Model Answers for Paper 3.3 2011-05

Q1.

a) *List and compare the appropriate orebody and host rock properties required for each of the following mining methods in a table: (Block Caving [6], Sub Level Open Stoping[6],Cut and fill [6]   18 Marks*

Property	**Block Caving**	**SLOS**	**C & F**
Dimensions and shape			
Continuity			
Dip			
Orebody Strength			
Orebody rock mass characteristics			
Host rock Strength			
Host rock mass characteristics			
Value			

Brady and Brown – Chapter 12

To be populated

b) *Describe how you would determine the orebody and host rock properties in a geotechnical investigation programme.   7 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.

Q2.

a) *Explain the difference between detonating and deflagrating explosives* *2 Marks*

Brady and Brown Chapter 17.

Deflagrating explosives, such as black powder, which burn relatively slowly, and produce relatively low blasthole pressure; detonating (high) explosives, which are characterised by superacoustic reaction rate and high blasthole pressure.

b) *Explain primary, secondary and tertiary detonating explosives.* *6 Marks*

Brady and Brown Chapter 17.

Primary explosives, such as lead azide, lead styphnate, or mercury fulminate, are initiated by spark or impact. They are highly unstable compounds, and used industrially only in initiating devices such as blasting caps, as the top charge. Secondary explosives require the use of a blasting cap for practical initiation, and in some cases may require an ancillary booster charge. Explosives in this category are formulated from chemicals such as nitroglycerin (NG), ethyleneglycoldinitrate (EGDN), or pentaerythrotetranitrate (PETN), mixed with other explosive materials and stabilizing agents. Tertiary explosives are insensitive to initiation by a standard (No. 6) strength blasting cap. Most explosives in this category are the dry blasting agents (DBAs) or slurry explosivesand blasting agents.

c) *Explain shock (brisance) energy and gas (bubble) energy.* *4 Marks*

Brady and Brown Chapter 17.

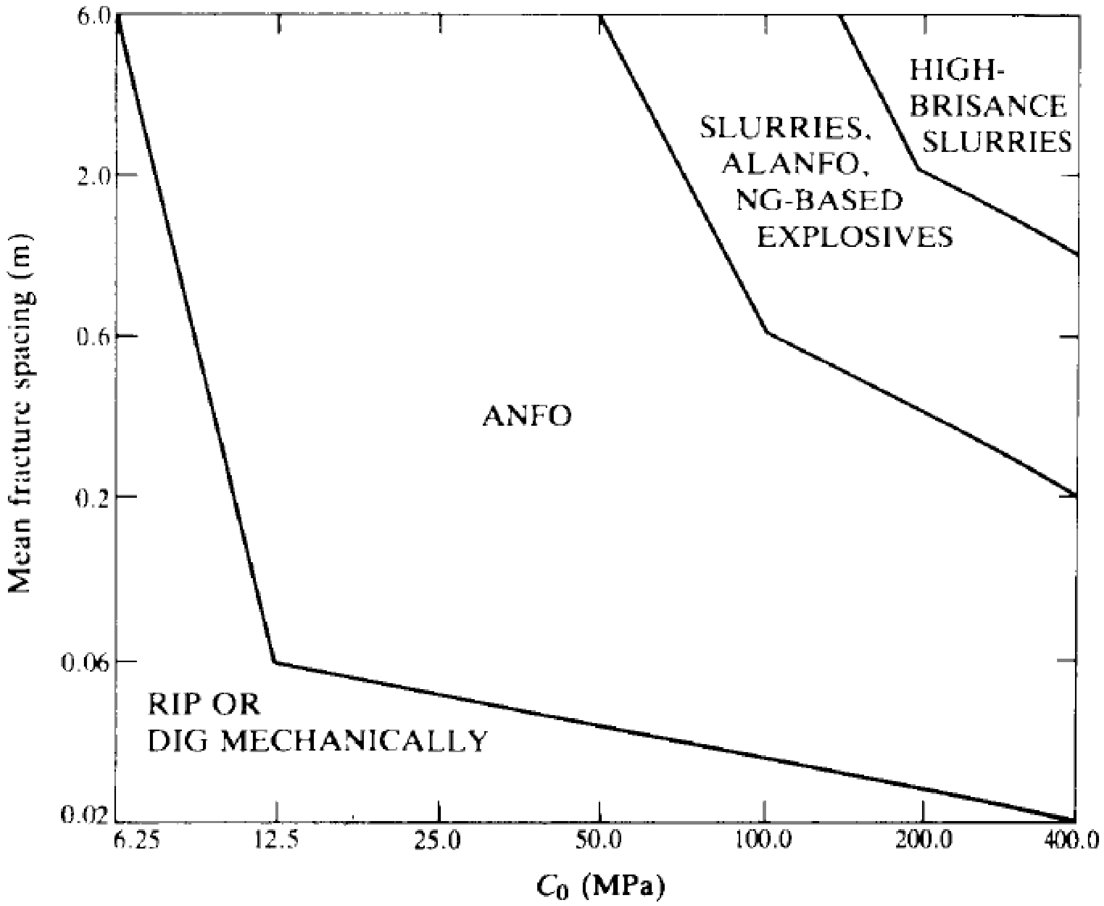
The release of the explosive's chemical potential energy does not occur in a single episode. The initial energy release associated with detonation (the shock energy) is followed by oscillation of the product gas bubble. Successive phases of energy output are identified with the bubble energy of the explosive, which represents energy possessed by the detonation product gas due to its high pressure. The term 'brisance' is used to indicate the potential 'shattering action' of an explosive. It is related directly to the detonation pressure of the explosive, which is itself related to detonation velocity. High-brisance explosives may be characterised by detonation velocities greater than about 5000 m s^{-1}. Explosives with detonation velocities less than 2500 m s^{-1} would be classed as low-brisance compounds.

