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Estimating Rock Mass Parameters in Block and Matrix Rocks in Devoll Valley

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Abstract: ***Devoll Hydropower Project in Albania consists of 3 power plants stretching from the village of Maliq to Banja. For the construction of Moglice hydropower, which is the upstream plant of the cascade, a 11 km headrace tunnel is planed from Moglice dam to Grabove underground powerhouse. Approximately 700-800 m of the tunnel will cross through heterogeneous rock masses consisting of different lithology blocks embedded in a fine grained sheared matrix. Estimating the rock mass parameters of this section for tunnelling purposes has been challenging and different methods of classification have been used. The paper at hand will describe the estimation of strength and deformability parameters of the rock mass through the usage of Hoek and Brown Criteria and RocLab software. A comparison will be made with the laboratory tests results to evaluate the effectiveness of the method.***

Keywords: strength, deformability, GSI, UCS, m_i constant.

1. Introduction

The classification of heterogeneous rock masses has always been challenging for geotechnical engineers. It has always been difficult to estimate the overall behavior of this rock types although the information gathered for the single components of the rock mass may be broad. In this case the rock mass characteristics have been estimated by the usage of Hoek and Brown Criteria identified in 1997, and adjusted for the heterogeneous characteristics of the Rocks [1]. Three main input parameters have to be identified in the field for calculating the rock mass behavior. These parameters are:

- Uniaxial Compressive Strength (USC) σ_{ci}
- The m_i constant for the friction character of minerals comprising the rock
- Geological Strength Index GSI

A new set of relation have been identified between GSI, m_b, s and a, related to the above mentioned input parameters [2]. Than newly introduced equations for calculating C and ϕ have been used. All these calculations have been facilitated by RocLab program.

2. Methodology

This section describes the methods used for determining the input parameters and calculating the overall rock mass behavior.

2.1 Uniaxial Compressive Strength of intact rocks

UCS values can be determined through laboratory test performed in intact rock samples although for heterogeneous rock masses intact samples are difficult to be collected in the surface. Several undisturbed samples taken from geological drillings have been tested but not the entire area is covered with drillings so the simple field tests for estimating UCS has been used with grades ranging from R0 to R6 for extremely week to extremely strong rocks. From the data gathered in the field it results that block within the block and matrix rock mass vary from R3 medium strong to R5 very strong.

2.2 m_i constant

The mi constant can be estimated in laboratory from the triaxial test on rock samples, and in the field by a qualitative description as described from Hoek and Brown [3].

Rock type	Class	Group	Texture			
			Coarse	Medium	Fine	Very fine
IGNEOUS	Plutonic	Light	Granite 32 ± 3; Granodiorite (29 ± 3)	Diorite 25 ± 5		
		Dark	Gabbro 27 ± 3; Norite 20 ± 5	Dolerite (16 ± 5)		
	Hypabyssal		Porphyries (20 ± 5)		Diabase (15 ± 5)	Peridotite (25 ± 5)
	Volcanic	Lava		Rhyolite (25 ± 5); Andesite 25 ± 5	Dacite (25 ± 3); Basalt (25 ± 5)	
		Pyroclastic	Agglomerate (19 ± 3)	Volcanic breccia (19 ± 5)	Tuff (13 ± 5)	

Figure 1: mi constant values for igneous rocks [1]

The values for each material depend on the grain size, and crystalline structure. High values of the constant are related to high values of friction and interlocking. Mi has been estimated for all the rock types encountered in the studied area.

2.3 Geological Strength Index

The GSI value is determined based on the GSI chart for peridotites and related rocks. Area 1 of the chart includes massive peridotites with high strength and widely jointed. Joints are week and filled with serpentine. Area 2 includes poor to good peridoties or serpentine with highly alerted joints. Area 3 includes sheared and alerted serpentine. Area 4 includes highly sheared serpentine with week properties and soft fragments. The studied area can be seen to belong to area 4 with GSI values ranging from 10-20, but individual fragments can have higher value as well.

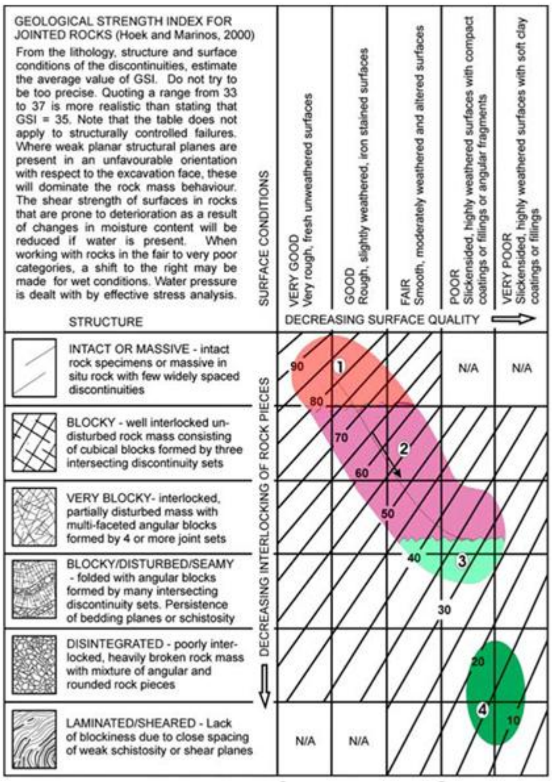

Figure 2: GSI values for peridotites and related rocks [4],[5]

