Improving Quality of Granulometric Composition at Open-Pit Mines of Construction Materials to Reduce Well Diameter

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Improving Quality of Granulometric Composition at Open-Pit Mines of Construction Materials to Reduce Well Diameter

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Abstract. The paper suggests an approach to solving the issue of the quality of granulometric composition of rock mass after its loosening by explosion. Effects of the percentage ratio of the standard piece to the total mass of the rock are a relevant problem, which is solved by reducing the diameter of the blast hole. This approach is caused by the best distribution of the explosive on the unit being processed. The blasting unit has both natural and induced fracture systems that divide the solid into blocks, and reducing the well diameter leads to a thickening of the well grid, and thus increasing the probability of placing a charge in every rock block separated by a crack, being a density separation plane from the physical point of view. Constant specific consumption is a prerequisite of the quality of crushing.

1. Introduction

Due to large-scale works in the field of rock destruction by explosion, a large number of methods have been developed to calculate given quality of crushing based on energy characteristics of the explosive [1].

The quality of rock destruction is characterized mainly by the uniformity and size of crushing, percentage of output of large oversized pieces, condition of the bench toe, and width of the rock mass breakdown. Being an initial stage of mining, explosive destruction determines effectiveness of any subsequent production processes: loading, transportation, mechanical crushing and processing of mineral raw materials. Therefore, destruction quality management is one of the main tasks of production.

Granulometric composition is the main parameter for normal operation of a mining company [2], percentage content of an average piece in the destroyed rock affects all processes from loading to crushing, in open-pit mines of building materials.

The structure of the charge has a significant effect on the degree of crushing of the rock mass, namely: the shape of the charge, the height of the charge column, the presence and parameters of the air gaps, and the energy characteristics of the explosives used. All these elements change the parameters of the explosive pulse and through it affect the quality of rock crushing by explosion.

2. Ways to solve the issue

Both theoretical and practical studies are performed on this issue, both in our country and abroad. For the moment, there is no generally accepted opinion on the influence of the charge diameter on the quality of explosive preparation of the rock [3, 4].
A number of researchers think [5, 6] that blasting small-diameter wells is the most cost-effective to get a given degree of crushing of strong rocks. Such conclusions were made on the basis of experiments held in laboratory and industrial conditions during explosion of single charges or in single-row arrangement of wells on the bench toe. In addition, these studies were performed in marble blocks, granites, quartzites, i.e. in large-block strong rocks.

Other researchers [7], on the contrary, came to a different conclusion on the influence of the charge diameter of the rock mass. As a result of the use of single-row and multi-row short-delayed blasting and blasting in the tense environment, iron ore companies have proved that increasing charge diameter improves crushing of rocks and increases overall technical and economic parameters of drilling and blasting operations.

Studies of the effect of explosions in rocks have shown that any increase in duration of an explosion on rock has a good effect on crushing. G I Pokrovskiy [8] has offered a formula to determine duration of an explosive pulse:

$$\tau = 1.16 \sqrt{R} \cdot \sqrt[3]{\frac{C_{BB}}{\gamma}} \cdot \sqrt[3]{V} \cdot \sqrt{\gamma} \cdot \frac{1}{\sqrt{E}} \cdot 10^{-3}$$

where $R$ — charge radius, m; $C_{BB}$ — the weight of the explosive charge, kg; $\gamma$ — volumetric weight of the rock, kg/m$^3$; $E$ — Young modulus of the rock, n/m$^2$.

This dependence shows that duration of the explosion exposure on the environment depends primarily on the charge radius. Consequently, any increase of the charge diameter would increase time of the explosion exposure on the environment and improve crushing [9].

3. Suggested way to solve the issue
The above-mentioned assumptions have been verified by the author in laboratory conditions. For that purpose, a number of experiments were performed on transparent models sized 400 X 400 m$^3$ (see table 1).

| $R$, m*10$^{-3}$ | $W$, m*10$^{-3}$ | $m$ char, kg*10$^{-3}$ |
|-----------------|-----------------|----------------------|
| 2               | 40              | 20                   |
| 3               | 60              | 45                   |
| 4               | 80              | 80                   |
| 5               | 100             | 120                  |
| 6               | 120             | 180                  |

Any increase in the charge diameter contributed to an increase of crack formation rate. Thus, for 22.4 microseconds, cracks managed to pass a distance of about 20 m*10$^{-3}$, and for that time at the charge diameter of 5-6 m*10$^{-3}$ cracks it extended to a length of 60-80 m*10$^{-3}$, i.e. their speed increased 3-4 times.

This circumstance was the main reason to improve intensity of crushing of brittle units by explosion as the charge diameter increases.

If we compare results of crushing at charge diameter of 2-3 and 5-6 m*10$^{-3}$, then it becomes quite obvious that as the charge diameter increases, crushing intensity would increase, rather than decrease. The same applies to the crushing uniformity. The larger the diameter, the higher is dynamics of amplitudes in the area of well-reproduced frequency band, what leads to a rapid increase of stress in the rock and more intensive crushing.

Along with this, influence of the charge diameter on quality of crushing of models from rock samples has been studied (ferruginous hornfelses with strength coefficient of 12-15 and 18-20). 12 models with...
charge diameter of 3, 4 and 5 mm*10⁻³ have been exploded for every of these categories of rocks. Bore holes in the models have been drilled parallel and perpendicular to stratification (see table 2).

