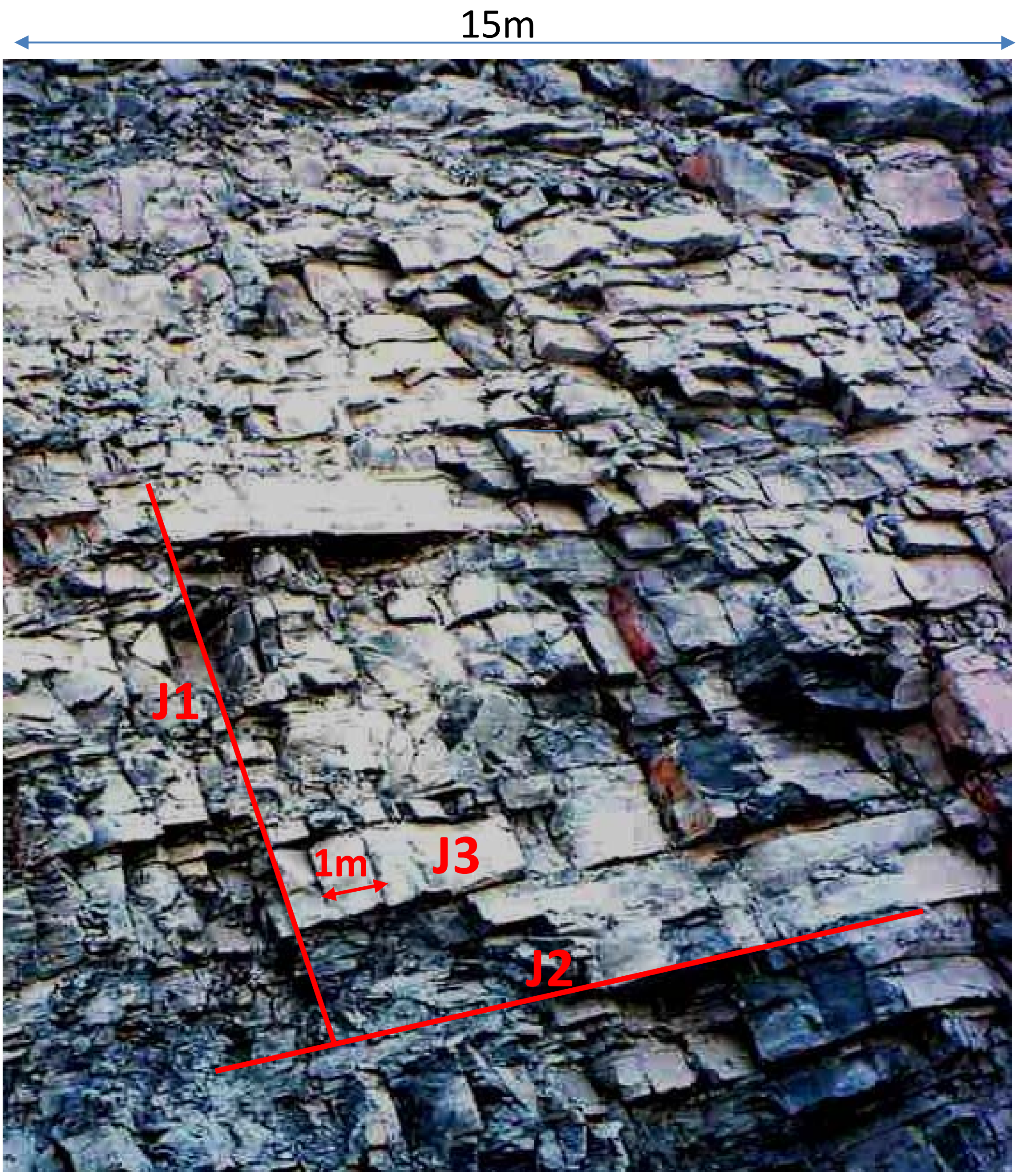
Model Answers for Paper 3.3 2010-05

Q1.

a) *Identify the joint sets and estimate their spacing from the attached photograph. Annotate your photograph to illustrate your observations (annotated photographs are to be handed in with your script). Determine the RQD using your estimated joint spacing.* *[6]*



