Model Answers for Paper 3.3 2013-05

Q1.

a) *List the important orebody properties that would influence the choice of mining method [10]*

Brady and Brown, Chapter 13, p 352

- Geometric configuration of orebody
  - Relative dimensions and shape
  - Related to the deposit's geological origin (seam, placer or stratiform)
  - Tabular (veins, lenses and lobes) extensive in two dimensions
  - Massive (pipes, porphry copper orebodies) with more regular shapes, with no geologically imposed major and minor dimensions
- Disposition and orientation
  - Depth below surface,
  - Dip
  - Orebody shape and continuity
- Size
  - Absolute size and volume
  - Strike length and orebody width
- Geomechanical setting
  - rock material properties
  - rock mass properties
  - orientation of discontinuities
  - alteration and weathering
  - structural geological features
  - virgin stress
  - chemical properties that may influence ore flow (re-cementing, sticky ore)
  - abrasive and communitive properties
- Orebody value and spatial distribution of value

- Average grade, cut-off grade, grade distribution
- Economic value of the orebody
- May define the shape and size of the economically mineable orebody

- Engineering environment
  - Effects on local groundwater flow patterns and contamination
  - Disturbance or rupture of the ground surface
  - Limiting surface waste disposal by placing mine waste underground
  - Mine gases: methane, hydrogen sulphide, sulphur dioxide, carbon dioxide or radon
  - Virgin rock temperature

b) Briefly describe a process for the selection of an appropriate mining method 4 marks

Process of selection of mining method (Brady and Brown, Chapter 13, p368)

- Carry out geological, mining and geotechnical investigations to establish orebody properties
- Establish the mining method most appropriate for the orebody or part of it
- Define the operational characteristics (mining scale, production rate, selectivity, flexibility and access)
- Adapt the mining method to suit local conditions

c) Describe how you would determine the orebody and host rock properties in a geotechnical investigation programme. 5 marks

Geological drilling programme to be defined by geologist. Geological logging and orebody definition by geologist.

Sample appropriate number of boreholes for geotechnical logging (core orientation as necessary). Geotechnical logging to be carried out to determine rock mass characteristics, geological weaknesses and joint orientations.

Mapping of rock exposures where available (eg open pit or outcrops). Joint orientations and characteristics, rock mass classifications)

Laboratory testing of intact rock (UCS, TCS, shearbox on joints)

Empirical estimation of stable stope dimensions or cavability - required for mining method selection.

Empirical evaluation of tunnels and service excavation stability and support requirements.

Numerical analysis as required.

d) Describe Bieniawski's RMR system to classify rock masses. 6 marks

(eg Stacey 2001, Best practice rock engineering handbook for "other" mines)

The Geomechanics Classification System derives a rock mass rating (RMR), obtained by summing 5 parameter values and adjusting this total by taking into account the joint orientations. The parameters included in the system are:

• rock material strength (UCS)

• RQD

• joint spacing

• joint roughness and separation

• groundwater

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The RMR value can range between zero and 100, and with its 5 finger parameter scale, this system is conceptually easier to apply than the Q System.

The Geomechanics Classification does not take account of the confining stress present in the rock mass, nor explicitly the number of joint sets. Considerable weight is given to block size since both RQD and joint spacing are classification parameters.

Q2.

a) *Briefly explain whether these orebody and geotechnical characteristics are suitable for the sub level caving method* *2 marks*

