National Exams - May 2005

92-MMP-B1, Applied Rock Mechanics

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.
3. Five (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.

QUESTION 1

{10} (1.1) The following triaxial compression failure data for rock cores has been measured. Using this data, determine the appropriate rock mechanical failure parameters for this rock material (unconfined compressive strength, cohesive strength and internal angle of friction), as established by both Mohr-Coulomb and Hoek-Brown failure locus plots. Demonstrate, by plotting and illustrating both failure locus plots for this data, how the failure parameter values were obtained.

Axial Failure Stress (σ_1), MPa	Sample Confining Stress (σ_3), MPa
52.3	0
64.0	4.0
74.4	8.0
88.0	12.3
93.3	15.0

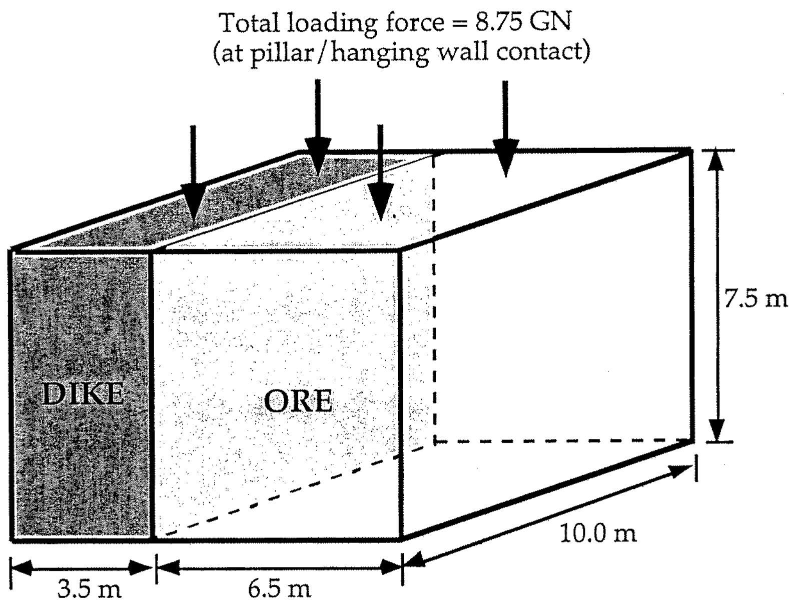
{4} (1.2) When asked to test an identical rock sample under a confining stress level (σ_3) of 30 MPa, at what axial stress (σ_1) level would you expect this sample to fail? Determine the stress limit graphically and numerically (using the Mohr-Coulomb failure locus parametric equation).

{4} (1.3) At two other sites within this same rock, major and minor principal rock stress conditions are anticipated to be (75.5 MPa, 27.5 MPa) and (69.5 MPa, 2.5 MPa) respectively. What conditions of stability should exist within the rock mass at these site locations?

{2} (1.4) For similar rock material, tested unconfined, it is anticipated that a momentary axial stress approximating 100 MPa will be applied. What measure of confinement stress must be applied to this specimen, prior to axial loading, to just prevent failure from occurring at this level of applied axial stress?

QUESTION 2

{10} (2.1) A room-and-pillar stope is planned to be developed within a horizontal ore deposit that is 7.5 metres thick. Pillars are to be square and sized at 10 meters on a side. At one site, a 3.5 metre wide vertical dike is known to cut through a pillar, as shown:



Across the hanging wall and footwall where this pillar has been excavated, a total superincumbent post-mining load equivalent to 8.75 GN has been measured to act through the pillar. The ore, waste and dike material physical properties are known to be:

E_{ore} = 55.8 GPa γ_{ore} = 32.5 kN/m^3 μ_{ore} = 0.28 UCS_{ore} = 124.6 MPa

E_{waste} = 41.3 GPa γ_{waste} = 26.9 kN/m^3 μ_{waste} = 0.26 UCS_{waste} = 212.7 MPa

E_{dike} = 97.3 GPa γ_{dike} = 28.1 kN/m^3 μ_{dike} = 0.19 UCS_{dike} = 143.5 MPa

Both the pillar ore and dike materials undergo similar, uniform axial (vertical) strain between the roof and floor contacts under the action of this total vertical load. Determine:

(i) the average axial pillar stress conditions existing within the ore and dike sections of this pillar, and the stability condition of each portion of the pillar

(ii) the percentage of the total superincumbent load which is being exerted on the dike and the ore portions of this pillar.

{10} (2.2) At another site on this same level within the mine (at a depth = 200 m), similarly sized pillars will be developed (10 m by 10 m square in plan view). Within one of these ore pillars, a horizontally-bedded dike, 3.5 metres thick, is observed. Assuming that the same total vertical loading force is exerted on this pillar (8.75 GN applied superincumbent load, as was given in part (2.1)), determine:

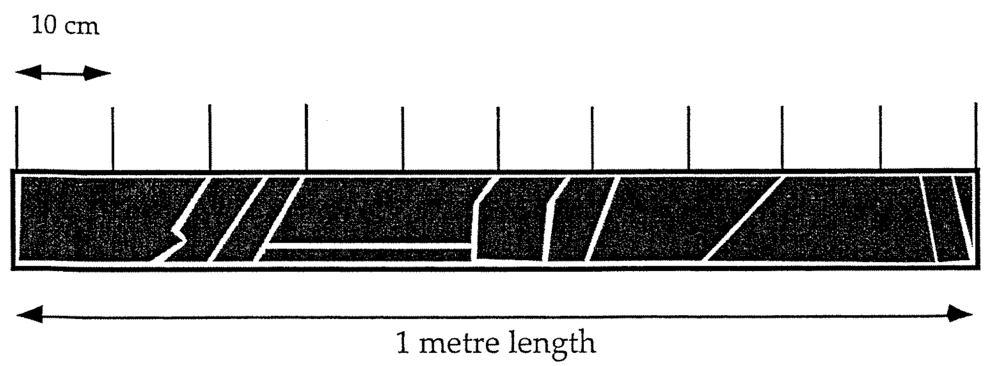
(i)the vertical pre-mining hanging wall stress and post-mining pillar stress conditions that act on the ore and dike pillar sections, and

