Chamber of Mines of South Africa

EXAMINATION PAPER

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SUBJECT:

CHAMBER OF MINES CERTIFICATE IN

ROCK MECHANICS:PAPER 2

SUBJECT CODE:
COMRMC

EXAMINATION DATE: October 2016
TIME:

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EXAMINER:
B VAN DER KEVIE

MODERATOR:
P GREYLING

TOTAL MARKS: [100]

PASS MARK: 60%

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NUMBER OF PAGES: 11(including answer sheet)

SPECIAL REQUIREMENTS:

1. Answer all questions.
2. Write your **<u>answers for Question 1 on the answer sheet provided</u>** at the back of the question paper and submit this with your script.
3. **Only 1 (one) correct answer for all questions in Question 1.**
4. References other than those provided are not permitted.
5. Hand-held electronic calculators may be used.
6. 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.

7. **<u>Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).</u>**
8. Show all calculations on which your answers are based.
9. Illustrate your answers by sketches of diagrams wherever possible.
10. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.
11. Answers must be given to an accuracy that is typical of practical conditions.
12. Cell phones are **<u>NOT</u>** allowed in the examination room.

QUESTION 1

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

Only 1 (one) most correct answer for all questions in Question 1. If more than one is ticked no marks will be given

1.1 Which **one** of the following rocks are not Igneous rocks?

a) Syenite
b) Gabbro
c) Gneis
d) Kimberlite
e) Trachyte (1)

1.2 Which **one** of the following rocks are not sedimentary rocks?

a) Mudstone
b) Shales
c) Coal
d) Hornfels
e) Limestone (1)

1.3 Which **one** of the following rocks are not Metamorphic rocks?

a) Quartzite
b) Shale
c) Slate
d) Migmatite
e) Marble (1)

1.4 Which **one** of the following statements is in**correct?**

a) There are many **normal faults** in the goldfields with throws exceeding 100 m. The largest inferred fault system strikes NS, west of the Klerksdorp goldfield, and has an estimated throw of 10 000 m (Strydom 1971). To the south of this area is a post-Transvaal fault with a well-stablished throw of 2 000 m and another of 5 000 m estimated from drilling. In the Free State goldfields, the largest fault exposed has a throw of 1 700 m. The northern limit of the Carletonville fault is a horst structure bounded by faults with throws of over 2 000 m. In the Evander goldfield, which is an extension of the main Witwatersrand basin and is intensely faulted, the largest fault has a throw of 300 m.

b) Bedding plane faults, as the name implies, strike and dip essentially perpendicular with the stratification but can locally cross-cut up or down through the succession. They are not present in all the major goldfields. Where they occur close to the reef horizon they not only complicate mining by displacing the reef, but the presence of secondary horsetail shears, splaying off the main fault, can cause difficult strata control problems (Roberts et al 1972).

c) The Witwatersrand Basin has experienced at least nine episodes of dyke and sill intrusion. Most of the intrusions are basic in composition, reflecting the major magmatic events that have occurred in Southern Africa. The oldest, associated with the mainly andesitic Ventersdorp lavas, are altered and relatively weak, UCS 140 – 180 MPa; whilst the more recent dolerite intrusions can be exceptionally strong, having UCS values of 300 – 750 MPa.

d) a and b (4)

1.5 Which **one** of the following instruments measure opening of discontinuities?

a) Petro-scope

b) Doorstopper

c) Geophone

d) Wire extensometer

e) GPR (1)

1.6 Which **one** of the following statements is in**correct?**

The greater the burden on a hole:

a) The longer will be the back–cracking away from the free face

b) The further the gases will penetrate any jointing in the rock mass

c) The greater will be concussion in the excavation, blasting out support damagingventilation columns and shaking down relaxed rock from the side and hangingwall.

d) The higher will the velocity of detonation (VOD) be. (1)

1.7 What is the ideal w:h ratio of squat pillars ?

a) 10

b) 5

c) 2-3

d) 15

e) 4 (1)

1.8 The results obtained from pull tests done on a capsulated grout from 200mm steel pipes are

1. 2.8 tons2. 3.2 tons3. 3.0 tons

What is the critical bond length based on the above results, when used in conjunction with 22mm diameter tendons produced from 500MPa steel.

a) 2.3m

b) 1.291m

c) 500mm

d) 300mm

e) 1.5m (4)

1.9 What is the most suitable mining method for a reef-body dipping at 80 degrees with a stoping width of 2m at shallow depth?

a) Scattered mining

b) Longwall mining

c) Longhole open stoping

d) Cut and fill mining

e) Block caving (1)

1.10 What is typical stope closure rates (mm/m face advance) for breast panel stoping in intermediate mining depths (1000m 2250m - B.S.)

a) 5mm

b) 10-30mm

c) 30mm

d) >30mm

e) <10mm (1)

