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# SPECIFICATIONS OF THE ROCK MASSIFS BY THE BLOCK SIZES

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# ХАРАКТЕРИСТИКИ МАСИВІВ ГІРСЬКИХ ПОРІД ЗА БЛОЧНІСТЮ

**Purpose.** To establish the granulometric composition of natural jointing in a massif by average distance between cracks in rock.

**Methodology.** The natural jointing percentage in the rock massifs has been determined experimentally by measurement of the block sizes in open cast mines of nonferrous metallurgy enterprises of Kazakhstan. The average extent of natural jointing of various massifs has been determined by block sizes. The mathematical model of mosaic structure of a massif has been developed. The regression line of blocks size distribution has been obtained. The methodology for estimation of the particles size distribution of the natural rock massif by their average size is offered.

**Findings.** Based on the experimental data the coefficients of the regression equation have been established for rock massifs different by block sizes. By applying the coefficients the inverse problem was solved, the particles size distribution of the natural rock massif has been estimated by their average size.

**Originality.** The regular changes in the granulometric composition of natural rocks depending on their size have been determined. The values of constants in equations of regression for rocks with different particles size.

**Practical value.** The developed method determines the percentage of natural jointing in the rock massif by the average distance between the cracks, which is fixed in the geological reports and other technical documentation of mining enterprises. The technique may be useful for projection of technological parameters of mining operations.

**Keywords:** *rock massif, natural jointing, distance between cracks, natural jointing average size, granulometric composition*

**Problem.** It is known that the rock massif consists of natural jointing of the different size and is characterized by particular granulometric composition. Thus, natural jointing is formed by cracks of the third order. There are cracks of three orders in the massif of rocks. The cracks of the first and second orders determine the resilience of rocks to drill and a refinement in crushers, and cracks of the third order predetermine results of explosive destruction of the rocks massif [1].

The latter include endogenous cracks occurring in metamorphic rocks due to the decrease of the rock volume. In addition, they include tectonic cracks developing in the rocks under the influence of tectonic forces, artificial cracks formed in the rocks during mining operations, and weathering cracks. The third order cracks have a significant stretch, measured in centimeters, meters or even kilometers. The size of their disclosure changes from $10^{-6}$ to $10^{-1}$m. These cracks can be filled in with other rocks or remain unfilled. The third order cracks characteristics is that they divide the massif for structural elements – jointing. [1]. There is the methodology of determining of the percentage of natural jointing in the rock massif by the average distance between the cracks in this work.

**The analysis of recent researches.** On the basis of a large number of researches by the interdepartmental commission for blasting operations, a common classification of rocks according to the degree of fracturing in the massifs was adopted (table 1) [2–4]. It shows that all massifs according to the degree of crack are divided into five categories: highly cracked, heavily cracked, medium cracked, small cracked and monolithic.

**The selection of unresolved part of a common problem.** In this classification there is no establishment of natural jointing percentage of various sizes in the rock massifs.

To detail the content of natural jointing in rock massif, we carried out the special research on quarries nonferrous metallurgy in Kazakhstan. Block sizes of massifs of Kounradsky, Akzhalsky and Sayaksky fields was measured on exposures immediately and in a photoplanimetric way. The classification of rock massifs is offered on the basis of conducted researches by the block sizes is given in table 2. The schedules of the percentage dependence of natural jointings from their average size are submitted on fig. 1.

This classification of rock massif by the block-size complies with the assigned task.

