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CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS OPTION

PART 2 - APPLICATIONS 11 November 1997

EXAMINER: Mr WJ de Maar

MODERATOR: Mr M Roberts

Maximum time allowed 3 hours (09:00 - 12:00)

ANSWER ALL QUESTIONS

A pass mark is 60 per cent.

EXAMINATION INSTRUCTIONS

1. References, other than those specified below, are not permitted.

2. Hand-held electronic calculators may be used.
   (NO PRE-PROGRAMMING).

3. 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.

4. **Write in ink on one side of the paper only.**

5. Show all calculations on which your answers are based.

6. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.

7. Graph paper is available from the invigilator.

PART 2 - APPLICATIONS - METALLIFEROUS OPTION

QUESTION 1

a) A deep level gold mine is planned for a single reef at a depth of 2 500 m below surface. A shaft from surface to access the new mine has two options either to leave a conventional "shaft pillar" or to mine out the reef around the shaft before the shaft reaches the reef plane.

Consider the two options carefully giving advantages and disadvantages for each option.

12 marks

b) A decision has been made to extract a circular shaft pillar on a gold mine at a depth of 1 600 m below surface with a single flat dipping reef. The shaft must remain operative during and after the period of shaft pillar extraction. The reef width is about 1,6 m.

i) From a rock mechanics point of view what information is required before the shaft pillar is extracted. How is this information acquired?

3 marks

ii) The induced stress and strain in the shaft barrel affects the concrete lining and steelwork. What parameters are normally applied to express the maximum tolerable levels of stress and strain for the lining and steelwork?

2 marks

iii) What instrumentation would you recommend to assist with safe working conditions whilst mining the shaft pillar?

3 marks

iv) What sequence of mining is preferred from a rock mechanics point of view when mining the shaft pillar?

2 marks

v) What stope support would you recommend while mining out the shaft pillar? Give reasons for your choice of support.

3 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS OPTION

QUESTION 2

As the Rock Mechanics Officer on the shaft you have been asked to scrutinise the layout of an underground LHD workshop. The depth of the workshop below surface is 2 000 m and will be located in flat dipping well bedded quartzites with some interbedded shales. The workshop will be overstoped by a longwall in about two years time. The stoping width is 1,5 m and the distance between the stope elevation and workshop elevation is 20 m.

a) i) Comment on the attached diagram on the design of the LHD workshop from a rock mechanics point of view. Recommend changes if they are required.

4 marks

ii) What effect is the overstoping likely to have on the conditions in the workshop?

4 marks

iii) Discuss the options to ensure long term stability of the workshop (this does not refer to the support).

4 marks

iv) Consider the mining layout and sequence of excavating of the workshop.

2 marks

v) Design the support system for the workshop stating the type, length and density of the support pattern.

4 marks

b) i) Calculate the average pillar stress if the extraction percentage is 81% and the primitive stress is 38 MPa.

1 mark

ii) Why is stress a vector quantity?

1 mark

iii) What does RCF stand for and what practical use does it have?

2 marks

PART 2 - APPLICATIONS - METALLIFEROUS OPTION

QUESTION 2 (Cont.)

iv) Explain what "a" and "b" values are in the context of backfill.

