Research Journal of Applied Sciences 11 (5): 245-250, 2016
ISSN: 1815-932X

Calculation Coefficient of Strength Decrease of the Rock Mass Fragments in the Shotpile

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Abstract: The results of the industrial experiment at the quarry of granite on gravel extraction have been presented; the investigation aim was to establish a relation of the strength properties on the rock mass fragmentations in the shotpile, taking into account the ruptured zone from the intension of explosive energy.

Key words: Industrial experiment, energy parameters, strength characteristics, rocks, explosion, explosive charge, ruptured zone, the rock strength

INTRODUCTION

The study is a logical continuation of the comprehensive investigation, presented in papers (Paramonov and et al., 2014; Paramonov *et al.*, 2014), the investigations were aimed at establishing patterns of energy performance influence on the explosive in the strength characteristics of the fragments in the shotpile as well as the investigation of sub-standard fractions output from different zones of rapture, depending on energy characteristics of explosive.

MATERIALS AND METHODS

According to results of the simulation experiments carried out on the equivalent materials the decrease of blasted rock mass and volume fraction of the sub-standard output of different rapture zones have been observed. After processing the results of the first and second stages of a comprehensive investigation, it was decided to reproduce the results of simulation experiments in the industrial environment (in terms of the studied granites). The industrial experiment has been described.

Specific energy consumptions of explosion have been changed by narrowing the well spacing relatively depending on the calibration shot (number 1). As a result of industrial experiments, observed dependence of the average fragments strength on specific energy consumption have been obtained and decrease strength coefficient against the specific energy consumption from explosion offset distance as well.

When comparing the experimentally obtained dependence for calculation the average fragments strength in natural conditions with the results of the calculated dependence on the model experiments on equivalent materials it can be concluded that the calculated dependence satisfactorily approximates the experimental data and is suitable for calculating the average fragments strength, both in general and in specific fracture areas on the basis of specific explosive energy.

The progressive economy in the mining industry tends to achieve the greatest benefit at the lowest cost and defines the tasks related to the integrated development of mineral deposits. If the mining sector companies are not interested in strategic planning production volume, taking into account the environmental management it is practically impossible to ensure the progressive development of economic-ecological system of subsoil use.

With the development of resource-intensive technologies the issues related to environmental management are becoming more and more important. The environmental management as a system of scientific, industrial, technological and organizational measures involves the complete use of extracted natural resources and, as a consequence, it reduces the number of resources consumed and replenishes the natural resources and uses the mineral resource appropriately (Bozhenov, 1994).

To develop the resource-saving methods the comprehensive mineral deposits exploration study of subsoil resources should be carried out as well as a comprehensive systematic assessment of rocks fractured and minerals mined.

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One of the major problems in the field of non-metallic building materials is uncontrolled crushing screenings output. For example, in the rubble manufacture from granite, gabbro-diorite, basalt crushing dropout yield is average 25% and carbonate rocks is 35% (Haro *et al*., 2003).

The explosion action on the solid mass when it is crushed causes to the strength reduction of the rock mass fragmentation; it significantly affects the amount of screenings output at the processing stage. A lot of researches have been carried out in this field (Sasaoka *et al*., 2015).

The failure limit figure on unixial compression for average fragmentations may characterize the rock mass to be processed. This approach allows us to control the amount of conditional output during the production-process for account of the strength changing of the processing raw materials.

Determining an optimal level of blasting rocks exposure on rock mass ensures the integrity of the mineral structure and is an actual scientific and practical problem of mineral resources rational use.

When calculating the parameters of drilling and blasting, using reasonable values of the specific energy consumption in each case it is possible to improve the quality of explosion due to the prediction of strength characteristics blasted rock fracture in the shotpile.

Drilling-and-blasting activity will certainly have a significant impact on the energy intensity of production processes at the stage of rock fragmentation and at the stage of further minerals processing.

In this regard, the study of energy consumption in the explosive of rock destruction together with the energy consumption and with the output volume of the end product is of high importance. It is necessary to study the relation of the energy consumption and the required quality of blasting rock mass preparation.

RESULTS

The relations between the level of explosive loading of the rock mass and decrease of the fragmentation strength characteristics in the shotpile have become an urgent task to solve.

Proceed from the results of simulative experiments, which are presented in the papers (Paramonov *et al*., 2014) number of explosions granite mass with different specific consumption have been carried out at the quarry for the production of crushed granite. Table 1 shows the parameters of drilling and blasting operations at the various series of explosions. As the explosive in all three series Nitronit E-70 was used. Specific consumption varied on account of spacing pattern approach.

