness of the infilling.
c) Increased surface roughness of a joint decreases the shear strength of the surface.
d) Joints usually occur in sets, a set being defined as a group of joints with different orientations.
e) b and a. (2)

1.3 Which of the following parameters **are not used** to classify a rock mass using Bieniawski's RMR system ?

a) Uniaxial compressive strength of rock material.
b) Rock Quality Designation (RQD).
c) Stress reduction factor (SRF)
d) Condition of discontinuities.
e) d and a

(2)

1.5 Which of the following statements does **not** belong to conventional hardrock Longwall mining:
a) Orebodies with a dip not exceeding 15 degrees.
b) Where reefs are relatively narrow
c) Where the ore body is of a high grade
d) In relatively undisturbed ground.
e) All of the above

(2)

1.6 In a stable or elastic pillar design which of the following criteria is **not** used in the pillar design:

a) K - ratio
b) Pillar strength
c) Safety Factor
d) Extraction Ratio
e) Pillar foundation strata strength

(2)

1.7 Which of the following statements belong to watergel and emulsion explosives (Ammonuim Nitrates).

a) Low cost
b) High VOD
c) Low water resistance
d) Excessive blasting fumes
e) a and b

(2)

1.8 Which of the following instruments are used to measure rock fracturing.

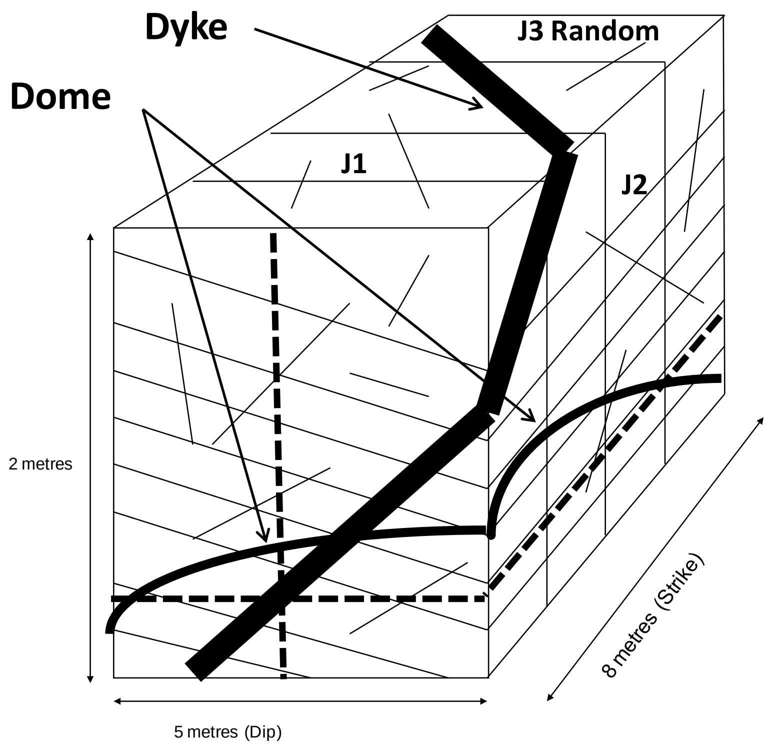
a) Petroscope
b) Accelerometers
c) Ground Penetrating Radar
d) a and c
e) a, b and c (2)

[20]

QUESTION 2 - GEOTECHNICAL ROCKMASS CLASSIFICATION

The rockmass below shows 2 joint sets and random joints on the UG2 reef horizon in a platinum mine in the Bushveld Igneous Complex. The joints are smooth and planar. There is 3 chrome seams (triplets) at 3m, 3.2m and 3.6m above the reef plane and not exposed. There is a Dyke and a dome structure as well. There is water dripping from all the joints . The joint filling is between 1mm and 3 mm. Calculate the Q rating using tables attached to the end of this paper.

Note: Show all steps and calculations used and finally comment on the stability of the excavation. Use the dotted lines in sketch below as the scan lines for your calculations. (Hint RQD= 115-3.3 x J_D). (20)



1) **Rock Quality Designation**

Strike = 5/8

S=0.625 joints per metre

Dip = 5/5

D = 1.0 joints per metre

Vertical =12/2

V = 6 joints per metre.

Therefore

J_D = 0.625 + 1 + 6

J_D = 7.625 **(3)**

RQD = 115 - 3.3 x J_D

= 115 – (3.3 x 7.625)

= 89.9%

RQD = 90 % **(2)**

2) Joint Set Number

J_n = 6 (2 joint sets and random joint)

(Remember to add 1 joint set for triplets)

J_n = 12 (2)

(from table 2, three joints plus random joints

3) Joint Roughness

The joints are smooth planar.

J_r = 1

(From table 3) (2)

4) Joint Alteration

>1 mm filling but less than 3mm.