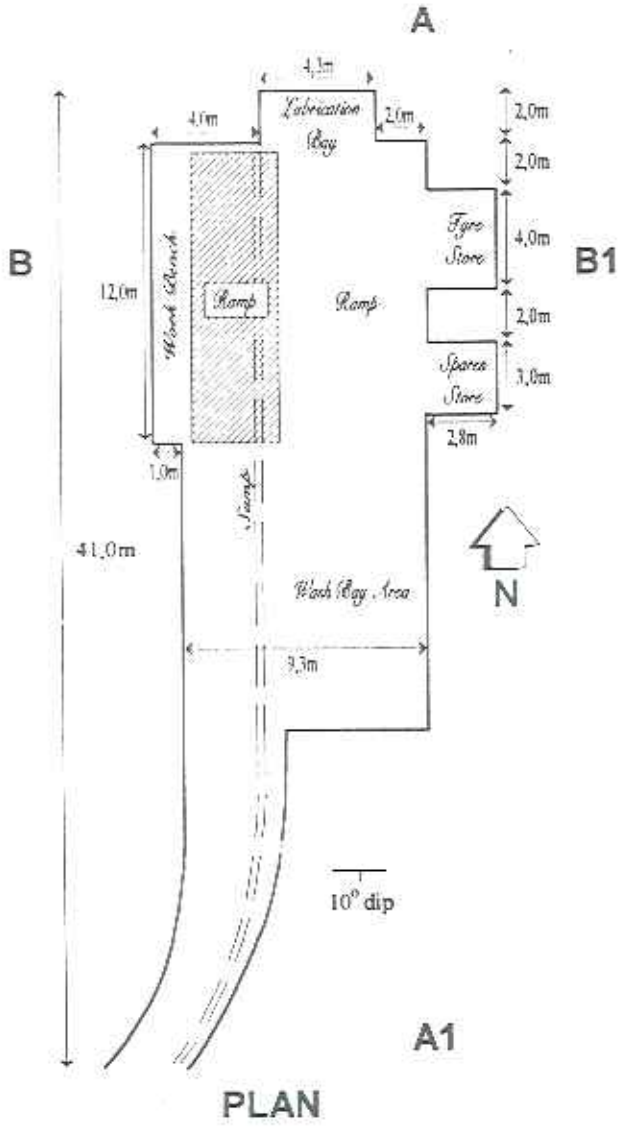
Sketch the graph of the load/deformation behaviour of backfill if the "a" value is 5 MPa and the "b" value is 0,3.

3 marks

TOTAL **25 marks**

Question 2(A)

LHD WORKSHOP



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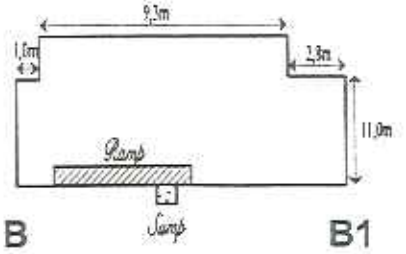

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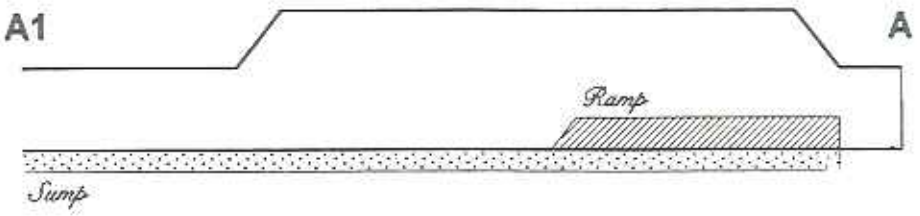

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PART 2 - APPLICATIONS - METALLIFEROUS OPTION

QUESTION 3

a) Describe the "doorstopper" method to obtain the in-situ principal virgin stresses. How are the readings used to calculate the stresses and their orientation?

5 marks

b) Many mines have reached a mature stage of their life span with remaining ore reserves being located in remnants.

i) Discuss the rock mechanics problems associated with remnants.

3 marks

ii) What precautionary measures should be taken for mining and support when extracting a remnant?

3 marks

c) List the mining related hazards which are associated with dykes and faults and how they affect mining. What measures are used to minimise the hazards?

6 marks

d) Using simple stress strain curves, describe:

i) brittle fracture
ii) ductile behaviour
iii) elastic-plastic material

3 marks

e) A point-load strength test is a quick method in the field to determine the strength of rock. How is the point-load index defined, what should be the approximate size of the test specimen and what is the relationship of the point-load index to the uniaxial compressive strength?

3 marks

f) What is hysteresis?

1 mark

g) What is homogeneity?

1 mark

TOTAL **25 marks**

PART 2 - APPLICATIONS - METALLIFEROUS OPTION

QUESTION 4

a) A platinum mine employing scattered mining at a depth of 600 m below surface has frequent backbreaks which occur at spans between 60 and 90 m. The support consists of solid timber packs spaced at 2,5 m centres. Natural separation planes occur 6 - 10 m above the hangingwall of the reef plane.

i) What are the likely causes of the backbreaks?

5 marks

ii) What investigations would you do to verify your answer in i?

