E3S Web of Conferences **417**, 01012 (2023) https://doi.org/10.1051/e3sconf/202341701012
GEOTECH-2023

Determination of the coefficient of loosening and explosion parameters in a clamped medium in the quarry

Utkir Nasirov[1], *Sherzod* Zairov[2*], *Farxodbek* Umarov[1], *Zokirkhodja* Ishankhodjaev[3], *Maqsud* Mekhmonov[2], and *Asliddinjon* Fatkhiddinov[4]

[1]National Research Technological University «MISIS» in Almalyk, Almalyk, 110100, Uzbekistan
[2]Navoi State University of Mining and Technologies, Navoi, 210100, Uzbekistan
[3]Almalyk Mining and Metallurgical Combine, Yoshlik-1 quarry, Almalyk, 110100, Uzbekistan
[4]Almalyk branch of Tashkent State Technical University, Almalyk, 110100, Uzbekistan

Abstract. The paper describes estimates developed for the change in the loosening coefficient of the rock mass depending on the mass of the emulsion explosive charge and the grid of wells. The parameters of blasting in a clamped medium have been determined. A formula for calculating the height of the retaining wall during the explosion of borehole charges using emulsion explosives has been developed. It includes the main parameters and determines the physical and mechanical properties of rocks, the parameters of the blasted block and the mass of the emulsion explosive charge.

1 Introduction

The method of blasting in a squeezed medium has several options that differ in the number of open surfaces, their location, the nature of the retaining wall and blasting schemes [1].

Due to the retaining wall and the lower speed of movement of the blasted mass in the horizontal plane, the duration of the explosion on the environment increases and the efficiency of its energy is increased.

As a result, this method of blasting provides an improvement in the quality of crushing rocks, the ability to control the shape and parameters of the collapse of the blasted rock mass and selective excavation, the reduction of preparatory and restoration work, the independence of the drilling and blasting processes from excavation and transportation.

The width of the retaining wall can vary from the maximum, which excludes the possibility of horizontal movement of rocks during the explosion, to the minimum, which does not prevent the movement of rocks. Specific limiting values of the width of the retaining wall are determined not only by the physical state and physical and mechanical properties of the rocks of the retaining wall, the height of the ledge, the design and magnitude of the charge, the parameters of the well pattern, the blasting scheme, but also the energy parameters of explosives.

* Corresponding author: sher-z@mail.ru

The optimal width of the retaining wall is determined by the target requirement for the result of the explosion. If the main goal is to reduce the width of the collapse, then the width of the retaining wall is increased. If it is necessary to reduce the degree of crushing, then a reduced width of the retaining wall should be taken.

Studies at the Muruntau open pit found that the optimal value of the width of the retaining wall in terms of the minimum cost factor is different for the purpose of regulating intensive crushing and for the purpose of regulating the collapse width. The value of the optimal width of the retaining wall for the purposes of crushing regulation is 40-50% less than for the collapse width regulation. Therefore, the width of the retaining wall should be taken depending on the goals and specific technical and economic conditions.

2 Materials and methods

In work [2-4], in the process of performing pilot work in the quarries of the Kyzylkum region, the main patterns of massif deformation during an explosion were studied and the main elements that determine the degree of massif deformation were identified.

The results of the work were evaluated by the loosening coefficient of the massif and the specific consumption of explosives, as the main regulating and controlling parameter.

The dependence of the loosening coefficient on the specific consumption of explosives is approximated by the equation

$$K_p=1{,}36q^{0{,}18}, \tag{1}$$

where q is the specific consumption of explosives, kg/m3.

The relationship between the loosening coefficient, the mass of the charge of the emulsion explosive and the distance between the wells has been established:

$$K_p = 1{,}22\left(\sqrt[3]{\frac{Q_{char}}{a}}\right)^{0{,}73}, \tag{2}$$

where Q_{char} is the mass of the emulsion explosive charge, kg; *a* – distance between wells, m.

The mass of the explosive charge per well is determined by the well-known formula:

$$Q_{well}=q \cdot H_y \cdot a \cdot b, \tag{3}$$

where b is the distance between the rows of wells or the length of the rock resistance line along the sole, m.

