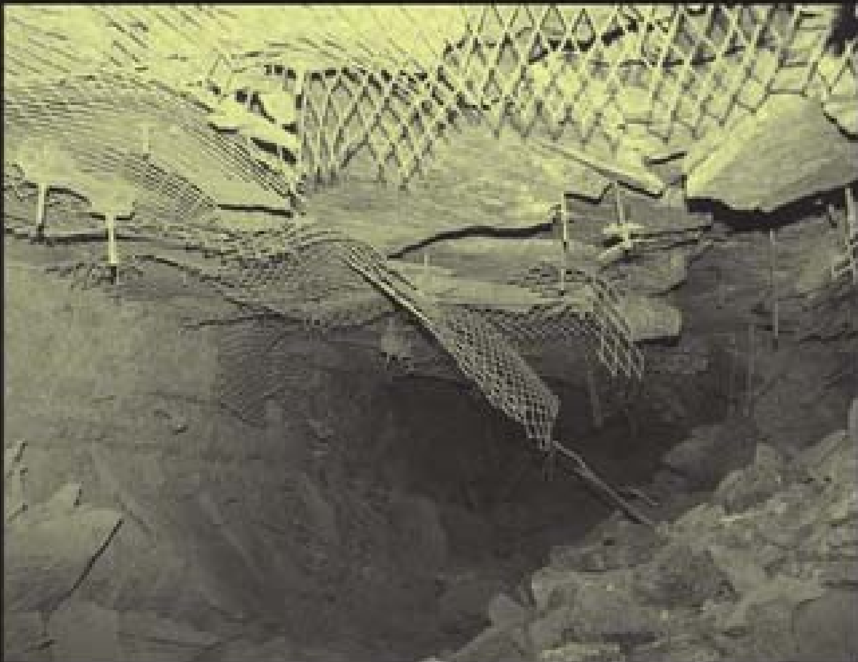
ERMR system and correlations with known rock mass rating systems, Rock Mechanics for Resources Published by T....

Milorad Jovanovski
Ss. Cyril and Methodius University

EUROCK 2013



Rock Mechanics for Resources, Energy and Environment

MAREK KWAŚNIEWSKI
DARIUSZ ŁYDŻBA
EDITORS

CRC Press
Taylor & Francis Group
A BALKEMA BOOK

Rock Mechanics for Resources, Energy and Environment – Kwaśniewski & Łydżba (eds)
© 2013 Taylor & Francis Group, London, ISBN 978-1-138-00080-3

Committees

EUROCK STEERING COMMITTEE

Giovanni Barla
Claus Erichsen
Dominique Fourmaintraux
Nuno F. Grossmann
John A. Hudson
Marc Panet
Frédéric Pellet, Chairman
Manuel Romana
Pekka Särkkä
Wulf Schubert
Luís Sousa
Ove Stephansson
Ivan Vrkljan
Walter Wittke

ADVISORY COMMITTEE

Xia-Ting Feng, President of the ISRM
John A. Hudson, Immediate Past President of the ISRM
Frédéric Pellet, Vice-President of the ISRM for Europe
Nuno F. Grossmann, Immediate Past Vice-President of the ISRM for Europe
Ivan Vrkljan, Vice-President of the ISRM at Large
Luís Lamas, Secretary General of the ISRM

Wulf Schubert	Austria
Jean-Pierre Tshibangu	Belgium
Sabid Zekan	Bosnia and Herzegovina
Predrag Miščević	Croatia
Petr Koniček	Czech Republic
Erik Johansson	Finland
Jian-Fu Shao	France
Claus Erichsen	Germany
Alexandros Sofianos	Greece
Giovanni Barla	Italy
Dominique J.M. Ngan-Tillard	The Netherlands
Charlie Chunlin Li	Norway
Carlos Dinis da Gama	Portugal
Erast Gaziev	Russia
Milan Tričković	Serbia
Claudio Olalla	Spain
Håkan Stille	Sweden
Jian Zhao	Switzerland
Reşat Ulusay	Turkey
Robert Zimmerman	United Kingdom

ORGANIZING COMMITTEE

Irena Bagińska	Wrocław University of Technology, Wrocław
Marek Cała	AGH University of Science and Technology, Cracow

2. *Laboratory and in-situ testing*

Rock Mechanics for Resources, Energy and Environment – Kwaśniewski & Łydżba (eds)

