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PREDICTING THE SHOTPILE OF BLASTED ROCK MASSAT A GRANITE DEPOSIT

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ABSTRACT

The article considers one of the main performance indicators of the drilling and blasting operations, namely the shotpile of the blasted rock mass. The main attention is paid to the automated prediction of the shotpile formation in the course of blasting. The presented calculation algorithm allows constructing the shotpile contour of the rock mass, given the initial conditions, considered estimated amounts, and the ballistics laws. The authors describe the operation of the developed software, which is based on the proposed calculation method to predict the shotpile of the blasted rock.

The article presents the analysis of the drilling and blasting operations at the Ponds-Mokhovoye-Yaskinskoye granite-gneiss quarry, during which the need to make changes in the parameters of drilling and blasting operations was revealed to ensure the quality of rock crushing and the formation of the shotpile of blasted rock mass providing given performance of mining and conveyor equipment.

Full-scale testing was carried out to verify the proposed software. The test results have shown satisfactory convergence of the calculated parameters of the shotpile of the blasted rock mass with the actual indicators.

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1. INTRODUCTION

To date, the development of mineral deposits on the daylight area dominates in the mining industry. At that, the main method of rock crushing is the method of borehole charges.

When assessing the blasting operations' performance, one of the main indicators is the parameters of the formed shotpile of the blasted rock mass, because these parameters have essential impact on the subsequent mining technological operations, reduction of productivity, and increase in the cost of mining operations due to the irrational formation of the shotpile.

A fairly large number of studies have been carried out in this field by leading scientists such as B.R. Rakishev, M.F. Drukovany,N.V. Melnikov, G.G. Lomonosov, and others

[2,9,5,11,14,17,19,20]. The authors,when calculating the shotpile parameters,use different computationmodels, which are based on the geometric scheme of the shotpile cross section. At that, researchers consider different cross sections, from triangular to composite, consisting of a set of several simple geometric figures.

The physical basis of modeling of the blasted rock mass shotpile is directly related to the physical and mechanical properties of the exploded rocks, the laws of ballistics, and the theory of rock destruction. Because of the complexity of the description of the shotpile formation process, to date there is no universally accepted theoretical description.

2. METHODS

To describe the rock destruction process by explosion, it is necessary to build a block model that allows dividing the exploded block into small calculating volumes. Thus, it is required to make a calculation for several million cells, which are influenced by the properties of rocks and other natural and technological factors, as well as the interaction between them at various points in times.

Based on the aforesaid, there is a need to develop algorithms and methods to perform quite time-consuming calculations to describe the shotpile formation process using modern software. The use of such a tool, along with the parallel application of other automated systems of drilling and blasting operations, will allow increasing the quality and operation speed of the mining area [7].

To develop such a system, we have taken as a basis the geometric model of the ledge cross section, proposed by S.V. Kopylov [4]. Figure 1 presents the location scheme of calculation zones in the volume, blasted by the borehole charge.

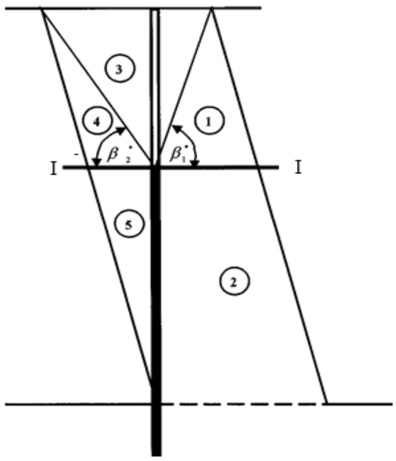

Figure 1 Scheme of the calculation zones location in the destroyed volume

According to this method [4], the calculation is based on the partition of the explosive mass into the same size volumesthat cannot guarantee the reliability of the constructed shotpile contour of the rock mass, since the disintegrated rock at different distances from the well will have completely different size parameters. Also, the influence of the delay time between the borehole charges, which has significant impact on the shotpile formation parameters, is not taken into account.

This article examines the application of mathematical prediction model of the initial stage of explosive destruction of rock mass proposed by S.G. Kabelko[3].

According to this model, at the initial stage, it is proposed to determine the distribution of the potential velocity field of the rock mass at explosive destruction caused bythe borehole charges based on the Laplace equation for a multiply-connected domain by solving the Dirichlet problem with boundary conditions.