*Table 1*

Classification according to the degree of rock fracturing

| Category of rock fracturing | The degree of massif fracture | The average distance between the natural cracks of all the systems, m | The content of large jointing (%) in the massif | | |
|---|---|---|---|---|---|
| | | | 0,3 m | 0,7 m | 1,0 m |
| I | High cracked (small block size) | up to 0.1 | up to 10 | 0 | 0 |
| II | Heavy cracked (medium block size) | 0.1–0.5 | 10–70 | up to 30 | up to 5 |
| III | Medium cracked (large block size) | 0.5–1.0 | 70-100 | 30–80 | 5–40 |
| IV | Small cracked (very large block size) | 1.0–1.5 | 100 | 80–100 | 40–100 |
| V | Almost monolithic (just large block size) | over 1.50 | 100 | 100 | 100 |

*Table 2*

Classification of rock massifs by block-size

| Classes of massifs by block sizes | Rock massifs block sizes (modularity) (the cracked degree) | The content of large jointing (%) in the massif | | | | | | | The average diameter of jointing, m |
|---|---|---|---|---|---|---|---|---|---|
| | | <0.20 | 0.21–0.40 | 0.41–0.60 | 0.61–0.80 | 0.81–0.100 | 1.01–1.20 | >1.21 | |
| I | Small block size (High cracked) | 82.0 | 10.3 | 7.0 | 0.5 | 0.2 | - | - | 0.15 |
| II | Medium block size (Heavy cracked) | 48.0 | 27.0 | 10,5 | 6.0 | 4.2 | 3.3 | 1.0 | 0.31 |
| III | Large block size (Medium cracked) | 29.5 | 20.2 | 14.0 | 11.8 | 10.6 | 8.7 | 5.2 | 0.50 |
| IV | Very large block size (Small cracked) | 17.5 | 16.1 | 14.6 | 13.2 | 12.7 | 12.9 | 13.0 | 0.69 |
| V | Highly large block size (Almost monolithic) | - | 3.0 | 8.0 | 13.0 | 18.0 | 26.0 | 32.0 | 1.00 |

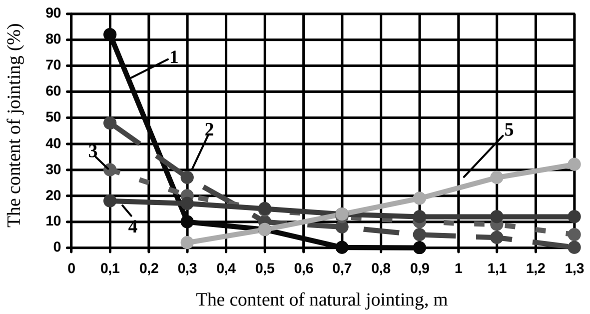


*Fig. 1. Specifications of the rock massifs by the block sizes: 1– small block size (high cracked); 2 – medium block size (heavy cracked); 3 – large block size(medium cracked); 4 – very large block size (small cracked); 5 – highly large block size ( monolithic)*

**Formulation of the research purpose.** In the technical literature on blasting the attention to the problems of the study of rock massif by blocking, determination of the percentage of natural rock partings in the massif was not sufficient, there are no methods for their determination. At the same time, we know that the granulometric composition of natural jointing of the massif depends on the fracture of rock massifs and blasted rock; it quality in a certain way is predetermined by the percentage of natural jointing in the rock massif. To identify these linkages there is a need to establish the natural particle size distribution jointing in rock mass on the average distance between the cracks.

**The main material.** The characteristics of rock massifs by the block size are given in Fig. 1, the choice of the regression lines was done based on percentage content of natural jointing for each class of rocks block-sizes.

In this research [6] we have shown that the content of natural jointing in different rock massifs block-sizes generally varies by the exponential law

$$y = ae^{bx}, \qquad (1)$$

where $a$, $b$ – constants for each class of block sizes; $x$ – natural jointing size.

To solve the inverse problem, the establishment of granulometric composition jointing in natural rock massif in their average size is necessary to establish the significance of constants of equation (1), depending on the size of the natural partings within 0.1, 0.2 ... 1.2m. For this purpose the unknown dependencies were graphed and are presented in fig. 2

