NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

DEPARTMENT OF CIVL, MINING AND PROCESS ENGINEERING

QUALIFICATION : BACHELORS OF ENGINEERING IN MINING ENGINEERING	
QUALIFICATION CODE: 08BMEG	LEVEL: 7
COURSE CODE: RMC711S	COURSE NAME: ROCK MECHANICS
SESSION: JUNE 2023	PAPER: THEORY
DURATION: 2.5 HOURS	MARKS: 80

SECOND OPPORTUNITY QUESTION PAPER	
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INSTRUCTIONS

1. Answer all questions.
2. Read all the questions carefully before answering.
3. Marks for each question are indicated at the end of each question.
4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.
2. Tracing Papers
3. Mathematical Instruments

THIS QUESTION PAPER CONSISTS OF 6 PAGES (Including this front page)

Instructions: Answer all questions.

Time allowed: 2.5 hours

Question 1 State of stress at a point in undergound is given below. Estimate the principal stresses and their directions. (20)

σ_{xx}	20.5MPa	σ_{xy}	-2.4 MPa
σ_{yy}	34.8 MPa	σ_{yz}	-8.0 MPa
σ_{zz}	8.1 MPa	σ_{zx}	5.2 MPa

a) Draw stress diagram (free body diagram) and indicate the stresses on it [5]

b) If the minor principal stress is 4.45 MPa, determine minor principal stress direction with respect to X, Y and Z axis. [15]

Question 2

a) Briefly discuss the need for rockmass classification system (6)

b) A 15 m span crusher for an underground mine is to be excavated in a granitic rock at a depth of 1500 m below the surface. The rockmass contains two sets of joints. These joints are undulating, rough and unweathered with very minor surface staining. RQD values range from 85% to 95% and laboratory test on core samples of intact rock give an average uniaxial compressive strength of 200 MPa. The principal stress directions are approximately vertical and horizontal, and the magnitude of horizontal principal stress is approximately 1.5 times that of the vertical principal stress. The rockmass is locally damp but there is no evidence of flowing water. Discuss the support requirements of the above excavation. Average unit weight of the rockmass is 26 kN/m^3. (14)

Question 3

a) What parameters are used to characterise fractures/joints in a rockmass? (10)

b) Two lines of having dip direction/dip 140/60 and 235/30 are known to lie in the same plane. Determine (15)

i. The dip direction and dip of the common plane [10]

ii. Internal angle between the two lines [5]

Question 4

a) Compare the soft and stiff testing machine and their influence on the post peak stress-strain curve with an example. (10)

b) Briefly describe in-situ stress measurement using the Flactjack method with the help of figures. (10)

ADDITIONAL INFORMATION

RMC711S June/July Exam

Angle stress marking with x, y, and z axis

$$A = \begin{vmatrix} \sigma_{yy} - \sigma_1 & \sigma_{yz} \\ \sigma_{yz} & \sigma_{zz} - \sigma_1 \end{vmatrix}$$

$$B = -\begin{vmatrix} \sigma_{xy} & \sigma_{yz} \\ \sigma_{zx} & \sigma_{zz} - \sigma_1 \end{vmatrix}$$

$$C = \begin{vmatrix} \sigma_{xy} & \sigma_{yy} - \sigma_1 \\ \sigma_{zx} & \sigma_{yz} \end{vmatrix}$$

Short on the Q-system

The *Q-system* for rock mass classification, developed at the Norwegian Geotechnical Institute (NGI) in 1974, originally included a little more than 200 tunnel case histories, mainly from Scandinavia (Barton et al., 1974). In 1993 the system was updated to include more than 1000 cases (Grimstad and Barton, 1993). It is a quantitative classification system for estimates of tunnel support, based on a numerical assessment of the rock mass quality using the following six parameters:

- Rock quality designation (RQD).
- Number of joint sets (J_n).
- Roughness of the most unfavourable joint or discontinuity (J_r).
- Degree of alteration or filling along the weakest joint (J_a).
- Water inflow (J_w).
- Stress condition given as the stress reduction factor (SRF); composed of
  - Loosening load in the case of shear zones and clay bearing rock,
  - Rock stress in competent rock, and
  - Squeezing and swelling loads in plastic, incompetent rock.