Taking into account the parameters of the blasting well and the explosive charge, one determines the reference angles β_1 and β_2 according to various calculation formulas, and then,based on the ballistics laws [1], calculates the flight path, rolling-down, and unrolling of the design volumes of the loosened rock mass.

3. RESULTS

Based on the accepted calculation model we have developed automated predicting system called RazvalPlus (ShotpilePlus) which allows constructing the shotpile contour of the rock mass [8].

The developed software package is based on RADStudioXE rapid application development environment, which combines DelphiXE and C++BuilderXE into a single integrated development environment and allows creating native applications running on four popular platforms, namely Android, iOS, Windows, and OS X. The applications are created using the same source code base, without losing the quality of applications, performance, and availability of corporate or cloud resources [10, 12, 16].

The program consists of two main tabs called Source data and Calculation.

First of all, when starting the program, one must set the input parameters of drilling and blasting operations. It is necessary then to start calculation cycle by clicking the Calculate button (Figure 2), which is followed by the display of the final results.

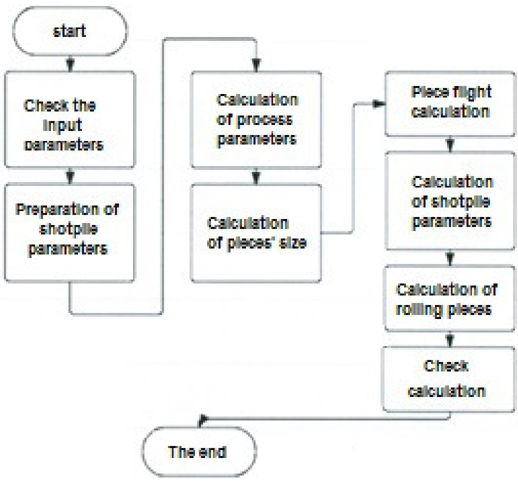

Figure 2 The general algorithm of the RazvalPlus software

After that, the calculation is completed, and the system starts the construction of the graphical part, i.e. the shotpile contour of the rock mass and the formed ledge, using the DrawGraph procedure.

This completes the program operation. If there is a need to change the source data, one should go to the "Source data" tab and enter new parameters. WhenclickingCalculate, thecalculationisrepeated.

To verify the theoretical background used as a core of the RazvalPlus software package, the calculation results were compared with the data obtained during the explosion produced at the Ponds-Mokhovoye-Yaskinskoye granite-gneiss quarry.

In the course of conducting mass explosion, the surveying of the block under preparation as well as the blasted rock mass was carried out by means of LeicaC10 compact pulsed highspeed laser scanner of geodesic accuracy class [15], after which the data were processed using Surpac software.

Figure 3 clearly shows how the area in which the rock was brokenis changing. At any time, the engineer can download the data to a personal computer and analyze the results of the performedwork, as well as determine the volume of the exploded rock mass.

However, the main indicators under consideration were those indicating the formed shotpile of the blasted rock mass. These parameters were defined using the function such as Construction of a section.

Thesectionpresented in Figure 4 shows the basic principle of displaying the shotpile formation after the explosion of borehole charges,as well as features of its parameters.

When overlapping two surfaces "before the explosion" and "after the explosion", it is possible to clearly see how has changed the worked off surface of the ledge.

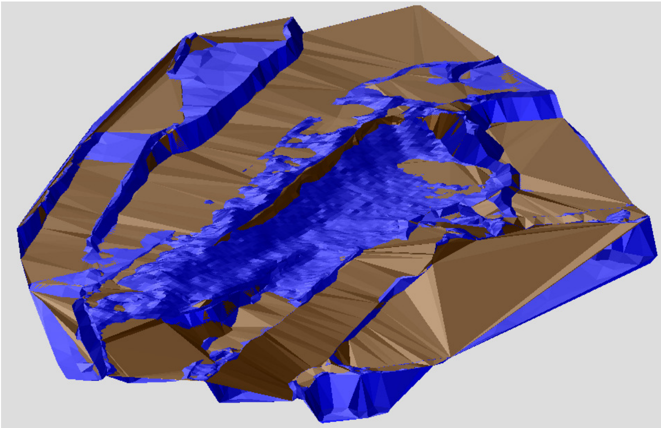

Figure 3 The surface of the work area;
brown – the surface before the explosion; blue – the surface after the explosion.

