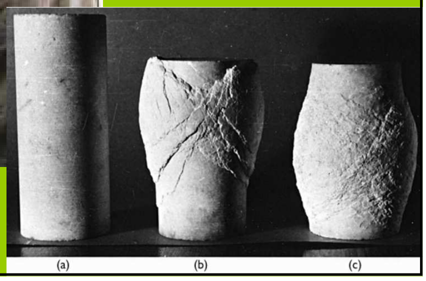
KLASIFIKACIJA STIJENSKE MASE

Stijenska masa

- klasifikacija stijenske mase

ČVRSTOĆA INTAKTNE STIJENE – materijala tla

• laboratorijski pokus jednoosne tlačne čvrstoće



• ilustracija redukcije posmične čvrstoće koja je uzrokovana pukotinama (slika)

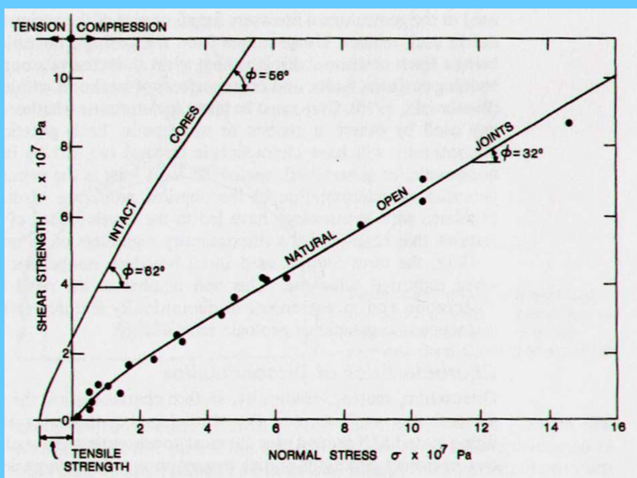
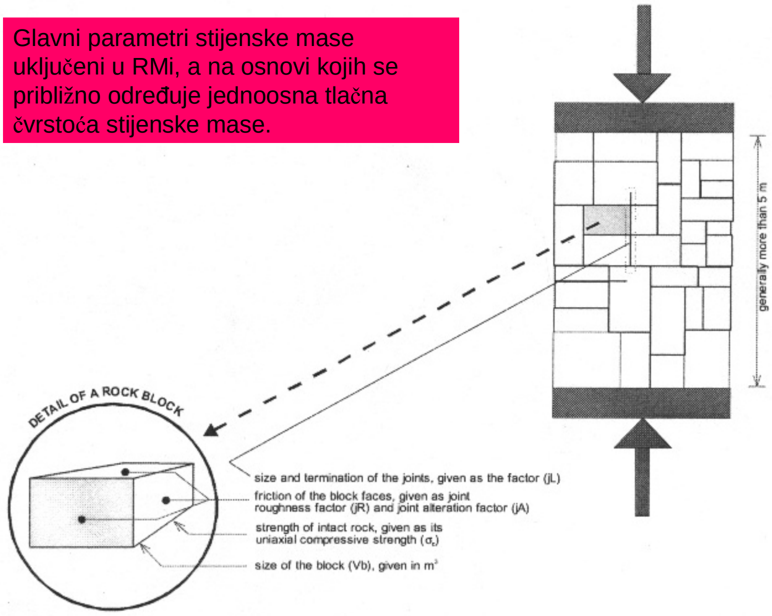


Figure 4.25 Comparison of Mohr strength envelopes of intact cores and natural open-joint shear strengths for quartz monzonite. (Reprinted with permission from Proc. 6th Symp. on Rock Mechanics, K. S. Lane and W. J. Heck, Triaxial Testing for Strength of Rock Joints, 1964, University of Missouri, Rolla.)