1.11 With respect to the mine health and safety act Chapter 14 which one of the following statements is incorrect:

At any underground mine where a risk of rock burst, rock falls or reef falls exists and at every other mine where a significant risk of rock burst, rick falls or roof falls exists, the employer may not permit any person, other than those persons examining and making safe, to enterany of the following areas at the mine until such areas are declared safe by a competent person:

a) The area between the face and the nearest line of permanent support; and

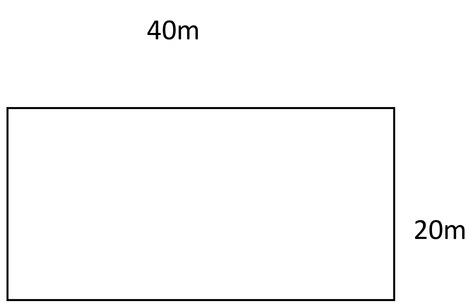
b) Access ways, travelling ways or places where persons need to travel or work;

c) Must ensure that only competent persons install, maintain and remove any support unit;

d) Must ensure that the input of a competent person is properly and timeously considered and integrated into the mine design, planning and operations

e) This competent person means a person who is at least in possession of either the Chamber of Mines certificate in Rock Engineering or a Chamber of Mines Strata Control Certificate in Rock Engineering. (2)

1.12 Calculate the <u>hydraulic radius</u> for the following shape:



a) 6,67
b) 2,00
c) 13,33
d) 10,00
e) 0,500 (2)

1.13 The typical width to height ratio for an elastic pillar would be:

a) ≤ 5

b) ≥ 5

c) ≥ 3

d) < 10

e) >5

(1)

1.14 $\text{Log}_{10}L \equiv 1 + M/2$ estimates, in meters, the source dimension resulting to a specific magnitude of seismic event. What is the estimated event magnitude if the source dimension is 1 000m?

a) 3,5

b) 4,0

c) 3,0

d) 5,0

(2)

1.15 What is the effective pillar width for a pillar measuring 7m x 4m?

a) 4m
b) 6m
c) 3m
d) 5m
e) 7m (2)

Total: 25

Question 2 (Mine Design, Support and instrumentation)

A new platinum mine is being planned in the Western Bushveld. The average depth of this single tabular orebody is 250m below surface. The dip of the orebody is 29 ° and the planned stoping width is 1,1m. The orebody is totally payable and is disrupted by only a few steep and flat dipping faults and dykes with displacements ranging from 3 to 5m. The host rock is jointed with 3 joint sets and a random joint set. This random joint set is normally flat dipping (<45°) and consist of a cohesion less soft Serpentinite infilling.

The hangingwall of the reef is Pyroxenite with a strength of 250 MPa. The orebody is Chromotite with a UCS of 50 MPa. The footwall is Anorthosite with a UCS of 100MPa. A Undulating Calcite Break (UCB) is in the hangingwalland the distance from TRC ranges from 0m to 6m into thehangingwall. The contact of the UCB is approximately 2cm thick with soft cohesionless Calcite as the infilling. The frequency and amplitude of the UCB varies significantly and is totally unknown and unpredictable.

2.1 What mining method would you consider to mine this orebody?
Give reasons for your answer

Conventional Scattered mining or Hybrid Scattered mining (stoping conventional and development trackless)

- Shallow mining (250m B.S.) favours scattered mining.
- Narrow orebody will not allow for board and pillar (trackless equipment will not fit) therefore conventional is only known method that can work
- Dip of Reef (29°) favoures scraper cleaning and therefore conventional stoping the only method.
- No major faulting to negotiate in development and stoping
- Elastic or stable pillars on gully yields good extraction ratios compared to other methods like board and pillar mining.
- Scattered mining allows pre-development and thus opening of ore reserves and good for exploration and water detection
- Strong hangingwall pyroxenite favours conventional stoping. (4)

2.2 What regional and local pillar system would you consider?
Give reasons for your answer.

Stable or Elastic pillars on the downdip side of gully. Regional pillars between raiselines

- Shallow depth requires stable pillars to prevent backbreak.
- If Safety Factor is too low (<1.6) Potholes can also serve purpose of regional support pillars if distribution is sufficient otherwise additional regional pillars.
- Pillars on downdip side of gully is easy to mine and yields good extraction ratio. (4)
-

2.3 What in-stope support system would you use?

Give reasons for your answer

Pre-stressed Minepoles

- Very stiff support system ideal for these shallow conditions.
- Cheapest support system available on market.
- *In stope roofbolting as primary support not recommended due to UCB.* (3)

2.4 What are the possible risks and challenges you would encounter with the UCB in the hangingwall ? Give possible actions and solutions for these challenges.

