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Increasing the Stability of the Sides of the Quarry by Forming a Concave Profile of the Slope of a High Ledge

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Abstract

The paper presents the results of the analysis of rational designs of non-working sides of the quarry and investigated the impact of blasting in the bordering zone on the state of the slopes of the ledges. A method has been developed to increase the stability of the sides of the quarry by forming a concave profile of the slope of a high ledge, ensuring the quality of the slope of the ledge, the complete safety of the contour array and the safety of mining operations.

Keywords: Mining Operations; Blasting Operations; Mass Explosions; Rocks; Drilling

Abbreviations: DBO: Drilling and Blasting Operations

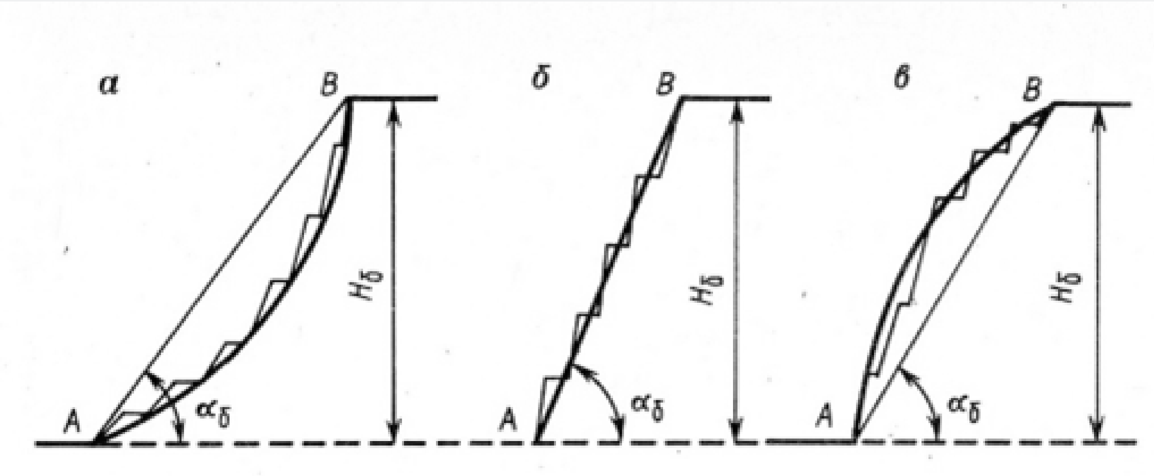
Introduction

At present, significant progress has been made in the world in the field of the using of contour blasting in surface mining, however, a number of key issues related to the choice of rational parameters of contour blasting, predictive evaluation and the choice of methods to improve the efficiency of special technology for cutting ledges have not been resolved. One of the most significant drawbacks is that the requirements of stability are not taken into account when choosing the parameters of drilling and blasting operations (DBO). The influence of special methods of conducting DBO on the stability of the slopes of ledges is only ascertained after the work is completed. In this regard, it is necessary to pay special attention on solving the issues of minimizing the destructive effect of mass explosions on the structural array and maintaining the stability of the slopes of ledges and their sides.

The existing methods of calculating the stability of slopes of ledges and sides of quarries allow us to determine the parameters of slopes of concave, convex and flat shapes (Figure 1) [1, 2]. Equally or unequally stable profiles of the sides of the quarry can be obtained by solving the problems of slope stability. In the first case, the reserve coefficient for the weakest surfaces remains constant regardless of the depth of the surfaces. In the second case, the reserve coefficient is variable with depth and, while ensuring the overall stability of the entire slope, is determined by the change in structural and technological factors in the height of the slope.

A number of researchers [3-10] have established the expediency of dividing the side into zones, considering changes in the physical and mechanical properties of rocks, surfaces of weakening and fracturing. In each zone of the side, considering the time factor, the angles of stable slopes are determined, the contours of which fit the optimal profiles. Such zones can be layers of strong rocks (C >20 MPa), medium strength (2 MPa ≤ C ≤ 20 MPa) and weak (C <2 MPa).

In addition to the three main forms of slopes, according to the condition of stability of individual zones, a fourth is possible - a combined form. The combination of individual forms in the zones gives a complex configuration of the side as a whole, which with some approximation can be attributed to one of the main forms. The choice of the optimal configuration of the profile of the quarry side must be carried out according to the condition of the stability of individual zones and the side as a whole, i.e., the safety of work, and the exclusion of unproductive costs for the separation of the sides.



a - concave; б - flat; в - convex; $\alpha_б$ - the angle of the side of the quarry; $H_б$ - side height

Figure 1: The main types of profiles of quarry sides according to the condition of stability.

Calculations of a flat slope profile have become the most widespread in mining practice. Due to the different service life of the sections of the side of the quarry, such a design does not satisfy the effective development of the deposit and is associated with unproductive excavation of overburden rocks on the lower horizons.

The use of optimal methods for cutting ledges in the extreme position will allow you to create ledges of great height by combining several technological ledges into one.

It is known that the creation of a shielded gap in highly fractured rocks or in rocks that have undergone residual deformations from the effects of mass explosions does not protect the onboard array from the crushing and seismic effects of mass explosions. Therefore, it is necessary to carry out the doubling and straining of stationary ledges in these conditions according to various technological schemes, considering mining and geological conditions. Analysis of studies on the use of special methods of conducting DBO in the design of ledge slopes has shown that the most effective way to limit the deformation zone behind the design separation surface is the use of pre-crevice formation [11].