ERMR system and correlations with known rock mass rating systems

M. Jovanovski & I. Peshevski
Faculty of Civil Engineering, University "Sts Cyril and Methodius" Skopje, R. Macedonia

ABSTRACT: Excavation Rock Mass Rating (ERMR) system is developed on the basis of numerous investigations for different civil engineering and mining projects in R. Macedonia. In this system, all Rock Masses are divided in seven classes. For each class, an adequate technology of excavation is suggested. Beside other analyses, the correlation of ERMR with known rock mass systems is given in order to have data for parallel use in solving of different practical problems. Notes about possible practical application of the system are analyzed and results presented in short. It can be underlined, that the ERMR system is more adequate for assessment of type of excavation technology for soft and hard rock, while for coarse grained sedimentary rocks, somewhat modified classification can be used.

1 INTRODUCTION

One of the main problems in rock engineering is to predict ease of excavation of rock masses in an appropriate manner. This is very significant in earthworks for civil engineering works and in surface mines because of the quantity of excavation masses. In fact, this is one of the key problems in organization and technology of excavation, prediction of costs and safety aspects.

Several authors give effort to establish acceptable methodologies for practical use in this important scientific and practical field, as: Franklin et al. (1971), Weaver (1975), Kirsten (1982), Abdullatif & Cruden (1983), Pettifer & Fookes (1994), Singh et al. (1987), Jovanovski (2001), Tsiambaos & Saroglou (2010).

In general, in all classifications, main parameters for assessment of excavatability are uniaxial compressive strength, weathering degree, spacing of discontinuities, hardness, seismic velocity, continuity, aperture, orientation and roughness of joints etc. Anyhow, no particular method is universally accepted because of the complex nature of the rock masses and difficulties in determination of the input parameters.

Having this in mind, a classification system called ERMR (Excavation Rock Mass Rating) is presented.

The classification is developed on the bases of numerous investigations for different structures, with a main idea to have possibility to determine easy of excavation for non-coherent and coherent soils, weak and hard rock masses in one method (Jovanovski 2001).

Beside the analyses, several correlations of ERMR with known rock mass systems are given in order to have basis for parallel usage of the system for different practical problems.

2 BASICS OF ERMR SYSTEM

The system is based on scoring, where the selection of classification parameters is done respecting principles that input parameters shall be obtained with quick and relatively simple tests, they should be relevant for the properties of the rock masses and that same property should not be taken into the evaluation twice or more times (Bieniawski 1974).

Input parameters are related and representative for the characteristics of the rock massif from one and intact rock parts from the other side.

As characteristics of the intact rock the uniaxial compressive strength (σc) or point load strength (Js) alternatively, bulk density (γ) and hardness are considered. Hardness, can be qualitatively expressed trough the Moss scale relative hardness (M) and quantitatively with value of Schmidt Hammer Rebound Value (SHRV). The correlation is defined with following equation after Jovanovski (2001):

$$SHRV = 8.72M - 0.04 \quad (1)$$

where SHRV = Schmidt Hammer Rebound Value; and M = hardness after Moss scale of relative hardness.

Characteristics of rock massif are presented with average joint spacing (Ls) or as alternative with rock quality designation parameter (RQD), condition of fracture walls (continuity, aperture, roughness, infill material etc).

Combining the ranges of values for individual parameters, the total rating is defined (Jovanovski 2001). The range of values for each rock mass class and ERMR class is presented in Table 1.

For all evaluation factors correlative curves are defined, with a main goal to have possibility to assign an adequate rating for all parameters. One example for bulk density is given with following equation, while the details are explained by Jovanovski (2001).

$$Rating\ (BD) = 0.7832 * BD - 18.32 \quad (2)$$

where Rating (BD) = an adequate value for rating for some value of bulk density; BD = bulk density of the rock mass in kN/m^3.

Table 1. ERMR class, rating and suggested excavation method.

ERMR class	ERMR rating	Excavation
I	<10	Easy digging
II	10–25	Digging
III	26–40	Hard digging
IV	41–50	Ripping
V	51–60	Hard ripping
VI	61–80	Blasting
VII	81–100	Hard blasting

In general, up to class III, the excavation method will be digging, for class IV and V ripping is dominant excavation method, while classes VI and VII are for blasting.