- Local FOG if UCB is ± ≤ 0.5m in hangingwall. Increase support density or mine up to UCB
- Minepole support system may prove to be too low Support Resistance if UCB is 6m in hangingwall. Support not able to carry load of a 6m beam and may become detached due to low tensile stress environment and resulting in local beam failure or backbreak. Increase support resistance by installing larger diameter minepoles or 2 or 3 minepole cluster lines.
- UCB intersect with other major joints, faults or potholes creating large blocks of unstable ground. In stope pillars cut adhock to increase stability in these areas where UCB intersects other major geological features. GPR can be used or drilling with borehole camera. (6)

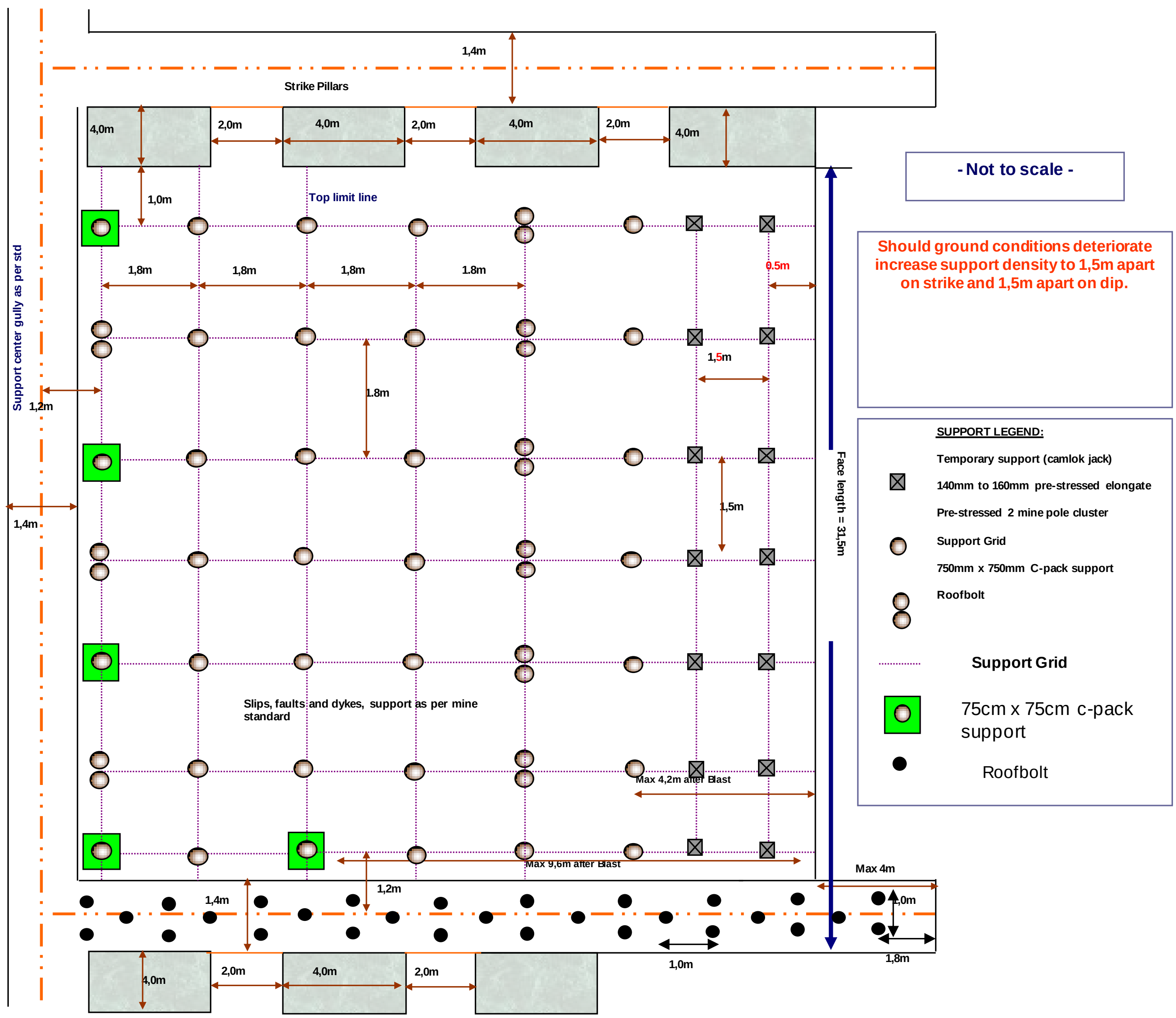
2.5 Name four possible Strata control/Geotechnical challenges to be expected and possible actions to minimize the risk of these challenges