At the same time, from the well capacity condition, the mass of the charge is equal to

$$Q = \frac{\rho_{вв}\pi d^2}{6H_y}. \tag{4}$$

Based on the known value of the well convergence coefficient m=a/b (for a square or staggered grid of wells), by jointly solving equations (5) and (6), we determine the parameters of the grid of wells:

$$W_{llr} = b = 0{,}72d\left[\frac{\rho_{вв}}{mq}\right]^{1/2}, \tag{5}$$

$$a = 0{,}72d\left[\frac{\rho_{вв}}{q}\right]^{1/2}. \tag{6}$$

The depth of the drill is taken equal to

$$L_{over}=(10 \div 15)d_{well}. \tag{7}$$

The mass to be blasted will be worked out qualitatively if the rock resistance line along the ledge foot and the line of least resistance (LRL) of rocks correspond to the energy capabilities of the emulsion explosive charge, which are determined mainly by the borehole charge diameter. At the same time, the size of the rock resistance line along the sole should provide safe conditions for drilling operations. It is this requirement that is decisive in substantiating the parameters for placing a borehole charge in a massif, according to which the rock resistance line along the sole should be at least

$$W_b \geq H_y \cdot Ctg\alpha + C, \quad (8)$$

where W_b is the safe (according to the conditions of drilling operations) length of the rock resistance line along the sole, m; α is the slope angle of the ledge, degrees; C is the minimum safe distance from the axis of the wells of the first row to the upper edge of the ledge.

The calculated of the rock resistance line along the sole W_p, which guarantees high-quality working out of the sole and achievement of the required degree of crushing of the rock mass, should be within:

$$W_b \leq W_p \leq W_{pr}, \quad (9)$$

where $W_{пр}$ is the limiting value of the rock resistance line along the sole for a given diameter of the emulsion explosive charge.

The calculated of the rock resistance line along the sole is determined by the estimated specific consumption of explosives for the selected diameter and the types of explosives used:

$$W_p = 0{,}9\left(\frac{p}{qm}\right)^{1/2}, \quad (10)$$

where p is the capacity of 1 r.m. wells, kg,

$$p = \frac{\pi d^2 \Delta}{4}, \quad (11)$$

d is the diameter of the borehole explosive charge; q is the calculated specific consumption of the emulsion explosive, kg/m^3; Δ is the emulsion explosive loading density, t/m^3; m is the coefficient of approach of charges (m=1 for a square grid of wells).

The limiting value of the rock resistance line along the sole for a given explosive charge diameter is determined by the formula:

$$W_{pr} = 53K_tK_zd\left(\frac{\Delta}{\rho e}\right)^{1/2}(1{,}6 - 0{,}5m), \quad (12)$$

where K_t is the massif structure coefficient (for deposits of the Kyzylkum region K_t=1.1); K_z – clamping factor during blasting with a retaining wall, K_z =0.75÷0.8; *e* is the efficiency factor of the emulsion explosive, *e*=1.

The line of least resistance Wllr, corresponding to the rock resistance line along the sole, is equal to

$$W_p = 0{,}9\left(\frac{p}{qm}\right)^{1/2} \sin\alpha. \quad (13)$$

With an increase in the line of least resistance, the loosening coefficient decreases, and with an increase in the mass of the emulsion explosive charge in the well, it increases, which confirms the feasibility of blasting with optimal parameters: the maximum possible line of least resistance and the minimum allowable mass of the emulsion explosive in accordance with the energy standards of crushing.

For a more accurate identification of the specific consumption of emulsion explosives, it is necessary to assess the degree of crushing and displacement of the blasted mass both in the horizontal and vertical directions during blasting on the retaining wall.

The horizontal displacement of the array during blasting on the retaining wall is determined by the formula:

$$l = 1{,}2(K_p - 1)H_y. \quad (14)$$

Taking into account formula (1), in order to predict the horizontal displacement of a massif during blasting on a retaining wall, it is necessary to use the formula:

$$l = 1{,}2H_y(1{,}36q^{0{,}18} - 1). \quad (15)$$

According to [5], the maximum width of the retaining wall is determined by the expression

$$L \frac{L_p}{1+50/F^3}_{n.c.max} \quad (16)$$

where F is the number of the group to which the rocks belong according to the SNiP classification. Determined from the ratio

