Ques + Answ

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS OPTION

PART 3 - GENERAL 13 May 1998

EXAMINER: Mr WA Naismith

MODERATOR: Mr W de Maar

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

ANSWER ALL QUESTIONS

A pass mark is 60 per cent.

EXAMINATION INSTRUCTIONS

1. References are not permitted.

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

3. Put 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 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.

QUESTION 1:

A pump chamber is to be developed in typical Witwatersrand quartzites at a depth of 2300m below surface. The chamber will be 60m long, 10m high and 10m wide.

(a) list five factors which could cause instability during development; (5 marks)

(b) use sketches to show the preferred excavation sequence; (5 marks)

(c) give recommendations regarding temporary and permanent support requirements. In particular, recommend when permanent support should be installed giving due regard to practicality; (10 marks)

(d) describe methods by which you can ensure that the recommendations which you make are correctly implemented; (5 marks)

(e) state any recommendations which you may make regarding layout of the pump chamber with respect to geology and to other excavations (such as pipe raises, settling and clear water dams); (5 marks)

TOTAL FOR QUESTION 1: 30 MARKS

QUESTION 2:

A twin haulage is to be developed at a depth of 3500m below surface in a gold mine. It is required that a development rate of at least 250 linear metres per month be achieved. The total length required is 2500m in each end. Both tunnels are to be developed in a conventional "horseshoe" shape with cross sectional area of $15m^2$. Strata in which the development will take place is believed to be quartzite with uniaxial compressive strength of 180MPa. Strata dip is 10° and several seismically active faults and dykes are expected to be encountered.

(a) list five features which will influence support requirements; (5 marks)

(b) define, using sketches, the conventional support pattern which you would recommend; (5 marks)

(c) write a short note to your manager motivating the use of shotcrete for this development. Pay particular attention to integration of the support phase into the development cycle; (10 marks)

(d) explain the method you would use to determine application parameters such as shotcrete thickness, strength, amount of fibre reinforcement and tendon spacing; (10 marks)

TOTAL FOR QUESTION 2: 30 MARKS

QUESTION 3:

Congratulations! You have just been appointed to a project planning team to advise on rock engineering aspects. The orebody under consideration is a tabular, low to medium grade chromitite in the Bushveld sequence. The stoping width is expected to average 0,9m and the dip of the seam to average 10°. The orebody outcrops on surface where it has been oxidised. When encountered elsewhere the orebody typically contains one or more thin chromite stringers within the first metre of hanging wall. A second, very low grade chromitite seam occurs approximately 10m into the hanging wall. It is expected that a maximum depth of mining will be in the order of 300m. The planned life of mine is 15 years.

(a) describe any rock engineering problems which you would expect to encounter during development of access from surface; (5 marks)

(b) use sketches to show a general stoping layout. Indicate all relevant dimensions and briefly discuss factors which you would consider when determining those dimensions; (10 marks)

(c) would your stoping layout change if the orebody was located, not at surface, but at a depth of 1300m? Justify your answer; (5 marks)

TOTAL FOR QUESTION 3: 20 MARKS

QUESTION 4:

Section 11 (1) of the Health and Safety Act (Act No 29 of 1996) requires that every employer must (a) identify hazards, and (b) assess risks to health or safety to which employees may be exposed while they are at work.

(a) if the term hazard means a source of, or exposure to, danger (i.e. anything in the working place which could cause injury to an employee), identify one rock related hazard which you would expect to find in an underground stoping situation and suggest methods of making employees aware of that hazard; (5 marks)

(b) describe a method of assessing rock engineering risks used on your mine or with which you are familiar. Use an example to assist you. Comment on the success, or otherwise, of the method; (10 marks)

(c) explain how risks, once they have been identified, are communicated to production staff; (5 marks)

TOTAL FOR QUESTION 4: 20 MARKS

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MODEL ANSWERS

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QUESTION 1

1 (a) Rock conditions expected :- quartzite with strength + 200 MPA; massive but containing joints bedding.