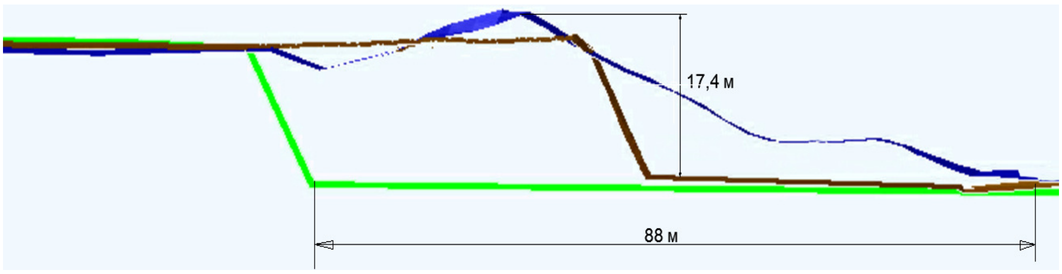

Figure 4 Section showing the shotpile of the rock mass

Prior to blasting in real conditions, simulation of blasting in the mine was produced using RazvalPlus software. Allparameterscorrespondedtotheactualvalues.

The result of the automated system operationto predict the shotpile contouris presented in Figure 5.

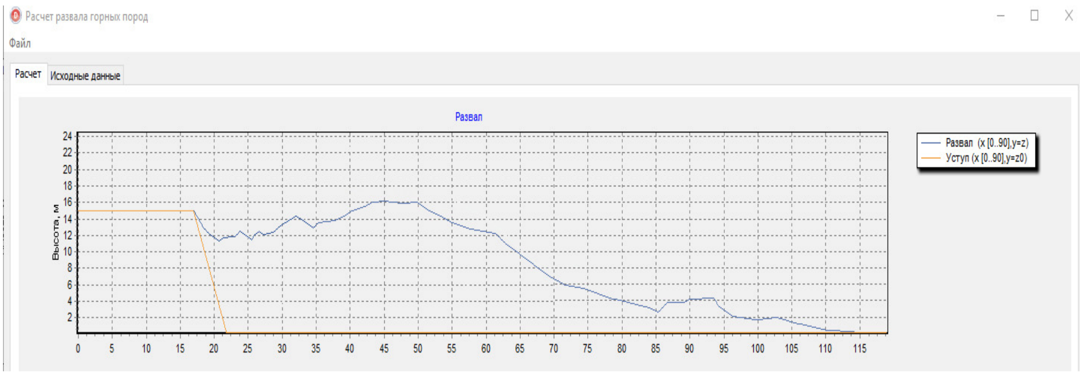

Figure 5 The shotpile contour of the blasted rock mass constructed using the RazvalPlus automated system.

Comparing the survey and calculation results, we can clearly see how accurately is the shotpile contour of the blasted rock mass predicted (Table 1).

Table 1 Comparison of the calculation results and actual performance

Measurementgrid	Experimental value of the level,m	Calculated value of the level,m	Absolute error of the shotpile height*, m
20	13	12	1
25	12.3	12	0.3
30	13.8	13.7	0.1
35	15	13.7	1.3
40	16	15	1
45	17	16.1	0.9
50	16.3	16	0.3
55	14	13.8	0.2
60	11.9	12.2	0.3
65	9.9	9.9	0
70	7.6	6.8	0.8
75	4.9	5.4	0.5
80	4	4.1	0.1
85	3.8	3	0.8
90	4	4.1	0.1
95	2.9	3	0.1
100	1.3	1.9	0.6
105	0.4	1.2	0.8
110	0	0.3	0.3
115	0	0	0

* - the average absolute error is 0.47 m

Analysis of drilling and blasting operations in the granite-gneiss Ponds-Mokhovoye-Yaskinskoye quarry showed that the existing drilling and blasting parameters were significantly dependent on the electric energy transmission line, which was guarded object, located in the immediate vicinity of the quarry.

Blasting operations are carried out using a sufficiently large amount of stemming material in the upper part of the wells, which, given the strong fracturing of rocks on the overburden horizon, leads to an abnormal output of the oversized fraction.

