Rock Mass Rating (RMR)

Need for Engineering Classification!

- They provide **better communication between planners, geologists, designers, contractors, and engineers**.
- An **engineer's observations, experience, and judgment are correlated and consolidated more effectively** by an engineering (quantitative) classification system.
- **Engineers prefer numbers in place of descriptions**; hence, an engineering classification system has considerable application in an overall assessment of the rock quality.
- An ideal **application** of engineering rock mass classification occurs in the planning of hydroelectric projects, tunnels, caverns, bridges, building complexes, hill roads, rail tunnels, and so forth.

Rock Mass Rating

- The geomechanical classification or the Rock Mass Rating (RMR) system was proposed by **Bieniawski (1973)** on the basis of his experiences in shallow tunnels in sedimentary rocks
- The classification has **undergone several significant evolutions** in the year 1975, 1976, 1979 and 1984
- **The Rock Mass Rating (RMR) System is a geomechanical classification system for rocks**, developed by Z. T. Bieniawski between 1972 and 1973. It **combines the most significant geologic parameters of influence and represents them with one overall comprehensive index of rock mass quality**, which is used for the design and construction of excavations in rock, such as tunnels, mines, slopes and foundations
- **To apply** the geomechanical classification system, a **given site should be divided into a number of geological structural units in such a way that each type of rock mass is represented by a separate geological structural unit**

Bieniawski (1973) proposed a **quantitative classification system** considering six parameters

- ❖ Uniaxial compressive strength (UCS) of intact rock material
- ❖ Rock Quality Designation (RQD)
- ❖ Spacing of Joint or discontinuity
- ❖ Condition of Joint or discontinuity
- ❖ Groundwater condition
- ❖ Joint orientation

* Assigned a rating (numerical value) to each condition & the total is RMR

1. Strength of Intact Rock Materials

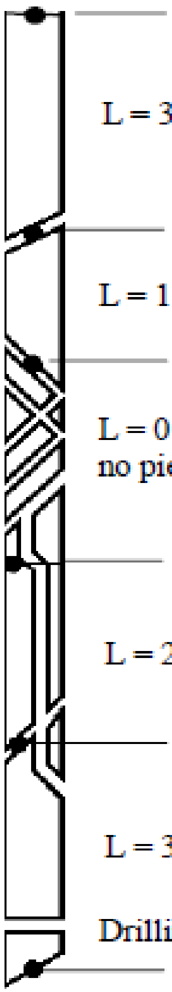
Strength of intact rock material
(Bieniawski, 1979 & 1984 and ISO14689)

Qualitative Description	Compressive Strength (MPa)	Point Load Strength (MPa)	Rating
Extremely strong*	> 250	8	15
Very strong	100 -250	4-8	12
Strong	50 -100	2-4	7
Medium strong*	25 - 50	1-2	4
Weak	5 - 25	use of uniaxial compressive strength is preferred	2
Very weak	1 - 5	-do-	1
Extremely weak	< 1	-do-	0

Note: 1. At compressive strength of rock material less than 1.0 MPa, many rock materials would be regarded as soil.
2. Terms in first column (*) redefined according to ISO14689.

Sources: Bieniawski, 1979, 1984; ISO14689-1, 2003

RQD Calculation (Direct Method)



Total length of core run = 200 cms

$$RQD = \frac{\Sigma \text{ Length of core pieces} > 10 \text{ cm length}}{\text{Total length of core run}} \times 100$$

$$RQD = \frac{38 + 17 + 20 + 35}{200} \times 100 = 55\ \%$$

Procedure for measurement and calculation of *RQD* (After Deere, 1989).

2. Rock Quality Designation

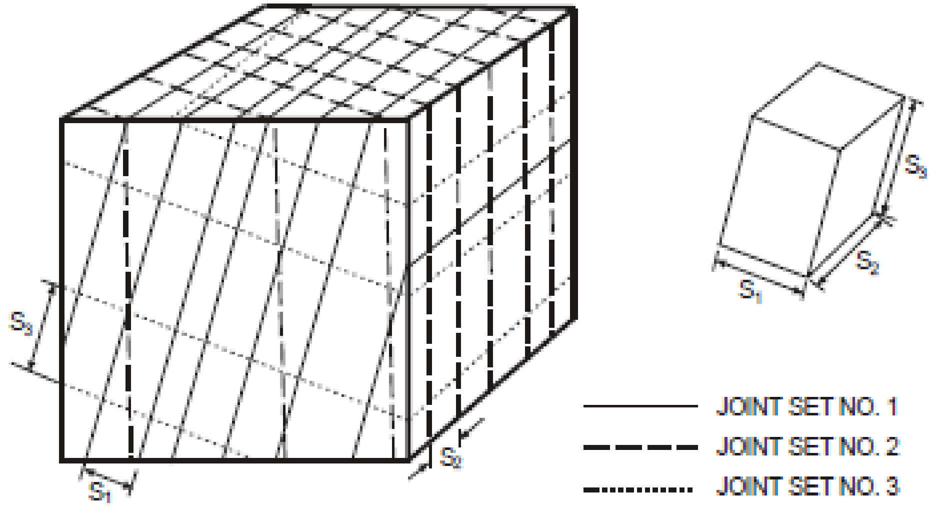
Rock Quality Designation

Qualitative description	RQD (%)	Rating
Excellent	90–100	20
Good	75–90	17
Fair	50–75	13
Poor	25–50	8
Very poor	<25	3

Source: Bieniawski, 1979.

