## **Applications and Limitations of Geotechnical Classification Systems**

## Megi Rusi<sup>1</sup>, Arbi Shehu<sup>2</sup>

<sup>1</sup>Department of Applied Geology, Geoinformatics and Environment, Polytechnic University of Tirana, Albania, megi.rusi@baugeologie.at

<sup>2</sup>Department of Mineral Resources Engineering, Polytechnic University of Tirana, Albania, arbi.shehu@gmail.com

#### **ABSTRACT**

During the feasibility and preliminary design stages of a project, when not enough detailed information on the rock mass and its stress and hydrologic characteristics is available, the use of a rock mass classification scheme can be of considerable benefit. This can be used as a check-list to ensure that all relevant information has been considered. It is possible that one or more rock mass classification schemes can be used to build up a picture of the composition and characteristics of a rock mass to provide initial estimates of support requirements, and to provide estimates of the strength and deformation properties of the rock mass.

Different classification systems place different emphases on the various parameters, that's why in our tunnel project we use 3 methods RMi, Q, RMR and compares the results.

One of the results of the comprehensive field work to clarify the geological conditions for the tunnelling works was a comprehensive data collection of rock and rockmass descriptions that contains information about lithology, petrology, mineralogy, texture, fabric and on-site evaluated rock and rockmass physical and mechanical properties. For further data processing the above mentioned rock- and rockmass-classifications were used to give comparable assessments for tunnelling conditions and lining requirements.

The paper at hand is an attempt to clarify, which systems of rockmass classification are best-fit to describe the rockmass conditions of the project area. Which were the limitations of each system used and how to improve their applications. The result is displayed in the geological longitudinal sections of the headrace Moglice – Graboves (Devoll Project, Albania). Consequently the paper at hand is an integrated part of the engineering geological contribution in the feasibility report for the client DHP in which GSI and little "q" systems were used as well.

#### INTRODUCTION

Devoll Hydropower (DHP) is a joint venture company of EVN (Austria) and Statkraft (Norway), which purpose is to develop, plan, construct and operate up to 3 hydropower plants along the middle reaches of Devoll river.

Besides the completion of the unfinished HPP Banje the project comprises at the present stage two new damsites for reservoirs, more than 30 km of waterway tunnels (headrace and tailrace tunnels) and two powerhouses, at least one of them constructed in a large cavern.

The regional geology covering tectonically very complicated geologic units a quite challenging background for the project. It is a fact, that excavating tunnels and caverns is one of the most important cost factor for such a project. That was the reason to start as early as June 2009 with the investigation works. (see picture.1)

In turn **baugeologie.at** started field work in June 2009. The author was part of the team since July 2009. The detailed geological mapping work with focus on engineering aspects was done based on the accordant sheets of the official geological maps of Albania scale 1:50.000. **baugeologie.at** succeeded in detailed mapping of the key areas for dam-sites and tunnel alignements.

One of the results of the comprehensive field work to clarify the geological conditions for the tunneling works was a comprehensive data collection of rock and rockmass descriptions that contains information about lithology, petrology, mineralogy, texture, fabric and on-site evaluated rock and rockmass physical and mechanical properties. For further data processing several rock- and rockmass-classifications exist to give comparable assessments for tunneling conditions and lining requirements.

After getting the results of the classifications performed, which are displayed in the geological longitudinal sections of the headrace Moglice-Graboves conclusions about the application and limitation were made. Consequently the paper at hand is an attempt to clarify, which systems of rockmass classification are best-fit to describe the rockmass conditions of the project area and which the limitations of each system used were and how to improve their applications.

#### 1. THE METHOD

A comprehensive field investigation program has been carried out in the project area, ranging from regional geological mapping, refraction seismic survey to core drillings and test pits. The investigation is mostly concentrated to key areas for the project such as dam sites, power station areas, and critical sections along tunnel alignments.

During the feasibility and preliminary design stages of a project, when not enough detailed information on the rock mass and its stress and hydrologic characteristics is available, the use of a rock mass classification scheme can be of considerable benefit. This can be used as a check-list to ensure that all relevant information has been considered. It is possible that one or more rock mass classification schemes can be used to build up a picture of the composition and characteristics of a rock mass to provide initial estimates of support requirements, and to provide estimates of the strength and deformation properties of the rock mass.