Taking into account the direct connection with the flyrock travel in the course of the shotpile formation, it is necessary to determine the optimal parameters of drilling and blasting operations providing high-quality crushing of rock mass to ensure the safety of the electric energy transmission line.

The most effective method of regulating the parameters of the shotpile of the rock mass is the use of various designs of borehole charges. According to studies [6, 13, 21], the design of the charge with the use of air gaps makes it possible to significantly increase the useful yield of the explosion due to more uniform distribution of the explosion energy on the rock.This technique allows achieving uniform and fine crushing of the rock (the size of the average piece decreases by 1.5-2 times).At that, the output of oversized pieces is reduced from 2 to 10 times. It is also worth noting the possibility of using the charge design with the active tamping, because in this case the duration of the impact of explosion products on the environment increases, and energy losses are reduced by reducing the velocity and amount of gases released into the atmosphere as compared to the inert stemming.

To assess the impact of blasthole charge structures on the parameters of the shotpile of the blasted rock mass, pilot tests were carried out for charges with air gaps, active tamping, and continuous tamping.

The height and width of the rock outburst were chosen as the main parameters of the shotpile.

Determination of the shotpile parameters of the blasted rock mass was carried out using a laser scanner Leica ScanStationC10. Based on the obtained data, the sections of the formed shotpile were constructed in the Surpac graphical data processing environment (Figures 6-9).

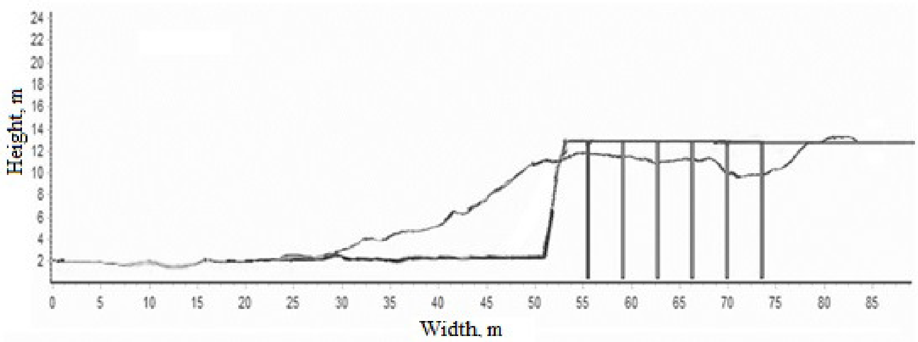

Figure 6 A shotpile section of the blasted rock mass when using borehole charges with air gaps. Block No. 86, level 55/43

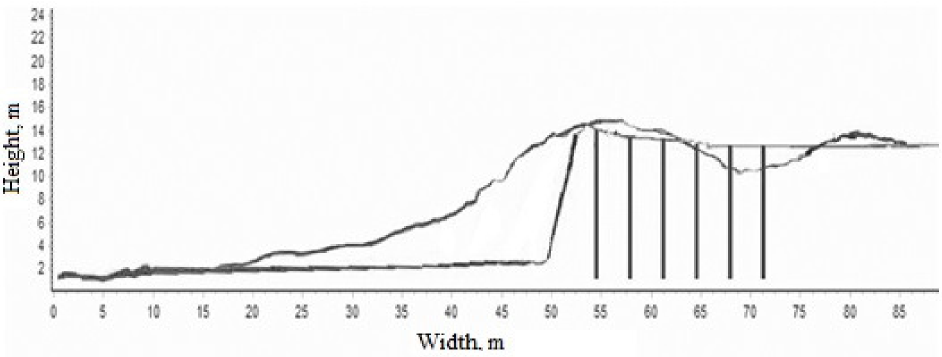

Figure 7 A shotpile section of the blasted rock mass when using continuous borehole charges. BlockNo. 87, level 55/43

