

Rock Mass Rating (RMR)

<http://www.edumine.com/tools/rock-mass-rating-rmr-calculations/>

$$\text{RMR} = J_{A1} + J_{A2} + J_{A3} + J_{A4} + J_{A5} + J_B$$

Rock Mass Rating System* *(after Bieniawski 1989)

A. Classification Parameters and Their Ratings							
Parameter	Range of Values						
A1. Strength of Intact Rock Material (see Field Estimates)							
Point-Load Strength Index	> 10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
Uniaxial Compressive Strength	> 250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
Rating J _{A1}	15	12	7	4	2	1	0
A2. Drill Core Quality - RQD (see RQD)	90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
Rating J _{A2}	20	17	13	8	3		
A3. Spacing of Discontinuities	> 2 m	0.6 - 2m	200 - 600 mm	60 - 200mm	< 60 mm		
Rating J _{A3}	20	15	10	8	5		
A4. Condition of Discontinuities (see E)	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 walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1 - 5 mm Continuous	Soft gouge > 5 mm thick or Separation > 5 mm Continuous		
Rating J _{A4}	30	25	20	10	0		
A5. Groundwater							
Inflow per 10 m tunnel length (L/min)	None	< 10	10 - 25	25 - 125	> 125		
Joint water pressure/ Major principal σ	0	< 0.1	0.1 - 0.2	0.2 - 0.5	> 0.5		
General Conditions	Completely dry	Damp	Wet	Dripping	Flowing		
Rating J _{A5}	15	10	7	4	0		

B. Rating Adjustment for Discontinuity Orientations (see Tunnelling)(see Dam Foundations)						
Strike and Dip Orientations		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Rating J_B	Tunnels and Mines	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	< 21
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. Meaning of Rock Classes					
Class No.	I	II	III	IV	V
Average stand-up time	20 yr for 15 m span	1 yr for 10 m span	1 wk for 5 m span	10 h 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)	< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m
Rating	6	4	2	1	0
Separation(aperture)	None	< 0.1 mm	0.1 - 1.0 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 < 5 mm	Hard Filling > 5 mm	Soft Filling < 5 mm	Soft Filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Rating	6	5	3	1	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	

**Some conditions are mutually exclusive. For example if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.

***Modified after Wickham et al (1972)

Assessment of Joint Orientation Favorability Upon Stability of Dam Foundations				
Dip 0° - 10°	Dip 10° - 30°		Dip 30° - 60°	Dip 60° - 90°
	Dip Direction			
	Upstream	Downstream		
Very favorable	Unfavorable	Fair	Favorable	Very favorable
Note: This table is based on experience and consideration of stress distribution in foundation rock masses. It assumes both the arch and the effects of gravity have an effect on a dam structure. The initial in-situ state of stress is not considered here, as in dam foundations in-situ stresses are mainly important when considering grouting, drainage curtains and the excavation sequence of foundations. For this last point, recent evidence shows that high horizontal stresses may be expected in near-surface rock masses.				

Rock Quality Designation* *(Deere, 1989)	
RQD	Rock Quality Classification
< 25%	Very Poor
25 - 50%	Poor
50 - 75%	Fair
75 - 90%	Good
90 - 100%	Very Good
The RQD is defined as the cumulative length of core pieces longer than 10cm in a run divided by the total length of the core run.	

Field Estimates of Uniaxial Compressive Strength					
Term	Uniaxial Compressive Strength (MPa)	Point Load Index (MPa)	Schmidt Hardness (Type L - hammer)	Field Estimate of Strength	Examples*
R5 Extremely Strong	> 250	> 10	50 - 60	Rock material only chipped under repeated hammer blows	fresh basalt, chert, diabase, gneiss, granite, quartzite
R4 Very Strong	100 - 250	4 - 10	40 - 50	Requires many blows of a geological hammer to break intact rock specimens	Amphibolite, sandstone, basalt, gabbro, gneiss, granodiorite, limestone, marble rhyolite, tuff
R3 Strong	50 - 100	2 - 4	30 - 40	Hand held specimens broken by a single blow of a geological hammer	Limestone, marble, phyllite, sandstone, schist, shale
R2 Medium Strong	25 - 50	1 - 2	15 - 30	Firm blow with geological pick indents rock to 5mm, knife just scrapes surface	Claystone, coal, concrete, schist. shale, siltstone
R1 Weak	5 - 25	**	< 15	Knife cuts material but too hard to shape into triaxial specimens	chalk, rocksalt, potash
R0 Very Weak	1-5	**		Material crumbles under firm blows of geological pick, can be scraped with knife	highly weathered or altered rock
Extremely Weak	0.25 - 1	**		Indented by thumbnail	clay gouge

*Well interlocked crystal fabric with few voids

**Rocks with a uniaxial compressive strength below 25 Mpa are likely to yield highly ambiguous results under point load testing