3. Determination of the Input Parameters

Referring to the lithology and geological characteristics of the rock type encountered in the alignment of Moglice-Grabove tunnel, 4 groups of rock types have been identified. The mollasic sediments, flysch rock masses, ophiolite rock mass and the mélange zone with heterogeneous characteristics which is the main objective of this paper and for engineering purposes is named the block and matrix zone. Approximately 700-800m of the tunnel will cut through this rock types, and for studding purposes this stretch is divided into 5 sections and the input parameters have been determined for each rock type identified in the section. Parameters have been identified in the field with the help of Marinos and Hoek tables for UCS, mi and GSI for rocks related to peridotite [4].

3.1 Section 1 of Block and Matrix Rocks

Section 1 of the Block and Matrix zone is approximately 100m long and is expected to cross sandstone, siltstone and sheared clay layers. The boundaries of this section are not well defined but due to the heterogeneous character of the rock mass with competent layers and shared layers it has been included in the Block and Matrix zone. The parameters determined for this section are summarized in table 1.

Table 1: Input parameters identified in the ield for section1

Lithology	UCS (Mpa)	GSI	mi constant
Siltstone/Sheared Clay	5-25	15-50	7±2
Sandstone	20-40	15-50	6.8±4

3.2 Section 2 of Block and Matrix Rocks

Section 2 of the Block and Matrix zone is approximately 40m long and is expected to cut mostly through clay stone and siltstone shale, with lenticular competent bodies of sandstone. The parameters determined for this section are summarized in table 2.

Table 2: Input parameters identified in the field for section 2

Lithology	UCS (Mpa)	GSI	mi constant
Siltstone- Claystone shale	25-50	15-30	7±2
Sandstone	20-40	15-30	6.8±4

3.3 Section 3 of Block and Matrix Rocks

This section is 280m long and is comprised by the tectonics conglobreccia which is in contact with Devoll ophiolitic massive. This rock type is considered to be the true tectonic mélange. Ophiolitic rock sequences are chaotically mixed with other rock types which represent lenticular bodies of limestone, sandstone, breccia etc. The transition between this sheared bodies and the surrounding intact rock is unpredictable and sudden.

Table 3: Input parameters identified in the field for section 3

Lithology	UCS (Mpa)	GSI	mi constant
Ophiolitic Clasts	100-250	10-25	25±5
Matrix	1-25	10-25	8±2
Limestone lenses	50-100	50-80	8±2
Sandstone layers	50-100	25-50	8±2
Volcanic Breccia	50-100	25-50	8±2

3.4 Section 4 of Block and Matrix Rocks

Section 4 is approximately 200m long and lies mostly in intensively sheared serpentines which are part of the Ophiolitic massive of Devoll and the contact with the ophiolitic mélange. The parameters identified for this section are summarized below.

Table 4: Input parameters identified in the field for section 4

Lithology	UCS (Mpa)	GSI	mi constant
Serpentine/Lhercholite	40-45	25-40	25±5
Shisto Serpentine	30-35	25-40	12±2
sheared Serpnentine	1-25	20-Oct	8±2

4. Estimating Rock Mass Parameters with RocLab

The rock mass strength parameters have been determined by the use of RocLab software program based on Hoek and Brown failure criterion. The Hoek and Brown classification parameters identified on site for the different rock types serve as the input data for the program to determine the strength parameters which are m_b, s and a.