J1: ±1m. J2: ±1m. J3: ±0.5m

Note that these are estimates accuracy is not critical – marks are given, providing the estimates are reasonable and the assumptions are indicated on the photograph. Candidates are not to be penalised for reasonable estimates (3)

J_v = 1/J1 + 1/J2 + 1/J3 + 1/random = 1/1 + 1/1 + 1/0.5 = 2.5

RQD = 115-3.3J_v = ±107 RQD ≈ 100 (3)

b) *Determine the vertical and horizontal stress at this depth. Classify the rock mass using the Q rating system. Use the estimated values determined in a) and use the photograph to approximate any additional information required. Provide brief explanations and/or calculations for your decisions on the input parameters for the rock mass classifications.. [10]*

Stress

Vertical stress = ρgh = 2700 x 10 x 150 = 4 MPa (1)

Horizontal stress = 1.5 x 4 = 6 MPa (1)

σ_c/σ_1 = 80/6 = 13 (1)

Q rating system (reasonable assumptions are given marks)

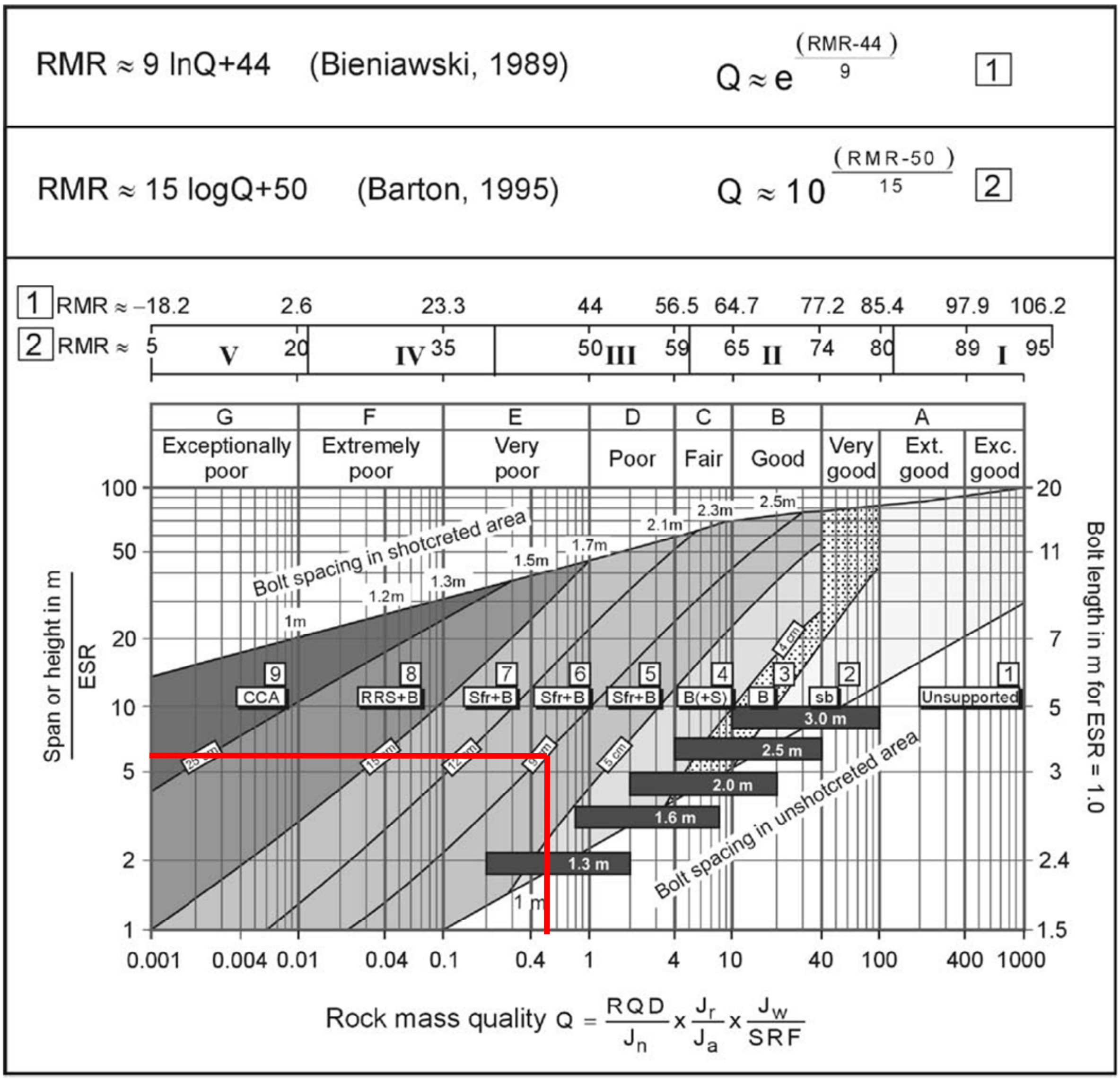
RQD	100	
Jn (3+random)	12	(1)
Jr (slickensided, planar)	0.5	(1)
Ja (2mm thick serpentinite)	8	(1)
Jw (no inflow)	1	(1)
SRF (no weakness zones indicated, σ_c/σ_1= 13 – medium stress)	1	(1)
Q = 100/12 x 0.5/8 x 1/1 = 0.5		(2)

