Geomechanics Classification
or
Rock Mass Rating System

RMR

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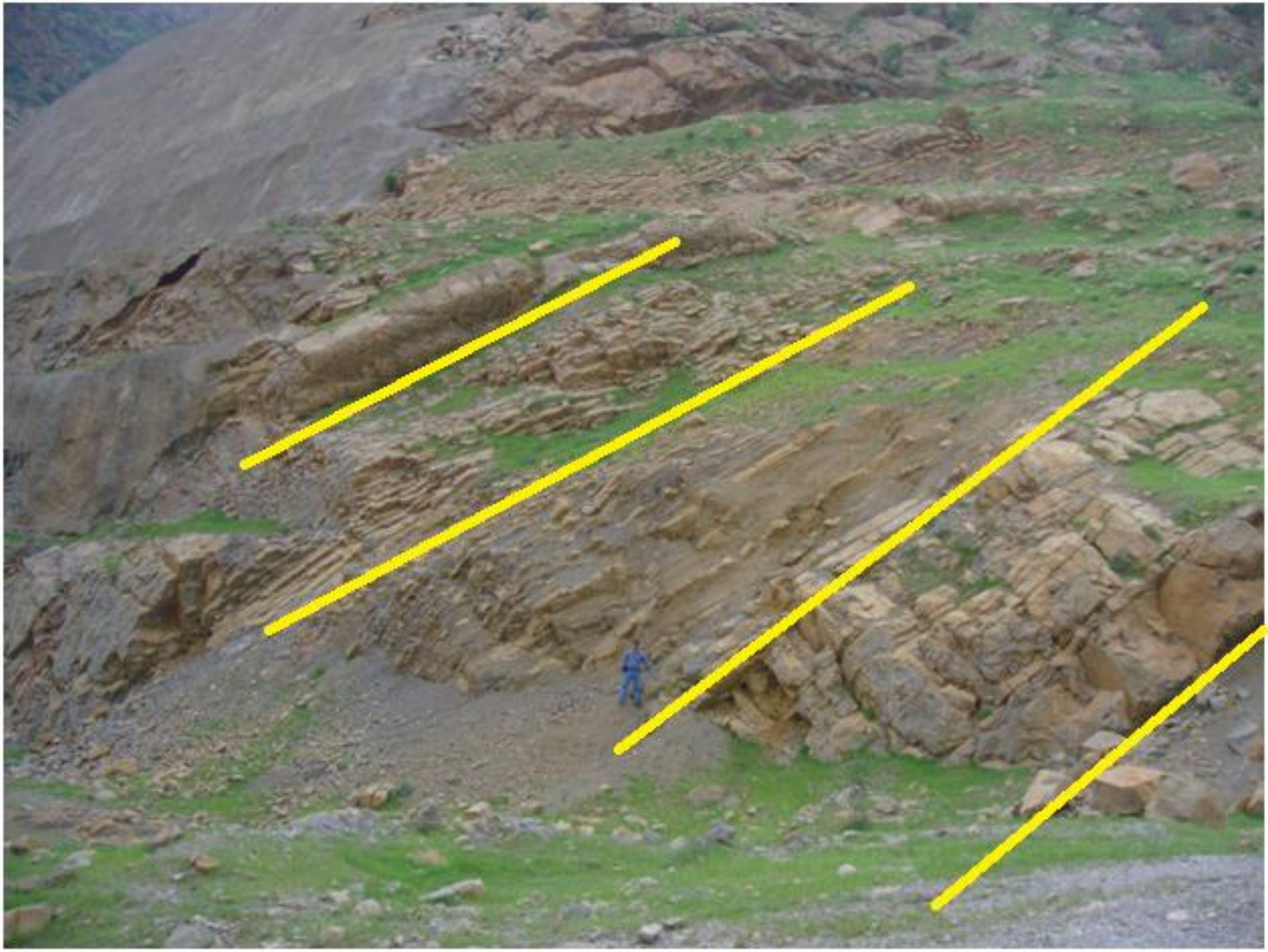
Rock Mass Classification System	Originator	Application Areas
Rock Load	Terzaghi, 1946	Tunnels with steel Support
Stand-up Time	Lauffer, 1958	Tunneling
New Austrian Tunneling Method (NATM)	Pacher, *et al*., 1964	Tunneling
Rock Quality Designation (RQD)	Deere, *et al*., 1967	Core logging, tunneling
Rock Classification for Rock Mechanical Purposes	Patching and Coates, 1968	For input in rock mechanics
The Unified Classification of Soils and Rocks	Deere *et al*., 1969	General
Rock Mass Rating (RMR)	Bieniawski, 1973	Tunnels, mines, slopes, foundations
Tunneling Quality Index (Q)	Barton, *et al*., 1974	Tunnels, mines, foundations
Rock Structure Rating (RSR)	Wickham, *et al*., 1974	Tunneling
Strength-Block Size	Franklin, 1975	Tunneling and mining
The Typological Classification	Matula and Holzer, 1978	General
Basic Geotechnical Classification	ISRM, 1981	General
Rock Mass Strength (RMS)	Stille, *et al*., 1982	Metal mining
Unified Rock Mass Classification System (URCS)	Williamson, 1984	General
Slope Mass Rating (SMR)	Romana, 1985	Slopes
Modified Rock Mass Rating (M-RMR)	Unal and Ozkan, 1990	Mining
Geomechanics Classification System	Laubscher, 1990	Mining
Rock Mass Index (RMi)	Palmstrom, 1995	Rock engineering
Rock Mass Number (N)	Goel, et al., 1995	Tunnels, mines, foundations
Geological Strength Index (GSI)	Hoek and Brown, 1997	All underground excavations
Geo-Engineering Classification	Ramamurthy, 2004	For intact and jointed rocks
Japanese Geotechnical Society JGS	Osada, *et al*., 2005	preliminary investigations
Rock Slope Stability (RSS)	Liu and Chen, 2007	Slope stability

