Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN STRATA CONTROL (COAL)	**EXAMINER:** R. GONSALVES
SUBJECT CODE: COMSCC	**MODERATOR:** O. SWAKAMISA
DATE: 07 OCTOBER 2025	**TOTAL MARKS:** 100
TIME: 14H00 TO 17H00	**PASS MARK:** 60%

NUMBER OF PAGES: 11 (including this page)

EXAMINATION FORMAT: CLOSED BOOK. NO REFERENCES OTHER THAN WHAT ARE PROVIDED ARE ALLOWED.

SPECIAL REQUIREMENTS:

1. Answer all the questions in legible English.
2. Write your ID number (no names) on the outside cover page of each script used and on any graph paper or other loose sheets handed in.
3. Show all calculations and check the calculations on which the answers are based.
4. Hand-held electronic calculators may be used for calculations. Reference notes may not be programmed into calculators.
5. Write legibly in black ink on the right-hand page only. Left-hand pages will not be marked.
6. Illustrate your answers using sketches or diagrams wherever possible.
7. Final answers must be given with accuracy typical of practical conditions; however, be careful not to use too few decimal places during your calculations, as rounding errors may result in incorrect answers.

   NB: Ensure that the correct unit of measure (SI unit) is used as marks will be deducted if the incorrect unit is used even if the calculated value is correct.
8. In answering the questions, full advantage should be taken of your practical experience as well as the data given.
9. You are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones and other smart devices are not allowed on your person and must be handed to the invigilators or left in your vehicle.

QUESTION 1. ROCK MASS CLASSIFICATION

1. Figure 1 shows the immediate roof of an incline development at a depth of approximately 180 m below surface.

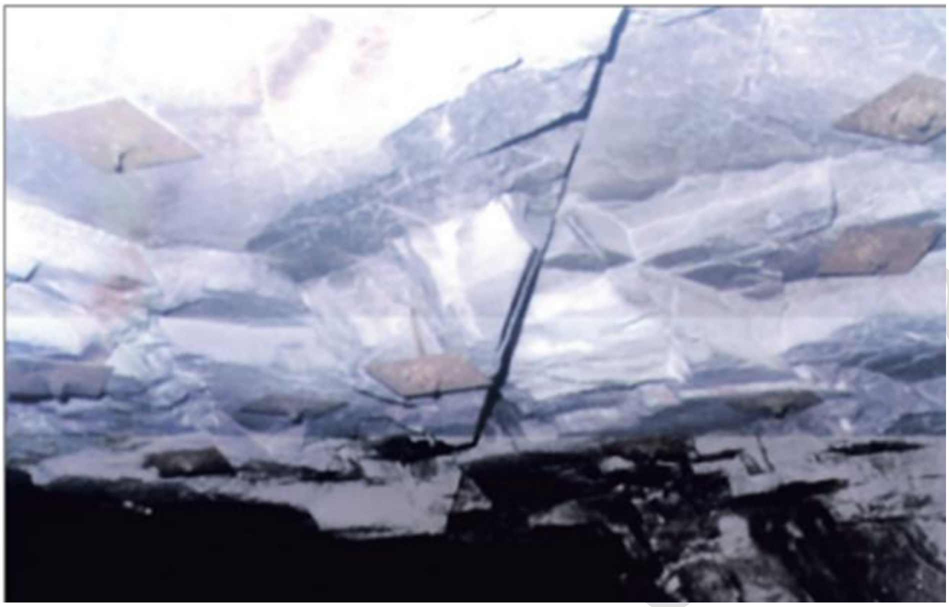


Figure 1: Immediate sandstone roof in an incline development at approximately 180 m below surface.

It has the following characteristics:

- The sandstone has a UCS of 90 MPa but is affected by several joints, resulting in a relatively blocky rock mass.
- It is estimated from visual observations that the RQD is good at 85% given the thickness of the bedding planes exposed, despite there being some thin layers that may result in core samples less than 10 cm in thickness.
- Apart from the bedding planes, there are two dominant joint sets present in the rock mass. There is also a fourth set present, but to a lesser extent.
- The joints are ‘planar and smooth” and are ‘tightly healed with impermeable filling with alteration index equal to 1.0’
- The area is dry.
- The depth to this specific position in the incline is 180 m below surface and is ‘medium stress, favourable stress conditions’ with the $\sigma_c/\sigma 1$ ratio in the range of 10-200.