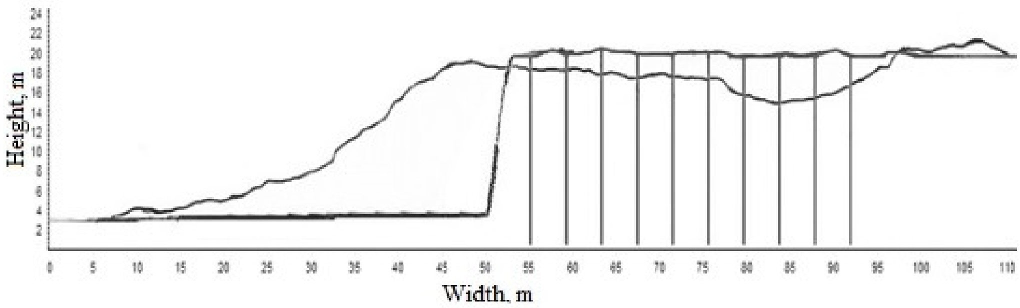

Figure 8 A shotpile section of the blasted rock mass when using active tamping. BlockNo. 109, level 44/27

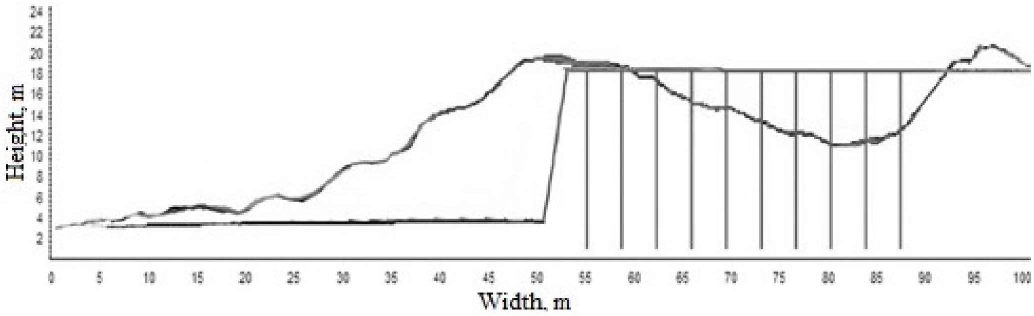

Figure 9 A shotpile section of the blasted rock mass when using inert stemming. Block No. 111, level 44/27

The granulometric composition of the destroyed rock mass was analyzed after each mass explosion using the WipFrag program manufactured by WipWare Inc. Canada [15,17,18]. Processing of the obtained results is given in Figures 10-11.

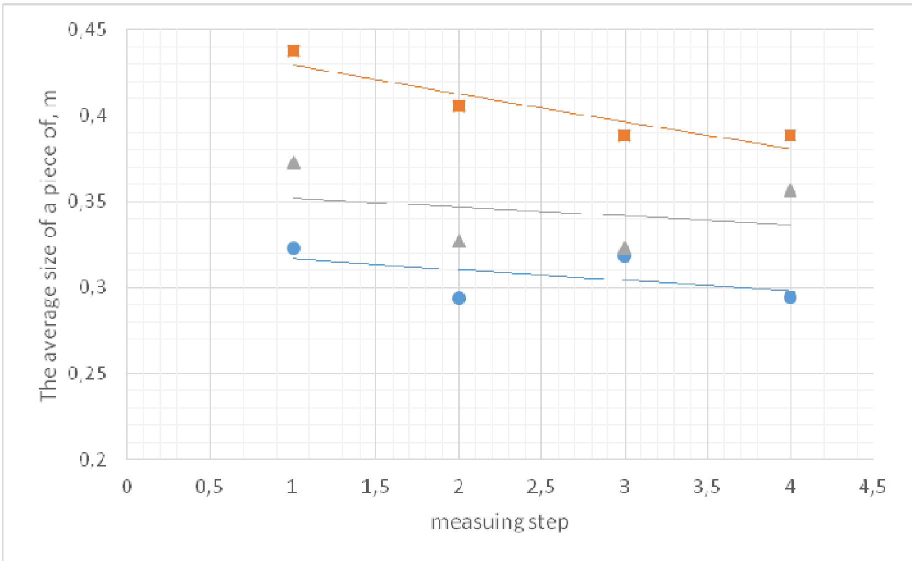

Figure 10 The average size of usual piece corresponding to various charge designsat four stages of photo surveying: stage 1 – immediately after the explosion; stage 2 – after extraction of 25 %; stage 3 – after extraction of 50%; stage 4 – after extraction of 75%.