d) *Explain how rock properties determine the performance of a particular explosive. Show the empirical correlation of the preferred explosive type for a range of rock strengths and fracture spacing in a sketch.* *10 Marks*

Brady and Brown Chapter 17.

Several rock properties determine the performance of a particular explosive in the medium. The capacity of the rock mass to transmit energy is related in part to the Young's modulus of the rock medium. The ease of generating new fractures in the medium is a function of the strength properties of the rock material, which may be represented for convenience by the uniaxial compressive strength C_0. The unit weight of the rock mass affects both the energy required to displace the fragmented rock, and the energy transmissive properties of the intact medium.

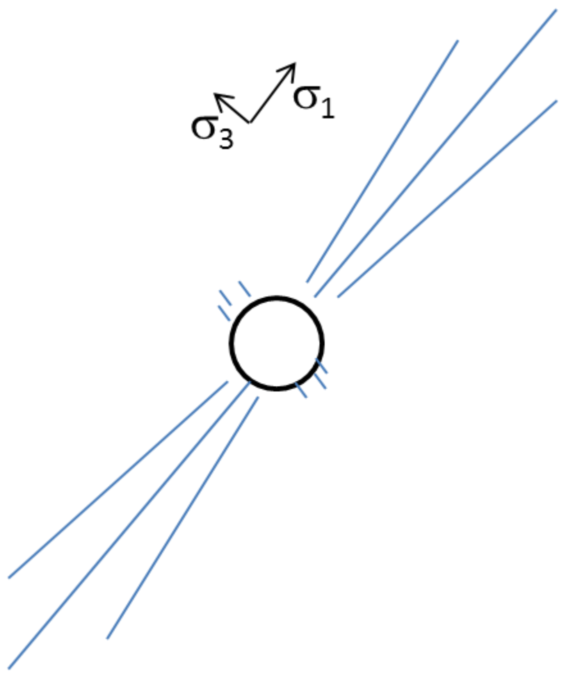
Efficient and successful performance of an explosive in a rock mass requires that its properties be compatible with those of the subject rock mass. An empirical correlation of the preferred explosive type, for a range of rock material and rock mass properties, is provided in the figure below. For very low average fracture spacing, or very low material compressive strength, the rock mass may be ripped or dug mechanically, rather than blasted. A significant observation from the figure is that ANFO is a suitable explosive for use in a wide range of rock mass conditions. The application of high-brisance explosives is justified only in the strongest, more massive rock formations.