Considering the information above, answer the following questions:

1.1.	Explain the concept of RQD and what it is used for in rock engineering.	(2)
1.2.	Explain the concept of a point load test and what it is used for in rock engineering.	(4)

1.3.	What would the typical value(s) be for a sandstone sample?	(1)
1.4.	Indicate the different parameters that are considered with the Barton's Q-Index. Use the information above and data tables provided to also assign values to each of these parameters.	(6)
1.5.	Use a formula to describe Barton's Q-Index and define the function of each quotient.	(4)
1.6.	Calculate the Q-Index above.	(1)
1.7.	The life expectancy of the block of ground being developed towards by the incline is several years. The bord width for the conveyor road is 9 m. The calculated Q rating puts the rock mass in rock class C 'fair': 1.7.1. What Excavation Support Ratio does the information provided suggest you use? 1.7.2. Determine the Span-to-ESR ratio? 1.7.3. What support recommendations would you make for this excavation?	 (1) (1) (5)
		[25]

QUESTION 2. PILLAR DESIGNS

2.	You are the appointed strata control officer on Mine X. It is a mechanised coal mine situated in the Highveld Coalfield. It uses the bord-and-pillar method to extract the No. 4 coal seam at an average depth of 54 m below surface. The No. 4 coal seam has an average thickness of 5.4 m; however, selective mining is applied, and only the bottom 3.8 m of the seam is mined.	
2.1.	The coal pillar load is calculated using Tributary Area Theory (TAT). Briefly explain this principle with specific reference to the assumptions, limitations and the adjustment required when the overburden consists of denser rock units. *You may use equations and sketches to aid your explanation.*	(5)
2.2.	Design the pillars for a normal production (tertiary) panel using the Salamon and Munro pillar strength formula. Determine the pillar centres, w:h ratio and percentage area extraction for this production panel. *State all your assumptions.*	(10)
2.3.	There is a portion of the coal reserve to the east of the mine where the No. 4 coal seam occurs at a depth of only 36 m below surface.	

2.3.1. State all the COMRO shallow mining guidelines/principles.	(5)
2.3.2. Your Mine Manager has tasked you as the responsible strata control officer to design a safe and stable pillar design for the panels located in this area. Determine the pillar centres, w:h ratio and percentage area extraction. *State all your assumptions.*	(10)
	[30]

QUESTION 3. ROOF SUPPORT AND BEAM STABILITY

3. As stated in Question 2, Mine X mines the No. 4 coal seam, which occurs at an average depth of 54 m below surface and has a seam thickness of 5.4 m. However, the mine applies selective mining to only mine the bottom 3.8 m of the coal seam. The No. 4 coal seam is divided into three portions as indicated in the generalised stratigraphic column below.