The strength characteristics of the raw materials in the plant were evaluated by the power of the average fragmentation resistance in the shotpile. To determine the average fragmentation after each excavator activity the shotpile of blasted rock mass was photographed. Conventionally, the shotpile was divided into 12 intervals. The scheme of the zones shooting is shown in Fig. 1. The planimetric analysis was carried out with the help of the linear method. The shotpile was delimited with the measuring tape coated with black and white stripes. The tape was applied every 10 m. The photographing was executed at the distance of 10 m from the shotpile and with two cameras (for reliability).

Table 1: Parameters of drilling-and-blasting activities

Items, No. blasting	Unit	Figure 1	2	3
Diameter (d)	mm	144	144	144
Subdrill death (L_{subd})	m	1.4	1.4	1.4
Well depth (L_{well})	m	13.4	13.4	13.4
Distance between the boreholes in a raw (a)	m	4.5	4.0	4.0
Spacing of wells abreast (b)	m	4.5	4.5	4.0
Stem bag length (l_{face})	m	3.0	3.0	3.0
Charge length (l_{charge})	m	10.4	10.4	10.4
Explosive bulk 1 m borehole (Q)	kg	16.4	16.4	16.4
Charge mass in borehole (Q)	kg	220	220	220
Average output g/mg/m from ($V_{borehole}$)	m^3	243	216	192
Specific explosive consumption (q)	kg m^{-3}	0.9	1.01	1.14

Table 2: The value of a medium-sized fragmentation

Sampling area	Number of explosive no. 1	no. 2	no. 3
1-1	0.380	0.385	0.421
1-2	0.401	0.330	0.237
1-3	0.310	0.280	0.314
2-1	0.267	0.380	0.374
2-2	0.370	0.355	0.251
2-3	0.330	0.320	0.398
3-1	0.340	0.360	0.325
3-2	0.385	0.315	0.341
3-3	0.478	0.261	0.242
4-1	0.258	0.365	0.372
4-2	0.350	0.251	0.352
4-3	0.285	0.452	0.289
Mean	0.346	0.337	0.326

The obtained photos were subjected to initial treatment in MapInfo and then in the software package WipFrag by the method described here (Maerz and Palangio, 1996). After each the excavator running a medium-sized piece was selected, measuring of the linear parameters of it was performed directly in the face, the measurement results were recorded in the table. A single sample was taken from various points of the face. The sizes of the average fragments from the various zones of the shotpile are presented in Table 2.

Samples selected in the face have been prepared for testing. Preparation of rock samples to the laboratory study consists of drilling out the cores of the selected fragmentations after the explosion and making the desired shape and size by the treatment in special stone-cutting machinery.