J_a = 2

(From table 4) (2)

5) Joint Water

Joints – dripping water

J_w = 0.5

(From table 5) (2)

6) SRF

One Dyke and a curved joint which is a possible dome structure. 7.5 is obtained from table 6. The curved joint or possible dome structure is the worst case.

SRF = 7.5 (Table 6) + 1 (from adjustment table 7 for triplets)

= 8.5 (3)

Printing error in exam paper- Note for UG2 triplets was omitted during printing

Therefore 7,5 -9 will be accepted for SRF

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

Q = 90/12 x 1/2 x 0.5/8.5

= 7.5 x 0.5 x 0.0588

= **0.21 to 0.25 accepted because of SRF variance**

This is classified as very poor rock mass. (4)

[20]

QUESTION 3

3.1 The short encapsulation pull test is used to measure the performance of a rockbolt / resin /rock system. The test is performed underground and is the ultimate performance test of a bolt/resin/rock system. It should replicate the procedures,consumables and equipment in use for the particular mine for that support system

Give a brief description of the test. Include in your answer the hole depth (encapsulation length) curing period, type of mesuremnts taken and load applied. (5)

Holes are drilled in a suitable safe site in a solid rockmass underground. (1)

Holes are drilled 250mm to 300mm deep (1)

The pull test need to be done after curing perion of at lest 1 hour and not more than 24 hours (1)

An axial load is applied with a pull tester in increments to the end of bolt and the bolt extension measured. This data is recorded (Deformation at what load) (1)

The load is applied until the bolt fails (1)

3.2 Calculate the resin capsule length required for full column grouting of a 2,2m x 20mm diameter resin bolt in a 28mm hole . The capsule diameter from supplier is 25mm.?

(2)

Method 1

Capsule length = (hole diam^2 - BoltD^2)/Capsule Diam^2 x encapsulation length

$=(0.028^2 - 0.02^2)/0.025^2 \times 2{,}2\text{m}$

$= 0.6144 \times 2.2$ m

$=1.352$ m

Method 2

Hole volume = 1.355×10^{-3} m^3

Bolt volume = 0.691×10^{-3} m^3

Capsule Area = 0.491×10^{-3} m^2

Annulus volume = $(0.001355-0.000691) = 0.664 \times 10^{-3}$ m^3

Capsule length = Volume / Area

0.664 / 0.491

= 1.352m

3.3 Comment on at least 2 other practical allowances or adjustments that can influence the above calculation that must be considered for this calculation.

Overdrill allowance

Drill-bit wear allowance (2)

3.2 Briefly describe 4 (four) development support characteristics used in the selection of a support system. In your answer give examples of such support units that are favourable or comply to these characteristics. Also give typical areas/environments where you would use the support ? (12)

1) **Initial stiffnes** (3)

a) It is the rate at which load is developed within the support system with deformation of the rockmass.

b) Pre-tensioned mechanical rope anchors, pre-tensioned rockbolts and shotcrete/TSL is an examoles of development support unit with high stiffness.

c) Typical areas - low stress environment (gravity)

2) **Yieldability** **(3)**

a) Where significant rockmass deformation is anticipated due to high stress environment, large stress changes or dynamic loading, the support system must be yieldable enough to accommodate this deformation.

b) Pre-tensioned mechanical rope anchors and yielding tendons,.

c) Typical areas - High stress deformation and seismically active areas.

2) **Energy absorbtion capacity** **(3)**

a) The yield capabilities in conjuction with is yield load will essentially define the amount of energy the support can absorb., particularly under dynamic loading conditions.

b) Pre-tensioned mechanical rope anchors and arched yielding sets with cribbing and m/l

c) Typical areas - seismically active areas.

2) **Areal coverage** **(3)**

a) In order to maintain the overall sintegrity of the excavation the potentially unstable rockmass between the tendons need to be confined by areal coverage support

b) Wire mesh and lacing and shotcrete/TSL

c) Typical areas - low deformation, no stress change (TSL and shotcrete) shallow mining or de-stressed areas

Table 6.2.1 Support element design characteristics

Support element	Initial stiffness	Yield capacity	Load capacity	Shear capacity	Comments (applicability)
Friction tendon: Split Set/Swellex	fair	fair	low	fair/poor	Simple installation, corrosion a problem, Primary support only.
End Anchored pre-tensioned:					
Rock stud	v good	poor	med.	fair	Used under low stress conditions. Cables used for large excavations.
Cable anchor	v good	fair	high	good	
Fully grouted					
Smooth bar	good	fair	med.	fair	Easily debonded, requires good grouting.
Rebar	v good	poor	med.	poor	High initial stiffness, requires good grouting.
Drill steel	v good	poor	high	poor	High shear resistance.
Yielding tendon	fair	v good	med.	fair/good	Good yieldability.
Cable tendon>4m	fair	fair/poor	high	good	Yieldability + flexibility, may require good grouting.
Wire loops <3m	fair	fair/poor	med.	good	
Sets					
Arches + cribbing	poor	fair	high		Areal coverage in poor areas.
Fabric					
Mesh and lace	poor	good	low		Areal coverage + flexibility, labour intensive.
Reinf. s/crete (50 mm)	good	fair/poor	med.		Areal coverage + limited deformability.
Reinf. s/crete (50 mm) & lace	good	good	good		Areal coverage + fair deformability.
Un-reinf. s/crete (50 mm)	good	poor	med.		Areal coverage in areas of low deformation.