3. Joint or discontinuity spacing

Spacing between two joints of same set



SPACING OF DISCONTINUITIES (Bieniawski, 1979)

Description	Spacing (m)	Rating
Very wide	> 2	20
Wide	0.6 - 2	15
Moderate	0.2 - 0.6	10
Close	0.06- 0.2	8
Very close	< 0.06	5

Note: If more than one discontinuity sets are present and the spacing of dicontinuities of each set varies, consider the set with lowest rating

The term "discontinuity" covers joints, beddings or foliations, shear zones, minor faults, and other surfaces of weakness

4. Joint condition

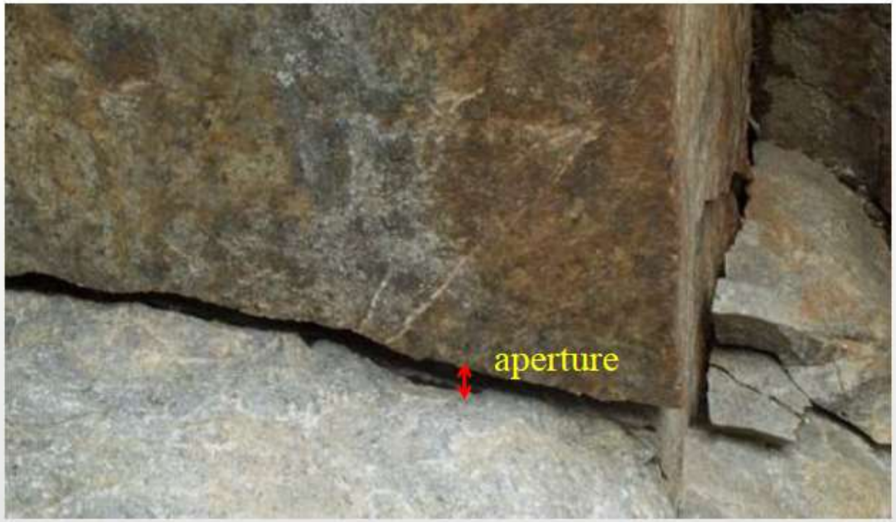
This parameter includes roughness of discontinuity surfaces, their separation (aperture or opening), length or continuity (persistence), weathering of the discontinuity surfaces (roughness), and infilling (gouge) material.

CONDITION OF DISCONTINUITIES (Bieniawski, 1979)

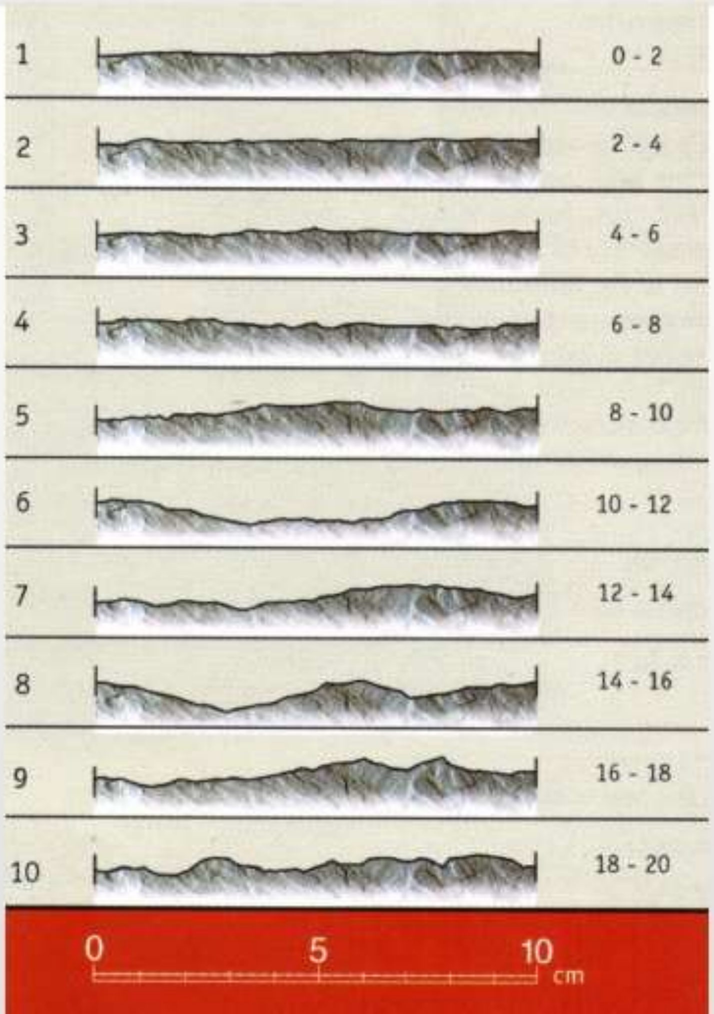
Description	Rating
Very rough and unweathered, wall rock tight and discontinuous, no separation	30
Rough and slightly weathered, wall rock surface separation <1mm	25
Slightly rough and moderately to highly weathered, wall rock surface separation <1mm	20
Slickensided wall rock surface or 1-5mm thick gouge or 1-5mm wide continuous discontinuity	10
5mm thick soft gouge, 5mm wide continuous discontinuity	0