Note: Sketch need not be accurate. Axes must be correct (values are not critical), regions must be shown, rip/ digging and high brisance explosives should be at the two extremes.

e) *Sketch the blast fracture pattern that would observe around a blast socket in an environment where there is a significant difference between the major and minor principal stresses. Clearly indicate the direction of principal stresses in your sketch*

3 Marks



Q3.

a) *Assuming that the access tunnels can be oriented either East West or North South, use the rockwall condition factor to explain to the mine manger which is the preferred orientation. Show your calculations and describe the expected fracturing, ground conditions and support requirements. Motivate your argument from both economic and safety perspectives* *16 Marks*

Rock UCS = 150 MPa

F = 0.8 (moderately jointed) accept 0.7 to 0.9 *(1)*

East West

σ_{yy} *= 80 MPa (parallel to tunnel axis)*

σ_1 *= 30 MPa*

σ_3 *= 30 MPa*

$$RCF = \frac{3\times30-30}{0.8\times150}$$

RCF = 0.5

North South

σ_{xx} *= 30 MPa (parallel to tunnel axis)*

σ_1 *= 80 MPa*

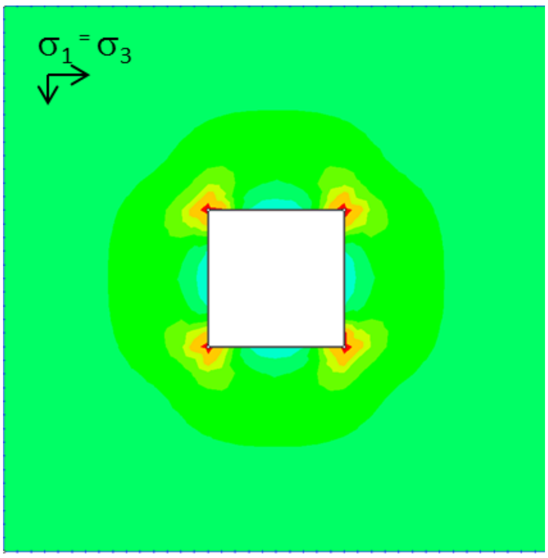
σ_3 *= 30 MPa*

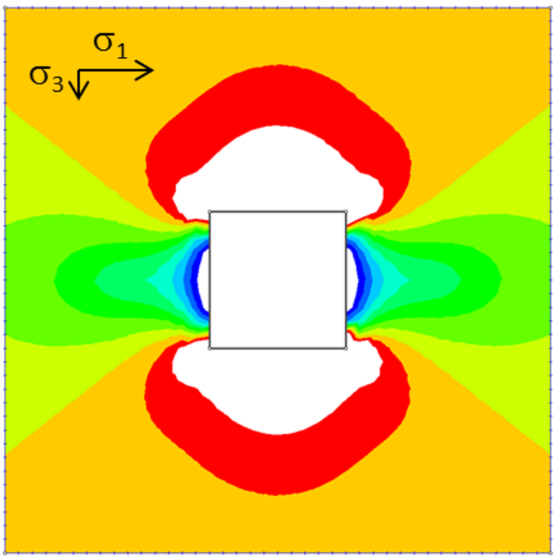
$$RCF = \frac{3\times80-30}{0.8\times150}$$