*Table 3*

Constants of massifs the block sizes and coefficients of the determination

| Block sizes of rock massifs | Constants | | Coefficients of the determination $R^2$ |
|---|---|---|---|
| | *a* | *b* | |
| Small block size ($d_e$ = 0.15m) | 154.60 | -7.50 | 0.96 |
| Medium block size ($d_e$ = 0.31m) | 59.32 | -3.00 | 0.96 |
| Large block size ($d_e$ = 0.50m) | 30.58 | -1.30 | 0.96 |
| Very large block size ($d_e$ = 0.69m) | 17.05 | -0.30 | 0.82 |
| Highly large block ($d_e$ = 1.00m) | 2.15 | 2.24 | 0.93 |

The coefficients a and b depending on the size of the natural jointing are generally described by the equations

$$a = c\,e^{kx};\ b = l\,\ln x + f, \qquad (2)$$

where *c, k, l, f* – constants of the equation; *x* – size of natural jointing.

For the considered conditions ($d_e$ = 0.15; 0.31; 0.50; 0.69; 1.0m), it is easy to see

$$a = 264{,}9e^{-4{,}52x};\ \ b = 4{,}023\ln(x) + 1{,}694. \qquad (3)$$

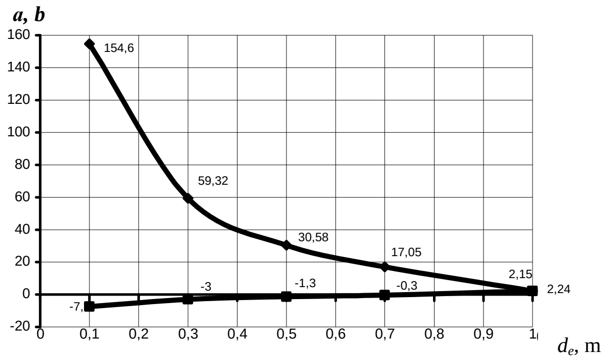


*Fig. 2. The dependence of the constants a and b of a medium-sized natural jointing*

The percentage of natural jointing in massif, is calculated from formula (1) with the substitution of the obtained significance a and b of the expression (3) by blocking grade is shown in table 4 are presented graphically in fig. 3. The comparison of these data with the experimentally established natural granule composition jointing in massif (table 2) shows that they coincide very closely.

Thus, the particle size distribution of natural rock massif jointing in the formula (1) can be calculated for any size fixed blocking. The significances of the coefficients *a* and *b* are determined by the dependencies (3). For the following sizes for certain permanent natural *a* and *b* have the following meanings:

1) for the small block size massifs with $d_e$=0.1m: *a*=167.1, *b*=-7.6; with $d_e$=0.2m: *a*=104.1, *b*=-5.0;

2) for the medium block size massifs with $d_e$=0.3m: *a*=65.3, *b*=-3.2; with $d_e$=0.4m: *a*=42.2, *b*=-2.0;

3) for the large block size massifs with $d_e$=0.5m: *a*=27.6, *b*=-1.1; with $d_e$=0,6m: *a*=23.4, *b*=-0.8;

4) for the very large block size massifs with $d_e$=0.7m: *a*=17.5, *b*=-0.3; with $d_e$=0.8m: *a*=15.3, *b*=-0.1;

5) for the highly large block massifs with $d_e$=0.9m: *a*=4.0, *b*=1.6; with $d_e$=1,0m: *a*=2.8, *b*=2.0.

The percentage of natural jointing results from this technique, with dimensions $d_e$ = 0.1, $d_e$ = 0.2, ... $d_e$ = 1,0m in the rock mass is given in table 5.

To visualize the data in table 5 they are graphically illustrated on the fig. 4–6. The fig. 4 shows the dependence of the percentage of natural building block jointing in massifs with average diameters: $d_e$ = 0.1m; $d_e$ = 0.2m (fig. 4, *a*) and medium block size massifs with average diameters: $d_e$ = 0.3m; $d_e$ = 0.4m (fig. 4, *b*).

The dependency charts are shown in fig. 4–6; they are identical to the charts shown in the fig. 3, which shows the unity of their nature.

According to the percentage of the natural specifications the coarse-jointing massifs are with average diameters of $d_e$ = 0.5m; $d_e$ = 0.6m (fig. 5, *a*) and very large block size massifs with average diameters $d_e$ = 0.7m; $d_e$ = 0.8m (fig. 5, *b*).

