	Param	cter	Ranges of values							
	Point-load strength index >10 4-10 2-4		I - 2 uniaxial		this low range, tial compressive st is preferred					
1	intact rock material	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 ROD		90 - 100	75 - 90	50 - 75	25 - 50		4 25		
_	(%)	Rating	20	17	13	8	3			
	Spacing of		>2m	0.6 - 2m	200 - 600mm	60 - 200mm	<60mm			
3	discontinuities	Rating	20	15	10	8		5		
4	Condition of discontinuities		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered wall rock	Slightly rough surfaces Separation < 1mm Highly weathered wall rock	Slickensided surfaces or Gouge <5mm thick or Separation 1 - 5mm Continuous	Sepa	gouge > thick or ration >	-5mm	
		Rating	30	25	20	10		0		
		Inflow per 10m tunnel length (l/min)	None	<10	10 - 25	25 - 125		>125		
5	Groundwater	ratio (joint water pressure)/(major principal stress)	0	<0.1	0.1 - 0.2	0.2 - 0.5	>0.5 Flowing			
		General conditions	Completely dry	Damp	Wet	Dripping			3	
		Rating	15	10	7	4	0			
В. (GUIDELINES FO	OR CLASSIFICAT	ION OF DISCONT	INUITY CONDITIO	NS					
	Param	octer			Ratings					
	Discontinuity leng	ath (nertistence)	<lm< td=""><td>1 - 3m</td><td>3 - 10m</td><td>10 - 20m</td><td></td><td>>20m</td><td></td></lm<>	1 - 3m	3 - 10m	10 - 20m		>20m		
_	Discontinuity leaf	gui (persistence)	6	4	2	1		0		
	Separation	(anerture)	None	<0.1mm	0.1 - 1.0mm	1 - 5mm		>5mm		
	Soperation	(aperture)	6	5	4	1		0		
Roughness		Very rough	Rough	Slightly rough Smooth		Slickensided		led		
	Konku	iness	6	5	3	1		0		
Infilling (gouge)		Hard filling			Soft filling					
		None	≺mm	>5mm	<5mm	>5mm				
		6	4	2	2	0				
Weathering			Unweathered	Slightly weathered	Moderately weathered	Highly weathered	De	compo	ied	
· · · · · · · · · · · · · · · · · · ·		6	5	3	ı	0				

C.EFFECT OF DISCONTINUITY ORIENTATIONS IN TUNNELLING

	Strike perpendicul	er to tunnel axis			
Drive	with dip	Drive against dip			
Dip 45 - 90	Dip 20 - 45	Dip 45 - 90	Dip 20 - 45		
Very favourable	Favourable	Pair	Unfavourable		
Strike paralle	l to tunnel axis	Irrespecti	ve of strike		
Dip 20 - 45	Dip 45 - 90	Dip	0 - 20		
Fair	Very unfavourable		air		

D. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS

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

E. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Description	Very good rock	Good rock	Pair rock	Poor rock	Very poor rock	
Class no.	I	п	ш	IV	٧	
Rating	100 - 81	80 - 61	60 - 41	40 - 21	<20	

F. MEANING OF ROCK MASS CLASSES

Class no.	I	14	1111	IV	٧
Average stand-up time	20yr for 15m span	lyr for 10m span	lwk 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 mck mass (deg)	>45	35-45	25 - 35	15 - 25	<15