- Pillar robbing - monthly pillar reports, visits, panel ratings
- Backbreak – check pillar robbing monthly report and panel ratings and regular visits
- In-stope support installation poor quality – Regular visits and on site training
- Brows – improved drilling and blasting and support of geological features both sides.
- Drilling into hangingwall and poor drilling in general (burden etc) – Training, visits and awareness.
- Poor blasting practices- Training, visits and awareness.
- Support failures – not enough or insufficient support - Training, visits and awareness.
- Face shape poor – support lines incomplete, poor breaking of face and support blasted out.- Training, visits and awareness.
- High stoping width due to blasting and drilling – use low VOD explosives improve drilling
- Hazardous Jointing – cut adhoc pillars increase support eg. Clusters.
- Pillars scaling due to low strength of reef – shotcrete or strap pillars. (8)

Total: 25

Question 3 (Mine support and design)

You are the Senior rock Engineer on a Bushveld Mine. The mining method is scattered mining with a raiseline spacing of 200m. Panels are 32m long, breast and with elastic (stable) pillars on the gullies. The layout and support standard is depicted in the sketch below. The average depth is 150m below surface the stoping width is 1.1m and the dip of the reef is 20°. The host rock is jointed with 2 joint sets and a random joint set. This random joint set is normally steep dipping (>70°) and consist of a cohesion less soft pegmatoidal infilling.



3.1 Recently progressive pillar failures are being experienced and it is becoming more common in the back areas in certain areas. These failures take the form of pillar spalling, hour-glassing and sometimes violent bursting.

3.1.1 Briefly name 4 possible reasons (Mining and/or Rock Engineering) for this pillar scaling in the back area?

- Pillar design is insufficient (size of pillars)
- Pillars are being robbed.
- Due to low strength of the reef pillars are failing
- Soft footwall causing punching of pillars into footwall
- Designed panel length not adhered to.
- K value not correct.
- Jointing and/or different weaker reef encountered.

(4)

3.1.2 How will this affect the current stoping and why ?

- Tensile fractures will develop causing FOG and proressive failure will result in panels being lost due to FOG and eventually whole stopes collapsing due to large scale backbreak.

(2)

3.1.3 What corrective measures will you take to ensure the future stability of the panels?

You can use the support standard to mention the possible supportchanges and why as a guideline.

In- stope Support modifications <u>will not resolve</u> pillar failures.

- Shorter panel lengths to be investigated Use Hydraulic radius calcs and Modified stability number to determine stable spans.
- Re-design pillars by using modelling or re-calc pillar sizes using weaker reef encountered.
- Investigate k value in pillar design.
- Do UCS tests on reef material to see if it changed.
- Investigate possible placement of dip stability pillars between raiselines.
- Use additional in stope pillars or re-raising to increase pillar percentage (2)

3.1.4 Name 2 types of instrumentation you can install to monitoror measure factors or conditions that can affect future stability once corrective action has been taken to give early warning to prevent a possible re-occurrence?

- Closure metres.
- Extensometer (rod or wire)
- Closure ride stations.
- Sonic Extensometers etc. etc

(2)

3.1.5 The instrumentation listed in 3.1.4: Explain with sketches how this instrumentation work and the outputs/results you obtain from it.

All of the instruments below will suffice.

9.3.1 Closure Meters

Closure meters, sometimes also called **convergence meters**, are probably the most frequently installed rock mechanics monitoring devices in the South African hard rock mining industry. This is due both to the importance of convergence in the mining situation and the relative simplicity of the devices. Closure meters are used to determine the convergence of the boundaries of underground excavations. This is usually achieved by determining the amount by which two opposite walls of an excavation (i.e. hangingwall vs footwall or left sidewall vs right sidewall) move towards each other.

(a) Spring vernier closure meter and four-peg closure/ride station

This device consists of a spring vernier and a suitable measured length of wire trace (Figure 9.3.1), and is used to measure relative displacements between bolts installed in the skin of excavations. It is used for measuring convergence over short distances, with its maximum operational length being limited to 4 m due to the soft nature of the spring in the meter. The accuracy of this device is not particularly high at 1.0 mm, but it is adequate for most tasks. Frequency of measurement depends on closure rate, but typically readings are taken daily or at least every second day.

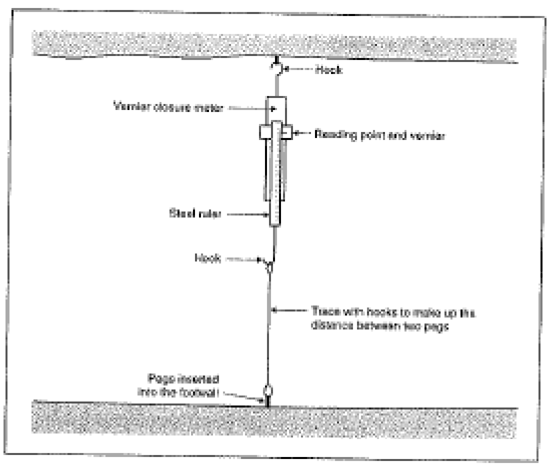


Figure 9.3.1 Schematic of spring vernier closure meter

This is a low cost device, is reasonably robust, and is easy to use and carry. Only one instrument is required per monitoring site, together with appropriate lengths of wire length of measuring tape attached to the free end will just protrude from the collar of the borehole. Readings made on these tapes against a reference point at the collar of the borehole (usually on a collar pipe) are used to determine the axial deformation along the borehole relative to the deepest anchor position. A tensioning system is required at reading time to ensure consistency of readings; this is usually some form of plumb bob which is hooked onto the end of each tape in turn. Remote and continuous readout can be achieved by attaching a potentiometer to each wire and using a data logger.