In a practice, several special cases can occur. For example, for coarse grained non-coherent rock masses, large boulders can be secondary blasted. In certain cases, selection of excavation method depends on the available mechanization. For an 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.

Sometimes, excavation method depends on the morphology of the terrain and the type of structure. For an example, ripping is rarely used in tunnelling, in difficult morphological conditions and tight excavations for bridge foundations and concrete dams, even if the properties of the media allow it.

In cases when 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 should be agreed.

It is obvious that for each specific problem, evaluation 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.

3 CORRELATIONS OF ERMR AND OTHER CLASSIFICATION SYSTEMS

In the rock engineering practice, it is useful when several classification methods are used in parallel. The idea is to perceive the degree of correlation between different approaches, because the rock mass classification systems have some common parameters, therefore a link might be expected between the ERMR and other well known rating systems.

The established correlations are presented with the following equations:

$$ERMR = 0.76RMR + 17.98 \quad (3)$$

$$ERMR = 11.68\log Kr + 27.77 \quad (4)$$

$$ERMR = 0.87RMR(w) + 1.48 \quad (5)$$

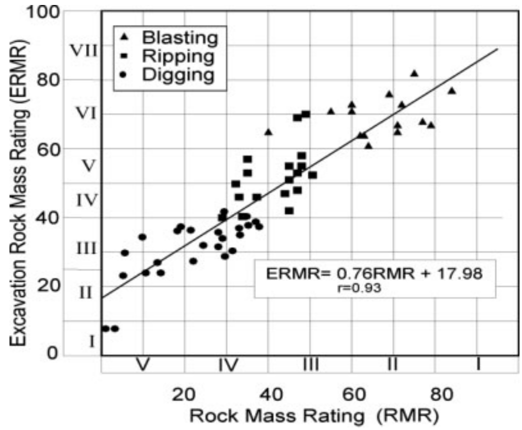


Figure 1. Correlation between ERMR value and Rock Mass Rating after Bieniawski.

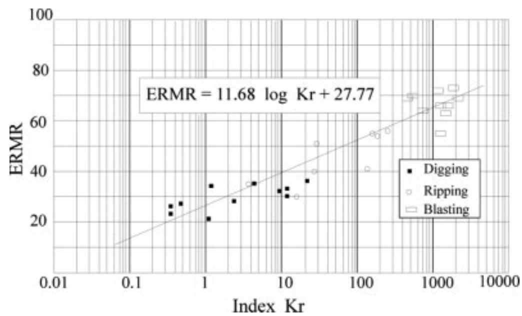


Figure 2. Correlation between ERMR value and Kr-value from Kirsten classification.

$$ERMR = 25.67 + 9.66 * Vp$$
$$ERMR = 26.43 * Vp \quad (6)$$

where ERMR = Excavation Rock Mass Rating; Kr = Rippability index after Kirsten: RMR = Rock Mass Rating after Bieniawski; RMR (w) = Ripability Mass rating after Weawer; and Vp = value of P-wave velocity in km/s.

Graphical presentation of the defined correlations is given in Figures 1–4.

It can be noted that determination coefficient for all cases has very high values from $R^2 = 0.8$ to $R^2 > 0.95$ which indicates a very strong connection between the analysed parameters.

The data for correlation are obtained from more than 45 case histories for large civil and mining projects, so it is considered that for initial phases of planning, the method can be very useful for practical application.

4 PRACTICAL APPLICATION OF ERMR SYSTEM

The proposed classification method can be used at a first place to choose adequate technology of

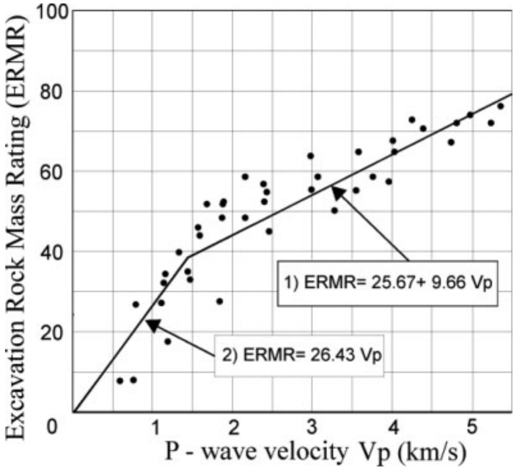


Figure 3. Correlation between ERMR and velocity of P-waves.