Candidates must demonstrate an understanding of the process and select reasonable values. Values are estimated from the estimated joint spacings and descriptions provided.

c) *Determine the required support for a 10 m wide crusher chamber at the depth of mining using the empirical chart. Annotate the relevant chart and hand it in with your script. [5]*

ESR = 1.6 (Crusher is a permanent mine opening) (1)

Span/ESR = 10/1.6 = 6.25m (1)



4m long bolts, spaced2.5m apart

90cm thick shotcrete. (3)

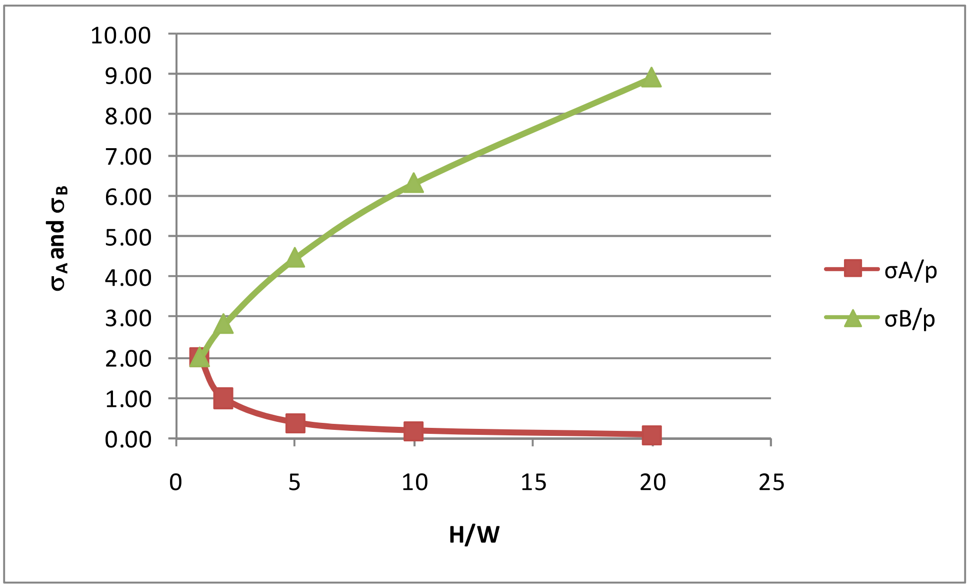
d) Briefly discuss what other approaches you could use to improve confidence in the design. [4]

- Review precedent practice on the same operation. Support practiced under the same conditions
- Kinematic analysis to determine the support requirements for blocks
- Stress analysis – numerical modelling.

