Investigation of the patterns of collapse formation and determination of optimal parameters of the retaining wall during mass explosions at quarries

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Abstract. The paper describes methods developed to determine the change in the width and height of the collapse of blasted rocks, as well as the width and height of the retaining wall during the explosion of borehole charges using emulsion explosives depending on the parameters that determine the energy characteristics of emulsion explosives. It gives the details of the physical and mechanical properties of rocks and the parameters of the explosive block, a mathematical model describing the action of an explosion of a borehole explosive charge in an array, on the basis of which the kinematic parameters of rock expansion are determined.

1 Introduction

The parameters of the collapse of rocks depend on the features of its formation, determined by the conditions of blasting – "on the selected face" or "in a clamped environment" [1].

To date, the development of rational parameters for blasting in a squeezed medium using emulsion explosives in industrial conditions is considered the best option for creating or shaping the parameters of a retaining wall.

The use of the developed parameters of the collapse and the retaining wall makes it possible to ensure the preservation of the geological structure of the rock mass, increase the efficiency of explosives, reduce preparatory and restoration operations in case of an explosion on a ledge, improve safety and increase the productivity of loading and transport equipment. With a significant thickness of ore deposits, a method of separate blasting of ores and host rocks with natural "shielding" is recommended, which consists in using favorable structural-geological and mining factors as natural boundaries for blasting. To calculate the width and height of the collapse of blasted rocks during the explosion of borehole charges using emulsion explosives, formulas have been developed that include the main parameters

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that determine the energy characteristics of explosives and the physical and mechanical properties of rocks

2 Materials and methods

During the explosion "on the selected face", the destroyed rocks are shifted towards the slope of the ledge (Figure 1) [2]. The consequence of this displacement is an increase in the width of the collapse compared to the width of the exploding block while reducing the height of the collapse compared to the height of the exploding ledge [3, 4].

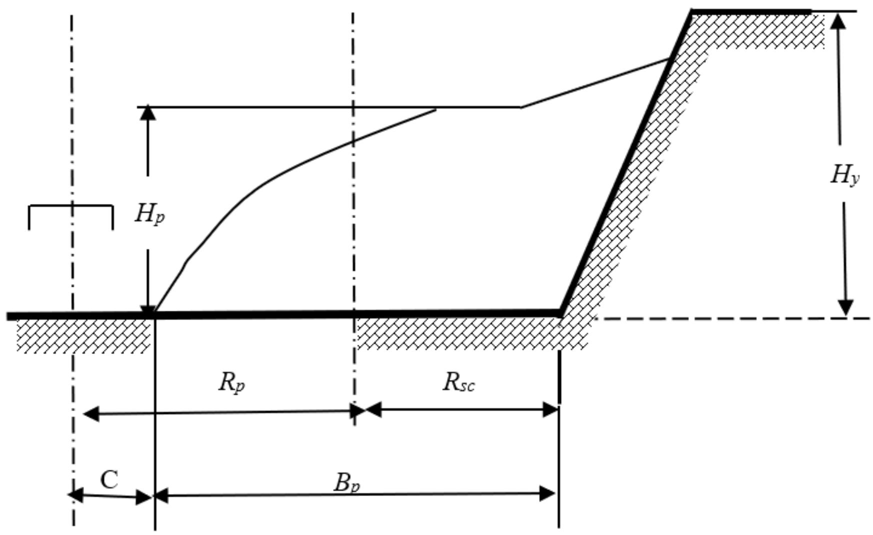

Fig. 1. The scheme of formation of the collapse of the rock during the explosion "on the selected face".

The height of the camber (Hp) in this case must meet the condition:

$$3H_{bucket} \leq H_p \leq H_{add}\,, \tag{1}$$

where H_{bucket} is the height of the excavator bucket, $H_{bucket} \approx 0{,}8\sqrt[3]{E_\kappa}$, m; H_{add} is the maximum allowable face height in the collapse of rocks after an explosion (H_{add} =H_{sc} for hydraulic and H_{add}=1,5H_{sc} for rope excavators of the "mechanical shovel" type), m.

At $H_y \leq H_{add}$, the collapse height will be obviously less than the maximum allowable face height, therefore calculations may not be checked, and at $H_y \leq H_{add}$, the collapse height should be lowered during an explosion to the maximum allowable face height by changing the number of rows of exploding wells and the specific flow rate of explosives or reduce the height of the ledge. You can use an excavator with other geometric parameters.

In [7-9], the parameters of the collapse were calculated, which is based on the law of dynamics of translational motion of a solid by inertia under the action of constant gravity.

The formula [7-9] for determining the air resistance coefficient depending on the drag coefficient is obtained:

$$b_c = \frac{\rho_v c_l}{2\rho\sqrt[3]{V_k}}, \tag{2}$$

where ρ_v is the air density, kg/m^3; c_l is the drag coefficient; ρ is the density of rocks, kg/m^3; V_k is the actual volume of blasted rocks, m^3.