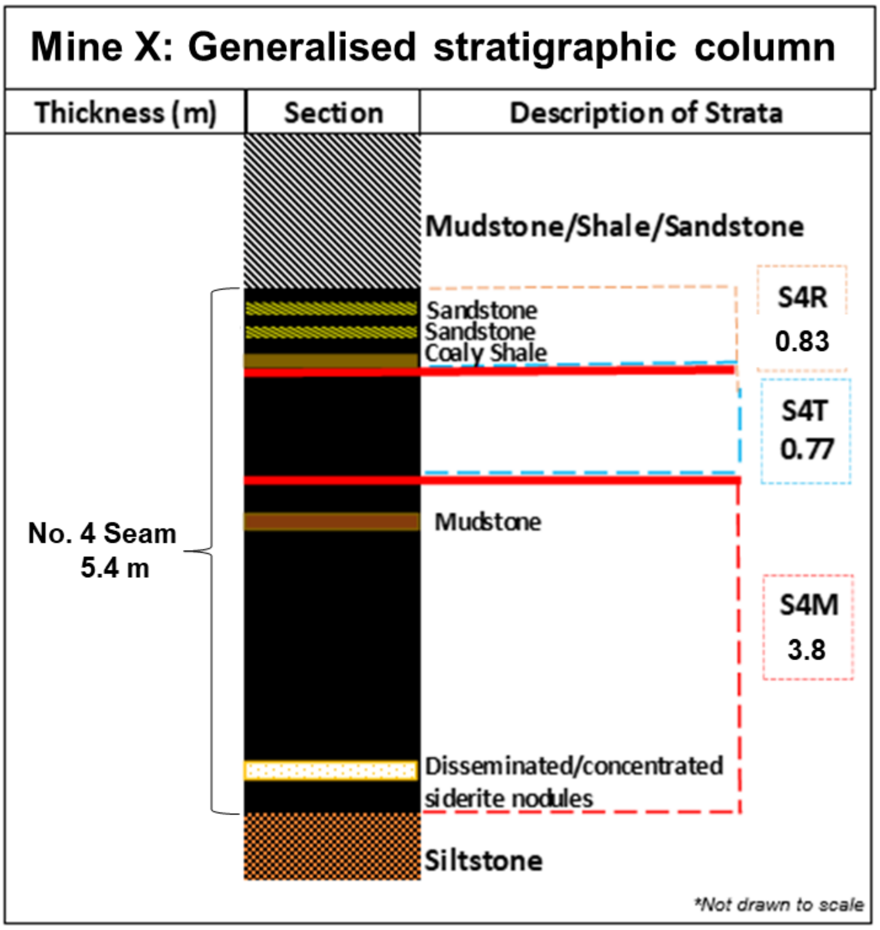


Figure 2: Generalised stratigraphic column focusing on the No. 4 coal seam.

3.1.	The appointed Rock Engineer for this mine has instructed that a coal beam of at least 0.5 m must be left above the S4M to avoid exposing the interlaminated shales and mudstones. What is the significance of leaving this 0.5 coal beam as the immediate roof?	(5)
3.2.	The mine generally installs 1.8 m long, full-column resin, roof bolts as normal systematic support. They furthermore install 4 m long roof monitoring devices (RMDs), also known as telltales, in all intersections.	
	3.2.1. Determine the required length of a resin capsule for a full-column resin installation of a 1.8 m long, 20 mm diameter roof bolt. The drill bit diameter is 25.6 mm. The diameter of the resin capsule is 23 mm. *State all your assumptions.*	(5)
	3.2.2. Explain the significance of full column resin installation. *Use sketches to assist with your explanation.*	(5)
	3.2.3. These roof bolts are installed using the reverse-spin (or spin-and-hold) method. Describe this installation method in detail. Also, describe the roof bolts used during reverse-spin installation.	(5)
3.3.	During one of your routine inspections, you see that an RMD is triggered in one of the intersections. You conduct a feeler gauge inspection and identify delamination at a depth of 2.3 m into the immediate roof.	
	3.3.1. What length roof bolts would you recommend to re-support this intersection? Also, calculate the length of the required resin capsules to ensure full-column resin installation of these recommended roof bolts?	(5)
	3.3.2. Calculate how many of the roof bolts (as recommended in 3.3.1) would be required to re-support this intersection if it has an area of 52 m². Assume the following: • The overlying roof consists of interlaminated shales and mudstones. • Each roof bolt has a maximum loading capacity of 16 tons. Note: Your design must have a safety factor of 1.5 and indicate the spacing of the additional recommended roof bolts. *State all your assumptions.*	(10)
		[35]

QUESTION 4. OPENCAST

Describe and discuss the following two opencast failure modes. Use sketches to show what they look like. Also indicate what controls you would recommend to contain each of these failure modes: a) Circular failure b) Wedge failure	 (5) (5)
	[10]

Total Mark = [100]