Study/look/observe the surface of the discontinuity: **Roughness, Tightness, Alteration, Infillings, etc-**

Roughness



Aperture



5. Groundwater Condition

Groundwater Condition

Inflow per 10 m tunnel length (L/min)	None	<10	10–25	25–125	>125
Ratio of joint water pressure to major principal stress	0	0–0.1	0.1–0.2	0.2–0.5	>0.5
General description	Completely dry	Damp	Wet	Dripping	Flowing
Rating	15	10	7	4	0

Source: Bieniawski, 1979.

* It is essential to identify the **"most critical condition"** for the assessment of the rock strata. This means that the geological features that are most significant for stability purposes will have an overriding influence

- Water-in-rush is an extreme condition, being faced in many Himalayan tunnel
- Water is responsible to faster weathering of rocks; Affects long-term behaviour in shallow tunnels
- Erodible binding/cementing material washed away with time (high pressure)

6. Joint Orientation

Adjustment for Joint Orientation

Joint orientation assessment for	Very favorable	Favorable	Fair	Unfavorable	Very unfavorable
Tunnels	0	−2	−5	−10	−12
Raft foundation	0	−2	−7	−15	−25
Slopes*	0	−5	−25	−50	−60

Design Parameters and Engineering Properties of Rock Mass

S. No.	Parameter/ properties of rock mass	RMR (rock class) 100–81 (I)	80–61 (II)	60–41 (III)	40–21 (IV)	<20 (V)
1	Classification of rock mass	Very good	Good	Fair	Poor	Very poor
2	Average stand-up time	20 years for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 1 m span
3	Cohesion of rock mass (MPa)*	>0.4	0.3–0.4	0.2–0.3	0.1–0.2	<0.1
4	Angle of internal friction of rock mass	>45°	35–45°	25–35°	15–25°	<15°

*These values are applicable to slopes only in saturated and weathered rock mass

*In tunnels, the values are found to be more because of confinement

Applications of RMR

- Rock Mass Rating RMR has found wide applications in various types of engineering projects such as **tunnels, slopes, foundations, and mines**
- A rock mass rating system provides a **method of incorporating some of the complex mechanics of actual rocks into engineering design**.
- Moreover, the system was the first to enable estimation of rock mass properties, such as the modulus of deformation, in addition to providing tunnel support guidelines and the stand-up time of underground excavations.

Thanks

	PARAMETER		Range of values // ratings						
1	Strength of intact rock material	Point-load strength index	> 10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range uniaxial compr. strength is preferred		
		Uniaxial com-pressive strength	> 250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
		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**	**5**		
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 discon-tinuities	Length, persistence	< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m		
		Rating	**6**	**4**	**2**	**1**	**0**		
		Separation	none	< 0.1 mm	0.1 - 1 mm	1 - 5 mm	> 5 mm		
		Rating	**6**	**5**	**4**	**1**	**0**		
		Roughness	very rough	rough	slightly rough	smooth	slickensided		
		Rating	**6**	**5**	**3**	**1**	**0**		
		Infilling (gouge)	none	Hard filling		Soft filling			
			-	< 5 mm	> 5 mm	< 5 mm	> 5 mm		
		Rating	**6**	**4**	**2**	**2**	**0**		
		Weathering	unweathered	slightly w.	moderately w.	highly w.	decomposed		
		Rating	**6**	**5**	**3**	**1**	**0**		
5	Ground water	Inflow per 10 m tunnel length	none	< 10 litres/min	10 - 25 litres/min	25 - 125 litres/min	> 125 litres /min		
		$p_w / \sigma 1$	0	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**		

p_w = joint water pressure; $\sigma 1$ = major principal stress

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS

		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
RATINGS	Tunnels	**0**	**-2**	**-5**	**-10**	**-12**
	Foundations	**0**	**-2**	**-7**	**-15**	**-25**
	Slopes	**0**	**-5**	**-25**	**-50**	**-60**

C. 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	GOOD	FAIR	POOR	VERY POOR

GROUNDWATER CONDITIONS

- In the case of tunnels, the rate of inflow of groundwater per 10 m length is determined.
- General condition can be described as completely dry, damp, wet, dripping, and flowing.
- If actual water pressure data are available

$$\frac{\text{water pressure}}{\text{major principal stress}}$$

- Major principal stress is vertical stress which is determined from the depth below surface and increases with depth at 1.1 psi per foot of the depth below surface.