ERMR System – an Useful Tool In Defining of Technology for Excavation

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Research paper

THIS ARTICLE PRESENTS THE BASIS OF CLASSIFICATION SYSTEM NAMED AS EXCAVATION ROCK MASS RATING SYSTEM (ERMR). The purpose for system development comes from the fact that in all civil engineering or minning projects, one of the key problems is to addopt technology of excavation on the characterisstics of natural environment, and to chosse and adequate equipement for excavation.

Methodology for establishing of ERMR system is based on ranking and scoring of carefuly choosen classification parameters. The parameters for classification and the range of parameters in each class is explained briefly. The system is correlated with some known rating rock mass systems.

The classification is developed on the bases of numerous investigations for different civil engineering and mining projects, as well as laboratory testings of rock mass parameters. The case histories used in developing of the ERMR system are noted. For each rock mass class, an adequate technology of excavation is suggested, and the excavation classes are corelated with unit price of excavation in different media.

The practical aplication of ERMR system is undelined.

Keywords

classification, excavation, technology of excavation, rock masses, parameters

INTRODUCTION

Predicting the ease of excavation of rock and rock masses is very significant for defining of technology and organisation of earthworks for civil engineering works and in surface mines.

On this important scientific and practical field, several authors gave effort to establish acceptable methodologies for practical use (Franklin et al., 1971), (Atkinson, 1971), (Weaver, 1975), (Kirsten, 1982), (Abdullatif and Cruden, 1983), (Scoble and Muftuoglu, 1984), (Pettifer and Fookes, 1994), (McLean and Gribble, 1985), (Singh et al., 1987), (Church, 1981) and another's. The reference that gives whole overview on this aspect is given by Tsiambaos and Saroglou (2009)

In the present article, the term excavatability is used to determine the ease of excavation of rock and rock masses that includes the methods of digging, ripping and blasting.

In general, methods used for the assessment of excavatability of rock masses take into account the uniaxial compressive strength, weathering degree, spacing of discontinuities, hardness, seismic velocity, continuity, aperture, orientation and roughness of joints etc. Any how, no particular method is universally accepted because of complex nature of rock masses and difficulties in determining of input parameters.

Having this in mind, a classification system called ERMR (Excavation Rock Mass Rating) is presented. It refers to all types of rock masses (non-coherent and coferent soils as well as weak and hard rocks).

The classification is developed on the bases of numerous investigations for different structures, in order to create prerequisites for over passing of current situation in world practice, where classifying of rock mass for excavation is insufficiently developed.

Principles of formation of the ermr system

The system is based on scoring, where the selection of parameters is done respecting the next principles:

- Input parameters can be obtained with quick and relatively simple tests;
- The parameters should be relevant for the properties of the rock masses;
- The same property should not be taken into the evaluation two or more times.

During selection of input parameters, it was taken in care all of them to be enough representative for the characteristics of the massive and intact rock parts.

As characteristics of the intact rock the next parameters can be considered:

- Uniaxial compresive strength **(σc)** or Point Load Strentgh index **(Js)** alternatively;
- Unit weight (γ) ;
- Hardness, which can be qualitatively expressed trough the Moss scale relative hardness (M) and quantitatively with value of Schmith Hammer Rebound Value (SHRV), using correlation SHRV=8.72M-0.04.

Characteristics of rock massif are presented with the next parameters:

- Degree of fracturing using average fracture spacing (**Ls)** or as alternative with rock quality designation parameter (**RQD)**
- Condition of fracture walls (continuity, aperture, roughness, infill material etc).

The effects of the orientation of discontinuities can be important for metamorphic rock masses and sedimentary flysch sediments, where the anisotropy is strongly expressed.

As an example, it is well known that most favourable conditions for ripping are if the direction of pushing of the bulldozer is perpendicular to the foliation and when the foliation itself has a steep dip angle. These dilemmas can be solved if we apply measurements and testing in this manner:

- Testing of anisotropy for intact rock parts;
- Defining of anisotropy of fracturing;
- Defining of the optimal orientation of excavation, and scoring of strength and fracturing in relation to possible direction of excavation.