Q-system of **Rock Mass Classification**

Joint Alteration Number, Ja	(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) l: Zones or bands of silty clay, small clay fraction (nonsoftening) m: Thick, continuous zones or bands of clay (see g., h., j: for description of clay condition)	6.0, 8.0 or 8.0-12.0 5.0 10.0, 13.0 or 13.0-20.0	6*-24*
Stress Reduction Factor, SRF	(i) 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) b: Single weakness zones containing clay or chemically disintegrated rock (excavation depth <50 m) c: Single weakness zones containing clay or chemically disintegrated rock (excavation depth <50 m) d: Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth) c: Single shear zones in competent rock (clay-free) (depth of excavation <50 m) f: Single shear zones in competent rock (clay-free) (depth of excavation <50 m) g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) (ii) Competent rock, rock stress problems h: Low stress, near surface j: Medium stress h: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability) m: Heavy rock burst (massive rock) (iii) Souezing rock; plastic flow of incompetent rock under	10.0 5.0 2.5 7.5 5.0 2.5 5.0 2.5 1.0 0.5-2.0 5-10	Reduce these SRF values by 25-50% if the relevant shear zones only influence but do not intersect the excavation a d/a a/a 200 13 Few case records available 200 13 where depth of crown below surface is less than span 10-5 0.66-0.33 width. Suggest SRF 5-2.5 0.33-0.16 such cases 4.5 0.16 such cases For strongly anisotropic stress field (if measured):
	(in) squeezing rock; pastic flow of incompetent rock under the influence of high rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on presence of water q: Mild swelling rock pressure : Heavy swelling rock pressure	5-10 10-20 5-10 10-15	when 55G fa ≤10, reduce σ and σ to 0.8σ, and 0.8σ; when σ fa > 10, reduce σ and σ to 0.6σ and 0.6σ, when σ fa = unconfined compressive strength, σ = tensile strength (point load), σ and σ = major and minor principal stresses)
			<u> </u>
Joint Water Reduction Factor,	a: Dry excavations or minor inflow, e.g. 5 l/min locally b: Medium inflow or pressure, occasional outwash of	J_ 1.0	Approx. water pressure (kg/cm²)
	joint fillings c: Large inflow or high pressure in competent rock with unfilled joints	0.66	1.0-2.5
[j		0.5	2.5-10.0 Factors of a fars and actimates
_ \$ -,	d: Large inflow or high pressure, considerable outwash of		Increase I if drainage measures
1 2	joint fillings	0.33	2.5-10.0 are installed
Yat	e: Exceptionally high inflow or water pressure at blasting, decaying with time	0.2-0.1	>10.0 Special problems caused by ice
2	f: Exceptionally high inflow or water pressure continuing	1	formation are not considered
Join	without noticeable decay	0.1-0.05	>10.0

joint set or clay filled discontinuity in a given zone, 4. When a rock mass contains clay, the factor SRF stability and is roughly accounted for as in the note in but the value of J/J_c abould relate to the surface most likely to allow failure to initiate. Thus, if the joint set less the strength of the interact rock is of little 5. The compressive and tensile strengths (σ_a and σ_c) of

hickly to allow failure to initiate. Thus, if the jours set or discontinuity with the ministrant value of JJ J is terminally orientated for stability, then a second, less favourably orientated for stability, then a second, less favourably orientated foint set or discontinuity may sometimes be more significant, and its higher walter of JJ J a should be used when evaluating Q. The second cases the strength of the intact rock to of tube?

In successive more strengths (q, and q) or to completely absent, the strength of the intact rock about the state crock should be evaluated to be evaluated to the strength of the intact rock and condition. A conservative estimate of strength and the stability will state to case the strength of the intact rock and condition. A conservative estimate of strength and the stability will state to case the strength of the intact rock and its strength of the intact rock and the strength of the intact rock and its strength of the

RMR = \(\sum_{\text{classification parameters}}\) + discontinuity orientation adjustment