Sustav Indeksa stijenske mase RMi (eng. The Rock Mass Index)

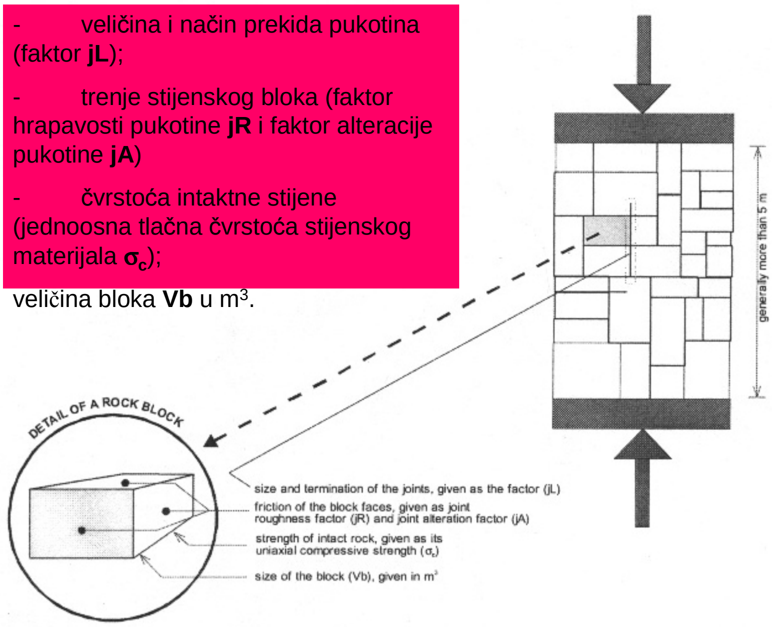
Glavni parametri stijenske mase uključeni u RMi, a na osnovi kojih se približno određuje jednoosna tlačna čvrstoća stijenske mase.



Sustav Indeksa stijenske mase RMi (eng. The Rock Mass Index)

- veličina i način prekida pukotina (faktor **jL**);
- trenje stijenskog bloka (faktor hrapavosti pukotine **jR** i faktor alteracije pukotine **jA**)
- čvrstoća intaktne stijene (jednoosna tlačna čvrstoća stijenskog materijala $\boldsymbol{\sigma_c}$);

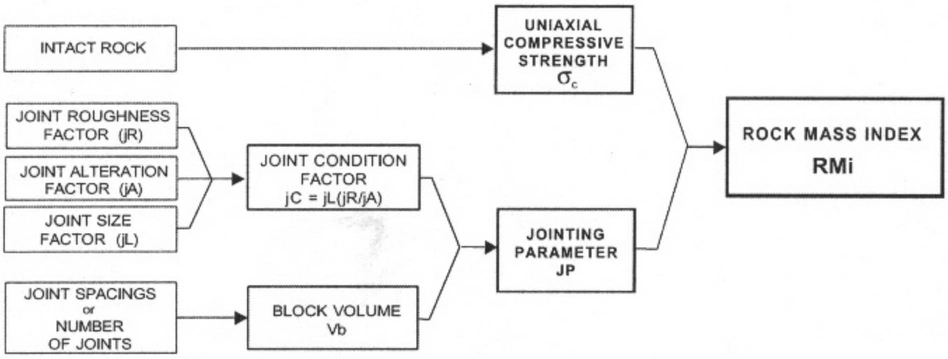
veličina bloka **Vb** u m^3.



- veličina i način prekida pukotina (faktor **jL**);
- trenje stijenskog bloka (faktor hrapavosti pukotine **jR** i faktor alteracije pukotine **jA**)
- čvrstoća intaktne stijene (jednoosna tlačna čvrstoća stijenskog materijala $\boldsymbol{\sigma_c}$);

veličina bloka **Vb** u m^3.

Dijagram toka sustava RMi

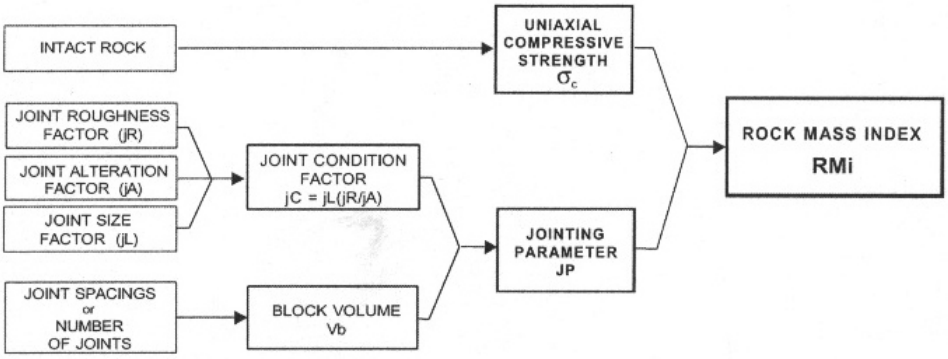


RMi se zasniva na principu da pukotine u stijenskoj masi reduciraju njezinu čvrstoću. On se stoga izražava kao: $RMi = \sigma_c x JP$.