Strata Control (Coal) Formula sheet

$$S = 7.2\frac{w^{0,46}}{h^{0,66}}$$

$$e\% = 1 - \frac{w_1 w_2}{C_1 C_2}$$

$$\sigma_{OR} = 5.47\frac{w^{0.8}}{h}$$

$$\sigma_{ML} = 6.61\frac{w^{0.5}}{h^{0.7}}$$

$$L = \frac{25HC^2}{w^2}$$

$$L = \frac{[25(H - T) + 30T)]C^2}{w^2}$$

$$\eta = \eta_o(1 + \frac{2\Delta w_0}{w})^{2,46}$$

$$n = SF\frac{\rho . g . t}{Pf}$$

$$Lb = \frac{d_c^2 \quad Lc}{D^2 - d^2}$$

$$\tau = \frac{Pf}{\pi . D . Lb}$$

$$\eta = \frac{\gamma \ L^4}{32 \ E \ t^2}$$

$$\sigma_{nj} = \frac{\gamma L^2}{2t}$$

$$\sigma_j = \frac{3\gamma L^2}{t}$$

$$FS = 288\frac{w^{2.46}}{Hh^{0.66}(w+b)^2}$$

$$\sigma_s = 7.2\frac{R_0^{0.5933}}{V^{0.0667}}\{\frac{0.5933}{\varepsilon}[(\frac{R}{R_o})^{\varepsilon} - 1] + 1\}$$

$$d_c = w - [0.00714 S_m H h C^2]^{0.333}$$

$R = m[\frac{h}{T}]^x$ (m/yr)

$T_L = [\frac{d}{mh^x}]^{\frac{1}{1-x}}$ (years)

m = 0.1799

x = 0.7549

$$L_c = 2T\sqrt{k_s + \frac{\beta}{D}} + 2(H - D)tan\emptyset$$

$$\beta = \frac{1.53}{\gamma_m} - 0.8$$

$$\gamma_m = 0.025\frac{D-T}{D} + 0.03\frac{T}{D}$$

$$S_m = 0.39h(\frac{W}{H})^{0.32}$$

$$T_m = 21.6S_m + 7\ mm/m$$

$$\varepsilon_{m+} = 4.2S_m + 1.7\ \mathrm{mm/m}$$

$$\varepsilon_{m-} = -9.1S_m - 2.8\ \mathrm{mm/m}$$

Strata Control (Coal) Data Tables

1 Rock quality designation		RQD
A	Very poor	0–25
B	Poor	25–50
C	Fair	50–75
D	Good	75–90
E	Excellent	90–100

Note: i) Where RQD is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate Q
ii) RQD intervals of 5 i.e .100, 95, 90 are sufficiently accurate

2 Joint set number		J_n
A	Massive, no or few joints	0.5–1.0
B	One joint set	2
C	One joint set plus random joints	3
D	Two joint sets	4
E	Two joint sets plus random joints	6
F	Three joint sets	9
G	Three joint sets plus random joints	12
H	Four or more joint sets, random, heavily jointed, 'sugar cube' etc.	15
J	Crushed rock, earthlike	20

Note: (i) For intersections use ($3.0 \times J_n$)
(ii) For portals use $2.0 \times J_n$

3 Joint roughness number		J_r
(a) Rockwall contact and (b) rockwall contact before 10 cm shear		
A	Discontinuous joints	4
B	Rough or irregular, undulating	3
C	Smooth undulating	2
D	Slickensliding undulating	1.5
E	Rough irregular planar	1.5
F	Smooth planar	1.0
G	Slickenslide planar	0.5

Note: (i) Descriptions refer to small-scale features and intermediate-scale features, in that order

(b) No rockwall contact when sheared		
H	Zone containing clay minerals thick enough to prevent rockwall contact	1.0
J	Sandy, gravelly or crushed zone thick enough to prevent rockwall contact	1.0

Note: (i) Add 1.0 if the mean spacing of the relevant joint set is greater than 3.0 m
(ii) J_r = 0.5 can be used for planar slickenslide joints having lineations, provided the lineations are orientated for minimum strength