The above six parameters are grouped into three quotients to give the overall rock mass quality:

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

- The first two parameters represent the overall structure of the rock mass, and their quotient is a relative measure of the block size.
- The second quotient is described as an indicator of the inter-block shear strength.
- The third quotient is described as the "active stresses".

The ratings of the various input parameters to the Q-value are given in Table 1.

The Q-value is related to tunnel support requirement by defining the equivalent dimensions of the underground opening. This equivalent dimension, which is a function of the size and type of the excavation, is obtained by dividing the span, diameter or wall height of the excavation (Dt) by a quantity called the *excavation support ratio (ESR)*, given as:

$$De = \frac{Dt}{ESR}$$

Ratings of ESR are shown in Table 2

The Q-value in Figure 1 is related to the total amount of support (temporary and permanent) in the roof. The diagram is based on numerous tunnel support cases. Wall support can also be found using the same figure by applying the wall height and the following adjustments to Q:

For $Q > 10$ use $Q_{wall} = 5Q$
For $0.1 < Q < 10$ use $Q_{wall} = 2.5Q$
For $Q < 0.1$ use $Q_{wall} = Q$

Table 1. Description and ratings for the input parameters of the Q-system (simplified from Grimstad and Barton, 1993).

***RQD** (Rock Quality Designation)*

Very poor	RQD = 0 - 25%
Poor	25 - 50
Fair	50 - 75
Good	75 - 90
Excellent	90 - 100

Notes:

(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, etc. are sufficiently accurate

***Jn** (joint set number)*

Massive, no or few joints	Jn = 0.5 - 1
One joint set	2
One joint set plus random joints	3
Two joint sets	4
Two joint sets plus random joints	6
Three joint sets	9
Three joint sets plus random joints	12
Four or more joint sets, heavily jointed, "sugar-cube", etc.	15
Crushed rock, earthlike	20

***Notes:** (i) For tunnel intersections, use (3.0 x Jn); (ii) For portals, use (2.0 x Jn)*

***Jr** (joint roughness number)*

a) Rock-wall contact, b) rock-wall contact before 10 cm shear	
Discontinuous joints	Jr = 4
Rough or irregular, undulating	3
Smooth, undulating	2
Slickensided, undulating	1.5
Rough or irregular, planar	1.5
Smooth, planar	1.0
Slickensided, planar	0.5

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

c) No rock-wall contact when sheared	
Zone containing clay minerals thick enough to prevent rock-wall contact	Jr = 1.0
Sandy, gravelly or crushed zone thick enough to prevent rock-wall contact	1.0

Notes:

i) Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m

ii) Jr = 0.5 can be used for planar, slickensided joints having lineations, provided the lineations are oriented for minimum strength

***Ja** (joint alteration number)*

	JOINT WALL CHARACTER		Condition	*Wall contact*
Contact between joint walls	CLEAN JOINTS	Healed or welded joints:	filling of quartz, epidote, etc.	Ja = 0.75
		Fresh joint walls:	no coating or filling, except from staining (rust)	1
		Slightly altered joint walls:	non-softening mineral coatings, clay-free particles, etc.	2
	COATING OR THIN FILLING	Friction materials:	sand, silt, calcite, etc. (non-softening)	3
		Cohesive materials:	clay, chlorite, talc, etc. (softening)	4

	FILLING OF:	Type	*Some wall contact* *Thin filling (< 5 mm)*	*No wall contact* *Thick filling*
Some or no wall contact	Friction materials	sand, silt calcite, etc. (non-softening)	Ja = 4	Ja = 8
	Hard cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	5 - 10
	Soft cohesive materials	medium to low overconsolidated clay, chlorite, talc,	8	12
	Swelling clay materials	filling material exhibits swelling properties	8 - 12	13 - 20