Different classification systems place different emphases on the various parameters, that's why the author uses 3 methods RMi, Q, RMR and compares the results.

### The Rock Mass Rating system (RMR)

The Rock Mass Rating system also called the Geomechanics Classification was first published in 1976 from Bieniawski. The following six parameters are used to classify a rock mass using this system:

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.

The Rock Mass Rating system gives the ratings for each of the six parameters listed above. These ratings are summed to give a value of *RMR*.

## The Rock Tunneling Quality Index (Q)

Barton of the Norwegian Geotechnical Institute proposed a Tunneling Quality Index (Q) for the determination of rock mass characteristics and tunnel support requirements in 1974. The numerical value of the index Q varies on a logarithmic scale from 0.001 to a maximum of 1,000 and is defined by:

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SFR}$$
 (1)

where:

RQD is the Rock Quality Designation  $RQD = \frac{\sum Length \cdot of \cdot core \cdot pieces \ge 10}{total \cdot length \cdot of \cdot core \cdot run} \times 100$  (2)

 $J_n$  is the joint set number

 $J_r$  is the joint roughness number

 $J_a$  is the joint alteration number

 $J_w$  is the joint water reduction factor

SRF is the stress reduction factor

## The Rock Mass Index (RMi)

The rock mass index was first presented in 1995 by Palmström A. This index has been developed as a general strength characterization of the structural material that a rock mass represents. The rock mass is a material much more complex in composition, structure, variability than most other structural materials. The presence of various defects (discontinuities) in a rock mass, which tend to reduce the inherent strength of the rock, constitutes the main feature in its behavior. This fact is the main principle of the Rock Mass index (RMi).

The RMi system has some input parameters similar to those of the Q-system. Thus, the joint and the jointing features are almost the same.

The input parameters in a general strength characterization of a rock mass are:

- the size of the blocks delineated by joints, measured as block volume;
- the strength of the block material, measured as uniaxial compressive strength;
- the shear strength of the block faces, measured as friction angle, and
- the size and termination of the joints, measured as length and continuity.

The main principle in the development of RMi has been focusing on the effects of the defects in a rock mass in reducing the strength of the intact rock. The RMi is thus defined as

$$RMi = \sigma c \times JP$$
 (3)

Where

 $\sigma c$  = the uniaxial compressive strength of the intact rock material, and

JP = the jointing parameter. It is a reduction coefficient representing the block size and the condition of its faces represented by their friction properties and the size of the joints.

The value of JP varies from almost 0 for crushed rocks to 1 for intact rock.

Its value is found by combining empirical relations jC (joint conditions) and Vb (block volume) in the following exponential equation derived from strength tests on large jointed samples.

$$JP = 0.2 \sqrt{jC \times V_b^D} \qquad (D = 0.37 jC^{-0.2}) \quad (4)$$

Where

$$jC = jR \times \frac{jL}{jA}$$
 (5) (jR-joint roughness, jL-joint length, jA-joint alteration)

## 1.1 THE CFASSIFICATION AND THEIR RESULTS

The work for the classification consists in inserting the input parameters collected in the field in the excel spread sheet (see fig.1)

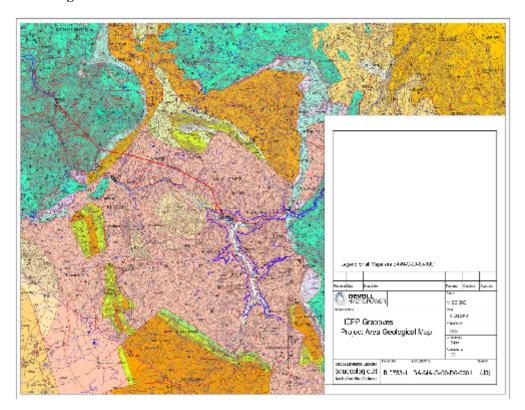
After classifying a selected number outcrops which concern the Moglice- Grabove tunnel area the results will be displayed in the followed tables.(see fig.2 and 3)