The number of measuring points depends on the size of hole. Typically a BX size hole can accommodate up to six anchors with accompanying wire trace, and an NX size hole up to ten. Although the accuracy of this system is limited to only ±1 mm, this is sufficient in many cases, and its simplicity and cheapness makes it a popular choice.

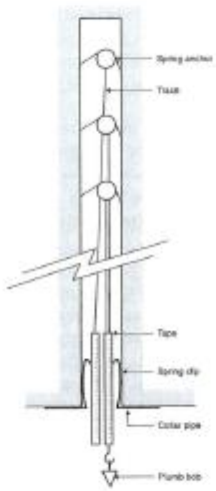


Figure 9.3.9
Schematic of wire extensometer.

(b) Rod extensometer

A rod extensometer is a system of grouted reference points in a borehole which are connected to a measuring head at the collar of the borehole by means of rods encased in PVC tubes (Figure 9.3.10). A dial gauge or an LVDT detects movement of the rods at the borehole collar. This system is more robust and more amenable to remote and/or continuous readout than the wire extensometer. This, together with its higher cost and somewhat more involved installation procedures, advocates its use for long-term monitoring projects, generally for critical excavations where these features are warranted.

The interpretation of results from this device follows along the same lines as for the wire extensometer. Accuracy is, however, much improved over the wire extensometer at a possible ±0.1 mm.

(4)

3.2 In a second geotechnical area different conditions are being experienced. The pillars are stable and not scaling or failing but the in-stope support (minepoles and Packs) are buckling and failing due to excessive closure.The area is dominated by a large amount of shear-zones being intersected. These shearzones are areas of intense jointing superimposed on the existing joint sets.

3.2.1 Briefly discuss the possible reasons for this support failing in the back area?

Use sketches to illustrate failure mechanisms.

Pillar modifications and/or additional pillars will not solve the problem because pillars are stable but in stope support must be modified. However, ad-hoc in stope support pillars on features of concern will assist.

Firstly beam failure or “backbreak” occur where the closure is excessive and the support unable to carry the overburden load. This results in the support failing and the consequence is unravelling of the hangingwall and eventually the panel is lost. This clearly indicates local deadweight between pillars that cannot be supported with the current support system. This is explained in figure below

Furthermore, due to the fact that the Modulus of the un-weathered material of the direct hangingwall is significantly higher than that of the super-incumbent weathered/oxidized layers, deflection of the upper layers results in shear and tensile failure of the lower more competent beam. The differential displacements of the low modulus weathered material and the relatively un-weathered immediate hanging-wall results in different displacements of the different beams. Although the differential modulus explains the shear and tensile failure of a relatively intact and competent hangingwall beam, the presence of numerous flat dipping cohesion-less layers,) and flat dipping joints (UCB) results in relatively thin cantilevers which could shear of if the lever-arm becomes too large; i.e. it is a cantilever rather than a beam.