Database of input parameters that served for the development of ERMR system and applied excavation method for analysed cases is given in Table 1.

No	Structure	Rock type	Fractu-re spacingLs (cm)	RQD (%)	Unit weight γ (KN/m ³)	Compressive strength (σc*) or Point Load strength index Js** (MPa)	Hardness (Moss scale)	Applied excavation method
1	Surface coal mine Suvodol (SCMS)	Silt stone (trepel)	10	22	Average 15	0.155-1.2*	1-1.5	Rotary dredger
2	SCMS	Siltstone (trepel)	200	100	Average 15	0.155-1.2*	1-1.5	Rotary dredger
3	SCMS	Coal	20	50-75	Average 12	3-6*	1-1.5	Rotary dredger
4	(SCMS)	Coal	200	100	Average 12	3-6*	1-1.5	Rotary dredger
5	Railway Kumanovo-Deve Bair (RKD)	Tuff	massive 200 cm	100	20.8-22	3.21-4.1*	2	Digging
6	RKD	Altered andesite	4- 6	0-25	23	42-52*	5-5.5	Digging
7	Quarry on dam „Kalica“	Altered diabase	6 -10	0-25	26	Assumption 50*	5.5	Ripping
8	Quarry for dam „Bargala“	Granite	10 - 35	50-60	25.4	133-239 (average 178)*	6-6.5	Blasting
9	Quarry for dam „Kozjak“	Marbleized limestone	45	60-82	27.4-28.4	75-87* (min 40 max 137)	3-3.5	Blasting
10	Tunnel 9 RKD	Albite-epidote-muskovite schist	10-30	55-60	26	Assumption 2-4**	4-5	Blasting
11	Tunnel 10 RKD	same	20-100	41-100	26	same**	4-5	Blasting
12	Quarry for dam, Oraovichka river:	Amphiboli-te	10-50	45-72	26.63-27	88-149*	5-6	Blasting
13	Dam “Studen-chica“	Phillitoides	3-5	0-10	23-24	Assumption around 2 Mpa*	2-2.5	Digging
14	Bridge Dlabochica (RKD)	Albite-sericite schist (Sab)	2-4	0-10	25.6	1-2.1**	3-4	Digging
15	Bridge Chankinci (RKD)	Sab	10-15	55-60	26.8	2-4**	4-4.5	Blasting
16	Dirferent zone for magistral road M-5	Micaschist	3.3	0-10	26	same**	2-3	Digging
17	Zone for M-5	Micaschist	6-8	10-21	25.8	same**	2-3	Ripping
18	Zone for M-5	Micaschist	10-12	25-30	25	1.79-2.51	2-3	Blasting
19	Cut for bridge from RKD km 46+950	tuffs	massive 1.5 m	80-90	23.06-23.62	8-17*	3-3.5	Combined Ripping - Blasting
20	Bridge at 48+803 RKD	Andesite tuff	15-20	52	20.15-22.05	9.5-16*	4-4.5	Blasting
21	RKD 49+540	Andesite	16-20	54	24.1-25.8	55*	5-5.5	Blasting
22	RKD	Sab	18-25	64-77	25.8-27.3	23-25*	4-4.5	Blasting
23	Highway Skopje-Tetovo	Marl to marlstones	10-15	45-50	21.47 -21.54	0.32-0.52**	2	Digging
24	Same	Marly sandstones	10-15	49	20.64-22.2	0.43-0.48**	2.5	Digging
25	Quarry „Micro-granulate“	Limestone	5-8	30-45	27.2	(average=74 MPa*)	3	Ripping
26	Surface mine for copper „Buchim“ SMCB	Andesite	20-50	82	27.03	7.68**	5-6	Blasting
27	SMCB	Gneiss	10-30	60	25.42	3.17-4.992**	5.5-6	Blasting
28	SMCB	Gneiss with ore	30-50	59	30.47	4.52-8.9**	6	Blasting
29	Access road to dam „Lojane“	Altered granodiorites	10-20	11-39	26.32	1.793-3.992**	5.5-6	Ripping
30	Quarry „Rajchica“-R	Carbonate breccia	6-10	0-10	22.3	10-14*	1.5	Digging - Ripping
31	R	Sandstone	4-6	25-30	24.3	39-46*	4	Ripping
32	R	Limestone	200-600	75-90	26.2	68-92*	3	Blasting
33	Cut on RKD	Sab	60-100	25-50	25.8	1-2.1**	3-4	Ripping
34	Zones along crude oil pipeline Solun-Skopje (OPSS)	Marlstones	40-60	25-50	22.2-24	5-18*	2	Digging - Ripping
35	OPSS	Sandstones	80-150	75-90	23.2-25.2	25-44*	3.5-4	Ripping
36	OPSS	Altered diabasses	20-40	<25	25.4-26	5-13*	4	Digging - Ripping
37	OPSS	Partially altered diabasses	8-10	45-60	25.6-26.2	45-60*	6	Ripping