Q2.

a) *Plot graphs of the stress concentration factor versus the H/W ratio. Use H/W values of 1,2,5,10, and 20 and K=1? [12]*

H/W	σ_A/p	σ_B/p
1	2.00	2.0
2	1.00	2.8
5	0.40	4.5
10	0.20	6.3
20	0.10	8.9



b) *The stress concentrations in the crown and sidewall change as H increases. How will this influence stability? Briefly suggest methods of managing stability. [5]*

Brady and Brown 14.4

The stress in the sidewall becomes a low compressive stress (or tensile if K>1), which will allow unravelling of a blocky rock mass. The backfill prevents this from occurring. The lift heights can be reduced if the sidewall conditions are poor.

The stress in the crown increases as the H/W ration increases. If the stress levels approach or exceed the rock strength, conditions in the crown will deteriorate due to fracturing or mobilisation of blocks. This can be managed by:

- Abandoning the stope and underhand stoping from a higher level
- Development of a new overhand stop at a higher elevation and leaving a pillar.
- Pre-reinforcement of the stope crown.

c) Describe, with the aid of sketches, how you would carry out pre-reinforcing of the crown using long cables. *[8]*

Brady and Brown Chapter 11.4.

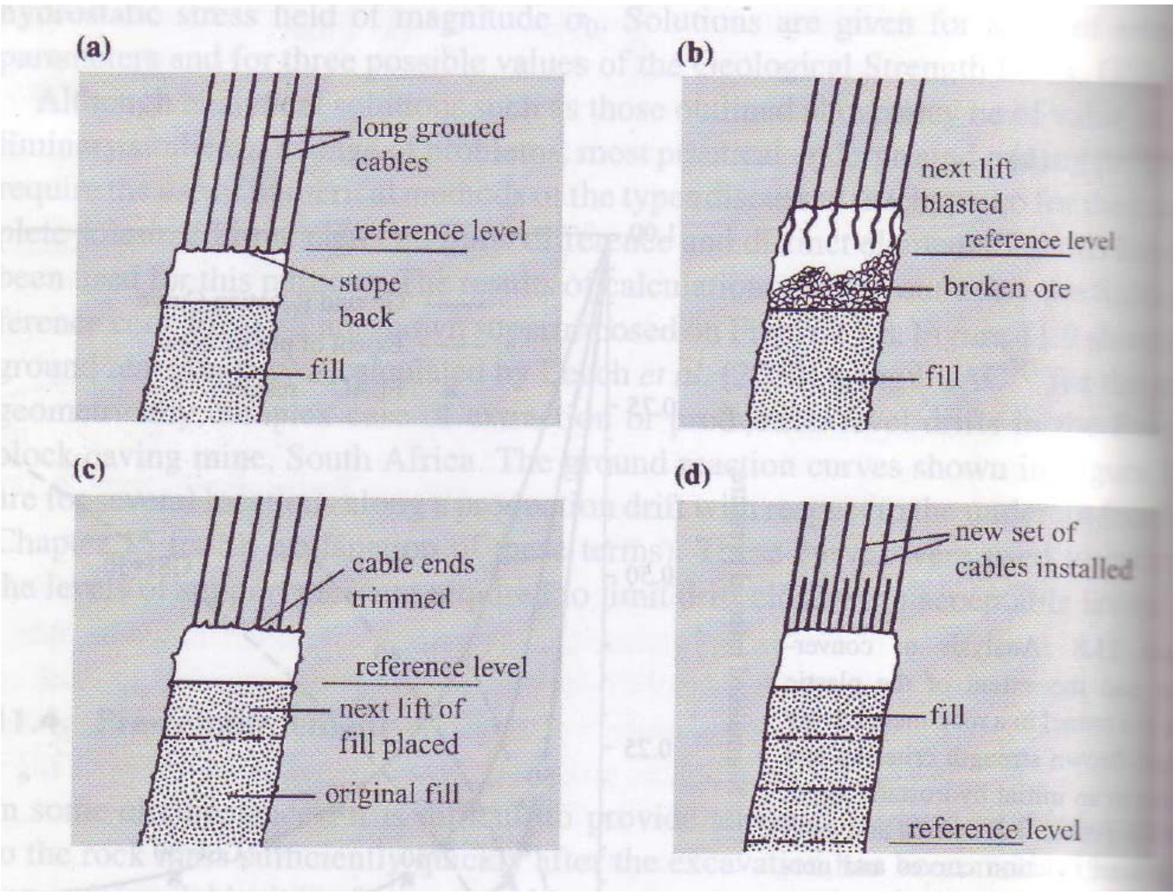
Hoek, Kaiser & Bawden 11.7.1

a) Long grouted cables are installed in the crown parallel to the stope walls (the length of several lifts).

b) The next lift is blasted,

c) Ore is removed and cable ends are trimmed

d) Successive lifts are mined until the minimum required cable support length is reached. New cables are then installed.