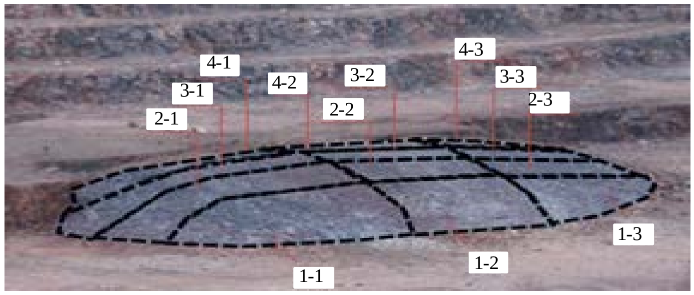

Fig. 1: The shotpile scheme zonally

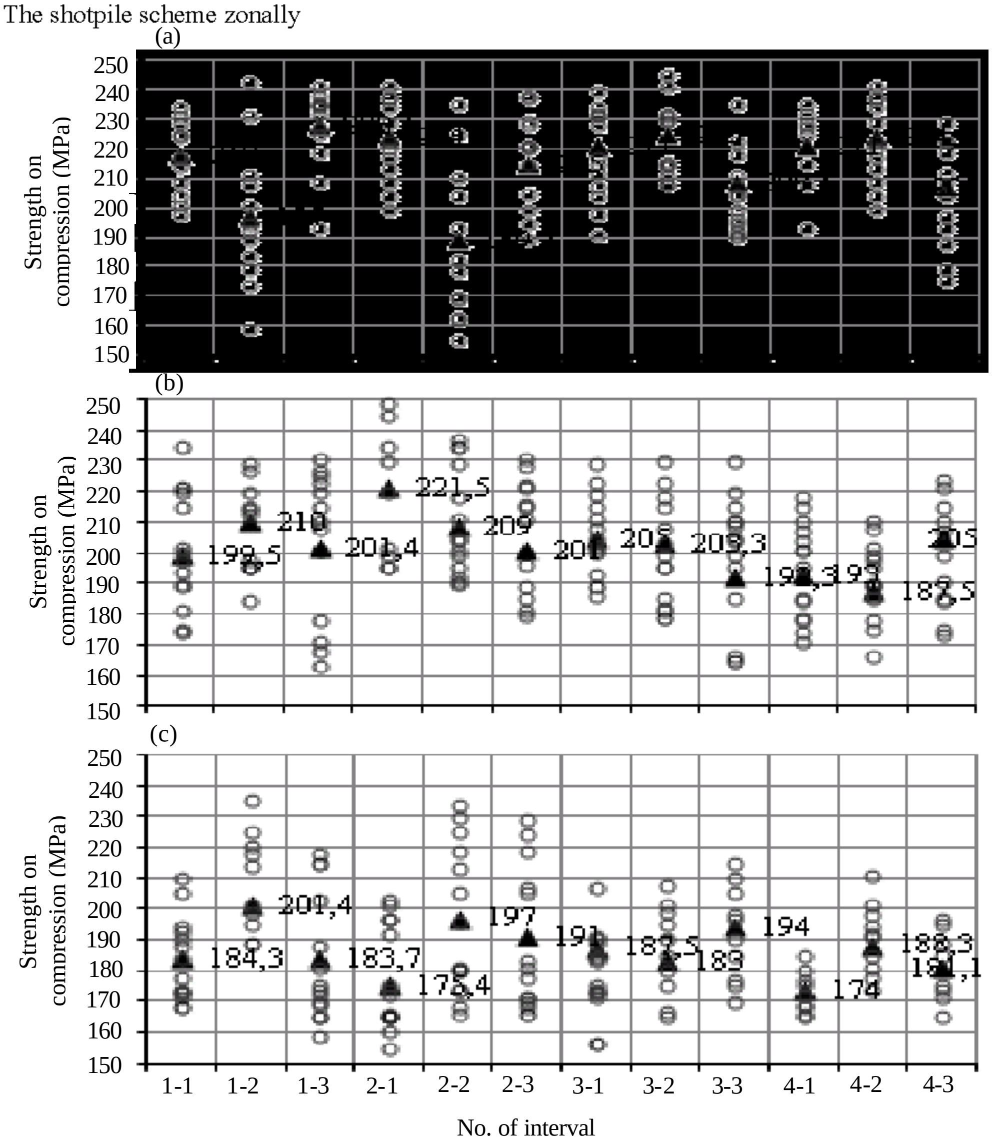

Fig. 2: The average strength of a medium-sized piece of the different zones of collapse: a-c) Explosion no 1-3

The size and number of manufactured rock samples were selected for each sample individually to meet the requirements of the representativeness of the sample and its actual volume. During testing the samples with flat parallel end face are perpendicular to the smooth side surface and have been destroyed by compression in a hydraulic press test MTS. The test results are shown in Fig. 2 and summarized in Table 3.

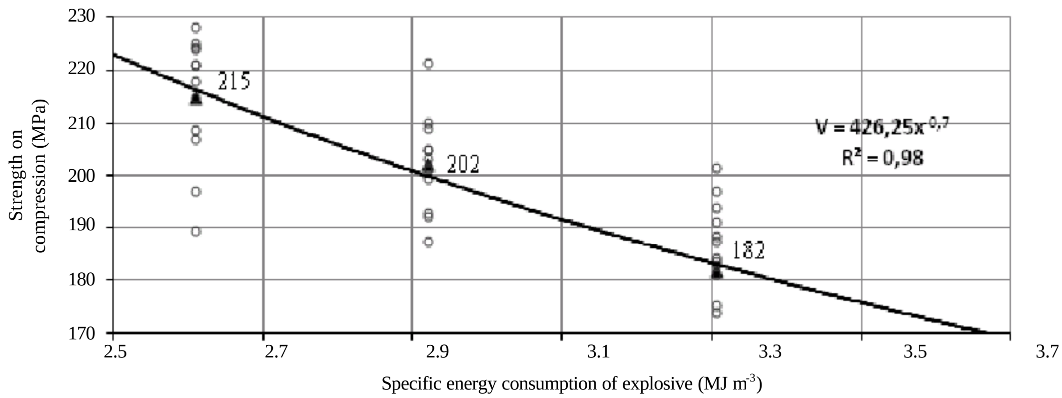

Fig. 3: Experimental dependence of the average fragmentation strength on the specific energy consumption of explosives