# 2 APLICATIONS AND LIMITATIONS OF THE USED CLASSIFICATION SYSTEMS

- 1. The better and comprehensive the description of the rockmass is, and the more of the requested parameters are well defined, the better results are achieved by any classification system.
- 2. Outcrops with clear lithologic and fabric conditions, that weren't subject to tectonic complications, normally are easiest to describe and allow all parameters to be reckoned as precise as possible. Within the bandwidth of properties of the rockmass entity these outcrops in general represent the more favorable side.
- 3. In contrary outcrops with complicated lithologic and fabric conditions as well as a multi-stage tectonic history are sometimes difficult to define and hardly to describe according to the requested input parameters of classification systems.
- 4. Consequently all classification systems will show a broader variation on the "unfavourable side" of the bandwidth.
- 5. Ideally, all the characteristics (smoothness, waviness, length) included in the joint condition factor of the systems should be measured accurately. Such measurements of the joints would generally be either extremely time-consuming or in most cases, practically impossible to carry out. Only a few joints in the rock mass can be observed

- and measured and extrapolations have to be made. This may result in a differing of the real quality of the rockmass.
- 6. Where the rock mass characterization is carried out *before* construction, uncertainties are introduced from the *interpolations* made between more or less known conditions at the surface and from various forms of *extrapolations* carried out from these (known) conditions to areas with unknown information. Except for wrong interpretations, improved characterization of the rock mass by RMi will generally increase the quality of the geological input data to be applied in evaluation, assessments or calculations. This will in turn lead to better designs
- 7. RQD is applied in the main classification systems as an input parameter for the block size or the jointing density. RQD is one-dimensional; therefore it is strongly directional. This was stressed among others by Bjerrum (1965). Therefore, Hudson and Priest (1983) and several other authors recommend carrying out core drillings in three directions to obtain reliable results. This is, however, an expensive solution to obtain information on the jointing.
- 8. Scanlines are a good solution for not selecting the better outcrops while maping.
- 9. The most important thing in having good results from classification systems is the experience and knowledge of the engineer at site.