Hoek, Carranza-Torres and Corkum, 2002	A new set of relationships between GSI, m_b, s and a is introduced to give a smoother transition between very poor quality rock masses (GSI < 25) and stronger rocks. A disturbance factor D to account for stress relaxation and blast damage is also introduced. Equations for the calculation of Mohr Coulomb parameters c and ϕ are introduced for specific ranges of the confining stress σ'_{3max} for tunnels and slopes. All of these equations are incorporated into the Windows program RocLab that can be downloaded from the Internet site www.rocscience.com. A copy of the full paper is included with the download.	$\sigma'_1 = \sigma'_3 + \sigma_{ci}\left(m_b \sigma'_3/\sigma_{ci} + s\right)^a$ $m_b = m_i \exp\left(GSI - 100/28 - 14D\right)$ $s = \exp\left(GSI - 100/9 - 3D\right)$ $a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right)$ $E_m(GPa) = \left(1 - \frac{D}{2}\right)\sqrt{\frac{\sigma_{ci}}{100}} \cdot 10^{((GSI-10)/40)}$ $\phi' = \sin^{-1}\left[\frac{6am_b(s + m_b\sigma'_{3n})^{a-1}}{2(1+a)(2+a) + 6am_b(s + m_b\sigma'_{3n})^{a-1}}\right]$ $c' = \frac{\sigma_{ci}\left[(1+2a)s + (1-a)m_b\sigma'_{3n}\right](s + m_b\sigma'_{3n})^{a-1}}{(1+a)(2+a)\sqrt{1 + \left(6am_b(s + m_b\sigma'_{3n})^{a-1}\right)/((1+a)(2+a))}}$ where, for tunnels $\frac{\sigma'_{3max}}{\sigma'_{cm}} = 0.47\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.94}$ - H is the depth below surface for slopes $\frac{\sigma'_{3max}}{\sigma'_{cm}} = 0.72\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.91}$ - H is the slope height γ is the unit weight of the rock mass

Figure 3: Equations for determining the Hoek and Brown strength parameters [2]

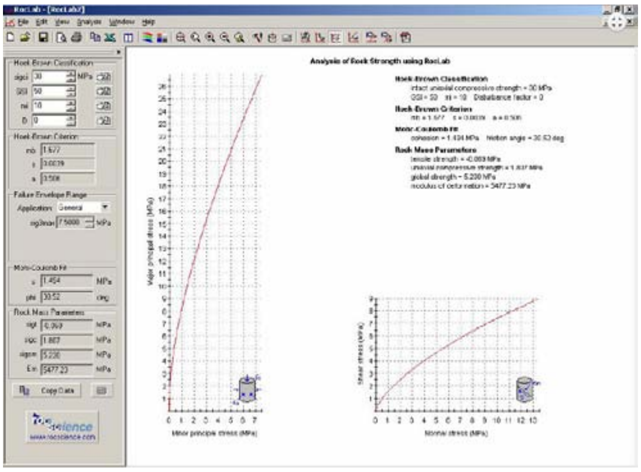

Figure 4: RocLab Working Window

In addition to the failure criterion parameters, RocLab calculates the Mohr- Coluomb fit parameters including cohesion and friction angle for the rock mass as well as tensile strength, uniaxial compressive strength, global strength and modulus of deformation.

5. Results and interpretations

The calculated parameters for all the encountered rock types are summarized in the table below. The laboratory test performed for determining these parameters show similar result with the parameters calculated with RocLab with only few slight differences. This indicates that this method is very useful for cases where drilling is not possible either due to difficult access and topography or lack of investments in a certain stage of the project or study.

Table 5: Output Parameters Calculated with RocLab

S. No	Lithology	%	mb	s	a	c	phi	sigt	sigc	sig g	E
1	Siltstone	40	0.558	4.00E-04	0.522	0.917	21.6	0.023	0.516	2.698	1732.1
	Claystone	60	0.336	0.0001	0.561	0.101	17.19	0.001	0.025	0.275	298.18
2	Sandstone	40	0.391	0.0001	0.511	0.711	18.61	0.011	0.239	1.979	974
	Claystone	60	0.155	2.33E-05	0.544	0.238	12.77	0.002	0.045	0.597	516.54
3	Ophiolitic Clasts		1.201	0.0001	0.561	5.094	27.49	0.01	0.749	16.786	1333.5
	Matrix	30	0.14	1.20E-05	0.561	0.218	11.77	0.001	0.028	0.536	400.06
	Limestone lenses		3.438	0.0205	0.502	4.693	36.5	0.417	9.938	18.624	19840
	Sandstone layes		1.792	9.00E-04	0.514	3.363	31.15	0.036	1.917	11.922	3958.7
	Volcanic breccia		2.003	0.0009	0.514	3.488	32.11	0.032	1.917	12.614	3958.7
4	Serpentine /Lhercolit	40	0.981	1.00E-04	0.52	1.512	26.08	0.005	0.36	4.846	1683
	Shisto Serpentine	10	0.374	0.0001	0.52	0.789	18.79	0.006	0.222	2.204	1360.4
	Serpentine sheared	50	0.105	7.46E-06	0.561	0.142	10.31	0.001	0.016	0.341	323.36

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Author Profile

Megi Rusi received the B.Sc. in Earth Sciences (2008) and M.Sc. degree in Engineering Geology and Hydrogeology (2010) from the Polytechnic University of Tirana, Faculty of Geology and Mining. In 2011 was accepted as a PhD candidate in Geosciences, Nnatural resources and Environment at the same faculty. During 2009-2015 she worked for the feasibility study and construction phase of Devoll Hydropower and Energji Ashta Hydropower Albania. From 2015 she is engaged as a lecturer of Applied Geology and Geotechnics at the Faculty of Civil Engineering, Metropolitan Univerity of Tirana, dedicated the scientific research office of the university as well.