The figure 6 shows the percentage of natural jointing in large massifs only with an average diameter of natural jointing $d_e$ = 0.9m; $d_e$ = 1.0m.

*Table 4*

Estimated particle size distribution of separately in natural rock massif

| Classes of massifs by block sizes | The massifs and their block sizes (the average diameter of jointing, m) | The content of large jointing (%) in the massif (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | <0.20 | 0.21–0.40 | 0.41–0.60 | 0.61–0.80 | 0.81–0.100 | 1.01–1.20 | >1.21 |
| I | Small block size ($d_e$ = 0.15m) | 76.77 | 17.83 | 4.14 | 0.96 | 0.22 | 0.05 | 0.02 |
| II | Medium block size ($d_e$ =0.31m) | 45.63 | 25.04 | 13.74 | 7.54 | 4.14 | 2.27 | 1.68 |
| III | Large block size ($d_e$ =0.50m) | 27.09 | 20.89 | 16.11 | 12.42 | 9.57 | 7.38 | 6.48 |
| IV | Very large block size ($d_e$ =0.69m) | 16.93 | 15.95 | 15.02 | 14.14 | 13.32 | 12.55 | 12.17 |
| V | Highly large block size ($d_e$ =1.00m) | 2.76 | 4.32 | 6.78 | 10.63 | 16.67 | 26.14 | 32.74 |