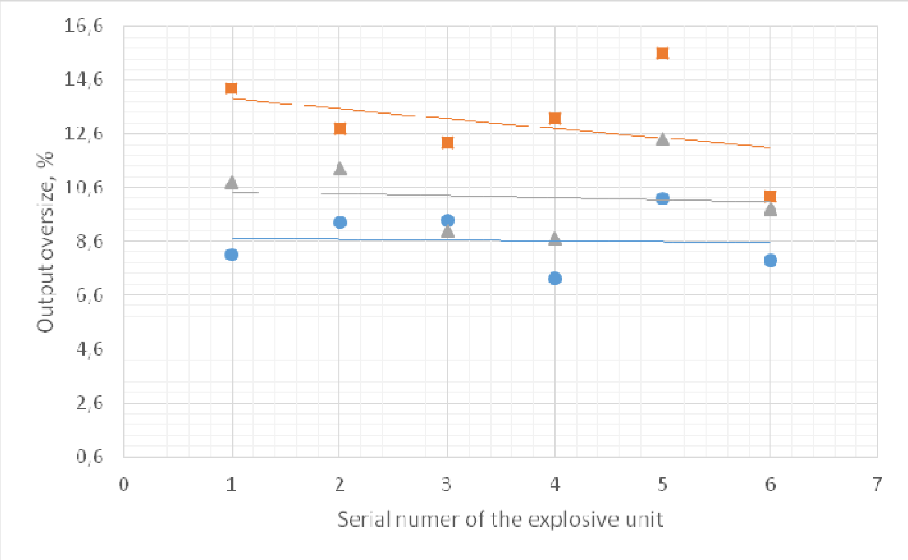

Figure 11 The percentage of oversized fraction output corresponding to different charge designs

The results of pilot tests are presented in Table 2.

Table 2 Results of pilot tests of various charge designs

	No of block	Shotpile height,m	Blowout width,m	$K_{w.sh.}$	$K_{h.sh.}$	Oversizedfraction, %
1	104[1]/105[2]/106[3] Level 55/43	11.0[1] 10.6[2] 11.8[3]	25.3 23.7 28.5	0.89 0.83 1.00	0.93 0.90 1.00	10.8 8.1 14.3
2	85/86/87 Level55/43	11.5 11.2 12.3	28.3 27.3 32	0.88 0.85 1.00	0.93 0.91 1.00	1 1. 3 9.3 12.8
3	96/97/98 Level55/43	14.3 13.9 14.9	24 25.1 28.4	0.85 0.88 1. 00	0.96 0.93 1.00	9.0 9.4 12.3
4	53/54/55 Level28/16	14.9 14.7 15.4	37.5 34.2 39.1	0.95 0.87 1.00	0.97 0.95 1.00	8.7 7.2 13.2
5	109/110/111 Level43/27	15.7 15.3 16.4	43.2 43.8 49.3	0.88 0.89 1.00	0.96 0.93 1.00	12.4 9.8 13.0
6	98/99/100 Level43/27	10.6 10.6 11.2	34.2 33 36.8	0.93 0.90 1.00	0.95 0.95 1.00	9.8 10.3 14

Note: design of charge: [1]–with active tamping; [2] – with air gap; [3] – continuous charge with inert stemming.

4. RESULTS

Application of the developed RazvalPlus software to predict the shotpile of the exploded rock mass, which takes into account a large number of factors influencing the formation process of the broken rock shotpile, showed satisfactory convergence of the calculation results with the actual indicators.

The conduction of experimental explosions demonstrated that the implementation of an air gap or active tamping into the charge design, while keeping the specific consumption of the explosive, resulted in a decrease in the oversized fraction output. The formation of the shotpile of the exploded rock mass is more "compact" due to the uniform effect of the explosion energy on the rock mass.

5. CONCLUSION

The proposed calculation method to predict the shotpile of broken rock, based on the mathematical model of the prediction of the initial stage of explosive destruction, made it possible to take into account the influence of disintegration of the mass in the course of shotpile formation of the rock mass.

The developed RazvalPlus software to predictthe shotpile of blasted rock mass showed the possibility of its application to calculate drilling and blasting parameters for various mining and geological,as well asmining engineering conditions.

Based on the experimental data, the correction coefficientswere determined to calculate parameters of the blasted rock mass shotpile:for the charge design involving air gap$K_{w.sh.}$ = 0.85 and $K_{h.sh.}$ = 0.92; while for the active tamping $K_{w.sh.}$ = 0.90 and $K_{h.sh.}$ = 0.95.

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