RCF = 1.8 *(4)*

Optimum orientation is East-West *(1)*

Stress Distribution elastic

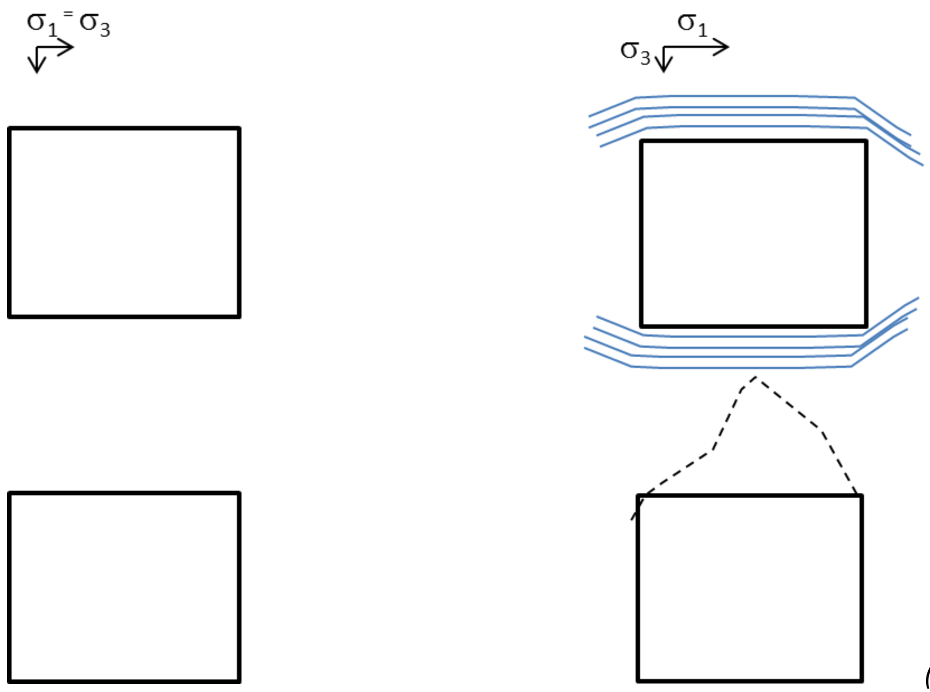




(4)

Expected Stress fracturing and conditions:

East West	North South
Limited or no fracturing	*Extensive fracturing in the roof/crown/hangingwall*
Excellent conditions	*Gothic arching or buckling of roof strata*



(6)

East West ***North South***

Primary support:

Spot bolts (depends on jointing) *Shotcrete to face, fully grouted tendons etc*

Secondary support:

Spot or pattern bolting *wire mesh, lacing, shotcrete, grouted ropes (2)*

Safety:

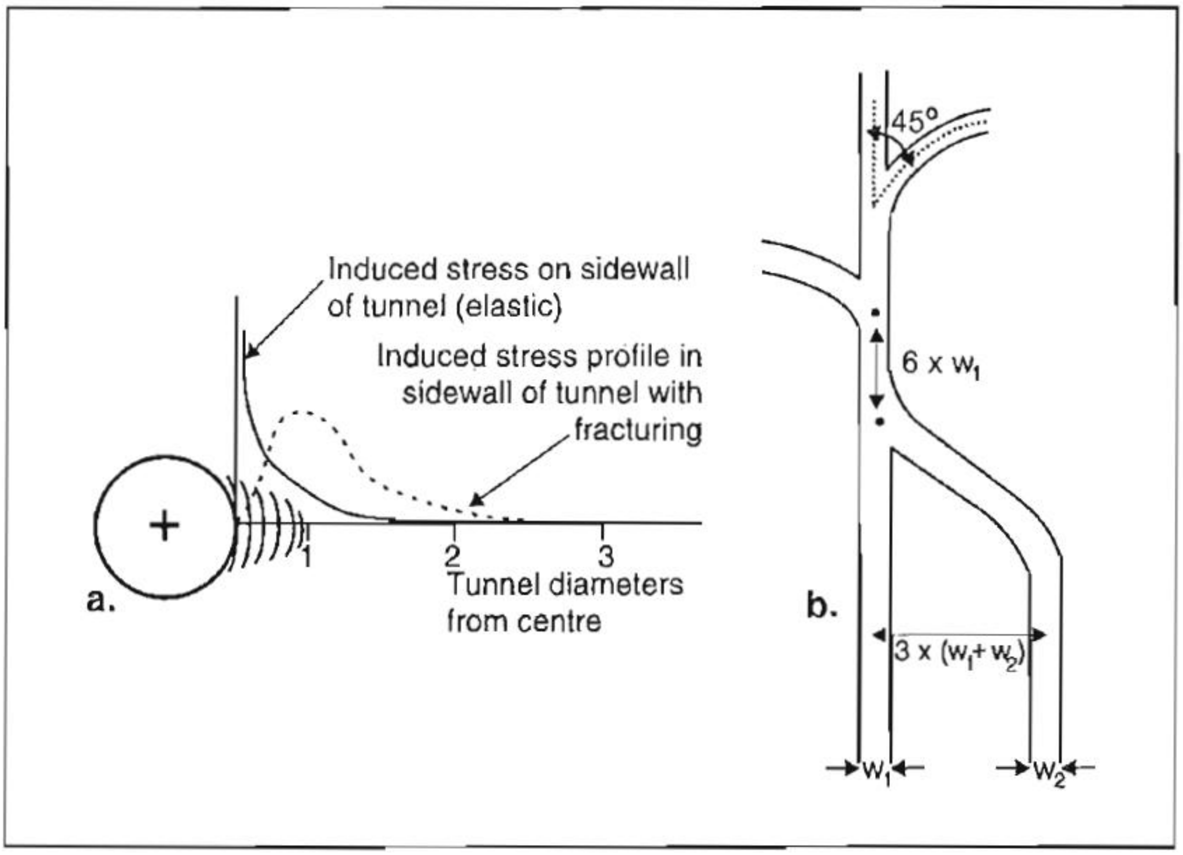
Low risk of rockfalls *rockfalls, strainbursts*