The equation is solved in a rectangular coordinate system [5]. It is recommended to determine the initial velocity of the rock flow throwing by the formula:

$$\vartheta_0 = \sqrt{\frac{2\eta q Q}{\rho}}, \text{ m/s}, \tag{3}$$

where η is the efficiency of the explosion to discharge, $\eta = 0.05$; q is the specific flow rate of explosives, kg/m^3; Q is the specific heat of the explosion, J/ kg.

A formula for determining the casting range of a rock stream has been developed [1, 5, 6]:

$$L = \vartheta_0 t\, c\, \text{芀}s\, \phi \frac{\rho_v c_l \vartheta_0^2 t^2}{4\rho \sqrt[3]{V_k}} cos\, \phi, \text{ m}, \tag{4}$$

where t is the time of movement of the rock flow, s.

$$t = \frac{\vartheta_0 \sin\phi + \sqrt{(\vartheta_0 \sin\phi)^2 + \left(\frac{\rho_v c_l}{2\rho\sqrt[3]{V_k}}\vartheta_0^2 \sin\phi + g\right)H}}{\left(\frac{\rho_v c_l}{2\rho\sqrt[3]{V_k}}\vartheta_0^2 \sin\phi + g\right)}. \tag{5}$$

3 Results

As a result of the research, a mathematical model describing the effect of an explosion of a downhole explosive charge in an array was developed, on the basis of which the kinematic parameters of rock expansion were determined and a computer program was developed in Borland Delphi 7.0, protected by certificate №. DGU 01771 [8].

Based on this model, a method for moving rocks by explosion has been developed that increases the efficiency of production of directional explosions by downhole explosive charges for discharge, the scientific novelty of which lies in the use of shortened borehole charges located in strong interlayers for efficient use of their energy and differentiated impact on the array in multi-strength rocks, which reduces the cost of excavation and loading operations and transportation, on the basis of which the methodology of their engineering calculation has been developed. The novelty of the method is protected by the patent of the Republic of Uzbekistan for invention № IAP 04242 [9].

The maximum width of the camber on the ledge is determined by the formula

$$L_1 = V\sqrt{\frac{H}{g}} + 0{,}5W. \tag{6}$$

In order to determine the width of the camber, its maximum height and other parameters by the throwing distance, it is necessary to adopt a model of the shape of the cross-section of the camber.

The values that determine the width of the collapse are: the energy of the explosive charge, the density of the rock, the acceleration of gravity and the line of least resistance.

The width of the rock collapse during the explosion of the first row of wells can be determined based on the theory of similarity and dimension:

$$L_0 = Wf\left(\frac{E}{\rho g W^4}\right), \tag{7}$$

where W is the line of least resistance, m; E is the energy of the BB charge, J; ρ is the density of the rock, kg/m3; g is the acceleration of gravity, m/s2; f is the rock strength coefficient on the M.M. Protodyakonov scale.

This equation, taking into account the rock strength coefficient *f*, can be written as follows:

$$L_0 = \frac{E}{f\rho g W^3}. \tag{8}$$

The total destructive effect of the explosion is proportional to the energy of the explosive charge and is determined by the full magnitude of the explosive pulse [10].

The main parameters of the emulsion explosive, which most affect the level of energy intensity of explosive destruction of rocks and cost savings for blasting, are considered to be:

– the absolute weight energy Et or the total ideal work of the explosive $E_п$ (mJ/kg);
– absolute volumetric energy, E_v (mJ/m^3);
– detonation pressure, P_D;
– pressure of gaseous detonation products in the well, P_c;
– detonation velocity, D, m/s;
– power factor, k_m;
– perfect explosion operation, E_p.

With a constant volume of the charging cavity, the energy reserve of the emulsion explosive varies proportionally to the volumetric energy [11]:

$$E_v=E_m\cdot\rho_{вв}, \quad (9)$$

where Ev is the absolute volumetric energy of the emulsion explosive, mJ/m3; Et is the absolute weight energy of the emulsion explosive, mJ/kg; ρвв is the charging density of the emulsion explosive, kg/m3.

The energy reserve of the emulsion explosive depends on the specific energy and density of the emulsion explosive, as well as the charge density.

The potential charge energy of an emulsion explosive is determined by the formula:

$$E_n=E_m\cdot\rho_{вв}\cdot V, \quad (10)$$

where V is the volume of the emulsion explosive, m3; ρвв·V=mвв is the mass of the explosive mвв, and Eт·ρвв is the volumetric concentration of the charge energy.

Thus, it is possible to regulate the volume concentration of the energy of the emulsion explosives and charges:

1) by regulating the specific energy of the emulsion explosives at the stage of its creation;
2) creating conditions for the flow of explosive transformation with the maximum release of the weight energy of the emulsion explosive;
3) by regulating the density of the emulsion explosive and the density of its charging.