[20]

QUESTION 4

4.1 The table below shows FOG statistics for Merensky stopes over the past few years. Calculate cumulative percentage fallout thickness for the workings. What percentage do you use for calculating the required support resistance and why ? (10)

Fallout Thicknes	Number of occurences			
	2015	2014	2013	TOTAL
0	**0**	0	0	0
0.5	**1**	4	3	8
0.6	**5**	6	2	13
0.7	**0**	1	6	7
0.8	**0**	2	6	8
0.9	**2**	5	4	11
1	**2**	2	1	5
Total	10	20	22	52

Fallout Thicknes	Number of occurences					
	2015	2014	2013	TOTAL	%	cum. %
0	**0**	0	0	0	0	0
0.5	**1**	4	3	8	15	15
0.6	**5**	6	2	13	25	40
0.7	**0**	1	6	7	13	54
0.8	**0**	2	6	8	15	69
0.9	**2**	5	4	11	21	90
1	**2**	2	1	5	10	100
Total	10	20	22	52	100	

(6)

Use 95 – 100 % which amounts to 0,95m. (1)

95% is an acceptable engineering design. If you select 100% the required support resistance will be catering for the odd FOG that is say 10m high and this is not practical nor feasible.

Another acceptable methodology is to filter out the odd or anomalous FOG that requires non-standardised treatment (like S-conditions in ABS) and then to cater for 100% of the "normal" FOT when designing standard support.

(3)

4.2 Calculate the required support resistance if the density of the rock is 3,4 tons/m^3 (2)

Required SR = 9.81 x (0.9m to 1m) x 3400 kg/m^3

= 31.6 to 33.4 kN/m^2

4.3 Your mine is using 150mm minepoles with a pre-stressing pot with inside diameter of 180mm. The pot is pre-stress on top of the minepoles to 12 Mpa. What is the pre-stressed load applied to each minepole on installation

Pre-stressed Load	= Stress x area of minepole	(1)
	= 12 Mpa x 0.018m^2	(1)
	= 212 kN	(1)

If candidate used the jackpot diameter instead of minepole diameter deduct 1 mark.

4.4 The in-stope support spacing is 1,8m on strike and 1m on dip (skin to skin). Using the tributary area of one minepole calculate the support resistance obtained with this single minepole on installation. Use and mention all your practical experience in answering the question. (8)

Centre to centre spacing is 1,8m + 0.15m = 1.95m and 1m + 0.15m = 1.15m

One mark for calc and 1 mark for identifying centre to centre to be used (2)

Jackpot Area = $0.0254m^2$

Force = Stress x Area

= 12Mpa x $0.0254m^2$

= 305 kN

SR = 305 kN /(1.95 m x 1.15 m)

= 136 kN/m^2 (1)

If candidate used or make mention of some acceptable method to de-rate u/g performance of support 2 additinal marks are obtained. (%, formula or just commented on u/g performance versus lab.) (2)

[20]

QUESTION 5

5.1 A shallow narrow reef mine in the Bushveld complex is using elastic pillars on the gully. The stoping width is 1m and the panel length is 31m. The dip of the reef is 22 degrees. The pillars are a 4m x 4m pillar layout with 2m vent holings in between with no siding. The density of the reef is $3270kg/m^3$ and the k constant falue is 76 Mpa. Calculate the Factor of Safety for this pillar system at a depth of 450m B.S. Use the given formulas below: (10)

$H_{eff} = (1+0.2692\ (w/h)^{0.08}) \times h$ (Formula 1)

Pillar stress = Load/ $W_{eff}\ ^{7.2}$ (Formula 2)

Pillar strength = $k \times We^{0.72} / He^{0.40}$ (Formula 3)

.No siding on the pillar in the gully therefore a H_{eff} must be calculated

- The optimum centre to centre panel span = 35m
- We = 2WL / (W+L) = 2*4*4/4+4 = 4m (2)
- He = $(1+0.2692\ (w/h)^{0.08})$ x h =1,302m (1)
- Calculate pillar stress by using Tributary Area Theory (TAT)
- Tributary area = 35m (2m+4m) = $210m^2$ (2)
- Load = 210 x 9.81 x 3270 x 450m = 3031zA.44 MPa (2)

- Pillar stress = Load/ $W_{eff}{}^{7.2}$
  $=3031/4^{7.2}$
  =189 MPa (1)

- Strength = 76 x $We^{0.72}$ / $He^{0.40}$ = 76 x $4^{0.72}$ / $1.302^{0.40}$ = 185.5 MPa (1)

- FOS = 185.5/189 =0.98 say 1 (1)

5.2 List and discuss the conditions where longwall mining can be used? (4)

At great depth (2000m or more)

High grade orebody since total extraction must be done

Relatively undisturbed ground since all geological features must be mined

Narrow reefs up to 2m but can be done up to 5m using double cut methods.