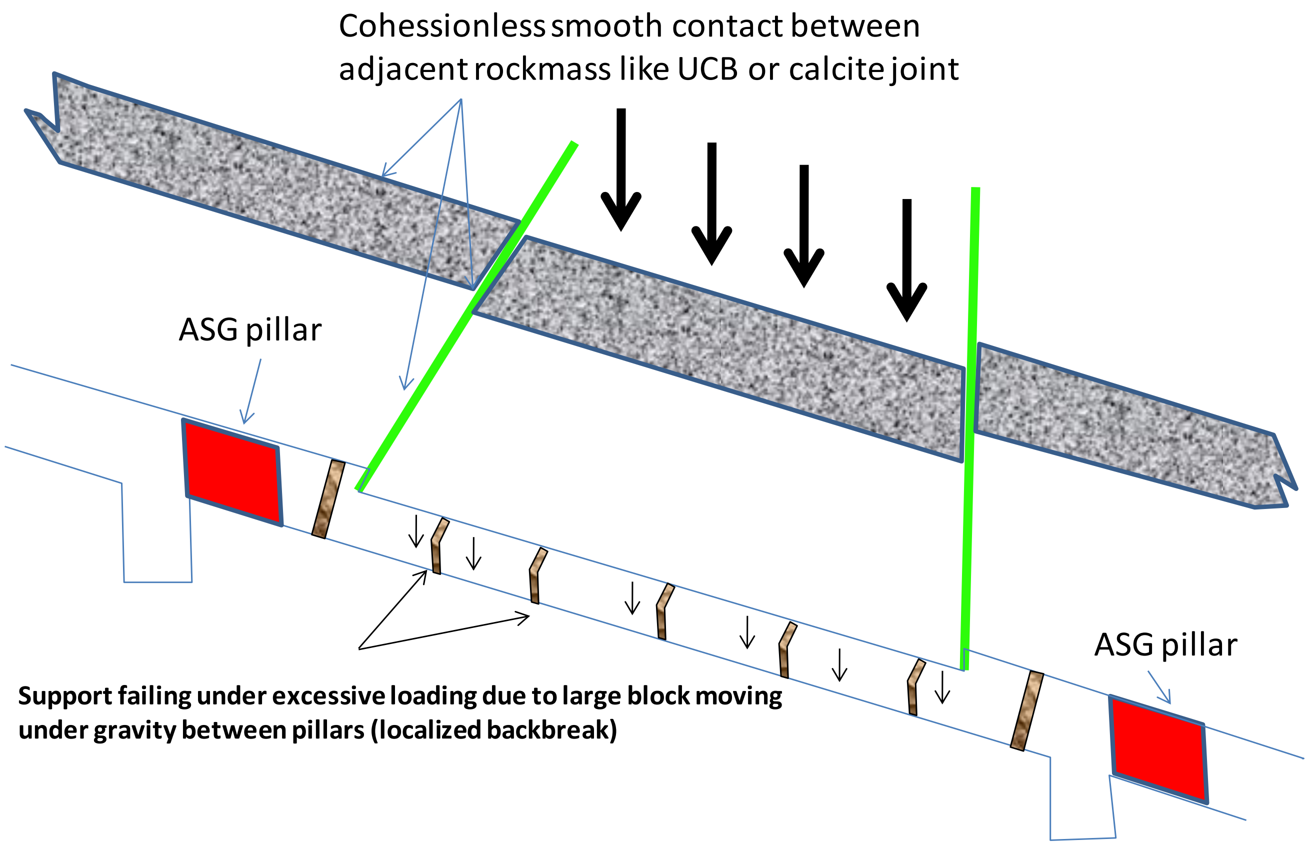


Figure showing localized backbreak between pillars

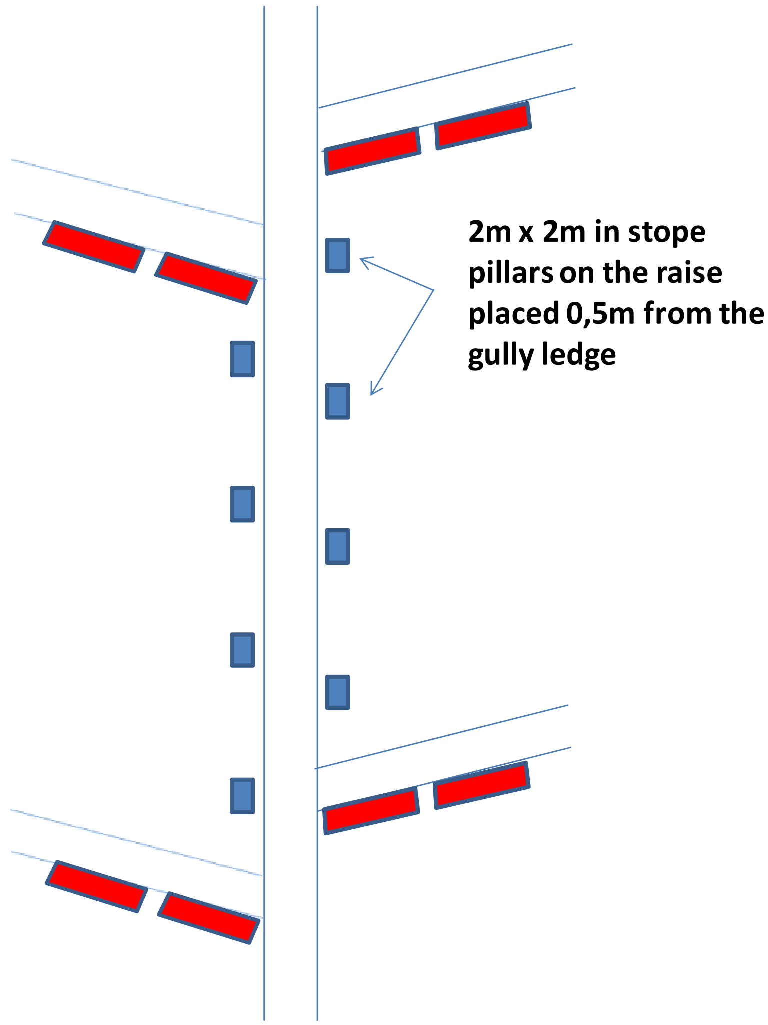
Secondly the FOG's and instability encountered can be local poor ground conditions. . The poor ground is intense jointing encountered and is referred to as the "shearzone". These FOG's can be erratic and not always on the plotted shearzone. Sympathetic jointing and the proximity thereof is believed to be the main reasons for the instability.