Gdje je:

- σ_c=jednoosna tlačna čvrstoća intaktne stijene (MPa), mjereno na uzorku visine 50 mm;

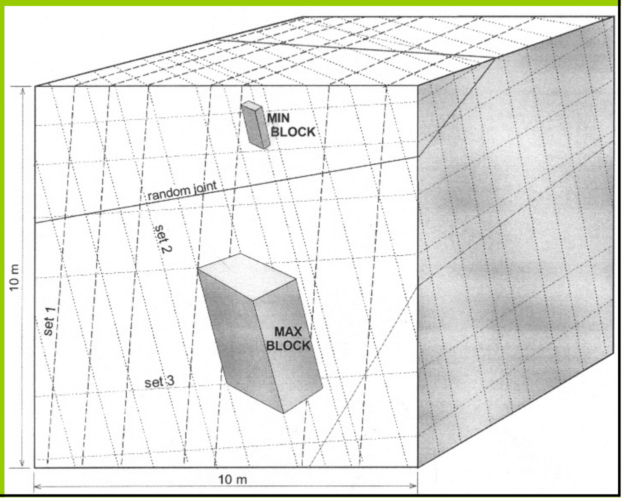
JP=parametar raspucanosti, koji odražava redukciju čvrstoće intaktne stijene koju uzrokuju pukotine. Kao što je prikazano na slici 2, JP uključuje glavne značajke pukotina u stijenskoj masi.



PRIMJER ODREĐIVANJA NUMERIČKIH VRIJEDNOSTI IZ KVALITATIVNIH OPISA

Prekambrijski crveni i sivi gnajsevi prosječne čvrstoće srednje su raspucani, a u njima dominiraju <u>3 seta diskontinuiteta</u>. Glavni set diskontinuiteta je folijacija gnajsa: duljina kontinuiranih diskontinuiteta je 2-5 m, a razmak 0.2-0.5 m.

Pukotine su valovite, hrapave, bez ispune. Stijenke pukotina se međusobno dodiruju, svježe su s mjestimičnom promjenom boje zbog trošenja. Blokovi u stijenskoj masi su ekvidimenzionalni, formirani po setovima koji su međusobno približno okomiti; razmak drugog seta je 0.5 m; razmak trećeg seta je 1 m.



Odredite RMi, tj. jednoosnu tlačnu čvrstoću opisane stijenske mase.

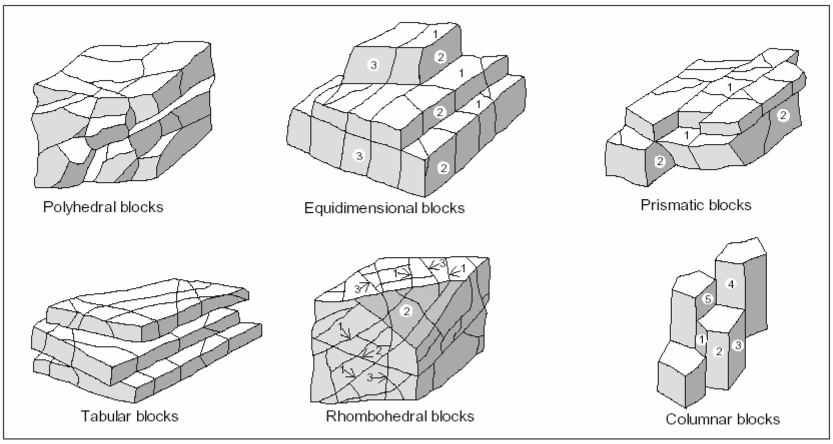


Figure 1 Examples of block shapes or the jointing pattern (from Dearman, 1991)