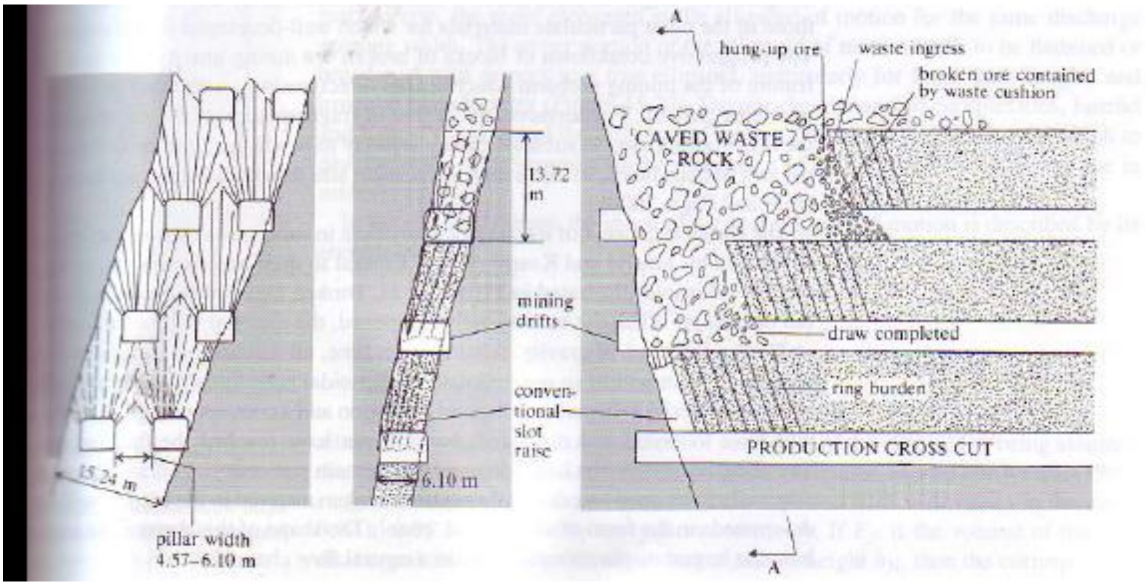
It is suitable for sub-level caving.

The orebody is relatively competent and may not cave easily, with the given size of the orebody footprint. The dip of the orebody is not optimal for block caving.

The host rock mass is relatively weak, which is expected to cave. Very small stopes would be required for sub-level stoping. The cost of longhole stoping with postfilling would be prohibitive, given the low grade.

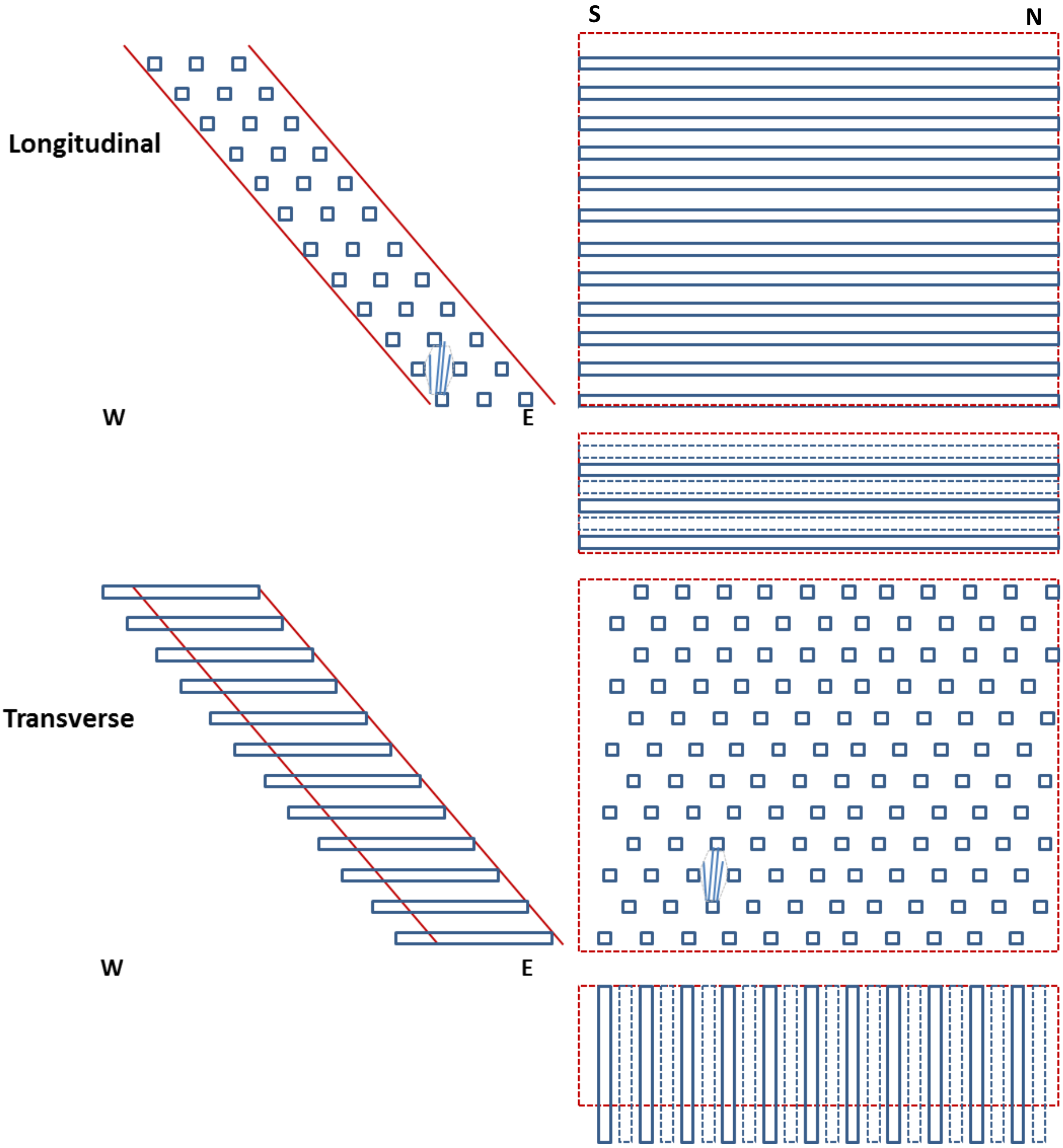
b) *Describe the sub level caving method. Sketch the production drives in plan and section, approximately to scale, for both longitudinal and transverse layouts for this orebody. Show the ring drilling pattern for a single drive.* *12 marks*