***Jw** (joint water reduction factor)*

Dry excavations or minor inflow, i.e. < 5 l/min locally	p_w < 1 kg/cm^2	Jw = 1
Medium inflow or pressure, occasional outwash of joint fillings	1 - 2.5	0.66
Large inflow or high pressure in competent rock with unfilled joints	2.5 - 10	0.5
Large inflow or high pressure, considerable outwash of joint fillings	2.5 - 10	0.3
Exceptionally high inflow or water pressure at blasting, decaying with time	> 10	0.2 - 0.1
Exceptionally high inflow or water pressure continuing without noticeable decay	> 10	0.1 - 0.05

***Note:** (i) The last four factors are crude estimates. Increase Jw if drainage measures are installed*
(ii) Special problems caused by ice formation are not considered

***SRF** (Stress Reduction Factor)*

Weakness zones intersecting excavation	Multiple weakness zones with clay or chemically disintegrated rock, very loose surrounding rock (any depth)	SRF = 10
	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation < 50 m)	5
	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation > 50 m)	2.5
	Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth)	7.5
	Single shear zones in competent rock (clay-free), loose surrounding rock (depth of excavation < 50 m)	5
	Single shear zones in competent rock (clay-free), loose surrounding rock (depth of excavation > 50 m)	2.5
	Loose, open joints, heavily jointed or "sugar-cube", etc. (any depth)	5

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

		σ_c / σ_1	σ_θ / σ_c	SRF
Competent rock, rock stress problems	Low stress, near surface, open joints	> 200	< 0.01	2.5
	Medium stress, favourable stress condition	200 - 10	0.01 - 0.3	1
	High stress, very tight structure. Usually favourable to stability, may be except for walls	10 - 5	0.3 - 0.4	0.5 - 2
	Moderate slabbing after > 1 hour in massive rock	5 - 3	0.5 - 0.65	5 - 50
	Slabbing and rock burst after a few minutes in massive rock	3 - 2	0.65 - 1	50 - 200
	Heavy rock burst (strain burst) and immediate dynamic deformation in massive rock	< 2	> 1	200 - 400

***Notes:** (ii) For strongly anisotropic stress field (if measured): when 5 < σ_1/σ_3 <10, reduce σ_c to 0.75 σ_c. When $\sigma 1/\sigma 3$ > 10, reduce σ_c to 0.5σ_c*

(iii) Few case records available where depth of crown below surface is less than span width. Suggest SRF increase from 2.5 to 5 for low stress cases

			σ_θ / σ_c	SRF
Squeezing rock	*Plastic flow of incompetent rock under the influence of high pressure*	Mild squeezing rock pressure	1 - 5	5 - 10
		Heavy squeezing rock pressure	> 5	10 - 20
Swelling rock	*Chemical swelling activity depending on presence of water*	Mild swelling rock pressure		5 - 10
		Heavy swelling rock pressure		10 - 15

Table 2 Ratings of the excavation support ratio (ESR) (from Barton et. al., 1974).

Type or use of underground opening	ESR
Temporary mine openings	3.5
Vertical shafts, rectangular and circular respectively	2.0 - 2.5
Water tunnels, permanent mine openings, adits, drifts	1.6
Storage caverns, road tunnels with little traffic, access tunnels, etc.	1.3
Power stations, road and railway tunnels with heavy traffic, civil defence shelters, etc.	1.0
Nuclear power plants, railroad stations, sport arenas, etc.	0.8

