PalArch's Journal of Archaeology of Egypt / Egyptology

UDC [622.063.23: 622.831: 622.13] (043.5)

MODELING OF CREATING HIGH INTERNAL PRESSURE IN BOREHOLES USING A NON-EXPLOSIVE DESTRUCTIVE MIXTURE

ZairovSherzodSharipovich,
https://orcid.org/0000-0002-1513-5683
Professor of the Department of Mining at the Navoi State Mining Institute,
Doctor of Technical Sciences, Professor.
190, avenue Galaba, Navoi, Uzbekistan, 210100.
E-mail: sher-z@mail.ru
UrinovSheraliRaufovich,
https://orcid.org/0000-0002-2910-9806
Professor of the Department of Automation and Control
at the Navoi State Mining Institute, Doctor of Technical Sciences
190, avenue Galaba, Navoi, Uzbekistan, 210100
E-mail: urinov.sherali@gmail.com
Ravshanova Muhabbat Husniddinovna,
Senior Lecturer, Department of Mining, Navoi State Mining Institute.
190, avenue Galaba, Navoi, Uzbekistan, 210100
TukhtashevAlisherBahodirovich,
https://orcid.org/0000-0002-9527-6207
Head of Department of Mining at the Navoi State Mining Institute,
Candidate of Technical Sciences, Docent,
190, avenue Galaba, Navoi, Uzbekistan, 210100
a.tukhtashev79@mail.ru

ZairovSherzodSharipovich, UrinovSheraliRaufovich, Ravshanova Muhabbat Husniddinovna, TukhtashevAlisherBahodirovich, MODELING OF CREATING HIGH INTERNAL PRESSURE IN BOREHOLES USING A NON-EXPLOSIVE DESTRUCTIVE MIXTURE-Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(6),ISSN 1567-214x

ABSTRACT

The purpose of the work is to develop a mathematical model for creating high internal pressure in boreholes using a non-explosive destructive mixture (NDC), which makes it possible to obtain a smooth separation of rocks in the massif.

When performing research work, complex research methods were used, including scientific generalizations, theoretical and experimental studies in laboratory and landfill conditions on the production technology and formulation development of NDC, mathematical modeling of creating high internal pressure in boreholes using NDC, mathematical programming methods, as well as methods of mathematical statistics and correlation analysis of test results using modern computer technology.

Keywords: *non-explosive rock destruction, non-explosive destructive mixture, borehole, mathematical modeling, high internal pressure, new composition of the rock, laboratory research, components from local raw materials, method for separating monoliths from the massif.*

Introduction. A mathematical model has been developed for creating high internal pressure in boreholes using NDC, which makes it possible to obtain a smooth separation of rocks in the massif; justified and obtained the interval version of mathematical model and solution algorithm, and the theorem is shown and the interval strip with limited width, proving that when using NDCs in a number of holes to obtain a smooth separation of rocks;a formula has been developed for determining the effective distance between contour holes when using NDC, which allows for an even separation of the rock mass.

Practical implementations. A method has been developed for separating monoliths from the massif using a new NDC composition, which makes it possible to silently split monolithic blocks, reduce the labor intensity of work performed, ensure environmental protection, reduce the cost of production and energy intensity of mining operations, and improve the safety of their conduct.

Materials. Currently, many methods of non-explosive destruction of rocks are known, in particular, mechanical methods (wedge, hydroclinic, diamond-rope sawing, stone-cutting drilling rigs and combines), methods based on liquid energy (hydrodynamic, physico-chemical pulse rupture, water impact, hydro-cutting, fluid breaking), thermal (thermal cutting), electric and electromagnetic (exploding of electric conductors, electric breakdown, thermal breakdown, high-frequency currents, melting, laser radiation, electromagnetic radiation), combined methods, etc. Most of these methods are at the stage of research and design development. Their industrial use is constrained by the lack of equipment, low reliability, high energy consumption, dangerous effects on humans, and high cost. All these disadvantages force us to look for ways to create cheap and promising ways to destroy strong rocks.

One possible solution to this problem is the use of static methods of rock destruction through the use of non-explosive destructive compounds (NDC).

To date, more than 100 different compositions of NDC have been developed in the world [1-20]. Their main disadvantages are a long time of destruction (8-24 hours) and a limited temperature mode of operation. At negative temperatures, the destruction efficiency is sharply reduced by slowing down the rate of hydration, and at high positive temperatures, an involuntary ejection of a mixture of NDC from boreholes and wells is observed, caused by a sharp increase in the rate of hydration. The reason for the release of the NDC mixture from the boreholes is an increase in the intraspuric vapor-gas pressure, which sharply increases when the transition of chemically unbound water to steam when the NDC temperature exceeds during hydration.