Brady and Brown, Chapter 13, p 366 and Chapter 15, p 452



The aim of the mining method is to induce free displacement or caving of the overlying rock. Production crosscuts or drives are established at relatively small intervals of about 15 to 20m, which should be designed to optimise draw of the ore. The ore is fragmented using blastholes drilled upwards in fans from the production drives. The ore is blasted against the caved waste. Ore is extracted selectively to ensure proper draw control and optimal caving.

Mining progresses downwards in the orebody, with each sub level being progressively eliminated as mining proceeds. Production drifts serve both drilling and tramming operations.



c) *Calculate the rockwall condition factor for individual production drives in both transverse and longitudinal layouts (ignore the effects of stress interaction between drives)* *5 marks*

Rock UCS = 130 MPa

F = 0.8 (RMR =70) accept 0.7 to 0.9

Note that it is important to correctly identify the stress orientation relative to drives.

Transverse	***Longitudinal***
σ_{yy} *= 65 MPa (parallel to tunnel axis)*	σ_{xx} *= 25 MPa (parallel to tunnel axis)*

σ_1 = 25 MPa

σ_3 = 25 MPa

$$RCF = \frac{3\times25-25}{0.8\times130}$$

RCF = 0.5

σ_1 = 65 MPa

σ_3 = 25MPa

$$RCF = \frac{3\times65-25}{0.8\times130}$$

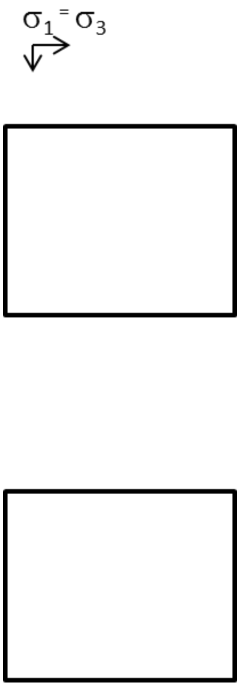
RCF = 1.6 *(5)*

d) Sketch the anticipated stress fracturing and damage around a production drive for both transverse and longitudinal layouts. 5 marks

Expected Stress fracturing and conditions:

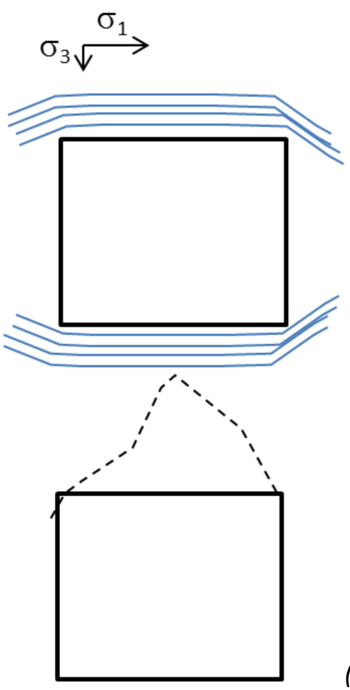
Limited or no fracturing

Excellent conditions



Extensive fracturing in the roof/crown/hangingwall

Gothic arching or buckling of roof strata



(6)

e) e) Explain whether a longitudinal or transverse layout would be optimal, taking into consideration both rock mechanics and production considerations. 2 marks

Transverse will be optimal. In wider orebodies, transverse sub level caving is generally preferred, since productivity can be improved, since more attack points can be designed. Stress damage will be greater in the longitudinal layout, which will influence safety, productivity and support costs.

Q3

a) *Determine the cave angle and the extent of the zone of failure on surface. Use this information to determine how far the shaft should be positioned from the orebody. Illustrate by means of a sketch* *8 Marks*