Geological Features

- faults, dykes and the weak ground associated with them are obvious factors.
- bedding planes and jointing can give rise to (often large) wedges in side and hanging wall .... if they are infilled with calcite/clay or have relatively smooth surfaces.

Mining Method

- sequence to minimise creation of and interaction of stress induced factors. In particular avoid mining from two directions to create a "pillar" which will be highly fractured and therefore "soft". Take note of adjacent excavations.

Mining Technique

- effect of blasting in particular over-break and damage caused by overburdening and overcharging.

- delays to cleaning which can prevent early support installation.

Support Installation

- in particular the timing of (permanent) support to ensure that rock mass loosening is minimised.
- quality of support : ensure that anchors are grouted as soon as possible after installation for example.

Other Factors

- ground water; possible but not likely
- seismic activity will be encountered but (hopefully) will be sufficiently distant that ppv's are insignificant.
- development of adjacent excavations causing concussion and stress interaction.
- weak ground either, or close to the excavation.

Comment

Although the question asks for a list, a few words to explain why the factor could cause instability shows that the candidate understands its significance. The thoughts developed in this part of the question will assist in formulating answers for parts (b) to (e). **(5)**

1 (b) The development sequence must cater for practical excavation in addition to following rock mechanics principles.

- minimise the extent of unsupported rock face.
- general "top down" sequence facilitates cleaning and support installation.
- multi cut to facilitate accessibility.

Comment: Clear sketches, plan and section are required. Three dimensional drawings often become confused. **(5)**

1 (c) Temporary support : should be capable of offering a support resistance of 20 - 50 kN/m². Achievable with rockstuds, split sets (shepherds crooks if significant deformation). Install as soon as possible after development to minimise rock mass loosening.

Permanent support : length based on span (0,5 x span) and height (0,5 x height) - but preferable to design using numerical models. Support resistance up to 140 kN/m² (probably lower in this case). System will include wire mesh and shotcrete or steel fibre reinforced shotcrete.

It is often preferable to install permanent support as soon as possible in the development sequence as this will not only minimise rock mass loosening but will practically be easier with better access to faces and hanging wall.

(10)

1 (d) Need to initiate a quality control programme:-

- check support spacing.
- monitor and train support installation
- monitor excavation sequence
- pull tests on tendons
- strength tests on shotcrete (preferably panels but cores are acceptable)
- rapid reporting system to senior management in case of deviations.
- long term monitoring using extensometers/closure meters.
  (in conjunction with an acceptable contingency plan)

(5)

1 (e)

- avoid high stress areas.
- avoid stress changes.
- apply 4 x diameter rule with respect to other excavations.
- domed roof (if not formed by a bedding plane).
- concave sidewalls.
- long axis of excavation on dip.
- avoid acute comers in the design.

(5)

QUESTION 2

2 (a) (I) Condition of the rock mass:- strength; joint spacing and orientation.

(ii) Initial stress state and changes in stress govern the strength and amount of yield within the system.

(iii) Size and shape of the excavation (particularly note the hanging wall wedge which can be formed).

(iv) Anticipated lifetime and importance (difficulty of installing lifetime support during development and/or refurbishment should be mentioned).

(v) Potential for seismic activity (particularly associated with ongoing features) influence support density and yield requirements.

(vi) Blasting practice.

2 (b) Candidates should illustrate this answer with details of support systems with which they are familiar. The system must include tendons, mesh and lacing - length, diameter and spacing should begin where relevant.

Additional support resistance may be required in parts of the tunnel intersected by seismically active geological features. Cone bolts may be considered appropriate in these areas.

Support spacings can be modified to address the hanging wall wedge problem in a square section tunnel (the horshoe shape should help). Use of 'T' tunnels in high risk areas can be considered.

(5)

2 (c) Basis of the motivation should be that shotcrete (if applied correctly) is a lifetime support and any additional cost can keep pace with development. Will be compensated by savings in remedial work. In addition shotcrete applied at the force provides total areal support for development crews (particularly in high stress areas where 'spitting' may occur). Shotcrete should be sprayed right at the face and can be incorporated into the support section of the development cycle. If logistics or rock mass conditions do not allow this, then spraying should take place as close t the face as possible and always before services are installed (air and water pipes and power cables). Additional wire mesh or cable anchor support can be installed behind the face and may or may not require an additional shotcrete application.