Thirdly a combination of the 2 mechanisms mentioned above can be present. This causes aggrevated ground control problems in the form of beam failure and local instability.

(4)

3.2.2 What corrective measures will you take to ensure the future stability of thepanels? You can use the support standard to mention the possible support changes and why as a guideline.

- Installa long anchors in raises.These anchors give confinement and stability of the rockmass in the hangingwall and will ensure that unravelling of this main artery will not take place for the life of the stope.
- Thin spray liners (TSL) in areas where jointing is excessive and very poor rockmass conditions are encountered. The areal coverage obtained from this support system is invaluable. TSL's can be applied quickly and easily in raises and is the only support method for very poor ground conditions that can otherwise not be supported with long anchors or roof support.
- Change over to 180-220cm minepoles with larger diamet jackpots thus giving increase support resistance to support beam up to 6m versus 3m for current system. Clusters and breaker lines can also be increase to give increased support resistance.
- Cut in stope pillars during ledging as per layout and figure bbelow. It must be stressed that cutting these pillars will require hand lashing for at least 3 blasts and is not very practical. However, correct blasting may place the majority of broken rock in the centre gully and thus making cleaning easier. The pillars must be cut atleast 0,5m from the centre gully ledge to prevent a high face in the centre line that may scale at a later stage and cause a FOG. These pillars must be cut as small as possible to ensure easy re-raising and minimal hand lashing whilst cutting these pillars and is therefore recommended to be 2m x 2m. These pillars will ensure long-term stability in the centre line and can possiblyreplace the long anchors in the raises, if proved practical.



(2)

3.2.3 The conditions and failures as described in 3.2 above is not always present in all areas and management requested you to pro-actively determine the areas where these conditions may prevail in future during the development stages before stoping commence. Discuss and describe the strategy you will follow to determine this and how you will implement this.

- Start mapping raises from development phase and determine Q rating and RMR to pro-actively identify areas of expected poor ground conditions. RMR mapping can be done on a 5-10m grid in raises. Put all info in a database and plot the results on a plan. Use these plans to install long anchors in identified raises and cut pillars during ledging.
- Current working can also be mapped to get additional data to plot MRM and Q to get a trend and classify different Geotechnical areas.

- Document this strategy in comprehensive report to be submitted to management and get “buy in” from them to ensure success and commitment.
- Also update COP and ad the FOG strategy.
- Standards and procedures can also be updated and amended to ensure compliance.

(5)

Total: 25

Question 4 (Mining support and Mining Support Design)

A wide range of materials are used in hydraulic backfilling operations and the pipeline flow behaviour of these mixtures varies considerably. It is shown that despite the large differences in constituent materials and flow behaviour, a common approach can be applied to analysing the flow of all hydraulic backfills. This is extended to include a rational design approach for backfill distribution systems.

4.1 Backfill is transported by pipeline from surface to stopesunderground. There are two basic types of backfill distributionsystems—free fall and full flow.

4.1.1 Briefly describe these 2 distribution systems (2)

- Free fall system is where backfill is supplied to a borehole or shaft column pipeline in which it falls freely under gravity until it reaches the air-backfill interface.
- Full flow system is where the air-slurry interface is maintained at surface level by ensuring that the system friction losses match the available gravity head.