Table 2. Granulometric composition of broken models.

| D_{char}, m*10⁻³ | Bore hole | f  | 0-2  | 2-3.5 | 3.5-5.5 | 5.5-10 | 10-20 | 20-30 | >20 | d_{cp,K}, m |
|------------------|-----------|----|------|-------|---------|--------|-------|------|-----|----------|
| 3                | Parallel to stratification | 12-15 | 2.9 | 7.7 | 7.6 | 26.8 | 45.5 | -  | -  | 1.09 |
|                  | Perpendicular to stratification | 12-15 | 5.1 | 8.2 | 11.3 | 23.2 | 46.0 | 6.2 | -   | 1.1   |
| 4                | Parallel to stratification | 12-15 | 7.7 | 7.7 | 11.1 | 27.5 | 46   | -   | -   | 0.98  |
|                  | Perpendicular to stratification | 12-15 | 3.3 | 3.9 | 6.7 | 20.7 | 54.8 | 10.6 | -   | 1.29  |
| 5                | Parallel to stratification | 12-15 | 4.9 | 6.1 | 6.5 | 19.2 | 41.2 | 17  | 5.1 | 1.44    |
|                  | Perpendicular to stratification | 12-15 | 3.2 | 9.6 | 5.6 | 32.6 | 44.2 | 4.8  | -   | 1.09  |
|                  |                         | 12-15 | 7  | 4  | 5.3 | 17   | 41.5 | 15.8 | 9.4 | 1.48    |
|                  |                         | 18-20 | 7.7 | 2.8 | 6.9 | 16.8 | 42.6 | 12.9 | 10.3 | 1.37   |
|                  |                         | 12-15 | 8.3 | 4.9 | 6.5 | 16.6 | 46.8 | 15.5 | 1.4 | 1.31    |

4. Results

Analysis of the granulometric composition of the crushed material of the models shows that the larger is the charge diameter, the larger is the yield of large fractions, and consequently the diameter of the average piece. However, crushing rate, expressed as the ratio of the line of the least resistance to the diameter of the average piece d_{cp}, is increased with the charge diameter. For example, at constant specific consumption of explosives with the charge diameter increased from 3 to 5 mm*10⁻³, the degree of crushing, when rock models were blown at f = 18÷20, increased by 21%, and at f = 12÷15 - by 33%. This indicates a more efficient use of the energy of explosives.

For the rocks that are characterized by a low rate of cracks, formation during destruction increasing well diameter worsens uniformity of crushing and increases percentage of yield of non-standard pieces. These rocks include deposits of dolomites, granites and other large-block structures. For these rocks, as practice shows, it is advisable to use a bit with a diameter of 100-200 mm*10⁻³.

The use of small-diameter wells to intensify crushing is sometimes conditioned by natural blockiness of the rock and screening role of cracks that divide the rock into separate pieces. Reducing the diameter enables placing wells inside every separate piece and thus avoiding influence of the screen.

The analysis of results of mass explosions at the open-pit mines of Korshunovskiy and Kachkanorskiy MPP is given below [9, 10]. Data of the research team of the plant on 24 mass explosions have been used for Korshunovskiy MPP, and for Kachkanorskiy MPP – those on explosions with breakage above 2 million tons of rock mass.

Wells of 190, 214.243 mm*10⁻³ in diameter (on chisel) have been drilled in these two open-pit mines. As a result, average yield of non-standard pieces (%) made for Korshunovskiy MPP for different diameters, respectively: 0.4, 0.6 and 0.7; and for Kachkanorskiy: 3.3; 3.9; and 5.3. In open-pit mines of natural stone any reduction of diameter of the wells and thickening of the well grid leads to the best distribution of explosives in the rock. Every natural rock has its own blockiness and with expansion of the well grid, it is not always possible to place a well in every natural block. When wells with a smaller diameter are used (provided that consumption of explosives remains the same), the well grid is thickened, enabling uniform distribution of the charge.
Thus, the reduction of the well diameter and further thickening of the well grid are effective only in open-pit mines of the natural stone.

![Figure 1. Photos of the rock breakdown: a – well diameter 165 mm*10^{-3}, b – well diameter 250 mm*10^{-3}.](image)

Experimental studies were performed on the granite quarry of Leningrad Region. Two blocks with diameter of 250 m*10^{-3} (Figure 1b) and 165 m*10^{-3} (Figure 1a) have been blown. It was followed by a photoplanimetric analysis of the results of blasting, which showed that any reduction of the well diameter was accompanied with reduced yield of non-standard pieces by 2%, and crushing quality improved by 15-20%.

5. Conclusions
Analyzing experimental and practical data, we may conclude that any wells of large diameters (200-300 mm) are the most effective at iron ore mines. This statement can be motivated by the fact that such crushing of the rock is economically most effective for further processing at the concentrating mill.

On the contrary, in any open-pit mines of natural stone, the use of large diameter wells has a negative effect on quality of the rock. Crushing and sorting equipment stipulates strict requirements for the quality of the rock; therefore, it is more efficient to reduce the well diameter and the well grid (100-200 m*10^{-3}).

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