5.3 List and describe the advantages of longwall mining? (3)

Very few remnants being created

Off-reef excavations and follow behind development in de-stressed ground.

On reef development minimal, only a sigle raise required for stoping long distances on strike.

5.4 List and describe 3 shortcomings of longwall mining (3)

Inflexibility - selective mining of high grade cannot be practised

No knowledge of geological conditions ahead of face

Creation of stoping abutments on strike pillars creating seismicity.

[20]

Answer sheet multiple choice (Question 1)
October 2015   Paper 3.1

ID Number | | | | | | | | | | | | | |

	a	b	c	d	e
1.1	☐	☐	☐	☐	☐
1.2	☐	☐	☐	☐	☐
1.3	☐	☐	☐	☐	☐
1.4	☐	☐	☐	☐	☐
1.5	☐	☐	☐	☐	☐
1.6	☐	☐	☐	☐	☐
1.7	☐	☐	☐	☐	☐
1.8	☐	☐	☐	☐	☐

1.	ROCK QUALITY DESIGINATION	RQD
A	Very Poor	0-25
B	Poor	25-50
C	Fair	50-75
D	Good	75-90
E	Very Good	90-100
Note:	a) Where RQD is reported as being less than 10, a value of 10 should be used and not more than 100. b) RQD need only be as accurate to the nearest 5 i.e. 100, 95, 90 etc..	

Table 1 : This table shows the different categories of rock classes and their corresponding RQD values.

2.	JOINT SET NUMBER	J_n
A	Massive, no to few joints	1
B	One joint set	2
C	One joint set plus random joints	3
D	Two joint sets	4
E	Two joint sets plus random joints	6
F	Three joint sets	9
G	Three joint sets plus random joints.	12
H	Four or more joint sets, random, heavily jointed.	15
I	Crushed rock	20
Note:	On UG2 include the intermediate and triplets as an additional joint set. On MR Footwall drives, if OPL's are a problem, include as an additional joint set	

Table 2: Adjustments to describe the joint set number for an underground site.

3.	JOINT ROUGHNESS NUMBER		J_r
A	Discontinuous joints		4
B	Rough or irregular	undulating	3
C	Smooth	undulating	2
D	Slickensided,	undulating	1.5
E	Rough or irregular	planar	1.5
F	Smooth	planar	1
G	Slickensided	planar	0.5
Note:	Descriptions refer to small scale and large scale in that order.		

Table 3: Adjustments for small scale roughness and large scale waviness of the joint plane.

4.	JOINT ALTERATION NUMBER	J_a
A	Tightly healed, hard rockwall joints, no filling	0.5
B	Slight infill, coating < 1mm	1
C	Joint filling > 1 mm	2
D	Joint filling > 3 mm	4
E	Zones or bands of disintegrated or crushed filling, open joints.	8
Note:		

Table 4: Adjustments for accounting for fill thickness along the joint planes.

5.	JOINT WATER	J_w
A	Dry	1
B	Dripping water	0.5
Note:		

6.	STRESS REDUCTION FACTOR	SRF
A	No shear, faults, dyke or weakness zone	1
B	One shear, fault, dyke or weakness zone	2.5
C	One shear, fault, dyke or weakness zone with blocky ground conditions	4
D	Curved joints or dome structure approaching a pothole, reef roll or OPL's	7.5
E	Curved joints or dome structure approaching a pothole, reef roll, OPL's with blocky ground conditions	8
F	Many faults, dyke and weakness zones.	9
G	Wide shear zone	10
Note:	Use adjustments in table 7 for specific for UG2 .	

Table 6 : SRF values for common geological features.

7.	ADJUSTMENTS FOR UG2 REEF HORIZON UG2 chromitite seam to intermediate/triplet middling	
A	< 30 cm	10
B	30 cm to 50 cm	8
C	50 cm to 1metre	4
D	> 1 metre	1
Note:		

Table 7 : Adjustments to be added to values from table 7, if the stope is on UG2.

Q - Rating	Ground Conditions
0.005 to 0.9	Very Poor
1 to 5	Poor
6 to 10	Good
10+	Very Good

Table 8 : Q-Value / Rock Mass Condition