Note: *-data for compressive strength (σc), **-data for Strength index (Js)

Table 1 **Database for classification, with data for applied excavation method**

Parameter	Class						
	I	II	III	IV	V	VI	VII
1.Compressive strength (σc)	Non-coherent soils	<1	1-5	5-10	10-30	30-70	>70
Point load strength index Is (MPa) (*)		<0.1	0.1-0.7	0.7-1.2	1.2 - 2	2.5-4	>4
Rating	0	3	5	8	10	12	20
2.Hardness according the Moss scale	Soil materials	1-1.5	1.5-2	2-3	3-5	5-6	>6
Value of SHRV	(SHRV<10)	10-13	13-17	17-26	26-35	35-50	>50
Rating	1	3	5	8	10	15	20
3.Unit weight γ (kN/m^3)	12-15	15-18	18-22	22-24	24-27	27-30	>30
Points	3	4	6	8	12	15	20
4.Joint spacing **Ls** (cm)	Non-coherent soils (**)	<2	2-6	6-10	10-30	30-200	>200
RQD(%)	0	0-10	10-25	25-50	50-75	75-90	90-100
Rating	0	4	8	13	16	18	25
5.Condition of fractures (***) (****)	Non-coherent soils	**1.**Smooth **2.**Continual **3.** Aperture > 10 mm, **4.**Soft infill (thickness >10 mm)	**1.** Smooth **2.** Continual **3.** Aperture 5-10 mm, **4.**Soft infill (thickness 5-10 mm)	**1.**Medium rough **2.** Continual **3.** Aperture <1-2 mm, **4.**Very altered walls	**1.**Rough **2.** Continual **3.**Aperture <1mm, **4.**Very altered walls	**1.**Rough **2.** Continual **3.** Aperture <1mm, **4.**Weakly altered walls	**1.**Very rough **2.**Discontin. **3.**Without aperture (tight) **4.**Unaltered walls
	type 1	type 2	type 3	type 4	type 5	type 6	type 7
Rating	0	1	2	4	7	8	15
Total rating as a score of individual ratings (ERMR)	**<10**	**10-25**	**26-40**	**41-50**	**51-60**	**61-80**	**81-100**
Possible method of excavation	Easy digging	Usual conditions for digging	Very hard digging, easy ripping	Ripping	Ripping-blast nto loesen	Blasting	Extremely hard conditions for blasting

Table 2: **Parameters and range of values in ERMR classification system**

The used parameters in classification procedure, range of values and ratings for each class is shown in table 2.

(*) Gradation of the strength of intact parts is partially changed after Weaver 1975,

(**) For non-coherent soils (coarse grained sediments), where the excavation is difficult because of possible presence of large boulders, some otrer classification system can be applied that can be used simmilar as for loading of blasted rock material.

(***)The condition of fractures can be defined as combination of more characteristics, as continuity, type of infill, roughness or aperture, and for mathematical calculation a given class is defined as type 1 to type 7, for which arbitrated value from 1 to 7 is assigned.

(****) The description is partially modified in relation to Bienawski's 1989 classification

In order to perceive the degree of correlation of the ERMR classification with other systems, in this paper two examples are given:

- Correlation ERMR=f (RMR)
- Correlation ERMR=f (Vp)

Where:

RMR - Rock Mass Rating system according Bieniawski

Vp -value for longitudinal seismic waves

Straight line regression model with high correlation coefficient (r) is presented on Figures 1 and 2.