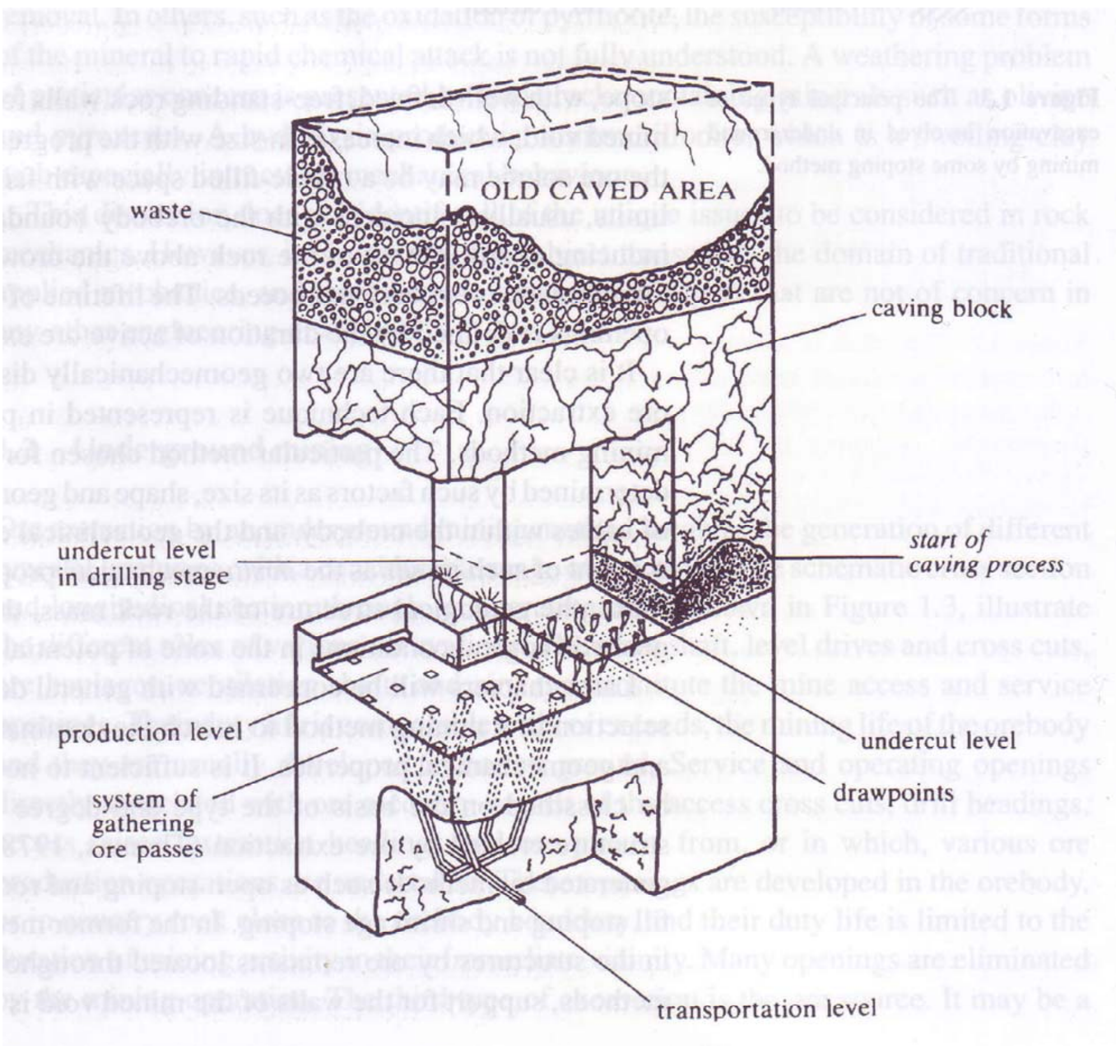
Q3.