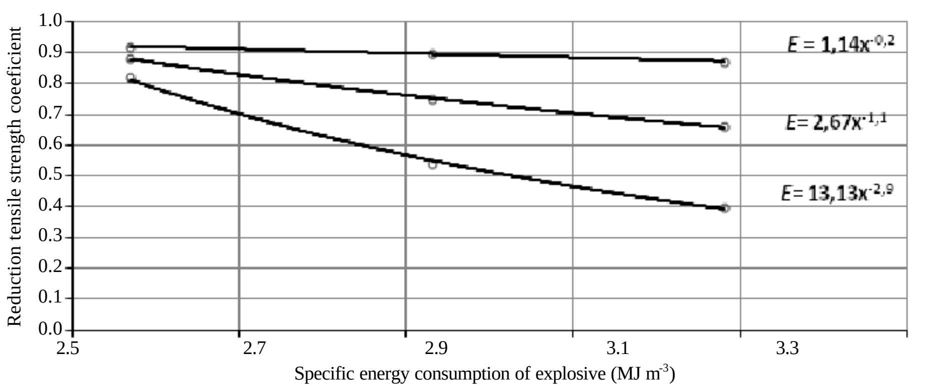

Fig. 4: Experimental dependence of reduction tensile strength on specific energy consumption of explosives from the distance of explosion source

Table 3: The value of compressive strength limits

	Average strength of the sample in compression (MPa)		
Sampling area	No 1	No. 2	No. 3
1-1	218.0	199.5	184.3
1-2	197.0	210.0	201.4
1-3	228.1	201.4	183.7
2-1	224.0	221.5	175.4
2-2	189.5	209.0	197.0
2-3	215.0	201.0	191.0
3-1	221.0	205.0	187.5
3-2	225.0	203.3	183.0
3-3	208.5	192.3	194.0
4-1	221.0	193.0	174.0
4-2	224.4	187.5	188.3
4-3	207.0	205.0	181.1
Mean	215.0	202.0	182.0

Knowing the value of specific consumption for different explosion set one can express the value of specific energy consumption:

$$E = qQ, \text{MJ/m}^{-3} \quad (1)$$

Where:

Q = Specific energy MJ kg^{-1}

q = Specific explosive consumption (kg m^{-3})

Having the results the power law dependence (Fig. 3) was obtained; it allows to predict the compressive resistance of a medium-sized fragmentation that is treated at the crushing mill, depending on the energy- specific:

$$\left|\sigma_{compr}\right|_{mean} = 426,25\ E^{-0.7} \quad (2)$$

Where:

Q = The specific energy consumption of explosives, MJ/m^3

$|\sigma_{compr}|_{mean}$ = The strength in uniaxial compression of a medium-sized fragmentation, MPa

If we consider the results presented in the papers (Haro *et al*., 2003) and take into account the fact that the strength of the average fragmentation of the blasted rock mass is a function of distance from the source of the explosion, it is possible to express the ratio of reduction strength for the studied granites relatively undisturbed material in each zone of from the specific energy consumption. Relation of the coefficients for reduction strength of the studied fragmentation in the zones has been presented in Fig. 4.

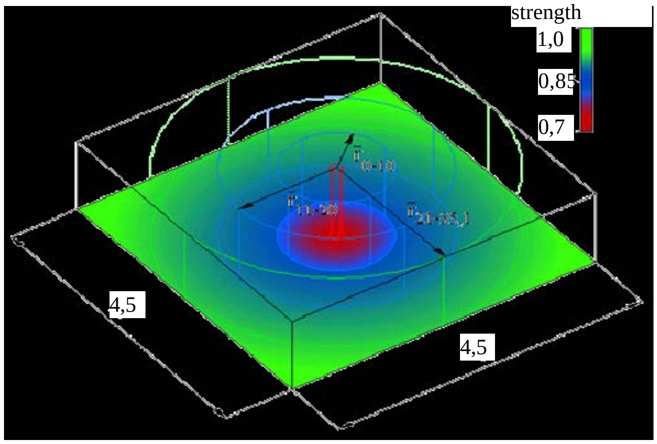

Fig. 5: The values distribution of the reduction strength coefficients zonally for specific energy consumption of explosives is equal to 2.61 MJ (Mathematica 10)