PARAMETAR	IZVOR	PODATAK	VRIJEDNOST PARAMETRA
jednoosna tlačna čvrstoća gnajsa	tablica 2		**σ_c =**
postojanost (duljina) diskontinuiteta	opis		**jL =**
hrapavost diskontinuiteta	opis		**jR =**
zijev/širina/ispuna	opis		**jA =**
		jR x jL / jA=	**jC =**
volumen bloka	opis		**Vb =**
parametar raspucanosti	slika 3		**JP =**
		σ_c x JP=	**RMi=**

Jednoosna tlačna čvrstoća, σ_c, intaktne stijene (tj. reprezentativnog uzorka stijenskog materijala) dobiva se iz laboratorijskih ispitivanja ili se procjenjuje priručnim identifikacijskim pokusima ili se preuzimaju iskustvene vrijednosti (prema tablici 2).

Faktor stanja diskontinuiteta, jC - određuje se na osnovi bodovanja opisa diskontinuiteta (jR-hrapavosti; jA-zijeva/širine, ispune, trošnosti stijenki; jL- postojanosti).

Volumen bloka, Vb - izravno se određuje/mjeri na izdanku.

JP - određuje se pomoću dijagrama prikazanog na slici 3, a iz vrijednosti jC (faktor stanja pukotine) i Vb (volumen bloka), koje se dobivaju prilikom terenskih istraživanja (opisivanja) izdanaka stijenske mase.

Tablica 1: način računanja RMi i vrijednosti parametara za računanje faktora stanja pukotine (jC).

TABLE A3-8 NORMAL RANGE OF COMPRESSIVE STRENGTH FOR SOME COMMON ROCK TYPES (data from Hansen, 1988 and Hoek and Brown, 1980) AND VALUES FOR THE *m* FACTOR IN HOEK-BROWN FAILURE CRITERION (from Hoek et al., 1992).

Rock name	Uniaxial compressive strength σ_c			Rating of the factor m_i 1)	Rock name	Uniaxial compressive strength σ_c			Rating of the factor m_i 1)
	low	average	high			low	average	high	
Sedimentary rocks					**Metamorphic rocks**				
Anhydrite		120'?		13.2	Amphibolite	75	125	250	31.2
Coal	16"	21"	26"		Amphibolitic gneiss	95	160	230	31 ?
Claystone	2'	5' 10'		3.4	Augen gneiss	95	160	230	30 ?
Conglomerate	70	85	100	(20)	Black shale	35	70	105	
Coral chalk	3	10	18	7.2	Garnet mica schist	75	105	130	
Dolomite	60'	100'300'		10.1	Granite gneiss	80	120	155	30 ?
Limestone	50*	100'	180*	8.4	Granulite	80'	150	280	
Mudstone	45	95	145		Gneiss	80	130	185	29.2
Shale	36"	95"	172"		Gneiss granite	65	105	140	30 ?
Sandstone	75	120	160	18.8	Greenschist	65	75	85	
Siltstone	10'	80'	180'	9.6	Greenstone	120'	170*	280*	20 ?
Tuff	3'	25'	150'		Greywacke	100	120	145	
Igneous rocks									
Andesite	75'	140'	300'	18.9	Marble	60'	130'	230'	9.3
Anorthosite	40	125	210		Mica gneiss	55	80	100	30 ?
Basalt	100	165	355"	(17)	Mica quartzite	45	85	125	25 ?
Diabase (dolerite)	227"	280"	319"	15.2	Mica schist	20	80*	170*	15 ?
Diorite	100	140	190	27 ?	Mylonite	65	90	120	
Gabbro	190	240	285	25.8	Phyllite	21	50	80	13 ?
Granite	95	160	230	32.7	Quartz sandstone	70	120	175	
Granodiorite	75	105	135	20 ?	Quartzite	75	145	245	23.7
Monzonite	85	145	230	30 ?	Quartzitic phyllite	45	100	155	
Nepheline syenite	125	165	200		Serpentinite	65	135	200	
Norite	290"	298"	326"	21.7	Slate	120'	190'	300'	11.4
Pegmatite	39	50	62		Talc schist	45	65	90	10 ?
Rhyolite		85'?		(20)					
Syenite	75	150	230	30 ?					
Ultra basic rock	80'	160	360						