3 marks

iii) What changes would you introduce to the stope support?

3 marks

b) Describe the location, function and problems associated with the following pillars:

i) Crush pillars
ii) Boundary pillars
iii) Bracket pillars
iv) Stabilising pillars

10 marks

c) State the functions of:

i) Face support
ii) Regional support

4 marks

TOTAL **25 marks**

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ANSWERS - QUESTION 1

EARLY EXTRACTION OF SHAFT PILLAR

Advantages

early revenue
no stress build up on edge of shaft pillar
no high induced stress and strain for shaft lining and steelwork
no high induced stress for service excavations in shaft pillar area
no extraction of highly stressed pillar

Disadvantages

require facility for ore removal
require and monitor for good quality backfill to be placed
must mine out considerable area around the shaft to avoid tensile failure in shaft
substantial support required in shaft close to the reef intersection
possible floating steelwork
risky - an error can result in large financial loss
concrete lining in reef area is likely to buckle
lack of detailed geological knowledge

CONVENTIONAL SHAFT PILLAR

Advantages

no backfill required
well known method
only has stress and strain problems in the shaft at a late stage of the shafts life
only has build up of stress concentration on edge of pillar at a late stage of the shaft life.

Disadvantages

ties up ore reserves
high stress and strain in shaft at late stage of life of shaft
shaft is likely to suffer from high seismicity
service excavations suffer from high induced stress
require quality support (expensive)
require dense support (expensive)
require experienced mining personnel who can work in difficult mining conditions

B) 1. Establish stress field in shaft pillar. this can be measured or inferred
Numerical modelling to establish induced stress and strain in shaft
numerical modelling to establish stope sequence
establish mining method and stoping width
establish expected seismicity
establish backfill and other stope support requirements

2. Induced vertical strain for lining - 0.2×10^{-3}
induced vertical Strain for steelwork - 0.4×10^{-3}
maximum induced stress 15 M Pa
maximum total stress 100 M Pa

3. Load cells in cages and skips alarm to warn driver
closure meter in stopes
extensometer (piano wire) in shaft to measure sidewall movement
seismic network with alarm system

4. Centre outwards
support inner pillar area first
stoping to progress symmetrically outwards

5. Stiff backfill and stiff packs
rapid yielding hydraulic props
satellite pillars and stiff packs
satellite pillars and stiff backfill

ANSWERS - QUESTION 2

A) 1. reduce length and height
avoid irregular shape
increase length to include bays
eliminate notches in hangingwall
smooth out profile (reduce stress concentrations)

2. high induced stress causes failure of sidewalls
interaction between stope and workshop (workshop moves upwards towards stope)
after overstoping workshop lies in tensile zone
hangingwall failure in tensile zone
steep stress gradients causes rock in hangingwall and sidewall to deteriorate

3. can leave large stability pillar over workshop
place stiff backfill in stope, reduce closure and high face stress (reduces induced stress)
leave crush pillars in stope to reduce closure and high face stress
relocate workshop to destressed area
mine with pillars to reduce high face stress and closure

4. 3 cuts
top centre then sides
bench others inwards

5. Hangingwall and Sidewall

6m anchor support spaced 3m apart
grouted 2,4m shepherd crooks at 1,5m spacing (maximum)
wire mesh and lacing
25 - 50mm gunnite

B) 1. 200 M Pa

2. Magnitude and direction

3. Rock wall condition factor

classifies the rock quality of the excavation to which support requirements are tailored

4. "a" is the stress on the backfill when deformed by ½ "b" and "b" is the ultimate compressibility of the backfill

ANSWERS - QUESTION 3

A) Brief description of method - strain rosette glued to end of borehole
strain is measured in each gauge - doorstopper is overcored and destressed strain values measured. Difference between reading the in situ stresses are calculated. Repeat with 3 holes drilled at right angles to get stress orientation

B) 1. high stress/rockbursts
seismicity
fractured ground
probably geologically complex (why left behind?)
Falls of ground
difficult strata control

2. support for rockburst conditions i.e. rapid yield
haudraulic props
dense support
mine towards solid
two escape ways
instrumentation to monitor seismicity (warning device)
require experienced personnel
reduce number of personnel
steady continuous advance
backfill support if possible

