Rock Mass Rating System

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

Parameter			Ranges of values						
1	Strength of intact rock material	Point-load strength index (MPa)	>10	4 - 10	2 - 4	1 - 2	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength (MPa)	>250	100 - 250	50 - 100	25 - 50	5 - 25	1 - 5	<1
		Rating	15	12	7	4	2	1	0
2	Drill core quality RQD (%)		90 - 100	75 - 90	50 - 75	25 - 50	<25		
		Rating	20	17	13	8	3		
3	Spacing of discontinuities		>2m	0.6 - 2m	200 - 600mm	60 - 200mm	<60mm		
		Rating	20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation <1mm Slightly weathered wall rock	Slightly rough surfaces Separation <1mm Highly weathered wall rock	Slickensided surfaces or Gouge <5mm thick or Separation 1 - 5mm Continuous	Soft gouge >5mm thick or Separation >5mm Continuous		
		Rating	30	25	20	10	0		
5	Groundwater	Inflow per 10m tunnel length (l/min)	None	<10	10 - 25	25 - 125	>125		
		ratio (joint water pressure)/(major principal stress)	0	<0.1	0.1 - 0.2	0.2 - 0.5	>0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
		Rating	15	10	7	4	0		

B. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS

Parameter	Ratings				
Discontinuity length (persistence)	<1m	1 - 3m	3 - 10m	10 - 20m	>20m
	6	4	2	1	0
Separation (aperture)	None	<0.1mm	0.1 - 1.0mm	1 - 5mm	>5mm
	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
	6	5	3	1	0
Infilling (gouge)	Hard filling			Soft filling	
	None	<5mm	>5mm	<5mm	>5mm
	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
	6	5	3	1	0

C. EFFECT OF DISCONTINUITY ORIENTATIONS IN TUNNELLING

Strike perpendicular to tunnel axis			
Drive with dip		Drive against dip	
Dip 45 - 90	Dip 20 - 45	Dip 45 - 90	Dip 20 - 45
Very favourable	Favourable	Fair	Unfavourable

Strike parallel to tunnel axis		Irrespective of strike
Dip 20 - 45	Dip 45 - 90	Dip 0 - 20
Fair	Very unfavourable	Fair

D. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS

Orientations of Discontinuities		Very Favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

E. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 - 81	80 - 61	60 - 41	40 - 21	<20
Class no.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

F. MEANING OF ROCK MASS CLASSES

Class no.	I	II	III	IV	V
Average stand-up time	20yr for 15m span	1yr for 10m span	1wk for 5m span	10h for 2.5m span	30min for 1m span
Cohesion of rock mass (kPa)	>400	300 - 400	200 - 300	100 - 200	<100
Friction angle of rock mass (deg)	>45	35 - 45	25 - 35	15 - 25	<15

RMR = ∑(classification parameters) + discontinuity orientation adjustment

Q-system of Rock Mass Classification

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

Joint Alteration Number, J_a	*(iii) No rock wall contact when sheared*		
	k: Zones or bands of disintegrated or rock and clay (see g:, h:, j: for description of clay condition)	6.0, 8.0 or 8.0-12.0	6°-24°
	l: Zones or bands of silty clay, small clay fraction (nonsoftening)	5.0	
	m: Thick, continuous zones or bands of clay (see g:, h:, j: for description of clay condition)	10.0, 13.0 or 13.0-20.0	

		SRF			
Stress Reduction Factor, SRF	*(i) Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated*		*Reduce these SRF values by 25-50% if the relevant shear zones only influence but do not intersect the excavation*		
	a: Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth)	10.0			
	b: Single weakness zones containing clay or chemically disintegrated rock (excavation depth <50 m)	5.0			
	c: Single weakness zones containing clay or chemically disintegrated rock (excavation depth >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			
			σ_c/σ_1	σ_t/σ_1	
	(ii) Competent rock, rock stress problems				
	h: Low stress, near surface	2.5	>200	>13	*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*
	j: Medium stress	1.0	200-10	13-0.66	
	k: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability)	0.5-2.0	10-5	0.66-0.33	
	l: Mild rock burst (massive rock)	5-10	5-2.5	0.33-0.16	
	m: Heavy rock burst (massive rock)	10-20	<2.5	<0.16	
	(iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressures		*For strongly anisotropic stress field (if measured): when $5 \le \sigma_1/\sigma_3 \le 10$, reduce σ_c and σ_t to $0.8\sigma_c$ and $0.8\sigma_t$; when $\sigma_1/\sigma_3 > 10$, reduce σ_c and σ_t to $0.6\sigma_c$ and $0.6\sigma_t$ (where σ_c = unconfined compressive strength, σ_t = tensile strength (point load), σ_1 and σ_3 = major and minor principal stresses)*		
	n: Mild squeezing rock pressure	5-10			
	p: Heavy squeezing rock pressure	10-20			
	(iv) Swelling rock; chemical swelling activity depending on presence of water				
	q: Mild swelling rock pressure	5-10			
	r: Heavy swelling rock pressure	10-15			