Information

Host rock metasediments MRMR = 65

Depth of base of block cave = 600 m

Cave Angle

Lateral confinement is provided by the broken ore in the cave

Cave angle = 70° *(2)*

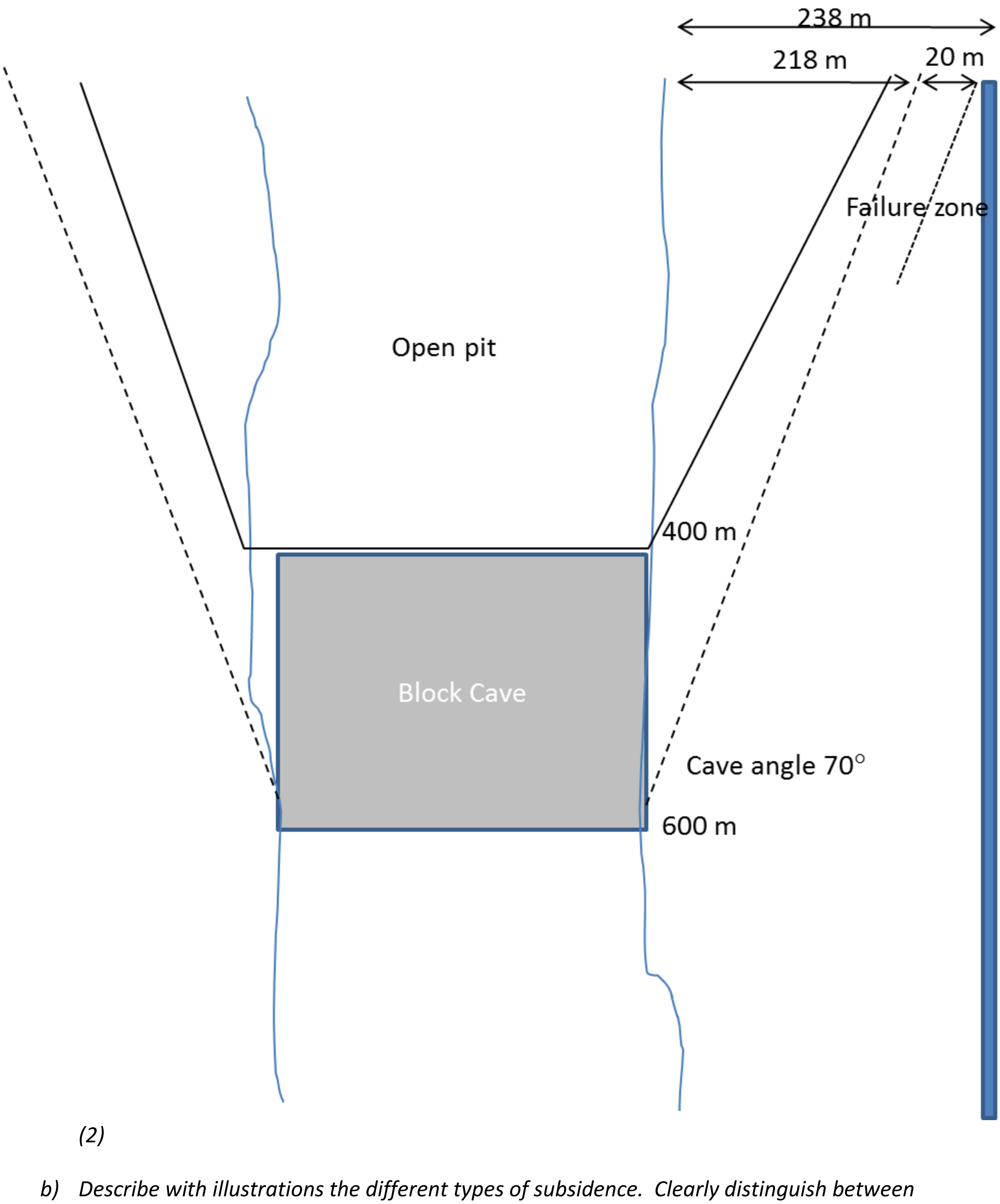
Extent of failure zone

Failure on surface

Extent = 20 m *(2)*

Horizontal distance from limit of orebody to a position on surface:

D = 600 / tan 70° + 20 = 238 m *(2)*



(2)

b) *Describe with illustrations the different types of subsidence. Clearly distinguish between continuous and discontinuous subsidence.* *[12]*

Brady and Brown p484

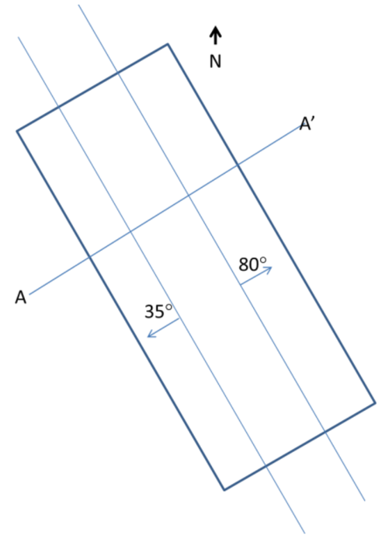
c) *Describe a typical subsidence monitoring programme. Include a list of the equipment used for subsidence monitoring.* *[5]*