Economic:

Low support cost *High support and labour cost*

High productivity *Delays due to rockfalls, cycle times etc (2)*

b) *Specify the required spacing between parallel tunnels and explain why this is necessary (use sketches as required).* *5 Marks*



Q4.

a) Calculate the tensile strength of the bolts and determine the critical bond length to ensure that the shear strength of the resin equals the tensile strength *8Marks*

The tensile strength for a 20mm diameter, 450 MPa high yield stress steel rock bolts is given by:

$$Tensile\ strength\ = 450\ \times 10^6\ Pa \times \pi \times (\frac{0.02}{2})^2$$

= 141kN

The bond length is defined as the length where the shear strength of the resin is equal to the tensile strength of the rock bolt.

The required bond length is given by:

$$L = \frac{141 \times\ 10^3 N}{\Pi \times 0.02m \times 2.5\ \times\ 10^6\ Pa}$$

= ***0.9m***

b) Calculate the required number of bolts per m^2 *4Marks*

Given:

	FoS	=	1.5
	ρ	=	4.2 t/m^3 for Banded Ironstone
	g	=	9.81m.s^{-2}
	P_f	=	141kN
	t	=	1.0 m
	n	=	Number of Rock Bolts required per m^2

$$n\ = FoS\ \frac{\rho g t}{P_f}$$

$$= 1.5 \times \frac{4.2\ tonnes.m^{-3} \times 9.81 m.s^{-2} \times 1.0m}{141kN}$$