$$f = \left(\frac{F}{2,5}\right)^2 \Rightarrow F = 2,5\sqrt{f}. \tag{17}$$

Given that

$$L_p = \frac{Q_{BB}\rho_{BB}\pi r_{char}^2 l_{char}}{f\rho g W^3}, \tag{18}$$

where Q_{BB} is the heat of explosion of the emulsion explosive, kJ/kg; $r_{зар}$ is the charge radius of the emulsion explosive, m; $l_{зар}$ is the height of the charge of the emulsion explosive, m, we determine the maximum width of the retaining wall, taking into account the energy parameters of the emulsion explosive:

$$L \frac{100 Q_{вв}\rho_{вв} V}{(F^3+50)(f\rho g W^3))}_{n.c.max} \tag{19}$$

where $Q_{вв}$ is the heat of explosion of the emulsion explosive, kJ/kg; $\rho_{вв}$ is the emulsion explosive loading density, kg/m^3; V is the volume of the emulsion explosive, m^3; ρ is rock density, kg/m^3; g is the acceleration of gravity, m/s^2; f is the coefficient of rock strength according to the scale of M.M. Protodyakonov; W is the line of least resistance, m.

The calculated width of the retaining wall, which ensures the minimum displacement of rocks during crushing, is determined by the formula:

$$L_{n.c.} = K_p W\left(\frac{\sqrt{2k_{uz}q_{BB}Q\mu}}{\sigma_{comp}} - 1\right), \tag{20}$$

where k_{uz} is an empirical coefficient that takes into account the use of explosion energy for crushing and moving the rock mass. Experimental studies [1] show that, depending on the specific consumption of the emulsion explosive, this coefficient ranges from 0.004 to 0.2; μ is the modulus of elasticity of the blasted rock, Pa (determined from experimental data or from the Cadastre of Rocks).

Taking into account formula (2)

$$L_{n.c.} = 0,1W\left(\sqrt[3]{\frac{Q_{char}}{a}}\right)^{0,73} \cdot \left(\frac{\sqrt{2k_{uz}q_{BB}Q\mu}}{\sigma_{comp}} - 1\right), \tag{21}$$

The magnitude of the collapse of the blasted rock mass from the lower edge of the retaining wall is determined by the formula:

$$L_{p.n.c} = \left(1 - \frac{L_{n.c}}{k_{p.c}W+L} b_{cnc}\right)\left(\frac{Q_{вв}\rho_{вв}V}{f\rho g W^3}\right), \tag{22}$$

where $L_{n.c}$ is the accepted width of the retaining wall, m; $k_{p.c}$ – coefficient of loosening of rocks of the retaining wall ($k_{p.c}$ =1.05÷1.1); b_{cnc} is a value that takes into account the influence of the forces of resistance of the retaining wall to rock displacement

$$b_{c.n.c} = \frac{k_{p.c}W + L_{n.c.max}}{L\sqrt{L_{n.c.max}}_{n.c.max}}. \tag{23}$$

Taking into account the energy parameters of the emulsion explosive

$$b_{c.n.c} = \frac{k_{p.c}W + \frac{Q_{вв}\rho_{вв}V}{(F^3+50)(f\rho g W^3)}}{\left(\frac{Q_{вв}\rho_{вв}V}{(F^3+50)(f\rho g W^3)}\right)^{1,5}}. \tag{24}$$

The control of horizontal displacements during the explosion «in a squeezed environment» is carried out mainly to control losses and impoverishment of the ore.

Taking into account formula (23), the magnitude of the collapse of the blasted rock mass from the lower edge of the retaining wall can also be determined by the formula

$$L_{p.n.c} = \left(1 - \frac{L_{n.c}}{k_{p.c}W+L} \cdot \frac{k_{p.c}W + \frac{Q_{вв}\rho_{вв}V}{(F^3+50)(f\rho g W^3)}}{\left(\frac{Q_{вв}\rho_{вв}V}{(F^3+50)(f\rho g W^3)}\right)^{1,5}}\right) \cdot \left(\frac{Q_{вв}\rho_{вв}V}{f\rho g W^3}\right). \tag{25}$$

The height of the retaining wall is determined by the formula:

$$B_{n.c.} = \frac{WK_p}{2}(1 + k_c), \tag{26}$$

where k_c is a coefficient that takes into account the acoustic rigidity of blasted rocks and uncut rock mass (in the conditions of deposits in the Kyzylkum region, it varies within 0.2÷0.3).