a) *Describe the following types of backfill and discuss the advantages and disadvantages in terms of transport, drainage, bulkhead requirements, risk and cost:* *[12]*

Brady and Brown: 12.4.9

In caving the primary fragmentation of the ore is accomplished by natural mechanical processes. The disintegration of the rock mass takes advantage of natural discontinuities, the stress distribution around the cave and the weak strength of the ore.

A caving block is defined initially. An undercut is then established by drilling and blasting immediately beneath the caving block. This should be large enough to induce caving of the block. A system of drawpoints is established beneath the undercut forming the production or extraction level. The ore can be extracted through a system of orepasses beneath the extraction level or with LHDs. When the caving initiates, the fragmented ore is removed at the extraction level, which induces flow in the caved material. This removes the confinement at the boundary of the cave. The rock mass forming the cave boundary begins to fracture and deform. The cave boundary continues to advance while the ore is continuously extracted.



b) Briefly describe how you would assess cavability using Laubscher's method, listing the information that you require for this assessment. [6]

Brady and Brown 15.5.2

Determine the footprint of the orebody to be caved and calculate the hydraulic radius (area/perimeter)

Carry out an investigation of the rock mass characteristics through a drilling programme and if possible geotechnical mapping should be carried out. Determine the following information:

- Rock strength
- Fracture frequency / joint spacing
- Joint condition (surface roughness and infill)
- Joint orientations
- Potential for weathering

Calculate the MRMR. Plot the hydraulic radius and MRMR on Laubscher's stability graph and determine whether this lies within the caving portion of the graph.

c) *Explain primary and secondary fragmentation. List five mechanisms of secondary fragmentation. [7]*

Brady and Brown 15.5.5

Primary Fragmentation: the separation of blocks from the back as the undercut is mined and caving is initiated.

Secondary Fragmentation: Fragmentation that occurs subsequently as blocks move down through the draw column to the draw points.

Mechanisms of secondary fragmentation (any five):

- Extension of pr-existing discontinuities
- Opening of filled or healed discontinuities
- Opening along bedding or schistosity planes
- Crushing under superimposed weight
- Compressive (shear) failiure of blocks under the influence of arching stresses within the cave
- Failure of individual blocks by induced tension produced by point loading or line loading at inter-block contacts within the caved mass
- Bending failure of elongated blocks
- Abrasion or "autogenous grinding" of block corners and edges to reduce block sizes and produce fines

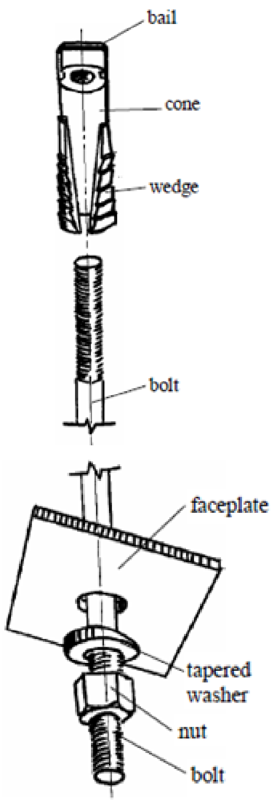
Q4.

a) *Describe with the aid of sketches, a mechanically anchored bolt. Discuss some of the limitations of this tendon and required control procedures. [9]*

Brady and Brown 11.6.2

Hoek, Kaiser, Bawden 12.2.1

A mechanical anchor is anchored within the rock using an expansion shell (indicated in figure below). This comprises a tapered cone with an internal thread and a pair of wedges held in place by a bail. The assembled expansion is anchored by a sharp pull on the bolt. The bolt is usually a solid bar, which is thread at each end. At the other end of the bar a faceplate, tapered washer and nut are fastened against the mouth of the hole. The mechanical anchor is fastened by tightening the nut, which ensures that it remains tensioned. The bolt should be tensioned to about 70% of the capacity of the bolt.