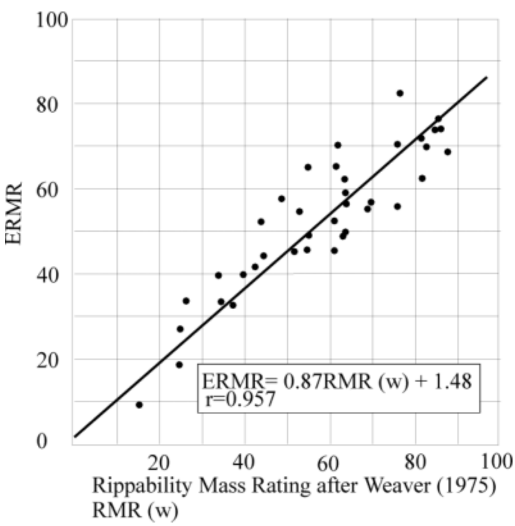


Figure 4. Correlation between ERMR and Rippability Mass Rating after Weaver (1975).

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, there are cases when alternative methods for excavations are possible.

Another important aspect for defining of excavation cost is possibility to connect ERMR value with the unit price for excavation per cubic meter (Fig. 5).

The diagrams are obtained using prices from several large civil engineering projects, as a lower and upper envelope. It is clear that this can be only method for fast prediction of the cost of excavation,

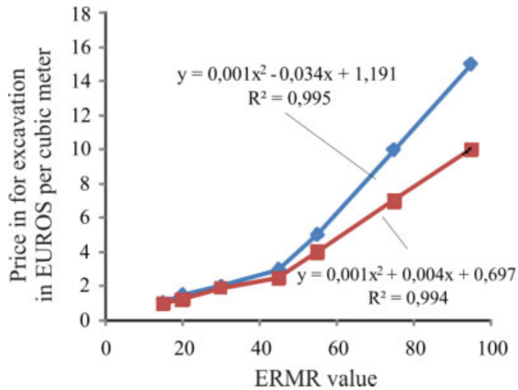


Figure 5. Prediction of unit price per meter cubic using ERMR value.

while the tendering price or real price of excavation shall be prepared according to the market and field conditions.

5 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, and for them a recommendations for possible method of excavation, mechanisation etc. is given.

The system well correlates with other classification systems (RMR after Bieniawski, value of longitudinal seismic Vp-waves propagation, Kirsten method and others).

Having in mind that the empirical methods are based on certain level of experience, the philosophy of the methodology it should be subjected to critical reviewing in time, and should be used in combination with other methods.

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

REFERENCES

Abdullatif, O.M. & Cruden, D.M. 1983. The relationship between rock mass quality and ease of excavation. *Bull IAEG* 28(1):183–187.

Bieniawski, Z.T. 1974. Geomechanics classification of rock masses and its application to tunneling. In *Proc. 3rd Int. Congr. Rock Mech.*, Denver, Colorado: I(A), 27–32. Washington, DC: National Academy of Sciences.

Franklin, A.J. 1970. Observations and tests for engineering description and mapping of rock. In *Proc. 2nd Int. Congr. Rock Mech.*, Belgrade: Paper 1–3, 1–6.

Kirsten, H. 1982. A classification system for excavation in natural materials. *Civ Eng S Afr* 24: 293–308.

Jovanovski, M. 2001. Methodology for investigation of Rock Masses a working media, Doctoral thesis, University "Sts Cyril and Methodius", Faculty of Civil Engineering, Skopje.

Jovanovski, M., Zileska-Pancovska, V. & Peshevski, I. 2011. ERMR System – an useful tool in defining technology of excavation. *Organization, Technology and Management in Construction, An International Journal* 3(2): 302–307.
Pettifer, G.S. & Fookes, P.G. 1994. A revision of the graphical method for assessing the excavability of rock. *Q J Eng Geol* 27: 145–164.
Tsiambaos, G. & Saroglou, H. 2010. Excavatability assessment of rock masses using the Geological Strength Index (GSI). *Bull Eng Geol Environ* 69(1): 13–27.
Weaver, J.M. 1975. Geological factors significant in the assessment of rippability. *Civ Eng S Afr* 17(12): 313–316.