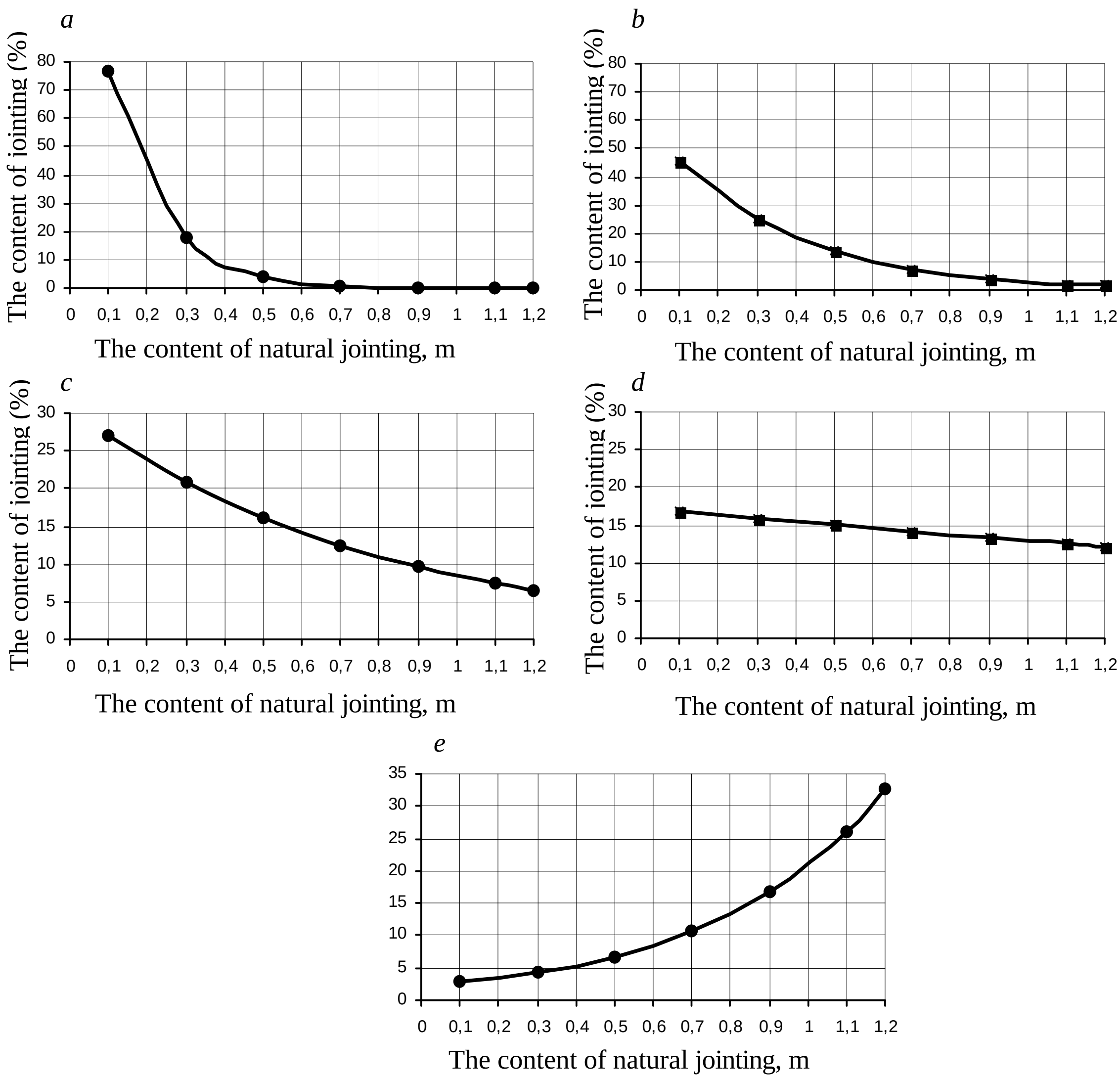


*Fig. 3. The estimated granulometric content of natural jointing in: small block size (a); medium block size (b); large block size (c); very large block size (d); highly large block size (e)*

*Table 5*

Content of natural jointing in rock massif and their block sizes

| Classes of massifs by block sizes | The massifs and their block sizes. The average diameter of jointing, m | The content of large jointing (%) in the massif (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | <0.20 | 0.21–0.40 | 0.41–0.60 | 0.61–0.80 | 0.81–0.100 | 1.01–1.20 | >1.21 |
| I | Small block size ($d_e$=0.1m; $d_e$=0.2m) | 78.1 | 17.1 | 3.7 | 0.8 | 0.2 | 0.0 | 0.0 |
| | | 63.1 | 23.2 | 8.5 | 3.1 | 1.2 | 0.4 | 0.3 |
| II | Medium block size ($d_e$=0.3m; $d_e$=0.4m) | 47.4 | 25.0 | 13.2 | 7.0 | 3.7 | 1.9 | 1.4 |
| | | 34.6 | 23.2 | 15.5 | 10.4 | 7.0 | 4.7 | 3.8 |
| III | Large block size ($d_e$=0.5m; $d_e$=0.6m) | 24.7 | 19.8 | 15.9 | 12.8 | 10.3 | 8.2 | 7.4 |
| | | 21.6 | 18.4 | 15.7 | 13.4 | 11.4 | 9.7 | 9.0 |
| IV | Very large block size ($d_e$=0.7m; $d_e$=0.8m) | 17.0 | 16.0 | 15.1 | 14.2 | 13.4 | 12.6 | 12.2 |
| | | 15.1 | 14.8 | 14.6 | 14.3 | 14.0 | 13.7 | 13.6 |
| V | Highly large block ($d_e$=0.9m; $d_e$=1.0m) | 4.7 | 6.5 | 8.9 | 12.3 | 16.9 | 23.3 | 27.3 |
| | | 3.4 | 5.1 | 7.6 | 11.4 | 16.9 | 25.3 | 30.9 |