4 Joint Alteration number		φ_r approx	J_a
(a) Rockwall contact (no mineral fillings, coatings only)			
A	Tightly healed, hard, non-softening, impermeable filling, .ie. quartz	-	0.75
B	Unaltered joint walls, surface staining only	25–35	1.0
C	Slighly altered joint walls, non-softening mineral coatings, sandy particles, clay-free disintegrated rock	25–35	2.0
D	Silty or sandy-clay coatings, small clay fraction (non-softening)	20–25	3.0
E	Softening or low friction clay mineral coatings, kaolinite or mica, chlorite, talc, gypsum, graphite, small quantities of swelling clays	8–16	4.0
(b) Rockwall contact before 10 cm shear (thin mineral fillings)			
F	Sandy particles, clay free disintegrated rock	25–30	4.0
G	Strongly over-consolidated non-softening clay mineral fillings (continuous but <5 mm thickness)	16–24	6.0
H	Medium or low over-consolidated softening clay mineral fillings (continuous but <5 mm thickness)	12–16	8.0
J	Swelling clay fillings i.e. montmorillonite (continuous but <5 mm thickness). J_a value depends on % of swelling clay-sized particles and access to water	6–12	8–12
(c) No rockwall contact when sheared (thick mineral fillings)			
K L M	Zones or bands of disintegrated or crushed rock and clay (see G, H, J, for description of clay condition)	6–24	6,8 or 8–12
N	Zones or bands of silty or sandy-clay, small clay fraction (non-softening)	-	5.0
O P R	Thick, continuous zones or bands of clay (see G, H, J, for description of clay condition)	6–24	10, 13 or 13–20

5 Joint water reduction factor		Water pressure (kg/cm³)	J_w
A	Dry excavation or minor flow < 5 l/min locally	<1	1.0
B	Medium inflow or pressure occasional outwash of joint fillings	1–2.5	0.66
C	Large inflow or high pressure in competent rock with unfilled joints	2.5–10	0.5
D	Large inflow or high pressure considerable outwash of joint fillings	2.5–10	0.33
E	Exceptionally high inflow or water pressure at blasting, decaying with time	>10	0.2–0.1
F	Exceptionally high inflow or water pressure continuing without noticeable decay	>10	0.1–0.05

Note: (i) Factors C to F are crude estimates. Increase J_w if drainage measures are installed.
(ii) Special problems caused by ice formations are not considered

6 Stress reduction factor		SRF
(a) Weakness zones intersecting excavation which may cause loosening of rock mass when tunnel is excavated		
A	Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth)	10
B	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation ≤ 50 m)	5
C	Single weakness zones containing clay or disintegrated rock (depth of excavation > 50 m)	2.5
D	Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth)	7.5
E	Single shear zones in competent rock (clay-free) (depth of excavation ≤ 50 m)	5.0
F	Single shear zones in competent rock (clay-free) (depth of excavation > 50 m)	2.5
G	Loose, open joints, heavily jointed or 'sugar cube', etc. (any depth)	5.0

Note: (i) Reduce these values of SRF by 25–50% if the relevant shear zones only influence but do not intersect the excavation

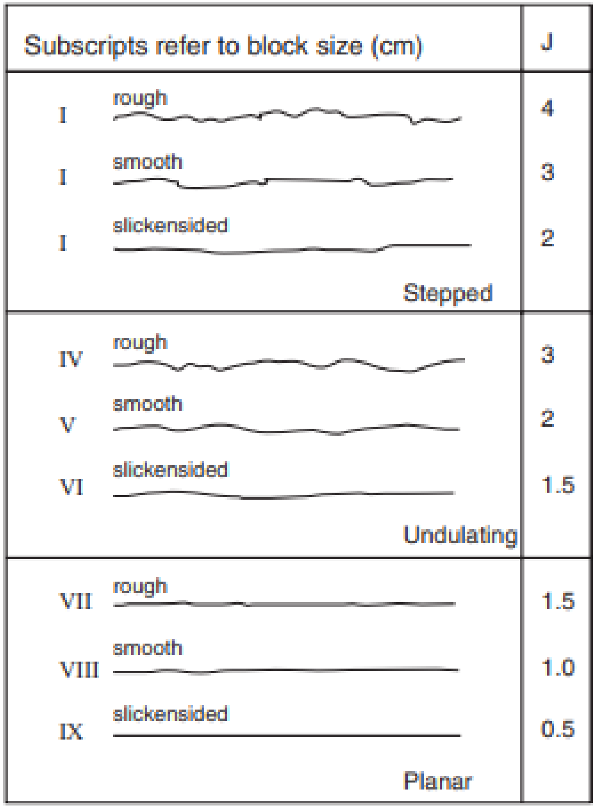
(b)	Component rock, rock stress problems	σ_c/σ_1	σ_θ/σ_c	SRF
H	Low stress, near surface, open joints	>200	<0.01	2.5
J	Medium stress, favourable stress conditions	200–10	0.01–0.3	1
K	High stress, very tight structure. Usually favourable to stability, may be unfavourable to wall stability	10–5	0.3–0.4	0.5–2
L	Moderate slabbing after > 1 hour in massive rock	5–3	0.5–0.65	5–50
M	Slabbing and rock burst after a few minutes in massive rock	3–2	0.65–1	50–200
N	Heavy rock burst (strainburst and immediate dynamic deformations in massive rock	<2	>1	200–400