## **Tables and Figures**



Picture 1 Geology along the tunnel layout

Tunnel:		Project-	CRABOVE HEPP Date: 14.Jun.10	w m	
Imput symbols are shown in this below, see also Peramoter tables!   Imput parameters		_		en e	5
Imput symbols are shown in time below; see also. Perameter tables!   Imput parameters	8			100	5
Imput parameters    Turnet sysm or dean eter (DI)	3			98	8
Turnet span or conneter (bit)  Vitural span or conneter (bit)  Conneter (bit)  Conneter (bit)  Conneter (bit)  Conneter (bit)  Vitural span or conneter (bit)  Conneter (bit)  Conneter (bit)  Vitural span or conneter (bit)				- INPUT	
Vilument stall begins (Wi) (vilument stall begins from (COS or e.)) 15 Mina (COmpressive strength of more (COS or e.)) 15 Mina (CO) 18	Ĭ		Input parameters	ů	Ţ
Page				_5,4	m m
Degree of Hook volume (Vb)	d (	Compressive	strength of rock (UCS or e.,)	16	MPa
15,3 million   15,5					% RQD = 71
Attent spacing   Atte	_			463	m <sup>p</sup> V/1 = 10,1
Ulock stapps. (x = catical blacks, b = stightly long or feel blacks, c = mod long or flet blacks, d = very long or be blacks.)  22 Jointing Joint sets. (x = models, b = 1 x et, c = 1 x et torachin. d = 2 x et, x = 2 x et torachin. (-3 x et, y = 3 x et torachin. (-1 x et a = 1 x et a = 2 x et a =	_	olling		- ÷	THUSAIT.
Solution   Joint Sets.   (x-numeric, b-1 well, c-1 well transform of-2 were, a-2 work transform (-3 were, g-3 work transform in cruelled)				-	٦,
Crientation of main junit set (a - very feworable; b - favorable; c - fair, d - unfavorable; e - very unfavorable; in real class patients of main junit set (a - very feworable; b - favorable; c - fair, d - unfavorable; e - very unfavorable; in real class patients of main junit set (a - very feworable; b - favorable; c - fair, d - unfavorable; e - very unfavorable; in real class patients of patients in wall class patients of patients. (a - discontine; b - strongly undustring c - mode undured a - stockers stockers and particle patients of patients of patients of patients. (a - crockers b - patients of patients. (a - crockers b - patients of patient	_			- <sub>b</sub> -	15
In wall   C   S   It was pure set   S   S   It was pure set   S			Orientation of in real	- c	18
Joint undulation: (a historian; historiany undulating circled; disabletic or sanctist coating the algority stered; disabletic or sanctist coating the algority coating the algority stered; disabletic or sanctist coating the algority coating the algority stered; disabletic or sanctist coating the algority coating the algority coating the algority of			main juril set (a = very favourable; b = favourable; c = fair, d = unfavourable; e = very unfavourable) =	c	¹s
North   No filing:   (a = heared; b = fresh # no filing; c = slightly abered; d = absorbed o = sanc/sit coating; f = day cook.]				•	S
sethering   Filling	)2 1			С	្នំទ
weethering   Filling					_
14 Joint langth: (a = crack; b = parting; c = x, shot; (0.1 lm); d = shot; (1.1 m); e = medium (3.10m); f = long (15.00m); g = seam or shear)  15 Joint separation: (a = none; b = x,tight (40.1mm); c = tight (0.1 0.5mm); d = medium (3.10m); b = open (2.0 10mm); f = x, op					5
15 Joint separation:   (a = none; b = vitight (#0.1mm); c = tight (0.1.0.5mm); d = modepen (0.5.2.5mm); c = open (2.5.10mm); f = v. open   25     16 Interfacking or compactness of motioness structurer   (a = very tight; b = tight or compact; c = disturbed; d = poorly interfacked;   25     16 Ground water introvice from the vice from t				ь	*a
Forcumed water inflow to financial or careers (a divide damp, blives, c dispang, d pushing, c flowing, f flexibly flowing) S  Siness Hatel (Apost for Q and RM) (a - very low suess level, b - low stress, c - moderate / medium stress, d - high stress)  Over- Rock spetting or brushing (a - rock bust, p - flexy bust) import or stressing (appearing (b - moderate squeeze, i - flexy squeeze))  Type: (a - multiple zones; k - single zone (syum; 1 - single zone (c)um; m - multiple sheers; q - crushed)  Weathors:  Thickness or width of zone (m): (walld for 6 - 20m wide zones)  Total Alic (for intestion of contents)		-			*8
Siness level (Apost for Q and RM) (a - very twissess level, b - low stress, c - moderate / medium stress, d - high stress)  Coor- Rock spetting or brushing (a - moderate stabiling, f - nock burst, g - fleavy burst) input or stressing (a moderate squaeza, i - heavy squaeza)  Type (i - multiple zones; k - single zone (solin; i - single zone (com; m - multiple shears; g - crushed)  Weakness  Thickness or width of zone (m): (Apoid for 1 - 20m wide zones)  To cone (com) (primitation of com) (Apoid for 1 - 20m wide zones)	E I	nterlocking e	r compactness of makimass structure: (a = very tight; b = tight or compact; c = disturbed; d = poorly interlocked)		8
Over-   Rock spating or bursting   (a = moderate stabilities, f = nock burst, g = fleavy burst, f input or stressing   Squeezing   Squee	F (	Ground water	inflow to trimination careers —— (all dry or damp, bli wet, clidipping, dli gosling, clillowing, fill readly flowing)		's
strokeling (squeezing (h - moderate squeeze, i - heavy squeeze) SST  Type: (j = multiple zones; k = single zone (settin; h = single zone (settin; m = multiple sheers; q = crushed)  Weakiness  Zone  (tout   squaeze) (Orientation of in reef	11 :	iliexs level			
Weakness   Thickness or width of zone (m): (voild for 1 - 20m wide zones)   m	12		(Squeezing) (6 - moderate squeeze, i - heavy squeeze) SRC		5
2000   Indicendess or whath of zone (m): (wave for 1 - 2000 waste zones)  (south etc.)   Orientation of   in reef   3	1				
	12,	one			
in wall	٠,	Daniel, Cit. J	(a − very layourable, b − layourable, c − lan, d − unlayourable, e − very unlayourable)		** ***
MOTE: Swelling pock is not ineluded				l	74