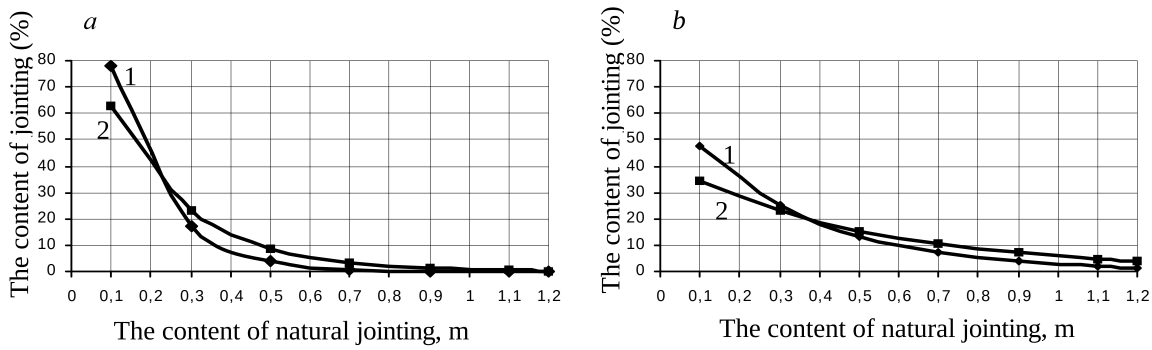


*Fig. 4. Percentage of natural jointing in small block size ($d_e$=0.1m, $d_e$=0.2m) (a) and medium block size ($d_e$=0.3m, $d_e$=0.4m) (b) massifs*

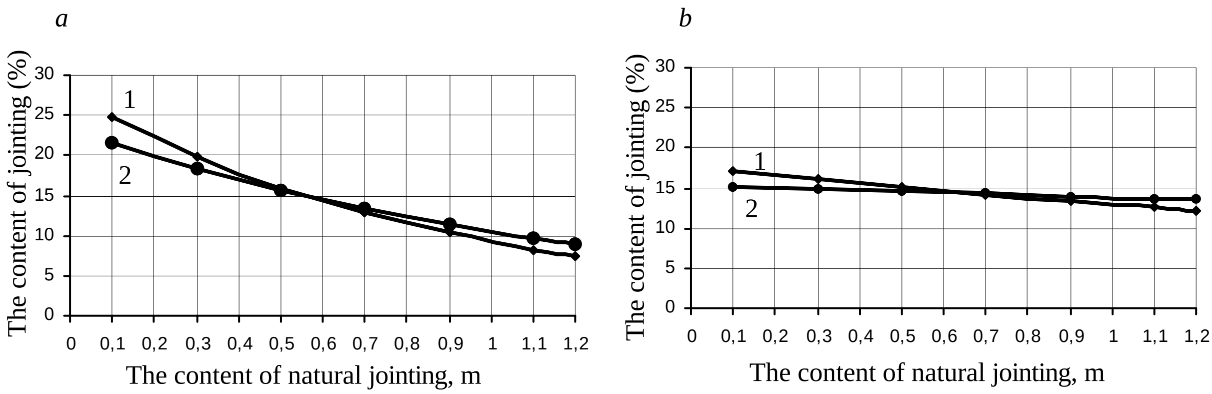


*Fig. 5. Percentage of natural jointing in large block size ($d_e$=0.5m, $d_e$=0.6m) (a) and very large block size ($d_e$=0.7m, $d_e$=0.8m) (b) massifs*

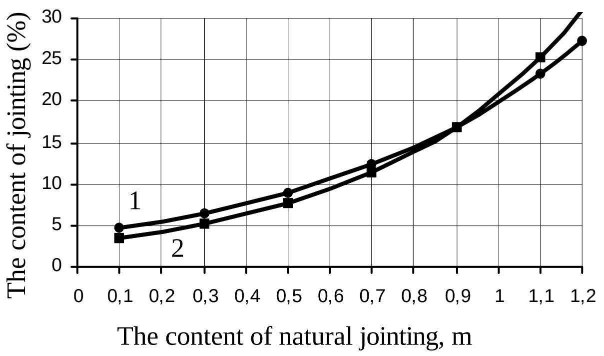


*Fig. 6. Percentage of natural jointing in highly large block size ($d_e$=0.9m, $d_e$=1.0m) massifs*

The analysis of the percentage content of natural jointing in small block size, medium block size, large block size, very large block size, highly large block size rock massifs that are shown in fig. 3–6, confirms the reality of the analytical determination of particle size distribution of natural jointing in them.