Note: (i) For strongly anisotropic virgin stress field (measured): when 5 ≤ σ_1/σ_3 ≤ 10, reduce σ_c to 0.75 σ_c. When σ_1/σ_3 > 10, reduce σ_c to 0.5 σ_c, where σ_c = unconfined compression strength, σ_1 and σ_3 are the major and minor principal stresses, and σ_θ = maximum tangential stress (estimated from elastic theory).
(ii) Few case records available where depth of crown below surface is less than span width. Suggest SRF increase from 2.5 to 5 for such cases (see H)

(c)	Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure	σ_θ/σ_c	SRF
O	Mild squeezing rock pressure	1–5	5–10
P	Heavy squeezing rock pressure	>5	10–20

Note: (iv) Cases of squeezing rock may occur for depth $H > 350\, Q^{1/3}$ (Singh et al., *1992). Rock mass compression strength can be estimated from $q = 7\,\gamma Q^{1/3}$ (MPa) where γ = rock density in gm/cc (Singh, 1993)*

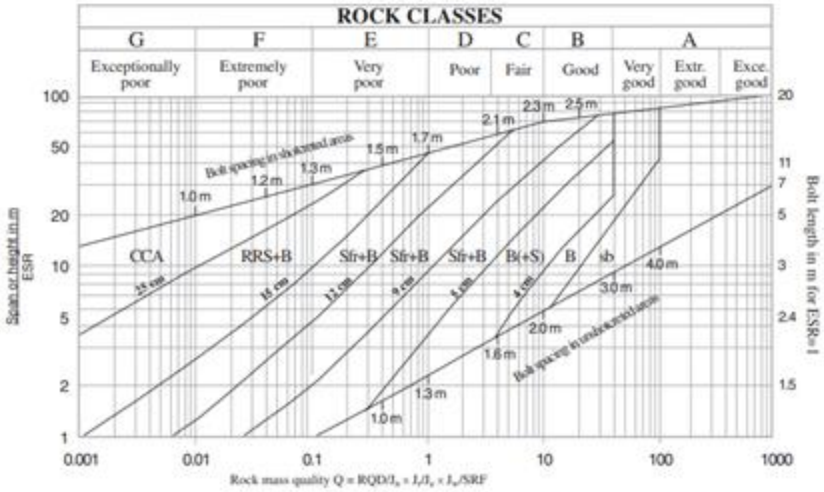
(d)	Swelling rock: chemical swelling activity depending on presence of water	SRF
R	Mild swelling rock pressure	5–10
S	Heavy swelling rock pressure	10–15



Example of joint roughness, J_r

Summary of recommended *ESR* values for selecting safety level

Type of excavation		*ESR*
A	Temporary mine openings, etc.	2–5
B	Permanent mine openings, water tunnels for hydropower (exclude high pressure penstocks), pilot tunnels, drifts and headings for large openings, surge chambers	1.6–2.0
C	Storage caverns, water treatment plants, minor road and railway tunnels, access tunnels	1.2–1.3
D	Power stations, major road and railway tunnels, civil defence chambers, portals, intersections	0.9–1.1
E	Underground nuclear power stations, railway stations, sports and public facilities, factories, major gas pipeline tunnels	0.5–0.8



Support system and *Q*-rating. The abbreviations in the Figure have the following meanings: *CCA* = cast concrete lining, *RRS* = reinforced ribs of shotcrete, *B* = bolts, *Sfr* = fibre-reinforced shotcrete, *sb* = spot bolts and *S* = un-reinforced shotcrete