Q-system of Rock Mass Classification

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

(iii) No rock wall consact when sheared k: Zones or bands of distintegrated or rock and clay (see g.; h.; j. for description of clay condition) 12	10004 1720	iss classification	SRF	
Single weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth) 5.0	Joint Alteration Number, Ja	k: Zones or bands of disintegrated or rock and clay (see g:, h:, j: for description of clay condition) 1: Zones or bands of silty clay, small clay fraction (nonsoftening) m: Thick, continuous zones or bands of clay (see g:, h:, j: for	5.0 10.0, 13.0 or	6°-24°
Single weakness zones containing clay or chemically disintegrated rock, (excavation depth <50 m) 10.0			SRF	Reduce these SRF values by 25-50% if the relevant
b: Single weakness zones containing clay or chemically disintegrated rock (excavation depth <50 m) c: Single weakness zones containing clay or chemically disintegrated rock (excavation depth >50 m) d: Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth) c: Single shear zones in competent rock (clay-free) (depth of excavation >50 m) g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) (ii) Competent rock, rock stress problems h: Low stress, near surface j: Medium stress k: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability) l: Mild rock burst (massive rock) (iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure n: Mild squeezing rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on pressence of water q: Mild swelling rock pressure mild swelling rock pressure q: Mild swelling rock pressure q: Mild swelling rock pressure mild swe		loosening of rock mass when tunnel is excavated a: Multiple occurrences of weakness zones containing clay		shear zones only influence but do not intersect the
c: Single weakness zones containing clay or chemically disintegrated rock (excavation depth >50 m) d: Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth) e: Single shear zones in competent rock (clay-free) (depth of excavation >50 m) f: Single shear zones in competent rock (clay-free) (depth of excavation >50 m) g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) f: Low stress, hear surface j: Medium stress k: High-stress, very light structure (usually favourable to stability, may be unfavourable for wall stability) l: Mild rock burst (massive rock) (iii) Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on pressence of water g: Mild swelling rock pressure mild swelling rock pres		b: Single weakness zones containing clay or chemically		
disintegrated rock (excavation depth > 50 m) d: Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth) e: Single shear zones in competent rock (clay-free) (depth of excavation > 50 m) g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) (ii) Competent rock, rock stress problems h: Low stress, near surface j: Medium stress h: Low stress, near surface j: Medium stress h: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability) l: Mild rock burst (massive rock) (iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure n: Mild squeezing rock pressure p: Heavy squeezing rock pressure q: Mild swelling rock; chemical swelling activity depending on pressence of water q: Mild swelling rock pressure did swelling rock pressure mild			5.0	ļ
surrounding rock (any depth) e: Single shear zones in competent rock (clay-free) (depth of excavation <50 m) f: Single shear zones in competent rock (clay-free) (depth of excavation <50 m) g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) [ii) Competent rock, rock stress problems h: Low stress, near surface j: Medium stress k: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability) l: Mild rock burst (massive rock) [iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure n: Mild squeezing rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on pressence of water q: Mild swelling rock pressure mild swelling rock p		disintegrated rock (excavation depth >50 m)	2.5	
f: Single shear zones in competent rock (clay-free) (depth of excavation >50 m) g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) (ii) Competent rock, rock stress problems h: Low stress, near surface j: Medium stress k: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability) l: Mild rock burst (massive rock) (iii) Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure n: Mild squeezing rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on presence of water q: Mild swelling rock pressure like of the stress in competent rock (clay-free) (depth of exavation >5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 g: Loose open joints, heavily jointed or 'sugar cube', etc. (any depth) 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.		surrounding rock (any depth)	7.5	
stability, may be unfavourable for wall stability) 1: Mild rock burst (massive rock) 1: Mild rock burst (massive rock) (iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure 1: Mild squeezing rock pressure 1: Mild squeezing rock pressure 5-10 (iv) Swelling rock; chemical swelling activity depending on pressence of water 4: Mild swelling rock pressure 5-10 5-2.5 6-2.6	ř.		5.0	
stability, may be unfavourable for wall stability) 1: Mild rock burst (massive rock) 1: Mild rock burst (massive rock) (iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure 1: Mild squeezing rock pressure 1: Mild squeezing rock pressure 5-10 (iv) Swelling rock; chemical swelling activity depending on pressence of water 4: Mild swelling rock pressure 5-10 5-2.5 6-2.6	D C		2.5	
stability, may be unfavourable for wall stability) 1: Mild rock burst (massive rock) 1: Mild rock burst (massive rock) (iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure 1: Mild squeezing rock pressure 1: Mild squeezing rock pressure 5-10 (iv) Swelling rock; chemical swelling activity depending on pressence of water 4: Mild swelling rock pressure 5-10 5-2.5 6-2.6	1 1		2.0	
stability, may be unfavourable for wall stability) 1: Mild rock burst (massive rock) 1: Mild rock burst (massive rock) (iii) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressure 1: Mild squeezing rock pressure 1: Mild squeezing rock pressure 5-10 (iv) Swelling rock; chemical swelling activity depending on pressence of water 4: Mild swelling rock pressure 5-10 5-2.5 6-2.6	8 5	(any depth)	5.0	
the influence of high rock pressures n: Mild squeezing rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on presence of water q: Mild swelling rock pressure iii Mild swelling rock pressure iii Mild swelling rock pressure iii Mild swelling rock pressure ivi Mild swelling rock pressure iii Mild swelling rock pressure	Stress Redu	h: Low stress, near surface j: Medium stress k: High-stress, very tight structure (usually favourable to stability, may be unfavourable for wall stability) l: Mild rock burst (massive rock)	1.0 0.5-2.0 5-10	2000 213 Few case records available where depth of crown below surface Is less than span 10-5 0.66-0.33 increase from 2.5 to 5 for 5-2.5 0.33-0.16 metals case case
r: Heavy swelling rock pressure 10-15		the influence of high rock pressures n: Mild squeezing rock pressure p: Heavy squeezing rock pressure (iv) Swelling rock; chemical swelling activity depending on	10-20	when 5≤0/0,≤10, reduce 0, and 0, to 0.80, and 0.80; when 0/0,>10, reduce 0, and 0, to 0.60, and 0.60, (where 0, = unconfined compressive strength, 0, = tensile strength (point load), 0; and
a: Dry excavations or minor inflow, e.g. 5 Vmin locally b: Medium inflow or pressure, occasional outwash of joint fillings c: Large inflow or high pressure in competent rock with unfilled joints d: Large inflow or high pressure, considerable outwash of joint fillings c: Exceptionally high inflow or water pressure at blasting, decaying with time f: Exceptionally high inflow or water pressure continuing without noticeable decay Approx. water pressure (kg/cm²) 1.0 2.5-10.0 Factors c to f are crude estimates. Increase J if drainage measures are installed 0.2-0.1 >10.0 Special problems caused by ice formation are not considered				
Second and the pressure of the second and the sec	actor,		J_ 1.0	
unfilled joints d: Large inflow or high pressure, considerable outwash of joint fillings e: Exceptionally high inflow or water pressure at blasting, decaying with time f: Exceptionally high inflow or water pressure continuing without noticeable decay 0.5. 2.5-10.0 Factors c to f are crude estimates. 1.6. 2	ion F	joint fillings	0.66	1.0-2.5
joint fillings Exceptionally high inflow or water pressure at blasting, decaying with time f: Exceptionally high inflow or water pressure continuing without noticeable decay 0.33 2.5-10.0 are lusticalled are lusticalled 0.2-0.1 >10.0 Special problems caused by ice formation are not considered	educi J.	unfilled joints	0.5	raciors c so j are criace estimates.
Exceptionally high inflow or water pressure at blasting, decaying with time f: Exceptionally high inflow or water pressure continuing without noticeable decay 2	F 2	joint fillings	0.33	
without noticeable decay 0.1-0.05 >10.0 formation are not considered	Wate	blasting, decaying with time	0.2-0.1	Special proviems culties by ice
	Joint		0.1-0.05	>10.0 formation are not considered