C) rockbursts
falls of ground
seismically prone (history)
can be soft or hard
soft = falls of ground
hard = retains high stress - can burst
fault slip = plane of weakness = rupture = seismicity
difficulty in mining through hard dyke
flat fault danger of collapse
water ingress - weakens rockmass = falls of ground
may have to change mining/panel direction
leave bracket pillar
increase support density
constant monitoring of stope rockmass behaviour
seismic monitoring/hot spots

D)

E) $Is = \frac{P}{D^2}$ where P = load applied, D = diameter
and Is is the pointload index
50 mm in diameter
24 x Is

F) Incomplete recovery of strain during unloading due to used up energy

G) Material that has the same properties throughout

ANSWERS - QUESTION 4

A. 1. softness of packs allow separation in hangingwall
depth is shallow, therefore high tensile zone
separation at natural parting planes (tensile environment)
packs not stiff enough to prevent separation
loss of horizontal confinement
excessive beam deflection

2. instrumentation
extensometers for 10m into hangingwall
closure meter
boroscope/petroscope to look into borehole into hangingwall to see where separation occurs
load cells in packs
compare daily advance, face position, rate of advance
numerical modelling (actual versus theoretical)

3. stiff backfill and elongates
crush pillars and elongates
narrow panels/spans
crush pillars and grout packs

B. 1. slender pillars in deep to shallow mines
residual strength provides stability to rockmass
useful where reef is weaker and yields
supplies resistance up to critical level
allows large strata movement
minimizes loss of ore reserves
if pillars are pre-fractured can result in pillar run
must be cut slender enough not to build up high stress
difficult in high stoping widths due to geological structure effecting pillar - premature failure

2. statutory pillars between mines
18m minimum (water pillar)
used to compartmentalize mining areas in shallow mines
prevents interaction between mines e.g. water
line of defence against regional collapse
usual design, span < 1/4 depth
locks up substantial ore reserves
conservative approach to offset poor design

3. usually found against geological structure
barrier against seismic activity
prevention/reduce seismicity
limit high stress on geological structure
minimize/displace zone of positive ESS

reduce potential of dyke bursting
difficult to determine width of bracket pillar
the reaction of faults and dykes to high stress is unpredictable making design of pillar widths difficult

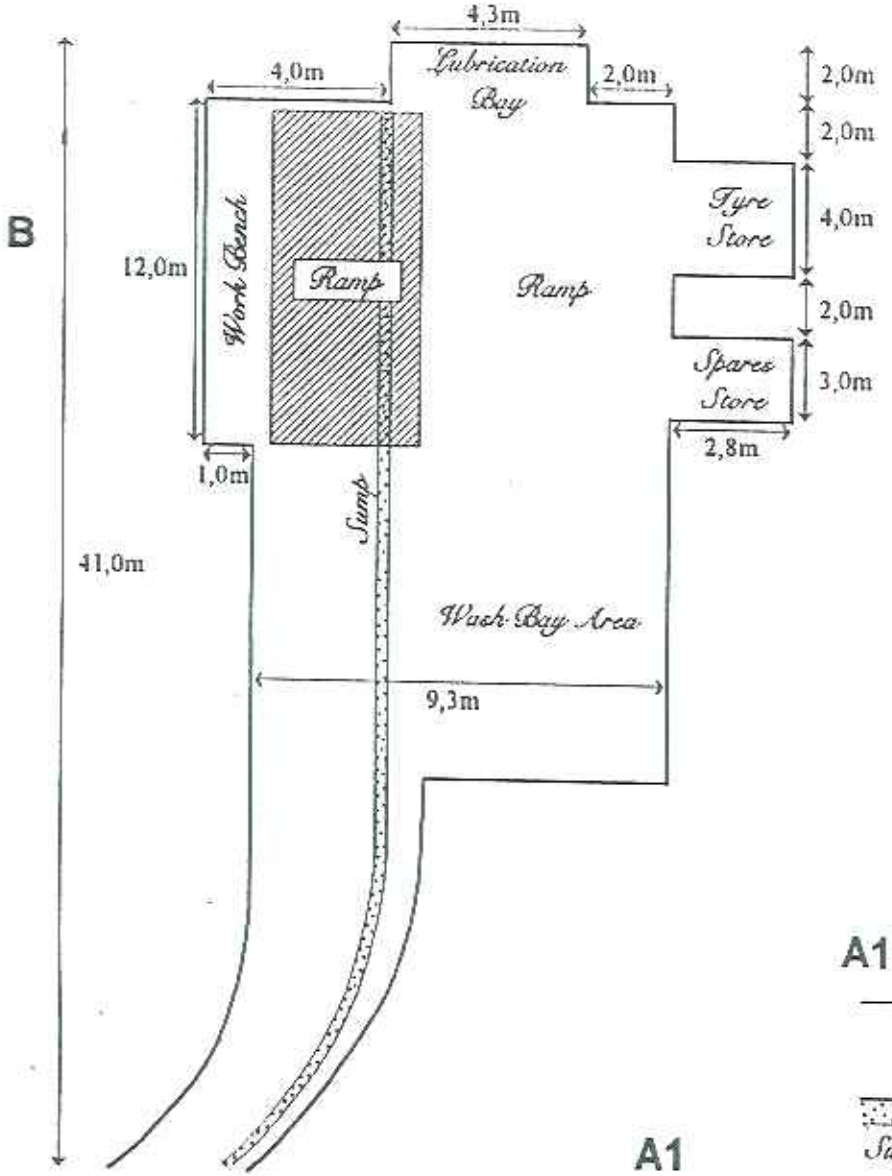
4. usually found in deep highly stressed mining environments
allows partial extraction at depth
regional support
limit ESS and ERR and rockburst incidents
limits spans
foundation failure
mining problems of accessing highly stressed pillars
strata control problems adjacent to pillars
high stress and seismicity in pillars