4.1.2 Discuss and describe 4 disadvantages of a free fall system (4)

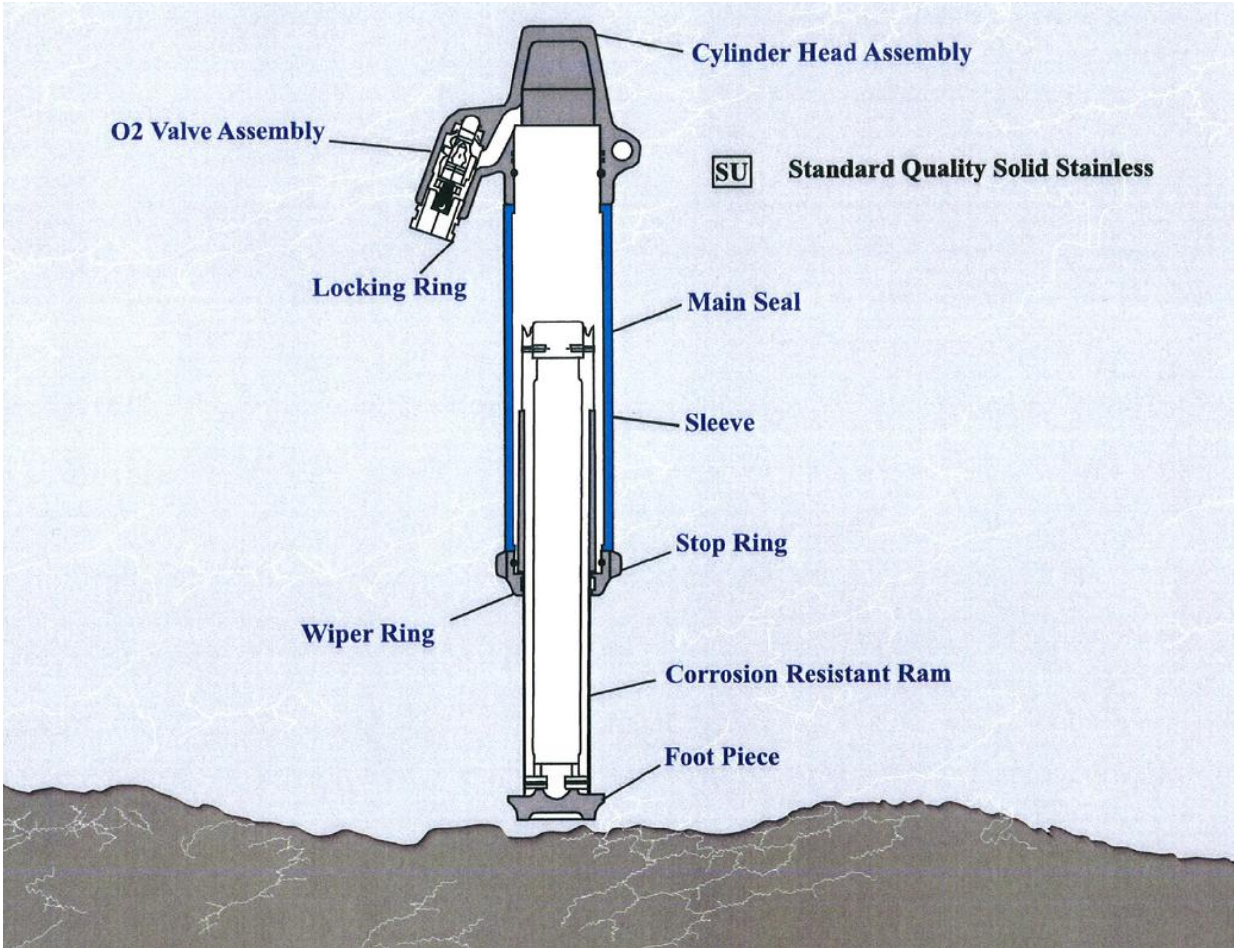
- High pipeline wear rates
- Pipe bursting due to high impact pressures
- In case of blockage normal pipeline pressures exceed by significant margins
- Due to negative pressures generated due to free fall it can lead to air entrainment in backfill leading to operational problems at the stopes.

4.1.3 Discuss and describe 2 advantages of a full flow system (2)

- Pipeline wear rates are minimized.
- Pipe bursting, blockages and failures are minimized.

4.2 Rockburst Hydraulic props are extensively used in the deep level gold mining.

4.2.1 Discuss and describe with the aid of sketches the integral parts of a Hydraulic Rockburst prop. Also name and describe 2 accessories that can be used.



Acessories include headbords and load spreaders, conical extensions, release tool and pump

(7)

4.2.2 Discuss the principles of operation of a Hydraulic Rockburst prop. (4)

The Rockburst prop slow yields typically at 200kN during closure giving a slow yield support which does not damage either the footwall or hangingwall. In case of a seismic event the prop builds pressure to typically 400kn and then yields rapidly, enabling the force of the rockburst to be transferred from the hangingwall to the footwall at 40 tons. The rapid yielding takes place in excess of 3 metres per second. After the event the prop sheds pressure and resets to typically 200kN offering support for rockfall and closure.

4.2.3 Give 3pro's and 3 Con's of Hydraulic rockburst props as a support system (6)

Pros.

- Very good in seismically active area – absorbing energy and protecting hangingwall and footwall.
- Prop is re-usable.
- Blasting barricades can effectively be used.
- Remote tensioning reducing FOG whilst tensioning
- Blast on resistant
- Close face aerial support
- Support of hangingwall during blast
- Ergonomic design
- Modular design for easy maintenance
- Corrosion resistant

Cons

- High initial capital outlay.
- Expensive to maintain and service.
- Heavy to transport
- Pumps is expesive to buy and maintain.
- Difficult to monitor stock levels and tracking system difficult.
- Neglect of prop and equipment will incure big financial losses.

Total: 25

Answer sheet multiple choice (Question 1)
October 2016 Paper 3.2

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

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