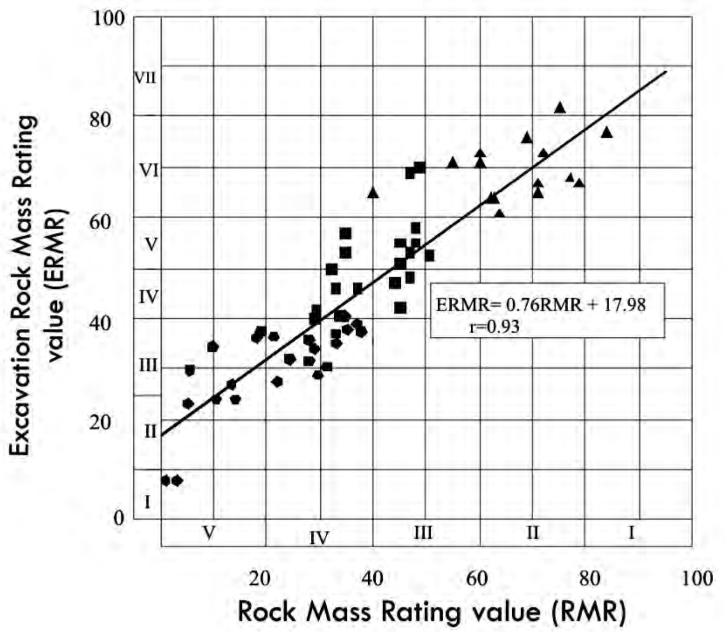

Figure 1. Correlation between ERMR and RMR systems

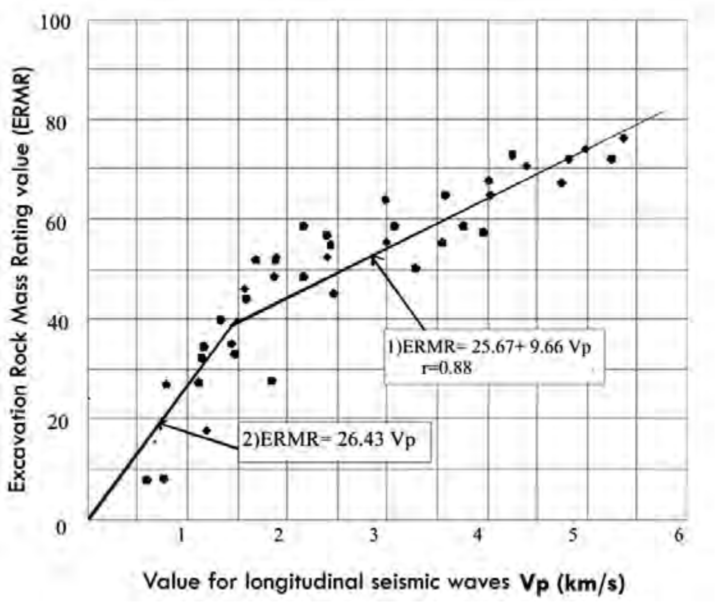

Figure 2. Correlation between ERMR an value of elastic longitudinal seismic Vp-waves

As special cases at classification of rock masses the next ones can be numbered:

- For coarse grained non-coherent rock masses classification with large boulders, depending on the conditions, the boulders can be moved away, or secondary blasted (the payment is defined separately).
- For weak claylike rocks without visible joints, for average distance and condition of fractures a value of points=0 is adopted.
- In certain cases, selection of excavation method depends on the available mechanization, so classes III and IV should be treated as interclass (example, if we have a bulldozer type D9 or D9G, the media will be excavated with hard ripping, and in opposite we will apply blasting procedure).
- In certain cases, selection of excavation method depends on the morphology of the terrain and the type of structure (example, ripping is rarely used in tunnelling, in difficult morphological conditions and tight excavation, as excavation for bridge foundations and concrete dams, even if the characteristics of the media allow it).
- In certain cases, where on short distances different characteristics of the rock mass change very often, combined way of excavation can be used
- In cases where conditions for blasting are extremely hard, where the specific consumption of explosives is increased and where closely spaced blast holes are needed, special cases for payment shall be agreed.