Soil materials2):
Very soft clay σ_c = 0.025 MPa Soft clay σ_c = 0.025 - 0.05 MPa Firm clay σ_c = 0.05 - 0.1 MPa
Stiff clay σ_c = 0.1 - 0.25 MPa Very stiff clay σ_c = 0.25 - 0.5 MPa Hard clay σ_c = > 0.5 MPa
Silt, sand: assume σ_c = 0.0001 - 0.001 MPa

* Values found by the Technical University of Norway, (NTH) Inst. for rock mechanics.
' Values given in Lama and Vutukuri, 1978.
" Values given by Bieniawski, 1984.

UNIAXIAL COMPRESSIVE STRENGTH, σ_c of intact rock	**value** (in MPa)	found from laboratory tests (or assumed from handbook tables)
BLOCK VOLUME, Vb	**value** (in m³)	measured visyally at site (or estimated from borehole cores)
JOINT CONDITION FACTOR, jC	**jC = jR x jL / jA**	ratings of jR, jA and jL in the tables below

JOINT ROUGHNESS FACTOR (jR) *(the ratings of jR are based on Jr in the Q-system)*

(The ratings in ***bold italic*** are similar to Jr)		Large scale waviness of joint plane				
		Planar	Slighty undulating	*Undulating*	Strongly undulating	Stepped or interlocking
Small scale smoothness of joint surface	Very rough	2	3	4	6	6
	Rough	***1.5***	2	***3***	4.5	6
	Smooth	***1***	1.5	***2***	3	4
	Polished or *slickensided* *)	***0.5***	1	***1.5***	2	3
	For filled joints jR = 1 For irregular joints a rating of jR = 5 is suggested					

*) For slickensided surfaces the ratings apply to possible movement along the lineations

JOINT ALTERATION FACTOR (jA) *(the ratings of jA are based on Ja in the Q-system)*

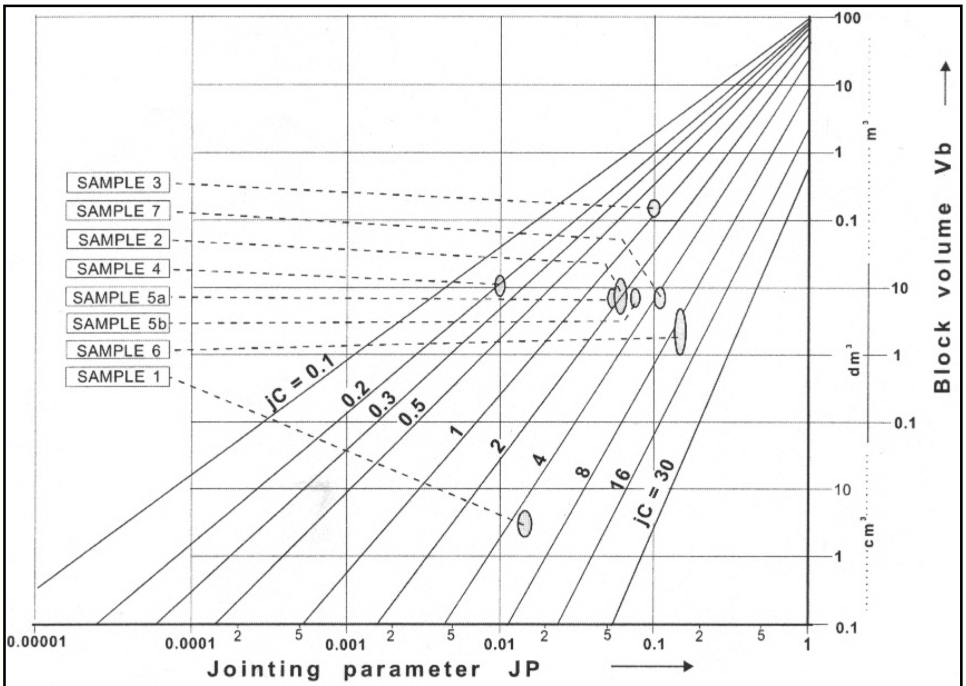
	JOINT WALL CHARACTER		Condition	***Wall contact***
Contact between joint walls	CLEAN JOINTS:	Healed or welded joints	filling of quartz, epidote, etc.	0.75
		Fresh joint walls	no coating or filling, except from staining (rust)	1
		Altered joint walls	- one grade higher alteration than the rock	2
			- two grades higher alteration than the rock	4
	COATING or THIN FILLING OF:	Friction materials	sand, silt calcite, etc. without content of clay	3
		Cohesive materials	clay, chlorite, talc, etc.	4