Classification Procedure

The following six parameters are used to classify a rock mass using the RMR system (Geomechanics Classification).

1.Uniaxial compressive strength of rock material.
2.Rock quality designation (RQD).
3.Spacing of discontinuities.
4.Condition of discontinuities.
5.Groundwater conditions.
6.Orientation of discontinuities.

To apply the RMR system, the rock mass is divided into a number of structural regions such that certain features are more or less uniform within each region. Although rock masses are discontinuous in nature, they may, nevertheless, be uniform in regions when, for example, the type of rock or the discontinuity spacing are the same throughout that region. In most cases, the boundaries of structural regions will coincide with major geological features such as faults, dykes, shear zones, *etc*.



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		>2 m	0.6 – 2 m	200 – 600 mm	60 – 200 mm	<60 mm		
	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 walls	Slightly rough surfaces Separation < 1 mm Highly weathered wall	Slickensided surfaces or Gouge < 5 mm thick or Separation 1 – 5 mm Continuous	Soft gouge > 5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/min)	None	<10	10 – 25	25 – 125	>125		
		Ratio $\frac{\text{Joint water pressure}}{\text{Major principal stress}}$	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. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		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	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m 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

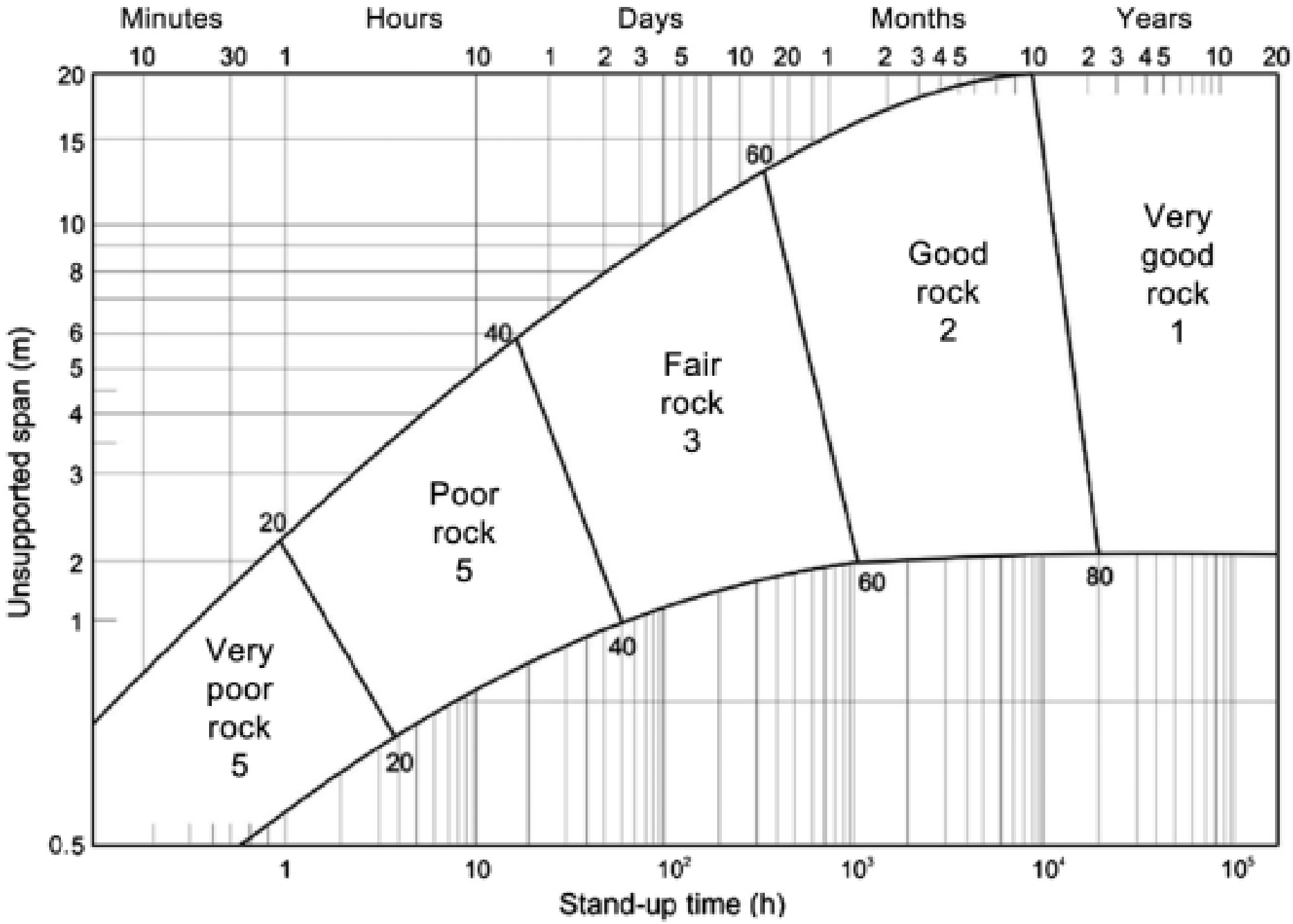
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