		J_w	Approx. water pressure (kg/cm²)	
Joint Water Reduction Factor, J_w	a: Dry excavations or minor inflow, e.g. 5 l/min locally	1.0	<1	
	b: Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0-2.5	
	c: Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5-10.0	*Factors c to f are crude estimates. Increase J_w if drainage measures are installed*
	d: Large inflow or high pressure, considerable outwash of joint fillings	0.33	2.5-10.0	
	e: Exceptionally high inflow or water pressure at blasting, decaying with time	0.2-0.1	>10.0	*Special problems caused by ice formation are not considered*
	f: Exceptionally high inflow or water pressure continuing without noticeable decay	0.1-0.05	>10.0	

joint set or clay filled discontinuity in a given zone, but the value of J_r/J_a should relate to the surface most likely to allow failure to initiate. Thus, if the joint set or discontinuity with the minimum value of J_r/J_a is favourably orientated for stability, then a second, less favourably orientated joint set or discontinuity may sometimes be more significant, and its higher value of J_r/J_a should be used when evaluating Q.

4. When a rock mass contains clay, the factor *SRF* appropriate to 'loosening loads' should be evaluated. In such cases the strength of the intact rock is of little interest. However, when jointing is minimal and clay is completely absent, the strength of the intact rock may become the weakest link, and the stability will then depend on the ratio rock-stress/rock-strength. A strongly anisotropic stress field is unfavourable for stability and is roughly accounted for as in the note in the table for *SRF* evaluation.
5. The compressive and tensile strengths (σ_c and σ_t) of the intact rock should be evaluated in the saturated condition if this is appropriate to present or future *in situ* conditions. A conservative estimate of strength should be made for those rocks that deteriorate when exposed to moist or saturated conditions.

Q-system of Rock Mass Classification

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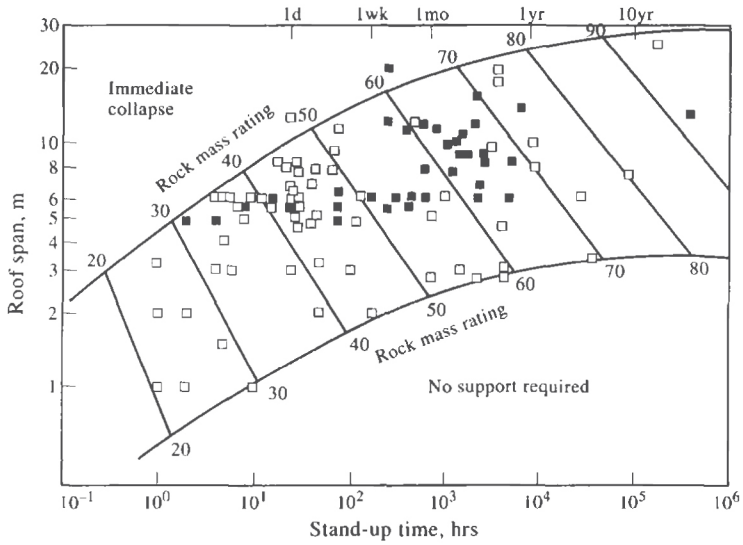
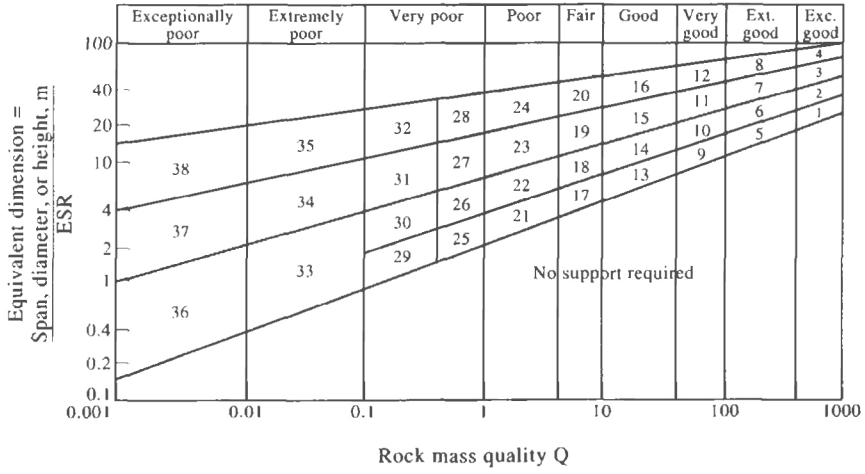
Applications of rock mass classification systems



Excavation stand-up time for the RMR system.



Support requirements for the *Q*-system (for fuller details see Bieniawski, 1989).