Taking into account formula (2), we determine the height of the retaining wall by the formula

$$B_{n.c.} = 0{,}61W(1 + k_c)\left(\sqrt[3]{\frac{Q_{зар}}{a}}\right)^{0{,}73}. \quad (27)$$

3 Results

Figure 1 shows the change in the coefficient of loosening of rocks depending on the mass of the emulsion explosive charge. The dependence obtained shows that with an increase in the mass of the emulsion explosive charge from 100 to 450 kg, the loosening coefficient increases from 1.13 to 1.33.

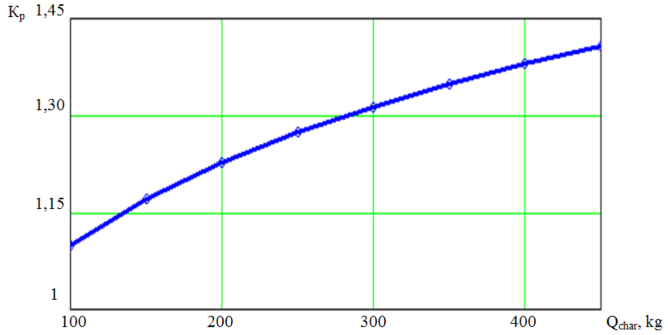

Fig. 1. Change in the coefficient of loosening of rocks depending on the mass of the emulsion explosive.

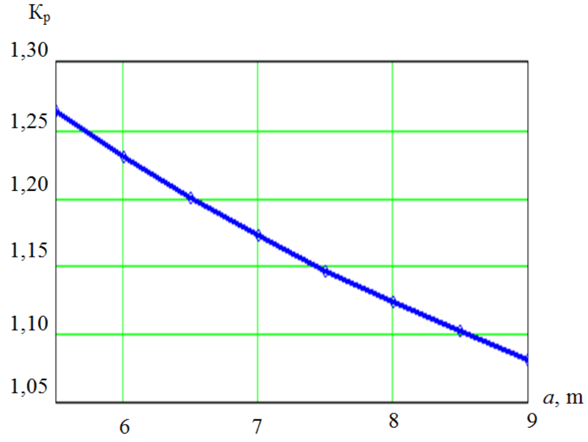

Fig. 2. Change in the coefficient of loosening of rocks depending on the distance between wells.

Studies have established a change in the loosening coefficient of the massif depending on the grid of wells (Figure 2). The obtained dependence shows that with an increase in the distance between wells from 5.5 to 9 m, the coefficient of loosening of rocks decreases from 1.27 to 1.08.

4 Conclusion

Thus, the change in the loosening coefficient of the rock mass depending on the mass of the charge of the emulsion explosive and the grid of wells was established, and the parameters of blasting in a clamped medium were determined. To calculate the height of the retaining wall during the explosion of borehole charges using emulsion explosives, a formula was obtained that includes the main parameters that determine the physical and mechanical properties of rocks, the parameters of the blasted block and the mass of the emulsion explosive charge.

References

1. Yu.V. Stenin, D.S. Panfilov, *Calculations of the parameters of the process of drilling and blasting preparation of rocks for excavation* **2,** *Calculation of blasting parameters in the transport development system*: *Tutorial* (Yekaterinburg, ed. USGU, 2017)
2. N.I. Kuchersky, *Modern technologies in the development of primary gold deposits* (Moscow, Ore and metals, 2017)
3. Sh.Sh. Zairov, D.R. Makhmudov, Sh.R. Urinov, Gornyi Zhurnal **9** (2018). https://doi.org/10.17580/gzh.2018.09.05
4. U.F. Nasirov, S.A. Ochilov, A.A. Umirzoqov, Journal of Advanced Research in Dynamical and Control Systems **12(7)** (2020)
5. F.A. Avdeev, V.L. Baron, N.V. Gurov, *Regulatory reference book on drilling and blasting* (Moscow, Nedra, 1986)
6. N.I. Kuchersky, *Modern technologies in the development of indigenous gold deposits* (Moscow, Ore and metals, 2007)
7. 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)