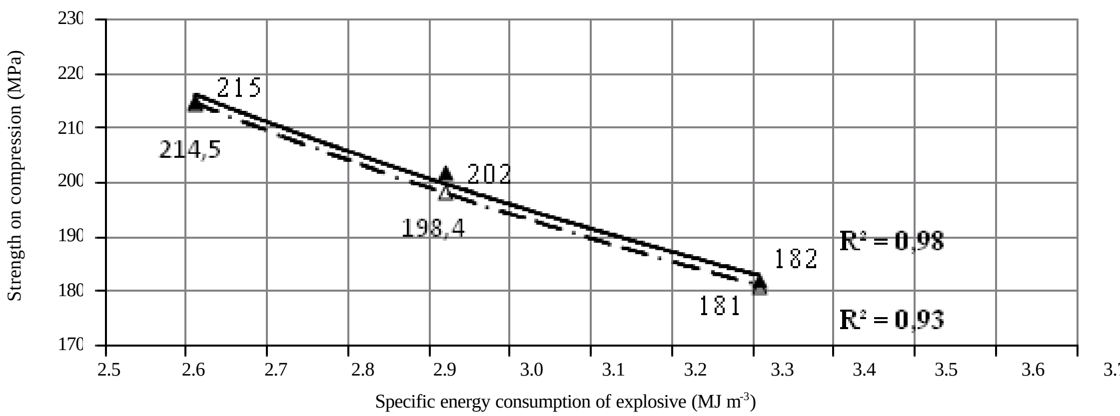

Fig. 6: The strength dependence of the average fragmentation on the uniaxial compression from the specific energy consumption of explosives for the conditions studied granites 1- experimental curve ; 2 - calculated curve in the expressions of 4

Thus, the strength of average fragmentation after explosion taken into account the ruptured zone can be presented in the following expression:

$$\left|\sigma_{compr}\right|_{mean} = \sum_{i=1}^{n} \left|\sigma_{compr}\right|_{m} k_i \frac{V_i}{V_{general}}, \text{ MPa} \qquad (3)$$

Where:

V_i = The volume of ruptured zone, m^3

$V_{general}$ = The volume, which is accounted on all zones m^3

$|\sigma_{compr}|_m$ = Rock strength on the unixial compression before the explosion,

K_i = Zonally reduction strength coefficient

n = Ruptured zone number

In the software package Mathematica 10, guided by the results of industrial and laboratory experiments the calculation of the average strength was executed, according to the Eq. 3.

The overall data of the explosion no. 1 is shown in Fig. 5. The strength of granite on uniaxial compression under quarry condition is 240 MPa. Specific energy consumption of explosives, according to the calculations of the Eq. 1 is 2.61 MJ. Substituting the calculated data in the expression for finding the decrease strength coefficient of resistance to fracture zones, presented in Fig. 4, we'll find the strength value of the uniaxial compression for an average size fragments in the shotpile. The results of the calculated values were correlated with the experimental curve (Fig. 6).

According to the results of calculation and experiment, it was found that the change in the strength of the average fragmentation on the uniaxial compression from the specific energy consumption of explosives in the range of 2.5-3.5 MJ kg^{-3} for the study of rocks is determined by the power law dependence:

$$\left|\sigma_{compr}\right|_{mean} = 428,25\,E^{-0,7}, \text{MPa} \quad (4)$$

When comparing the experimentally obtained dependence with the calculated dependence Eq. 4, it is shown that it is a satisfactory approximation of the experimental data and is suitable for calculating the strength of the average fragmentation both in general and in specific areas of destruction on the basis of specific energy explosives consumption.

DISCUSSION

Summarizing the result of the industrial experiment in natural conditions taking into account the destruction when carrying out the simulated experiments *in vitro* (Paramonov *et al*., 2014) it is possible to draw a conclusion that decrease in the strength of an average fragmentation in the shotpile depends on specific explosive energy consumption o and is defined by total reduction strength coefficient for the various zones of destruction.

CONCLUSION

The results presented in the publication were obtained as part of the scientific and methodological activity as the main tasks of the state higher education institutions and scientific organizations in the field of scientific research.

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