The width of the collapse of the exploded rocks is recommended to be determined by the formula:

$$L_p = \frac{Q_{BB}\rho_{BB}\pi r_{char}^2 l_{char}}{f\rho g W^3}, \quad (11)$$

where Q_{BB} is the heat of explosion of the emulsion explosive, kJ/kg; r_{char} is the radius of the charge of the emulsion explosive, m; l_{char} is the height of the charge of the emulsion explosive, m.

The height of the collapse can be determined by the formula [1, 10]:

$$B_p = H_y\sqrt[4]{\frac{N}{H_y q_p}}, \text{m}, \quad (12)$$

where H_y is the height of the ledge, m; N is the number of rows of exploding wells, pcs.; q_p is the specific consumption of explosives, kg/ m^3.

4 Conclusion

As a result of mathematical processing of numerous statistical materials of experimental and pilot-industrial explosions [12, 13], it is recommended to determine the specific consumption of explosives for the conditions of the quarries of the Kyzylkum region by the formula:

$$Q=0.01–K_a\sigma_{comp}\, lnd_{ave}, \quad (13)$$

where $К_a$ is the coefficient of adaptation to the conditions of a particular quarry, equal to 0.0034 for the Muruntau quarry and 0.0028 for the Kokpatas and Daugyztau quarries; $\sigma_{сж}$ is the compressive strength of rocks, MPa; d_{cp} is the average diameter of a piece of blasted rock mass, m.

Taking into account (13), the height of the collapse of the exploded rocks is determined by the formula:

$$B_p = H_y \sqrt[4]{\frac{N}{H_y \cdot (0.01 - K_a \sigma_{comp} \ln d_{ave})}}. \quad (14)$$

Grammonite 79/21 was adopted as the reference explosive. Therefore, when using other explosives, the coefficient of relative energy concentration of the $K_э$ is introduced into the calculation formula, taking into account the energy characteristics and the density of charging into the well of the new explosive.

Then formula (14) will take the form

$$B_p = H_y \sqrt[4]{\frac{K_e \cdot N}{H_y \cdot (0.01 - K_a \sigma_{covp} \ln d_{ave})}}. \quad (15)$$

The coefficient of relative energy concentration of emulsion explosives varies from 0.87 for nobelan 2080 to 1.16 for nobelite 2000.

Thus, the change in the width and height of the collapse of the exploded rocks, as well as the width and height of the retaining wall during the explosion of borehole charges using emulsion explosives, depending on the parameters determining the energy characteristics of the emulsion explosives, the physical and mechanical properties of rocks and the parameters of the exploding block, has been established.

References

1. Yu.D. Norov, Sh.Sh. Zairov, Mining Bulletin of Uzbekistan **4** (2015)
2. I.P. Bibik, S.K. Rubtsov, D.V. Sytenkov, *Management of explosive preparation of rocks in technological flows of quarries* (Tashkent, Fan, 2008)
3. N.N. Kazakov, S.D. Viktorov, *Determination of the parameters of the collapse of a rock mass beaten off by an explosion at quarries, Technological problems of destruction in mining production processes* (Moskow, 2004)
4. B.M. Yavorsky, A.A. Detlaf, *Handbook of Physics for engineers and university students* (Moskow, Nauka, 1974)
5. Yu.D. Norov, D.S. Ivanovsky, Sh.Sh. Zairov, Gorny Vestnik of Uzbekistan **4** (2008)
6. I.P. Bibik, Sh.Sh. Zairov, D.S. Ivanovsky, Sh.R. Urinov, Mining Bulletin of Uzbekistan **3** (2010)
7. I.P. Bibik, Sh.Sh. Zairov, D.S. Ivanovsky, Mining Journal **12** (2010)
8. Yu.D. Norov, I.P. Bibik, Sh.R. Urinov, Sh.Sh Zairov, D.S. Ivanovsky, *Kinematic parameters of rock explosion*, Certificate of official registration of the computer program No. DGU 01771 on application no. DGU 2009 0019 (2009)
9. Yu.D. Norov, I.P. Bibik, Sh.Sh Zairov., D.S. Ivanovsky, *Method of moving rocks by explosion*, Patent for invention No. IAP 04242. Registered in the State Register of Inventions of the Republic of Uzbekistan (2010)
10. V.D. Savinkov, *Development of effective means and methods of explosive rebounding in conditions of negative temperatures and highlands*, Diss. ... candidate of Technical Sciences (Bishkek, 1998)
11. N.V. Melnikov, L.N. Marchenko, *Explosion energy and charge design* (Moscow, Nauka, 1964)
12. N.I. Kuchersky, *Modern technologies in the development of indigenous gold deposits* (Moscow, Ore and metals, 2007)

13. V.N. Sytenkov, U.Yu. Davranbekov, I.P. Bibik, *Design of borehole charges during explosive loosening of rocks in quarries*: textbook. Stipend (Navoi, NSMI, 2004)