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CHARACTERISTICS AND COMPARATIVE ANALYSIS OF THE ESTIMATION METHODS OF THE REAL STRENGTH OF ROCK MASSES

Abstract: *The importance of estimation of real durability of mountain massifs at development of mineral deposits is marked. The comparative analysis of various methods of an estimation of durability of mountain massifs, in particular numerical methods, tests on samples of rocks, graph-analytical methods and on normative data is executed.*

By results of the analysis of different methods of an estimation of durability of massifs the factors influencing on durability of mountain massifs. The comparative analysis of foreign and domestic methods of an estimation of durability of mountain massifs in view of their numerical indicators is carried out. Examples of indicators of rock massif condition used in foreign researches, such as RMR (Rock Mass Rating), RQD (Rock Quality Designation), RMi (Rock Mass index) and Hoeck-Brown criterion are given.

It was found that all of them, regardless of domestic or foreign affiliation, depend on the state (index) of fracturing of the rock massif. Comparison of numerical indices of rock massif strength estimation reduced to relative units showed their identity with insignificant deviations related to the conditions of their determination.

Keywords: *rock massif; strength index; structural weakening coefficient; actual strength; fracture modulus; ultimate strength; degree of massif disturbance.*

Introduction. Evaluation of the strength of rock massifs is very important in the mining industry. It allows you to choose the right construction technology before building tunnels, mines or other engineering structures, as well as in the development of mineral deposits.

The task of assessing the strength of rock masses is complex and requires the use of various methods and approaches. A comparative analysis of the different rock strength assessment methods helps to establish certain patterns and factors that influence rock strength reduction, and provides insight into the feasibility of applying a particular method to specific conditions. It helps engineers and geologists to make reasonable decisions on safety and efficiency of construction and operation of mining enterprises.

Among the methods of assessment the most common are analytical methods, tests on rock samples (experimental), graph-analytical methods and normative values of strength indicators. It is important to compare domestic and foreign methods of assessing the strength of rock masses to bring them into mutual correspondence.

Purpose and Objectives. The aim of this article is to carry out a comparative analysis of existing foreign and domestic methods for estimating the strength of rock massifs to further determine their numerical indicators. Therefore, the task of the present study is to determine the factors influencing on the decrease of strength of massifs depending on their structural structure.

Material and results of the study. It is well known that each rock massif has its own structural structure. In particular, it has a system of natural cracks, layering, different degrees of watering and other indicators [1-3]. That is, the rock mass is characterized by spatial heterogeneity of its structure. Therefore, there is almost always a difference in the overall strength of the rock massif and the rocks of which it is composed. In order to assess the degree of this difference in the domestic scientific community introduced the concept of "structural weakening coefficient", which is expressed as the ratio of the uniaxial compressive strength of the rock massif to the laboratory sample of the rock from which this array is composed [4].

Foreign scientists do not apply the concept of structural weakening coefficient, but in their studies to study and establish the strength properties of the rock mass, they use other indicators that characterize a certain state of the rock mass. In particular, Roshöff K., Lanaro F., and Jing L. offer to assess the state of the rock massif *RMR* (Rock Mass Rating) [5]. Scientists Hoek E., Carranza-Torres C.T. and Corkum B. recommend for this indicator of rock quality *RQD* (Rock Quality Designation) [5]. To evaluate the state of the rock mass, Palmstrom A., in his scientific work, offers to use the index of rock mass *RMi* (Rock Mass index) [6]. There is also in the scientific community the Hoek-Brown method, a criterion for the transition from the strength of a laboratory rock sample to the total strength of the massif [7]. For the vast majority of the above-mentioned

indicators, depending on the state of the rock massif, given numerical values and / or proposed formulas for their calculation.

Let us briefly analyze domestic regarding the definition of the coefficient of structural weakening and foreign studies on the study of indicators of assessment of the state of the rock massif [8]. In particular, domestic regulations recommend that the specified coefficient of structural weakening determined by the average distance between cracks in rocks (Table 1).

Table 1 – The value of the coefficient of structural weakening of the array K_c

Average distance between cracks in rocks, m	K_c
More than 1,5	0,9
1,5…1,0	0,8
1,0…0,5	0,6
0,5…0,1	0,4
less than 0.1	0,2

Other scientific sources recommend that the value of the coefficient of structural weakening depending on the type of disturbance of the rock massif (Table 2) [8].

Table 2 – Value of structural massif weakening coefficient K_c

Type of rock mass disturbance	Monolithic weakly fractured structures	Medium cracked	Heavily cracked	Crushing zones, geological disturbances
Structural weakening coefficient K_c	0,8	0,5	0,4…0,3	0,2…0,1

In the Design Guide of mine workings ensures the graph of the coefficient of structural weakening of the rock mass from the modulus of fracturing of rocks (Fig. 1).