(ii)the vertical deflections that can be expected to develop within each pillar section (ore and dike material) and over the entire height of the pillar between the hanging wall and footwall contacts due to the vertical stress increase experienced by the pillar rock when it is first excavated.

QUESTION 3

Answer each of the following sections by briefly responding or selecting the most appropriate multiple choice answer from the list provided. In order to obtain full marks, you must justify your answer.

{10} (3.1) For the following sketch, showing a one metre long section of recovered drill core, what numerical estimate of RQD would you estimate for the core length and what rock quality condition would you associate with this rock? Provide a brief description of the RQD classification technique, explaining its applicability for assessing rock character in a "stand-alone" fashion and in combination with other commonly-used rock mass classification techniques.



{10} (3.2) A room-and-pillar stope is to be developed at a depth below ground surface of 950 metres. The average bulk density of the hanging wall waste rock is 21.53 kN/m^3 (existing between the tabular ore body and surface), and it is known that the host ore exhibits an average unconfined compressive strength approximating 132.5 MPa.

It is planned that an array of square pillars will be left to support the stope roof and that a constant pillar centre-to-centre distance of 25 metres will be maintained between all pillars. Two design cases are to be implemented - one in which pillars are to be constructed at 10 metres width, the other in which pillar widths will be set at 14 metres.

For these two cases of development, the differences in post-development pillar stress and extraction ratio conditions will be best reflected by:

(a) (45 MPa, 10%)
(b) (65 MPa, 10%)
(c) (45 MPa, 15%)
(d) (65 MPa, 15%)

QUESTION 4

{5} (4.1) An open pit mine is to be designed and developed within rock which is known to be influenced locally only by two well defined joint systems. On the pit face which is to be investigated, and which is designed to dip at an angle of 55°, it is known that one of the joint systems (Joint #1) will strike parallel to the pit face, dip into the pit and be undercut by the face. This joint system is known to exhibit the following strength properties: $C_1 = 102.3\ kN/m^2$

$\phi_1 = 29°$

The second joint feature, known as Joint #2, has been determined to dip vertically and to strike perpendicular to the pit face. Joint #2 strength properties include: $C_2 = 29.3\ kN/m^2$

$\phi_2 = 32°$

For this portion of the sloping pit face, an equation has been derived to relate the Factor of Safety against sliding versus excavation depth below the level of the pit crest (H) for the three dimensional block model which has been interpreted. The Safety Factor equation (assuming no reinforcement) takes the form:

$$F.S. = \{24.49\,H + 1749.77\} / \{33.26\,H\}$$

Based upon the information given, determine the initial depth below the pit crest at which mining might induce block sliding failure.

{15} (4.2) Pit excavation is planned to proceed to an ultimate depth of 225 metres. In order to prevent unanticipated slope failure, wedge reinforcement is planned using two possible techniques, these being either application of:

-tensioned cable bolts installed perpendicular to Joint #1 plane surfaces, with each cable tensioned to 650 kN <u>or</u>

-solid steel inserts, each being 20 cm in diameter and 30 metres long, which are to be installed perpendicular to Joint #1 plane surfaces (where the steel shear strength is estimated at 5.65×10^4 kN/m^2).

Determine the number of each type of reinforcement that will be required to stabilize potential failing wedge blocks to Safety Factors of 1.0 and 1.5.

QUESTION 5

Briefly answer each of the following, using sketches to illustrate your answers:

{10} (5.1) Explain how the presence of water and ground acceleration, induced by either blasting or seismic events, can separately affect the stability of open pit walls structures. For each of the two influences (exposure to groundwater and ground vibration), present two different cases, and show by illustrative example, how wall stability can be (a) detrimentally affected and (b) beneficially affected (or remain unchanged).

{10} (5.2) Describe the major functions of ground support media used to reinforce underground mine excavations. Provide examples of typical reinforcement media, and differentiate between support methods that are used to:
(a) reinforce/improve the structural capabilities of near-excavation rock zones and
(b) provide purely surface support enhancement for underground excavations.

Explain and differentiate between the mechanisms of support that can be developed using passive and active rock dowel systems. In your response, provide descriptions of the methods of installation and an explanation of the processes whereby bolt or dowel tensions are developed for each system.

QUESTION 6

Provide brief answers to each of the following:

{5} (6.1) What information can be obtained from the Point Load Index strength test, how is this technique used to provide quantitative rock strength data and what single major drawback exists when utilizing this data?

{5} (6.2) What purposes may be served by re-testing overcored rock specimens under conditions of triaxial confinement after completion of in-hole strain measurements?

{5} (6.3) Explain the terms "convergence" and "subsidence" as they pertain to underground excavations.

{5} (6.4) It is known from a large database of in-situ measurement that generalized trends of underground stress behaviour exist within Canadian Shield rock formations. Describe the general in-situ stress trends that are known to exist and limitations which must be placed before using such general data for site specific mine design purposes. Provide examples of variation in general trend data.