(10)

2 (d) There is not rigorous design methodology the industry to deal with conventional support in a fractured, inelastically deforming rock mass so design of an engineered support system such as shotcrete presents a particular problem.

Design methodologies are:-

- Numerical modelling using codes such as FLAC or UDEC where the rock mass response stress change for different support system parameters can be investigated (but this, of course, needs validation by monitoring performance at a test site).

- "Trial and error" in which particular shotcrete support systems applied to particular rock masses are subjected to stress changes and their performance monitored. This is an acceptable methodology but could prove costly if the system is inadequate and rehabilitation is required.

- Use of empirical rock mass classification systems (such as Barton) which allow transfer of experience from other areas.

(10)

Total : 30 Marks

QUESTION 3

(a) (I) Weathered a weakened rock will require careful excavation and strong stiff support.
(ii) Weathering can weaken joint planes and other discontinuities.
(iii) Ground water can corrode support and induce pore pressures
(iv) Pillars left as support can be oxide and weakened which reduces their load bearing capacity.
(v) Weakening of hanging and/or footwall can reduce support effectiveness.

Note:

Although the k-ratio may be high (up to ± 5) the stress magnitudes are likely to be low. At 300m, 6v = 10MPa max and 6H = 50 MPa. Can this value induce failure in rock types expected?

(b) Layout should be similar to that shown in figure 1.3 of the 1988 guide and should incorporate both regional and stope pillars.

Footwall access to raise lines should also be shown (unless on-reef development is chosen).

Factors to be considered when determining dimensions include:-

i) depth below surface and extent of tensile zone to be supported - regional spacing is approximately D/4.
ii) overall stiffness of overburden determines pillar loading
iii) stable panel spans determined from experience - stress levels low and dominant failure mode is fallout of large blocks between joints.
iv) Stope pillars dimensions required to prevent failure (and yet continue to provide an acceptable extraction percentage). - w/h ratio of 5 or more is preferable.

(10)

v) gulleys can be ahead of face. No sidings are required.

(c) Factors which would change include:-

i) spacing between regional support pillars.
ii) panel pillars would become crush pillars rather than support pillars.
iii) development is preferably off-reef.
iv) face configuration preferably underhand.

(5)

Total 20 Marks

QUESTION 4

(a) The obvious hazard in a stoping environment is the hanging wall. This is "the source of danger" - a fall of ground is not a hazard but something which results from the hanging wall hazard.

Other hazards could include:-

Support - which could fail to adequately support the hanging wall. Blasting practice - which could damage the hanging wall. Methods of making employees aware of the hazard include:-

- ongoing safety programmes
- formal and on the job training
- involvement in hazard identification exercises

Assistance of health and safety representatives should be sought.

(5)

(b) A suitable <u>system</u> would examine a number of factors. For example, in a stoping environment, a risk index could include:-

- panel situation relative to adjacent panels i.e. one leading/lagging; both leading/lagging.
- face shape (possibly linked to ERR)
- condition and location of gullies and sidings
- proximity to geological structures and whether these are seismically active
- face angle with respect to geological structures
- general geological complexity
- closure rates, fracturing and other observed conditions.

Scores are allocated to each factor and rated at surface plan inspection or underground inspection. High scores generally indicate high risk. **(10)**

Use of a system such as MRMR is essentially correct but may not be able to satisfy cause - consequence identification requirements.

(c) Similar methods as (a) with emphasis on continuing communication and 'refreshing' is applicable to the workforce.

At more senior levels, risk can be communicated at monthly planning meetings, through specific reports on 'issues', through regular seismic reports and by means of regular audits of practice. Regular meetings within a rock engineering department on a mine can be used to generate awareness of risk and methods of reduction.

Availability of into to all personnel via LAN is encouraging. **(5)**