Figure 1. Spread sheet for RMR, Q, RMi rock mass classification

rock type/ gov	922	J B awdwg	UIV northing	elearion	value BMR	IUE	with e.Q.		veine kini	1111	Bernario
14141	171	4000	4510000	7.8	60	E.i.	40.61	Very Small	1,01	E4	
Dr. Mills	1/2	969090	4510572	200	56	be	0.8	t an	23.5	Tal.	
tot sitte	1736	9000	4510.40	3.2	No.	Lan	11.96	Ched	1,0	Len	
141.44	1776	427777	4516040	7 6	<b>6</b> 3	F.ii	9,16	F.A.	1,72	E4	
Le Min	1756	913058	4510918	200	51	bas	6/8	t an	0,88	199	
ton sittle	125	9009	451040	37	M	Lan	6,10	Lan	197	Libra	
14.44	17%	4000	4510000	616	51	F.ii	95.77	South	9,72	E4	
Dr. Mills	1756	94.805	4510,888	202	51	be	18.25	Cond	2,23	Tal.	
tor site	1724	900	4510.86	3.5	34	Percent	2,6	15m	1,17	Very Free	BNI very provide to part effect on and seathering (lead city)
NAME OF TAXABLE	1794	40000	4516144	3.5	30	Perm	9,96	Per	0,00	Enterody Post	BM intends products for BOD and joint direction and academing (both log).
Dr. Mila	1776	91880	4510278	200	17	bas	12.55	Cood	1,89	74	
Distribution (Control of Control	1575	9310	4510451	3.0	11	Lan	1145	Ched	134	Len	
14.44	173.1	4000	4510164	3.5	50	F.ii	10.45	Soul	1/0	T4	
De alla	1195	91.876	4510184	202	50	bar	8,55	ter	1,18	74	
tot sitte	1736	90020	4510104	24	22	Lan	20.51	Ched	298	Len	
14.44	1736	220000	4510105	794	50	F.ii	17.40	Soul	2,17	Tá.	
Dr. Mila	276	90,0025	451373e		A	Coud	17.75	Cood	22,00	Cost	
(See state)	magri				21	Cond	15.41	Ched	1915	Lan	
nla					48		3,24		ryre		
IKKI					52.59		14 38		225		
18.2					24		23,61		22,00		
rotte end trubret					8,81		11.45		4/06		

use type	222	III M. contag	III Showthing	devidue	widos DMB	1991	within Q	12	Water Beer	III	H-marks
Continue	• •	441514	44000	4.11	25,00	Head	1.20	Photo:	11 21	Short	He prompted year ording the first multiple sustaines sound any depth (
Sancarre	742	440021	4500274	400	64,00	Cond	9.27	New Good	12.39	Cood	
Services	246	44/4/8	4:00:13	445	43.30	Page	111	No	9.35	Water Poper	the year pear que by according to Perfind out to foliation; this for gr
Spraggara	217	447612	4509020	467	60,00	Calc	195	Pere	2,04	7.00	see, that id ware decomposed day each pure secting
bandare	245	446511	4505/11	480	84.00	Good	10.45	Cod	0.0	100	RM Tabs due to Joint length (long) and Join, and children's born, ty and a wed)
No. day	-11	22/18	a anner	250	14,00	Hereit	33.	1-	1111	Stant	Charles per alministratival engent storing
nds					40.00		111		6.00		
					75,00		11,27		13,30		
TRACTION OF THE PARTY OF THE PA	-				75,00						
standard devotion					100		10,00		730		
SILTSTONE TYPES											
			J. Vinorting	elevation	value RMR	15/88	volue 0		Value Bret	IU	Herania
Sent dans (Mishae)	5.0		ANIMA	-44.0	41,00	1 400	5.01	1.6	0.0	Way Harry	The very pour quality arranging to \$Versione to good after about and west their
Sanah dan er Still dan er	924			242	51,00	Here	2.9%	Perm	1,02	-	Opening the destrict of the section of Jacks.
Sandalone Sitatora	200		4,400,00	403	49.00	3.0	2.23	Poor	108		Opport due to big number of joint retr Orandom
Sandranne Siterane Sandranne Siterane	3/2	447815	450002	471	\$7,00 44,00	Fair	770	Post	0/0	Par	way bearing at Auto Core region and
	"	11.00		"]	11,2	120					and the state of the state of
	H										
nia	1			' '	40.00		4,40		0,54		
1001					45,41		5.0		100		
					57,00		1000		1,32		
stanced covades					5.00		8.50		0.45		
CONGLOMERATES											
		urub.	UTN corting	learning 1	who RVR	DATE	when 0	0	Volum Brot	nu	Bernata
is the male	3.0				/2.00	Cood	55.00	Cod	11.00	Cond	HACKETA
Contractors	716			466	72.00	Good	7.00	Pere	19.00	Soci	U poer i due to multipole werk ness come at any depair (C
Didward:	- 60		4400		21.0	Month	121	- Paris	15.00	Stant	Committee to the control of the cont
in the make	215			124	73.00	Good	91.25	Coud	30.50	Cond	1,
Conformation	716		470700		73.00	Gend	31.25	Good	3.0	Sout	
					,-						
	L				71.10		LES		16.51		
							20,78		22.00		
THEN					71,00 74,00		0.70		20,00		