C 1. Prevents rockfalls
prevents hangingwall separation and loosening
maintains horizontal confinement

2. prevents collapse of large rockmass
reduces ERR
limits convergence
reduces spans

Question 2(A)

LHD WORKSHOP



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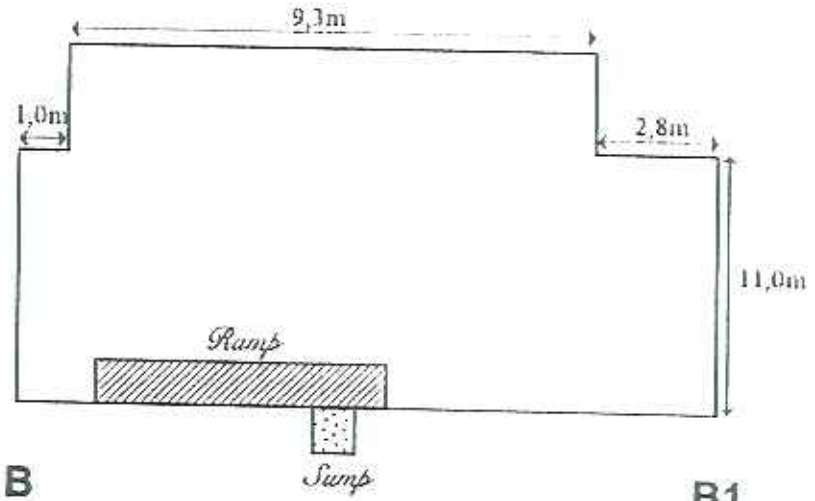

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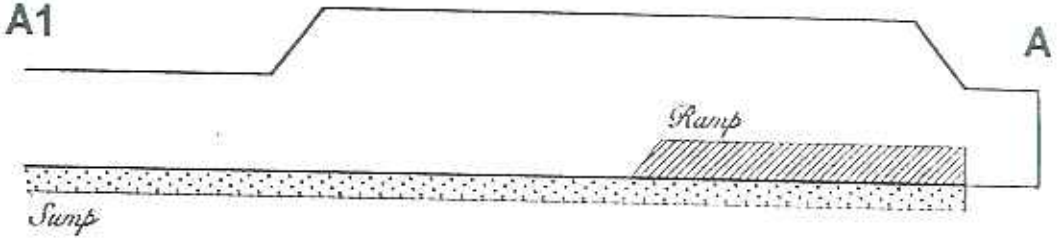

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