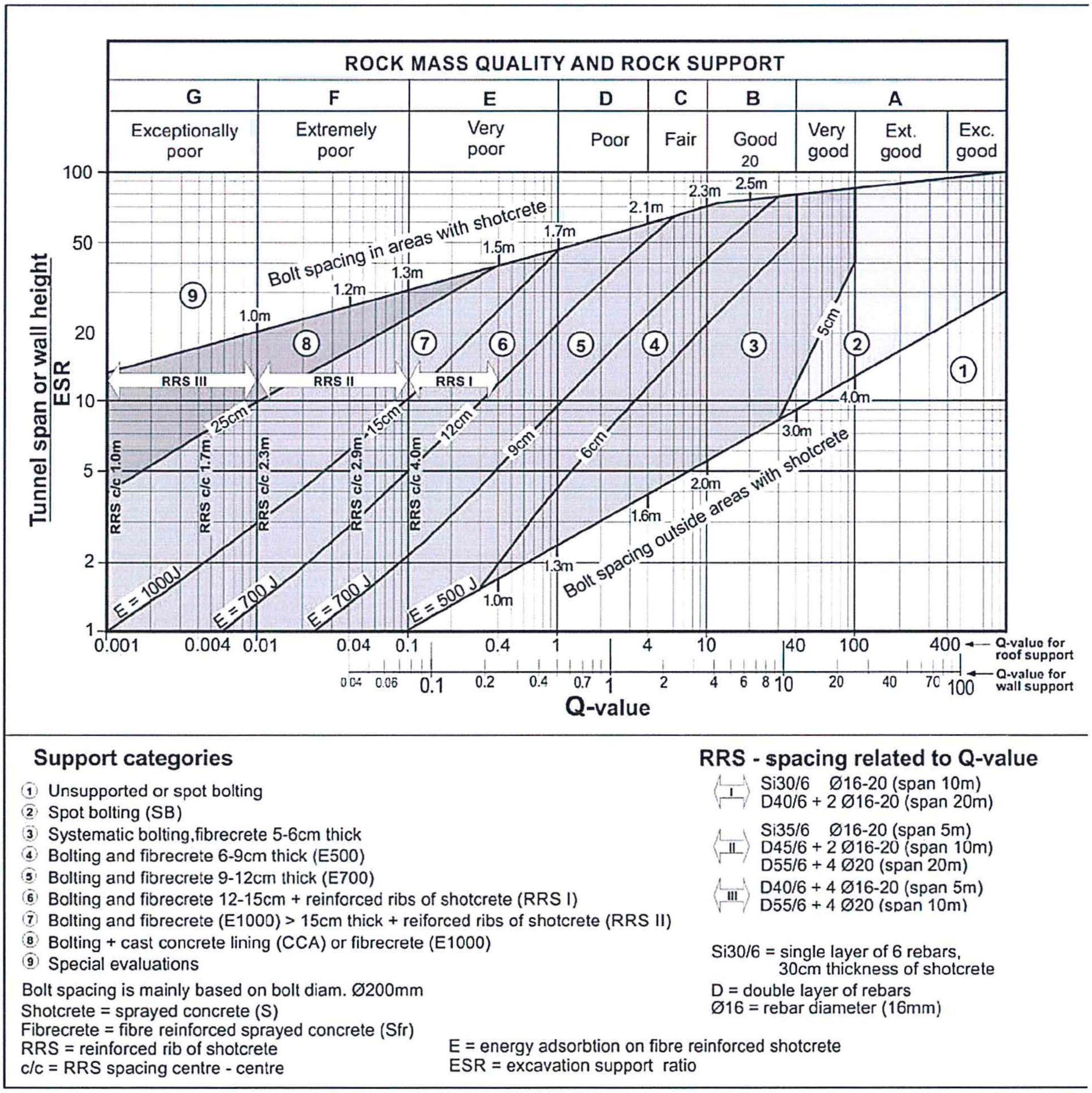

Figure 1 The Q system chart for rock support estimate, developed by the Norwegian Geotechnical Institute (NGI), (based on www.ngi.no, 2014). The Qwall values have been introduced in the chart

Equal Area Net
(Schmidt Net)