From all given examples, it is obvious that for every specific problem valuing of other external factors is needed, which can affect choice of method of excavation, and which are not included in the criteria of the classification itself. Also, it is desirable to make comparisons of the classification with some of the other systems, in other word their correlation.

Practical application of ERMR System

The proposed classification method can be used at a first place to choose adequate technology of excavation. It can be noted that blasting is required when ERMR values are higher than ERMR=60. Successful ripping is generally achieved for rock masses with ERMR values between ERMR=40-60. However, sometimes, alternative of ripping and blasting are possible, and some time using of excavation with hydraulic breakers or secondary blasting can be necessary.

For example, the data form Figure 2,

indicates that two general zones on the diagram can be divided. Curve 2 is for cases where the media shall be excavated with digging, while the curve 1 covers the cases of ripping and blasting.

Connected with ERMR value, the recommendations for excavation equipment is given in Table 3.

The diagram gives a range of values as a lower and upper envelope. It is clear that this can be only method for fast prognosis for cost of excavation, while the tendering price or real price of excavation shall be prepared according to market and field conditions.

recommended that the system should have primary importance for phases of designing before level of Main Design. Having in mind that the empirical methods are based on certain level of experience, it shall be a subject to critical reviewing in time, and should be used in combination with other methods.

ERMR value	<10	10-25	26-40	41-50	51-60
Possible mechanization	Excavator type RH5 (*)	Excavator Type RH8	Excavator RH9 or buldzoer D7	Buldozer type D8/D7	Buldozer type D9/D9G

Table 3: ERMR value and suggested excavation equipement

(*) Note- It is possible that some types of machines recommended in Table 3 are no longer manufactured, so similar machines for excavation for the named classes can be used.

From practical point of view, it is also important to establish some kind of connection between costs for excavation and rock mass class. Based on experiences and tendering data from several projects, one correlation is established between ERMR value with unit price for excavation per meter cubic (Figure 3).

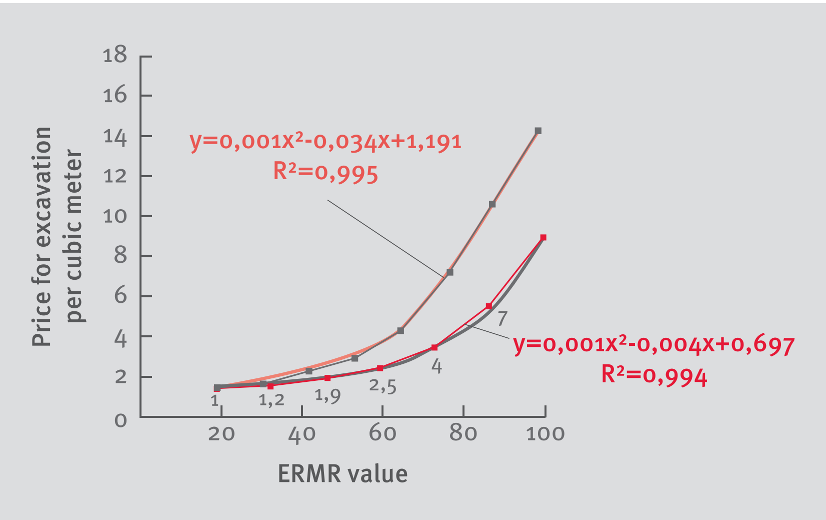

Figure 3. Prediction of unit price per meter cubic using ERMR value

Conclusions

Based on numerous investigations for specific structures Excavation Rock Mass Rating classification system is developed. All rock masses are divided in seven basic classes, where for each one of them recommendations are given for possible method of excavation, mechanisation etc.

The system well correlates with other classification systems (RMR value, as well as with the speed of longitudinal seismic Vp-waves propagation). In order to proper apply the current and suggested methods in the paper, it is

Any how, it can help a lot in defining of technology of excavation, selection of excavation equipotent and cost of excavation.

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