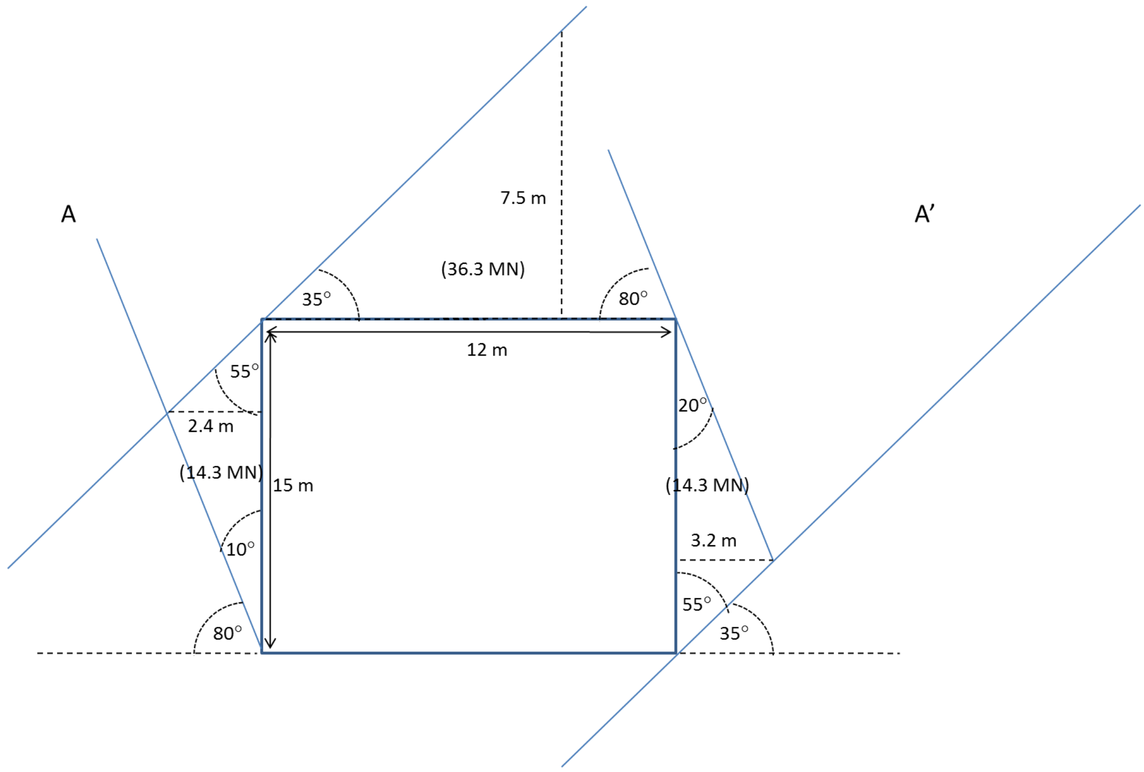
van der Merwe JN 1995 Practical Coal Mining Strata Control Sasol Coal Division Jhb Chapter 5

Q4

a) *Draw the excavation in plan view and show the joint traces (clearly show the orientation of the excavation and joints). Draw a vertical cross-section showing the largest wedges that can be formed in the roof and sides of the excavation (approximately in proportion). Calculate the height and weight of each of the wedges and indicate these on the drawing12 Marks*

Candidates should be able to identify that the strike of the joints is parallel to the long axis of the excavation and draw a section across the width of excavation showing the joints intersecting the corners of the excavation. One wedge in the roof and one in each side must be shown. (4)





Roof wedge

Wedge height

$$h = \frac{12 \times tan35 \times tan80}{tan35 + tan80}$$

h = 7.5 m (2)

Wedge Weight

W = 0.5 base x height x length x unit weight

W = 0.5 x 12 x 7.5 x 30 x 27

W = 36,300 kN = 36.3MN (2)

Side wedges

The two side wedges are the same size, just inverted.

Wedge height

$$h = \frac{15 \times tan10 \times tan55}{tan10 + tan55}$$

h = 2.4 m (2)

Wedge Weight

W = 0.5 base x height x length x unit weight

W = 0.5 x 15 x 2.4 x 30 x 27

W = 14300 kN = 14.3MN (2)

Calculations per unit length are also acceptable.

b) *5 Marks*

Number of bolts

N = Wf/B

N 36300 x 1.5/250 = 218 (3)

Area/cable

Area per bolt = (12x30)/218

= 1.65 m^2*/cable*

Pattern

10 cables per row (1.2 m spacing)

22 rows (1.4 m spacing)

Total cables = 220 *(2) for any reasonable pattern correctly calculated*

c) *7 Marks*

Choose wedge with 80° sliding angle *(1)*

Number of bolts

a = (90-80) + 15 = 25 *(1) calculation of angle of bolt relative to critical joint plane*

$$N = \frac{14300 \times (1.5 \times sin80 - cos80 \times tan32 - 0 \times A)}{250 \times (cos25 \times tan32 + 1.5 \times sin25)}$$

N = 65.2 *(3)*

Area/cable

Area per bolt = (15x30)/65

= 6.9 m^2/cable

Pattern

6 cables per row (2.5 m spacing)

11 rows (2.73 m spacing)

Total cables = 66 *(2) for any reasonable pattern correctly calculated*

d) *1 Marks*

Change the orientation of the excavation such that the major joints intersect at 45°. The more complex wedge geometries can be calculated using software such as Unwedge. If 380kN cables are used this would reduce the number of holes to be drilled. (1)