**Conclusions and prospects for the development.** The conducted researches have shown that by the average extent of natural jointing it is possible to establish the significance of coefficients a and b, and by means of the exponential law (1) find percentage of natural jointing in the rock massif.

Due to the fact that in geological reports and other technical documentation mining companies usually indicated only the average distance between the natural cracks of all orders ($d_e$), the developed method is the reliable tool for determining the particle size distribution of natural jointing in the rock massif.

The percentage of natural jointing in the massif is necessary to design parameters process mining to ensure the required quality of blasted rock crushing.

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Определение гранулометрического состава массива пород по среднему размеру естественных отдельностей: сб. трудов Международной научно-практической конференции „Инновационные технологии и проекты в горно-металлургическом комплексе, их научное и кадровое сопровождение" / Б.Р. Ракишев, А.М. Ауэзова, А.П. Калиева, А.Н. Дауренбекова – Алматы: КазНТУ, 2014. – С. 186–190.

**Мета.** Встановлення гранулометричного складу природних окремостей у масиві порід за середньою відстанню між тріщинами.

**Методика.** Експериментально встановлений процентний вміст природних окремостей у масивах порід безпосереднім виміром блочності на ряді кар'єрів підприємств кольорової металургії Казахстану. Визначений середній розмір природних окремостей у різних масивах за блочністю. Розроблена математична модель блочності масиву порід, встановлені лінії регресії гранулометричного складу природних окремостей. Запропонована методика визначення гранулометричного складу природних окремостей у масиві порід за їх середнім розміром.

**Результати.** За експериментальними даними встановлені значення коефіцієнтів рівняння регресії для різних масивів порід за блочністю. З їх використанням вирішена зворотна задача – визначений гранулометричний склад природних окремостей у масивах порід за їх середнім розміром.

**Наукова новизна.** Встановлені закономірності зміни гранулометричного складу природних окремостей масиву порід залежно від їх розмірів. Встановлені значення постійних величин рівняння регресії в залежності від розміру природних окремостей.

**Практична значимість.** Розроблена методика визначення процентного вмісту природних окремостей у масиві гірських порід за середньою відстанню між тріщинами, що фіксується в геологічних звітах та іншій технічній документації гірничого підприємства. Методика затребувана при проектуванні технологічних параметрів процесів гірських робіт.

**Ключові слова:** *масив порід, природна окремість, відстань між тріщинами, середній розмір природної окремості, гранулометричний склад*

**Цель.** Установление гранулометрического состава естественных отдельностей в массиве пород по среднему расстоянию между трещинами.

**Методика.** Экспериментально установлено процентное содержание естественных отдельностей в массивах пород непосредственным замером блочности на ряде карьеров предприятий цветной металлургии Казахстана. Определен средний размер естественных отдельностей в различных массивах по блочности. Разработана математическая модель блочности массива пород, установлены линии регрессии гранулометрического состава естественных отдельностей. Предложена методика определения гранулометрического состава естественных отдельностей в массиве пород по их среднему размеру.

**Результаты.** По экспериментальным данным установлены значения коэффициентов уравнения регрессии для различных массивов пород по блочности. С их использованием решена обратная задача – определен гранулометрический состав естественных отдельностей в массивах пород по их среднему размеру.

**Научная новизна.** Установлены закономерности изменения гранулометрического состава естественных отдельностей массива пород в зависимости от их размеров. Установлены значения постоянных величин уравнения регрессии в зависимости от размера естественных отдельностей.

**Практическая значимость.** Разработана методика определения процентного содержания естественных отдельностей в массиве горных пород по среднему расстоянию между трещинами, которое фиксируется в геологических отчетах и другой технической документации горного предприятия. Методика востребована при проектировании технологических параметров процессов горных работ.

**Ключевые слова:** *массив пород, естественная отдельность, расстояние между трещинами, средний размер естественной отдельности, гранулометрический состав*

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