	FILLING OF:	Type	***Partly wall contact*** Thin filling (< 5 mm)	***No wall contact*** Thick filling
Partly or no wall contact	Friction materials	sand, silt calcite, etc. (non-softening)	4	8
	Hard, cohesive materials	compacted filling of clay, chlorite, talc, etc.	6	6 - 10
	Soft, cohesive materials	medium to low overconsolidated clay, chlorite, talc, etc.	8	12
	Swelling clay materials	filling material exhibits swelling properties	8 - 12	13 - 20

THE JOINT SIZE FACTOR (jL)

TYPE	Length	Size	Continuous joints	Discont. joints*)
Bedding or foliation partings	< 0.5 m	very short	3	6
Joints	0.1 - 1 m	short or small	2	4
	1 - 10 m	medium	1	2
	10 - 30 m	long or large	0.75	1.5
(Filled) joint, seam or shear **)	> 30 m	very long or large	0.5	1

*) Discontinuous joints end i massive rock **) Often a singlularity and should in these cases be treated separately



Dijagram za određivanje vrijednosti JP, načinjen na osnovi 8 uzoraka (sive elipse)

RJEŠENJE

PARAMETAR	IZVOR	PODATAK	VRIJEDNOST PARAMETRA
jednoosna tlačna čvrstoća gnajsa	tablica 2		**σ_c = 130 MPa**
postojanost (duljina) diskontinuiteta	opis		jL = 1
hrapavost diskontinuiteta	opis		jR = 3
zijev/širina/ispuna	opis		jA = 1
		jR x jL / jA=	jC = 3 x 1/1 = 3
volumen bloka	opis		Vb = 0.1 – 0.25 m³
parametar raspucanosti	slika 3		JP = 0.175-0.23
		σ_c x JP=	**RMi= 22.75 - 30**

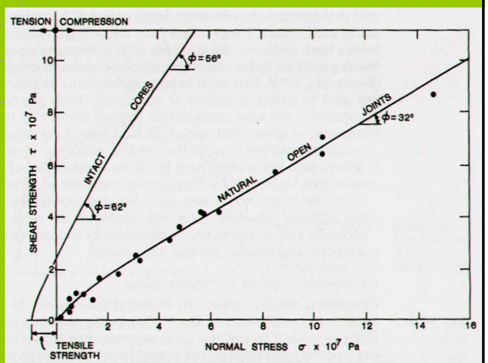


Figure 4.25 Comparison of Mohr strength envelopes of intact cores and natural open-joint shear strengths for quartz monzonite. (Reprinted with permission from Proc. 6th Symp. on Rock Mechanics, K. S. Lane and W. J. Heck, Triaxial Testing for Strength of Rock Joints, 1964, University of Missouri, Rolla.)