Limitations and controls:

Mechanical anchored bolts are end anchored and the failure of either the expansion shell, bar or faceplate and nut, will render the bolt ineffective:

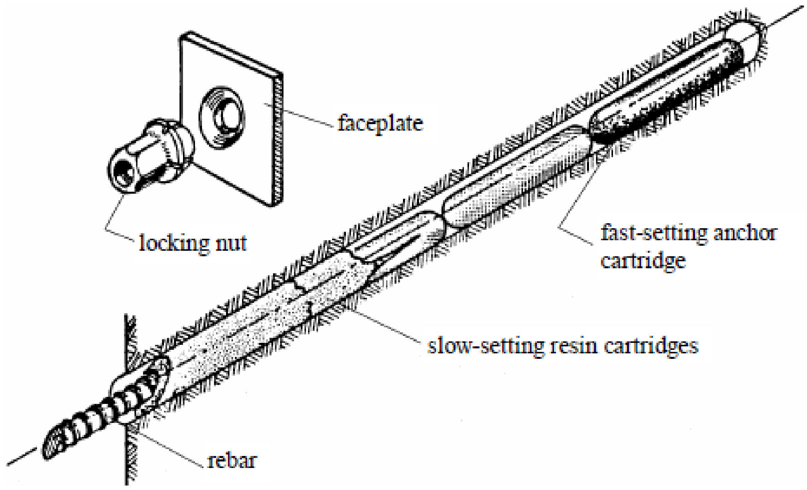
- Damage to faceplate due to blasting or machinery- grouting
- Loss of tension after blast makes the tendon inneffective - re-tensioning, post grouting
- Loss of anchorage due to joints in a weak, jointed rock mass – grouting
- Corrosion of components– galvanising, grouting

b) Describe with the aid of sketches, a resin grouted bolt. Discuss some of the limitations of this tendon and required control procedures. [9]

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.



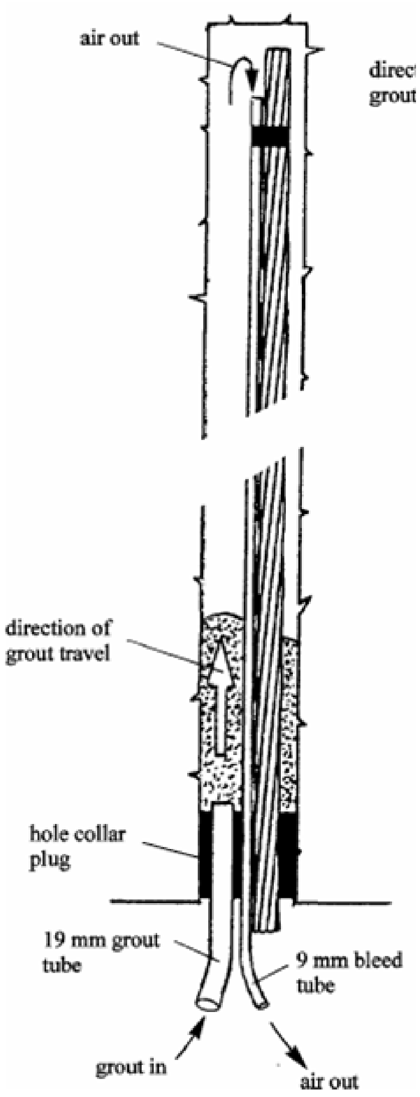
Limitations and controls:

- 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.

c) *Describe with the aid of sketches the breather tube method of installing cable anchors.   [7]*

Brady and Brown 11.6.3

Hoek, Kaiser, Bawden 13.5



Breather tube method

Grout is mixed with water/cement ratio of 0.4 or following the manufacturer's specifications if a specialised grout is used.

Grout is injected through the large diameter grout tube.

The air is bled smaller diameter breather tube, which extends to the end of the hole

Both tubes are sealed at the bottom of the hole by means of a plug (cotton waste, sponge, quick setting mortar

The grout flows upwards into the hole and displaces the air through breather tube

The hole is fully grouted when grout flows out of the breather tube.