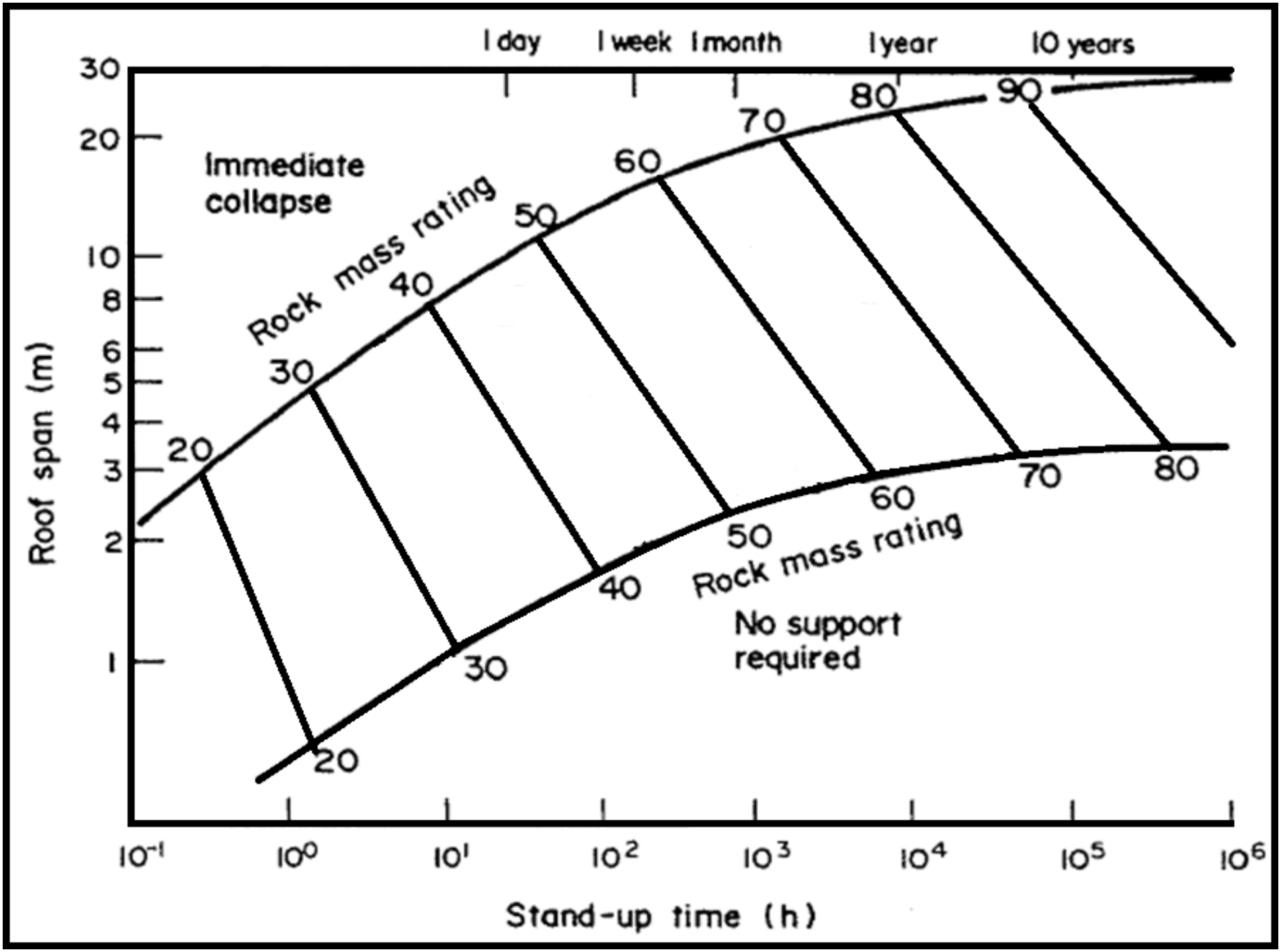
Discontinuity length (persistence) Rating	< 1 m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Rating	None 6	< 0.1 mm 5	0.1 - 1.0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Rating	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating	None 6	Hard filling < 5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

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

Application in Tunnels
Stand-Up Time
&
Roof Span


Minutes
Hours
Days
Months
Years
10
30
1
10
1
2
3
5
10
20
1
2
3
4
5
10
2
3
4
5
10
20
Unsupported span (m)
20
15
10
8
6
5
4
3
2
1
0.5
Very poor rock 5
Poor rock 5
Fair rock 3
Good rock 2
Very good rock 1
20
40
60
20
40
60
80
1
10
10^2
10^3
10^4
10^5
Stand-up time (h)

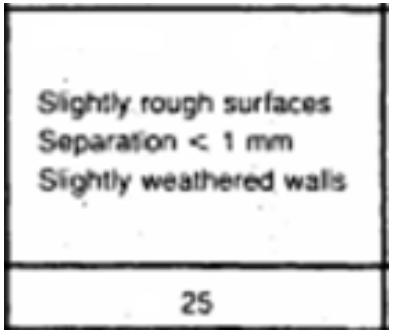

1 day
1 week
1 month
1 year
10 years
Immediate collapse
Rock mass rating
20
30
40
50
60
70
80
90
No support required
Roof span (m)
Stand-up time (h)