Indeks stijenske mase RMi (eng. The Rock Mass Index) – metoda izbora podgrade

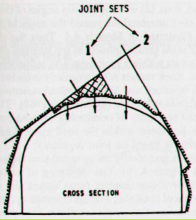


Figure 4.27 Unstable tunnel roof conditions caused by interaction of orientation and spacing of two joint sets. (From Cording et al., 1975)

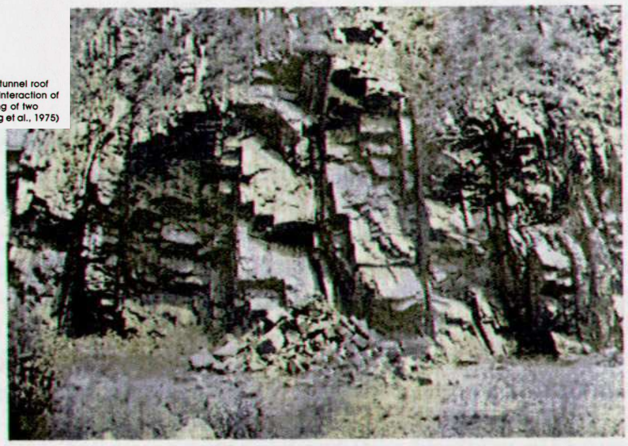


Figure 4.28 Rock falls caused by closely spaced multiple joint sets, with one set daylighted, Golden Gate Canyon, Colorado.

klasifikacija stijenske mase

- klasifikacije stijenske mase razvijene za određenu inženjersku primjenu: stabilnost stijenske mase u podzemnim prostorijama, zasjecima/usjecima i površinskim kopovima
- neke se mogu primijeniti samo za određenu namjenu, a neke i šire
- različit je broj kriterija klasifikacije

RMR klasifikacija (Bieniawski, 1974)

Table 4.19 Geomechanics Classification Parameters, Ranges, Ratings, and Classes

a. Classification Parameters and Their Ratings

1	USC of intact rock	>200 MPa	100–200 MPa	50–100 MPa	25–50 MPa	<25 MPa
	Rating	10	5	2	1	0
2	Drill-core quality RQD	90% to 100%	75% to 90%	50% to 75%	25% to 50%	<25% or highly weathered
	Rating	20	17	14	8	3
3	Spacing of joints	>3 m	1–3 m	0.3–1 m	50–300 mm	<50 mm
	Rating	30	25	20	10	5
4	Strike and dip orientations of joints	Very favorable	Favorable	Fair	Unfavorable	Very unfavorable
	Rating	15	13	10	6	3
5	Condition of joints	Very tight: separation <0.1 mm Not continuous		Tight: <1 mm and continuous No gouge	Open: 1–5 mm Continuous Gouge <5 mm	Open >5 mm Continuous Gouge >5 mm
	Rating	15		10	5	0
6	Groundwater inflow (per 10 m of tunnel length)	None		<25 l/min	25–125 l/min	>125 l/min
	Rating	10		8	5	2

b. Rock-Mass Classes and Their Ratings

Class No.	I	II	III	IV	V
Description of class	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock
Total rating	100←90	90←70	70←50	50←25	<25

Source: Modified from Bieniawski, 1974.

Table 4.20 Influence of Tunnel Axis, Strike and Dip of Joints, and Relative Direction of Tunneling on the Rating of Jointing for Use in the Geomechanics Classification

Strike perpendicular to tunnel axis				Strike parallel to tunnel axis	
Drive with dip		Drive against dip			
Dip 45°–90°	Dip 20°–45°	Dip 45°–90°	Dip 20°–45°	Dip 45°–90°	Dip 20°–45°
Very favorable	Favorable	Fair	Unfavorable	Very unfavorable	Fair
Dip 0°–20°: Unfavorable, irrespective of strike					

Source: Modified from Bieniawski, 1974.

- RMR zbroj je osnova za klasificiranje stijenske mase u 1 od 5 klasa (od jako dobre do jako loše)
- korelacija RMR-a i in situ modula deformacije (slika x)

Q-klasifikacija (Barton et al, 1974)