less favourably orientated joint set or discontinuity may sometimes be more significant, and its higher value of J/J_{μ} should be used when evaluating Q.

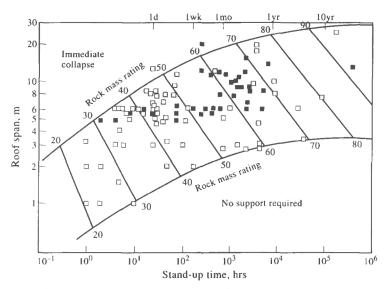
joint set or clay filled discontinuity in a given zone.

4. When a rock mass contains clay, the factor SRF but the value of I/I_s abould relate to the surface most likely to allow failure to inditate. Thus, if the joint set or discontinuity with the minimum value of I/I_s is favourably orientated for stability, then a second, is completely absent, the strength of the latent rock is of little 3 favourably orientated for stability, then a second, In such cases the strength of the intact rock is of little 5. The compressive and tensile strengths (σ_e and σ_e) of 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

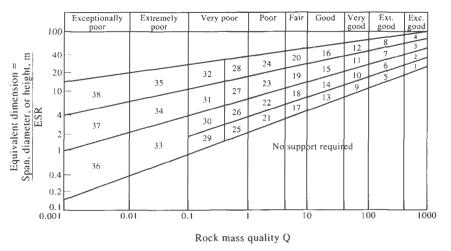
stability and is roughly accounted for as in the note in the table for SRF evaluation.

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

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).