Example

A tunnel is to be driven through slightly weathered granite with a dominant joint set dipping at 60^{o} against the direction of the drive. Index testing and logging of diamond drilled core give typical Point load strength index values of 8 MPa and average *RQD* values of 70%. The joints, which are slightly rough and slightly weathered with a separation of < 1 mm, are spaced at 300 mm. Tunneling conditions are anticipated to be wet. The *RMR* value is determined as follows:

Table	*Item*	*Value*	*Rating*
1: A.1	Point load index	8 MPa	12
1: A.2	*RQD*	70%	13
1: A.3	Spacing of discontinuities	300 mm	10
1: E.4	Condition of discontinuities	Note 1	22
1: A.5	Groundwater	Wet	7
1: B	Adjustment for joint orientation	Note 2	-5
		Total	59

Note 1. For slightly rough and altered discontinuity surfaces with a separation of < 1 mm, Table 1.A.4 gives a rating of 25. When more detailed information is available, Table 1.E can be used to obtain a more refined rating. Hence, in this case, the rating is the sum of: 4 (1-3 m discontinuity length), 4 (separation 0.1-1.0 mm), 3 (slightly rough), 5 (no infilling) and 5 (slightly weathered) = 21.



E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

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

Note 2. Table 1.F gives a description of 'Fair' for the conditions assumed where the tunnel is to be driven against the dip of a set of joints dipping at 60º. Using this description for 'Tunnels and Mines' in Table 1.B gives an adjustment rating of -5.

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**			
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)						
Strike and dip orientations		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	

The value of *RMR* of 59 indicates that the rock mass is on the boundary between the 'Fair rock' and 'Good rock' categories. In the initial stages of design and construction, it is advisable to utilize the support suggested for fair rock. If the construction is progressing well with no stability problems, and the support is performing very well, then it should be possible to gradually reduce the support requirements to those indicated for a good rock mass. In addition, if the excavation is required to be stable for a short amount of time, then it is advisable to try the less expensive and extensive support suggested for good rock. However, if the rock mass surrounding the excavation is expected to undergo large mining induced stress changes, then more substantial support appropriate for fair rock should be installed. This example indicates that a great deal of judgment is needed in the application of rock mass classification to support design.

It should be noted that Table 2 has not had a major revision since 1973. In many mining and civil engineering applications, steel fiber reinforced shotcrete may be considered in place of wire mesh and shotcrete.

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock *RMR*: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock *RMR*: 61-80	Full face , 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock *RMR*: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock *RMR*: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V – Very poor rock *RMR*: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Modifications to *RMR* for mining

Originally based upon case histories drawn from civil engineering, several modifications have been proposed in order to make the classification more relevant to mining applications

Laubscher (1977, 1984), Laubscher and Taylor (1976) and Laubscher and Page (1990)

Modified Rock Mass Rating system for mining MRMR. In situ and induced stresses, stress changes and the effects of blasting and weathering

Cummings et al (1982) and Kendorski et al (1983)

MBR (modified basic *RMR*) system

blast damage, induced stresses, structural features, distance from the cave front and size of the caving block

Homework

A mudstone rock mass at a depth of 200 m contains three fracture sets. One set comprises bedding planes; these are highly weathered, slightly rough surfaces, and are continuous with an orientation of 180/10. Another set is jointing; these joints are slightly weathered, slightly rough, and have an orientation of 185/75. The third set is also jointing; again, the joints are slightly weathered and slightly rough, and have an orientation of 090/80. The strength of the intact rock has been assessed as 55 MPa, and values for the RQD and mean fracture spacing are reported as 60% and 0.4 m, respectively.

Use the RMR system to classify this rock mass, and assess the stability of a 10 m wide excavation being driven from east to west.


Thank you