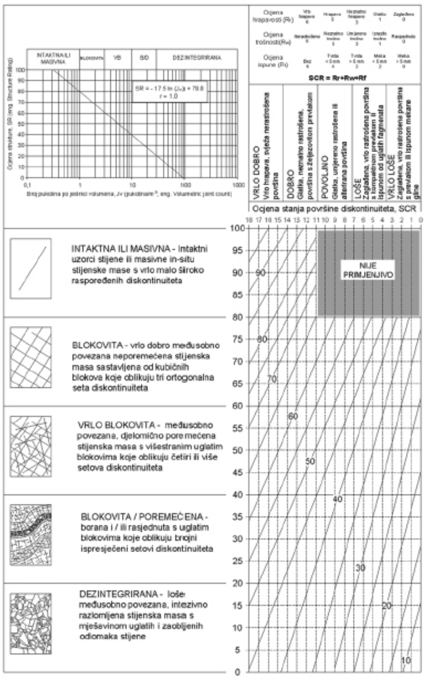
- razvijena za potrebe tunelogradnje
- tbl. 4.22
- mjera veličine bloka=RQD/J_n
- posmična čvrstoća među blokovima=J_r/J_a
- aktivno naprezanje na lokaciji=J_w/SRF
- produkt ova tri omjera koristi se za određivanje Q vrijednosti

Table 4.22 Descriptions and Ratings for Q-System Joint Set Number Parameter, J_n

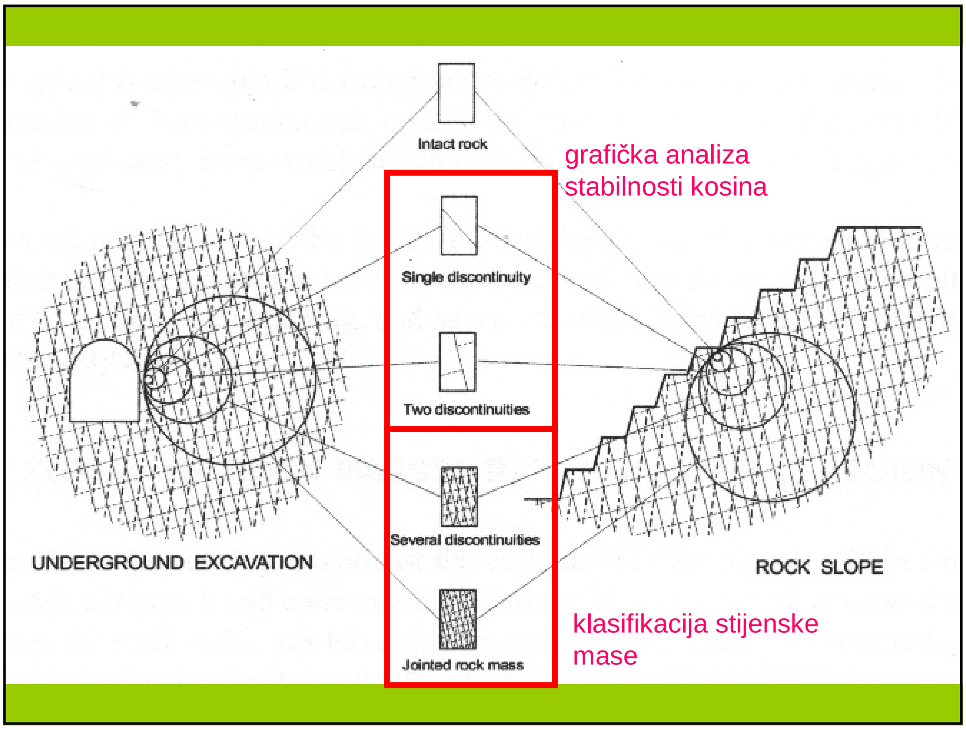
Joint Set Number	(J_n)
Massive, no or few joints	0.5–1.0
One joint set	2
One joint set plus random	3
Two joint sets	4
Two joint sets plus random	6
Three joint sets	9
Three joint sets plus random	12
Four or more joint sets, random, heavily jointed, "sugar cube", etc.	15
Crushed rock, earthlike	20

Source: Reprinted with permission from Rock Mechanics, Vol. 6, N. Barton, R. Lien, and J. Lunde, Engineering Classification of Rock Masses for the Design of Tunnel Support, 1974, Springer-Verlag.

GSI – geološki indeks čvrstoće



Slika 3-6. Predloženi dijagram za određivanje GSI vrijednosti


Intact rock
grafička analiza stabilnosti kosina
Single discontinuity
Two discontinuities
Several discontinuities
Jointed rock mass
UNDERGROUND EXCAVATION
ROCK SLOPE
klasifikacija stijenske mase