Figure 2. Resuling values from classification

rock-type (34 samples) Classification System	Ophiolith (18)	Conglomerate (	Sandstone (6)	siltstone (5)
RMR	ominantly lair, subordinate poorto good	dominantly good	dominantly good, secondary fair	dominantly fair
Q	dominantly good, secondary fair, subordinate poor	dominantly good, secondary poor	dominantly poor, secondary good, suordinate fair	dominantly poor, secondary fair, subordinate good
RMI	dominantly fair, secondary poor to very poor	dominantly good	dominantly good, secondary lair, subordinate very poor	dominantly fair to poor, subordinate very poor
synapsis	dominantly fair, subordinate poor / good	dominantly good, secondary poor	dominantly good, secondary fair, subordinate poor	dominantly fair to poor, subordinate good to very poor.

key to assign percentages	examples										
dominantly >50%	dominantly (stand alone)	dominantly/secondary dominantly/secondary- secondary	dominantly/subordinary dominantly from- to/subordinary	dominantly/secondary/ subordinate							
secondary < 50%	100%	60%/40%	20%/20%	50% / 30% / 10%							
subordinate < 20%		60% / 20% 20%	40% 40%/20%								

Figure 3 Classified Rock mass quality

#### **CONCLUSION**

After classifying a selected number outcrops which concern the Moglice- Grabove tunnel area the results are displayed in tables.

The use of three classification systems give a better check of the estimates made. Even if there are similarities between the three systems, the differences in their structures cause that the commonly used correlations between them can lead to errors.

As noticed from the results all the three systems work best in jointed rock in which the degree of jointing is the input parameter with the strongest influence on stability. This can be easily seen in the similar results of each classification in the jointed ophiolith rock.

Thus from a limited amount of input parameters (example in the siltstones), it is possible to find crude estimates of the RMR, Q and RMi values. Obviously, better and more accurate results will be found when the input values of all parameters are known and used.

There have turned up some difficulties when the input parameter of Jv, the volumetric joint count is estimated from the formula. These difficulties are caused from inaccuracy in the measurement and limits of the formula.

$$J_{V} = \sum \left(\frac{1}{S_{i}}\right) \frac{N_{V}}{5} \quad (6)$$

Where  $S_i$  is the joint spacing in meters for the actual joint set  $N_v$  is the number of random joints in the observed area.

There may be difficulties too when the block size is estimated from RQD because of limits to characterize massive rock and highly jointed rock.

Another limit is that they do not work well for many faults and weak zones.

#### REFERENCES

- [1] Geotechnical Study and Classification of Rock Mass in Devolli Valley for Engineering Purposes: Headrace Tunnel Moglice Gramsh. Megi Rusi ,Master thesis, Universiteti Politeknik i Tiranes, 2010
- [2] Rock Engineering, Hoek, Chapter 3- Rock mass classification
- [3] Comparing the RMR, Q, RMi classification systems. Part 1: Combining the input parameters of the three systems by Arild Palmström, PhD.
- [4] RMi- Rock mass characterisation system for rock engineering purposes. Arild Palmström, PhD thesiss Oslo University, Norway 1995
- [5] http://www.rockmass.net
- [6] <a href="http://www.herrenknecht.com">http://www.herrenknecht.com</a>