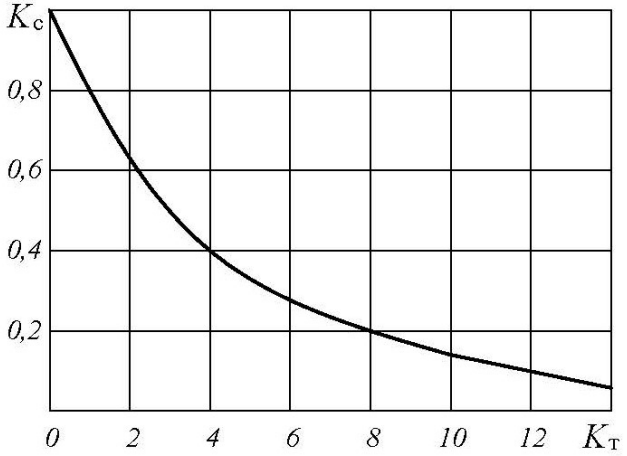

Fig. 1. Dependence of structural looseness coefficient K_c on fracture modulus $K_т$

In the U.S. is well known method of evaluation of massive rocks by the rock quality index *RQD* (Rock Quality Designation) [5], which is recommended to calculate by the following formula

$$RQD = Z\left(\sum \frac{l_i}{L}\right) \quad (1)$$

where Z –value of core recovery, %; Σl_i – total length of undisturbed core pieces with length not less than 10 cm, cm; L – length of investigated borehole interval.

To determine the quality index *RQD*, tables were made and graphs were plotted. Palmström presented a direct relationship between *RQD* and the specific fracturing of the rock mass:

$$RQD = 115 - 3{,}3J_v \quad (2)$$

where *Jv* is the volumetric number of fractures, that is, the total number of fractures per unit length of the massif.

Below are numerical values of the indicator *RQD* depending on the state of the massif, namely natural fracturing [5]. It should be noted that the quality of the rock massif corresponds to the domestic category of fracturing (Table 3).

Table 3 – The value of the rock mass condition indicator *RQD*

Quality of the rock massif	very poor	poor	satisfactory	good	perfect
Average distance between cracks, m	to 0.1	0,1-0,5	0,5-1,0	1,0-1,5	Over 1.5
RQD, %	to 25	25-50	50-75	75-90	90-100

In order to compare the methods of evaluation of rock massif based on *RQD* with the coefficient of structural weakening was combined them on one graph of the dependence on the modulus of fracturing (Fig. 2) [9].

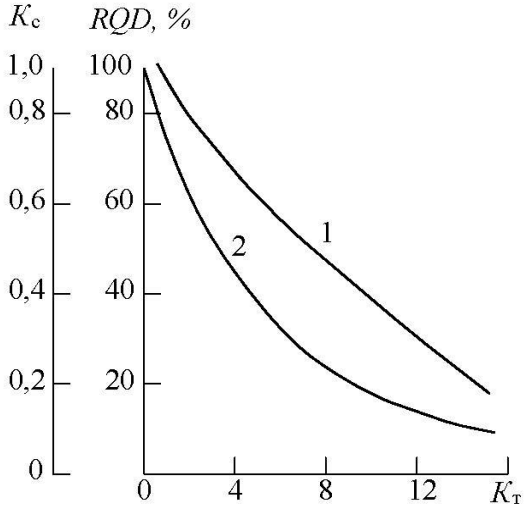

Fig. 2. Dependence of RQD values (1) and structural weakening coefficient K_c (2) on the fracture modulus $K_т$

Abroad, the classification of rock massifs according to the *RMR* (Rock Mass Rating) [5] is also popular. Table 4 shows the numerical values of *RMR* depending on the class of rock mass. The table shows that the rock massif is divided into five classes in the same way as the domestic classification of rocks by degree of fracturing.

Table 4 – Numerical values of *RMR* depending on the class of rock massif

Mountain range class	I	II	III	IV	V
Classification	very good	good	satisfactory	poor	very poor
The value of *RMR*, %	100-81	80-61	60-41	40-21	20-0

Conclusions. So, according to the results of the comparative analysis of methods of rock massifs durability estimation, it is established that all of them, regardless of domestic or foreign origin, are based on

the state (index) of rock massif's fracturing. This indicates that the essence of foreign indicators of rock massifs quality estimation (representation in percentage) is the same as the domestic coefficient of structural weakening (representation in relative units). Comparison of numerical indicators of rock massif strength evaluation, reduced to relative units, showed their identity with minor deviations associated with the conditions of their determination (see Fig. 2).

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ХАРАКТЕРИСТИКА ТА ПОРІВНЯЛЬНИЙ АНАЛІЗ МЕТОДІВ ОЦІНКИ РЕАЛЬНОЇ МІЦНОСТІ ГІРНИХ МАСИВ

Анотація: *Зазначена важливість оцінки дійсної міцності гірських масивів при розробці родовищ корисних копалин. Виконано порівняльний аналіз різних методів оцінки міцності гірських масивів, зокрема чисельних методів, випробувань на зразках порід, графоаналітичних методів та за нормативними даними.*

За результатами аналізу різних методик оцінки міцності масивів визначено чинники, які впливають на міцність гірських масивів. Проведено порівняльний аналіз закордонних та вітчизняних методів оцінки міцності гірських масивів з урахуванням їх чисельних показників. Наведені приклади показників стану гірського масиву, що використовуються в закордонних дослідженнях, такі як RMR (Rock Mass Rating), RQD (Rock Quality Designation), RMi (Rock Mass index) та критерій Хоека-Брауна.

Встановлено, що усі вони, незалежно від вітчизняної або закордонної приналежності, залежать від стану (показник) тріщинуватості гірського масиву. Порівняння чисельних показників оцінки міцності гірських масивів, приведених до відносних одиниць, показало їх ідентичність з незначними відхиленнями, пов'язаними з умовами їх визначення.

Ключові слова: *скельний гірський масив; показник міцності; коефіцієнт структурного ослаблення; дійсна міцність; модуль тріщинуватості; межа міцності; ступінь порушеності масиву.*