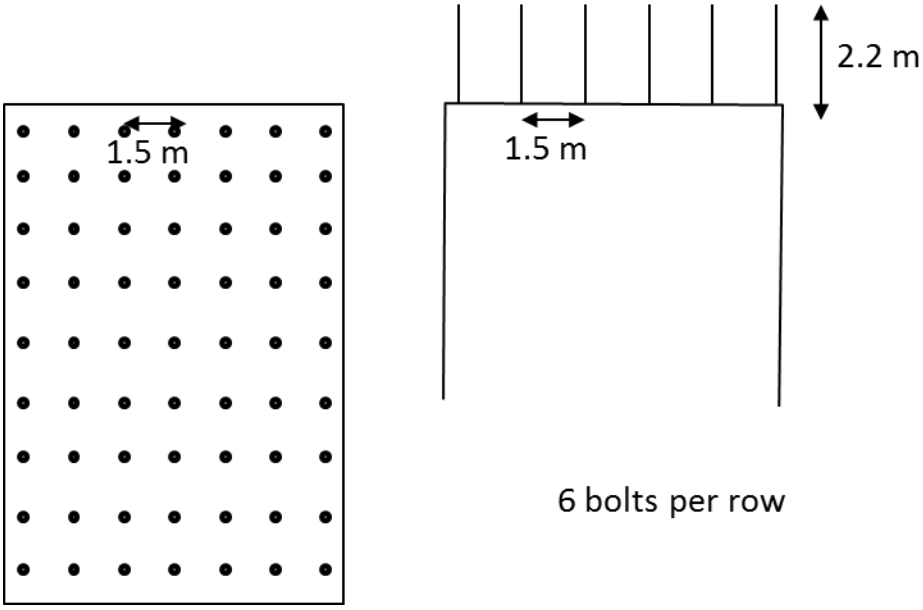
= ***0.44 Rock Bolts / m^2***

c) Draw the hangingwallsupport pattern for a 8 m wide bordin plan and section *4Marks*

Bolt spacing= ***1.51m***

The required rock bolt length is equal to 1.0m + 0.9m = ***1.9m***

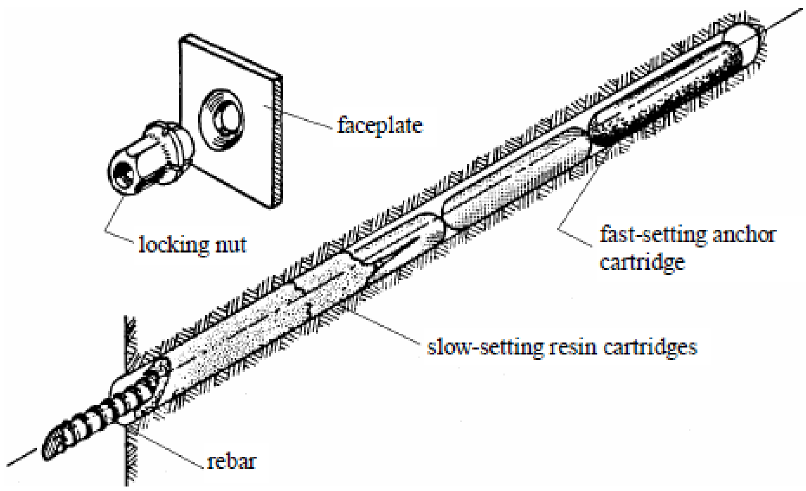
The next standard length of rock bolt commercially available is 2.2m, therefore this is the recommended rock bolt length.



d) Describe with the aid of sketches, a resin grouted bolt. Discuss some of the limitations of this tendon and required control procedures *9Marks*

Brady and Brown 11.6.2, Hoek, Kaiser, Bawden 12.2.2

A resin product is typically made up of two component cartridges containing a resin and catalyst in separate compartments. The cartridges are pushed to the end of the hole. A rebar is then pushed into the hole and spun into the resin cartridges by the drill. This breaks the cartridges and mixes the catalyst and resin. The resin sets within a few minutes, depending on specifications. A fast setting cartridge, which sets in about 30 seconds, is installed at the end of the hole, while the remainder are slow setting cartridges. The fast setting cartridge acts as the anchor and allows the rebar to be tensioned. This tension is locked in by the later setting cartridges, which results in a fully tensioned, fully grouted rockbolt.



Limitations and controls:

- Resin cartridges have a limited shelf life, which depends on the storage conditions and temperature – Purchase only as much as is required, ensure stock rotation and storage under conditions recommended by the manufacturer. Test the activity of the resin using a cartridge form each box.
- Ineffective mixing of resin – test and control spinning technique, control hole diameter and select rebar diameter to ensure that the resin annulus is within manufacturer specifications.
- In hot or cold underground environments the resin may not set or as required – Check manufacturers operating temperature range and select setting times for the mining environment. Use a bucket of water to control the temperature prior to installation.
- In some weak argillaceous rocks, the drillhole surfaces can become clay coated during drilling. This causes slipping of the resin cartridges during rotation, resulting in incomplete mixing and an unsatisfactory bond – use cement grout
- In highly fractured rock masses, the resin may seep into the surrounding rock mass, leaving voids in the resin column surrounding the rockbolt – use cement grout, use a pumped grout or resin system.