The use of pre-crevice formation is associated with additional costs for drilling contour wells, charging and blasting them using additional explosives and explosive devices. Therefore, the question of the expediency of this cutting method should be decided on the basis of a technical and economic calculation. This calculation is based on the condition that the cost of cutting should be less than the cost of the extracted volumes of rocks that are formed when the angle of inclination of the side increases [1].

The depth of the quarry at which it is economically feasible to use preliminary crevice formation is determined by the formula [9]:

$$H \geq \frac{2C_3}{C_B(ctg\alpha - ctg\alpha_3)\sin\alpha_3},$$

where C_3 - the cost of cutting 1 m^2 of slope, considering the costs of drilling and blasting a contour row of wells, sum; $C_в$ - cost of extraction of 1 m^3 of overburden rocks, sum; α - the angle of inclination of the side of the quarry without contour blasting, deg.; α_3 - angle of inclination with the use of contour blasting.

Considering the above, the design depth of the quarry is an important factor that should be considered when zoning the border area. Analysis of studies on the selection of parameters of contouring charges for creating a screening gap revealed the absence of a methodology that allows reasonably and unambiguously recommend the parameters of the DBO for specific mining and geological conditions. The currently known dependences allow only a rough estimate of the relationship between the main parameters of the contouring charges [12].

Due to the lack of theoretical dependencies for calculating the maximum permissible loads on the structural array, according to the condition of maintaining the stability of the slopes, it is necessary to work out the parameters of the DBO for each site that differs in the structure of the array or the physical and mechanical properties of rocks. To increase the stability of the slopes of the sides of the quarry, a method has been developed for forming a preliminary gap in the limiting contour of the sides of the quarry

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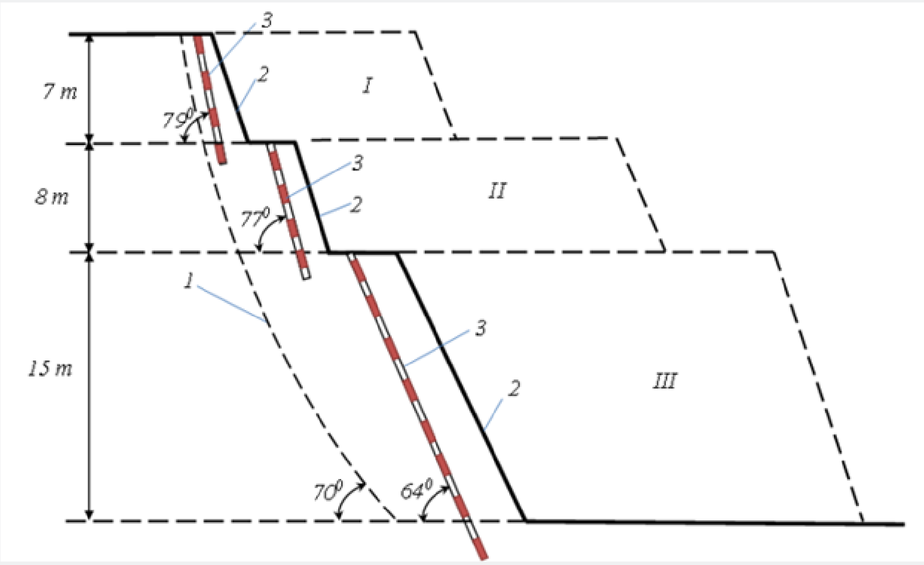
by forming a concave profile of the slope of a high ledge, which reduces violations of the massif and cracking, as well as reducing scree formation and landslide.

According to this method, when mining operations approach the final contour of the quarry, a ledge with a height of 30m is divided into approaches with horizons I, II and III (figure 2). Each horizon explodes separately. Horizon I explodes first, horizon II explodes next, and horizon III explodes last. As a result of the mathematical modeling carried out when dividing a high ledge into three sub-steps, rational heights and angles of slopes of each sub-step are established.



1 - the final contour of the quarry; 2 - the slope of the ledge of the quarry; 3 – the inclined contour well; I - the upper horizon; II - the middle horizon; III - the lower horizon

Figure 2: The scheme of cutting of ledges in the contour zone of the quarry.

At the first mass explosion, a number of inclined wells at an angle of 79° with a depth of 8m and a diameter of 110 mm are drilled by a drilling rig at a distance of 1 m from the design contour of the quarry at the upper ledge (horizon I) with a height of 7m, taking into account the prism of a possible collapse (<2.5 m) at a distance of 1m from the design contour of the quarry. The distance in a row between contour inclined wells is 2m.

During the second mass explosion, a number of inclined wells at an angle of 77° with a depth of 9m and a diameter of 110mm are also drilled in the middle ledge (horizon II) with a height of 8 m before crushing the array with downhole explosive charges. The distance in a row between contour inclined wells is also 2m. During the third mass explosion, a number of inclined wells at an angle of 64° with a depth of 17m and a diameter of 110mm are drilled in the lower ledge (horizon III) with a height of 15m before crushing the array with borehole explosive charges. The distance in a row between contour inclined wells is 2m.

Charges in all contour wells are formed from intermediate detonators with an emulsion explosive and a detonating cord in the form of garlands with a specific flow rate of 2kg/m. The formation of slope angles of high ledges up to 70° is possible in various geological, mining and climatic conditions. The application of the proposed sequence and parameters of the ledge construction ensures the quality of the ledge cutting, the complete safety of the contour array and the safety of mining operations.

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