The Navoi State Mining Institute is conducting research aimed at creating new types of products using components from local raw materials. The main objective of the research is to reduce the time of destruction and at the same time exclude the phenomenon of spontaneous emission of NDC from the hole.

To solve this problem, comprehensive studies of the self-expansion kinetics of NDC and mathematical modeling of the creation of high internal pressure in boreholes using NDC were carried out.

We will conduct a simulation of creating high internal pressure in the boreholes when using the NDC. According to the simulation, the following problem needs to be solved: at what location of the holes do the resulting cracks form a solid line after using the NDC? This task can be described in more detail as follows.

In a rock, you need to split some of this rock. For this purpose, the project needs to drill several holes. After that, these holes are filled with water, which, entering the reaction, expands and as a result, cracks begin to form around the holes. Moreover, these cracks can appear in any direction. The goal of this problem is how to get cracks that, connecting with neighboring cracks formed from other holes, would form a solid line.

Let's create a mathematical model of this problem: under what conditions do the points $M_1(x_1; y_1)$, $M_2(x_2; y_2)$, …, $M_n(x_n; y_n)$ lie on the same straight line? The solution to this problem is the following theorem.

Theorem. If the following condition is met: the distance between the points of the coordinate axes $x_1, x_2, \ldots, x_n$ and $y_1, y_2, \ldots, y_n$ must be equal, i.e.

$x_2-x_1=x_3-x_2= \ldots =x_n-x_{n-1}=a$, $y_2-y_1=y_3-y_2= \ldots =y_n-y_{n-1}=b$,

then the points $M_1(x_1; y_1)$, $M_2(x_2; y_2)$, …, $M_n(x_n; y_n)$ lie on the same straight line given by the equation

$$y-y_1=\frac{b}{a}(x-x_1). \qquad (1)$$

Evidence. To prove this theorem, we use the equation of a straight line passing through these two points, which is known from the course of analytical geometry

$$\frac{x-x_1}{x_2-x_1}=\frac{y-y_1}{y_2-y_1}.$$

Since all points must lie on the same straight line, they must satisfy this equation, i.e.

$$\frac{x-x_1}{x_2-x_1}=\frac{y-y_1}{y_2-y_1},\quad \frac{x-x_1}{x_3-x_1}=\frac{y-y_1}{y_3-y_1},\ \ldots,\quad \frac{x-x_1}{x_n-x_1}=\frac{y-y_1}{y_n-y_1}.$$

Adding both parts of these equalities, we get

$$\frac{x-x_1}{x_2-x_1}+\frac{x-x_1}{x_3-x_1}+\cdots+\frac{x-x_1}{x_n-x_1}=\frac{y-y_1}{y_2-y_1}+\frac{y-y_1}{y_3-y_1}+\cdots+\frac{y-y_1}{y_n-y_1}.$$

Given that $x_2-x_1=a, x_3-x_1=2a, \ldots, x_n-x_1=(n-1)a$, and also $y_2-y_1=b, y_3-y_1=2b, \ldots, y_n-y_1=(n-1)b$ and substituting them in the denominator of both parts of the last equality, we get

$$\frac{x-x_1}{a}+\frac{x-x_1}{2a}+\cdots+\frac{x-x_1}{(n-1)a}=\frac{y-y_1}{b}+\frac{y-y_1}{2b}+\cdots+\frac{y-y_1}{(n-1)b}.$$

We take the common factor from both parts of this equality, then we have

$$\frac{x-x_1}{a}\left(1+\frac{1}{2}+\cdots+\frac{1}{n-1}\right)=\frac{y-y_1}{b}\left(1+\frac{1}{2}+\cdots+\frac{1}{n-1}\right).$$

By reducing the expressions in parentheses in both parts of the equation and performing a simple conversion, we get:

$$y-y_1=\frac{b}{a}(x-x_1)$$

or

$$y-y_1=\frac{y_k-y_{k-1}}{x_k-x_{k-1}}(x-x_1). \qquad (2)$$

the required equation. The theorem is proved.

If we denote by k the angular coefficient, i.e. $k = tg\varphi = \frac{b}{a}$, then we get, known from the course of analytical geometry, the equation of a straight line passing through a given point in a given direction

$$y - y_1 = k(x - x_1). \quad (3)$$

Consequence.

a) If all points of the ordinates are equal to the same number, i.e.

$$y_1=y_2=y_3= \dots =y_n=c,$$

then the last equation will look like

$$y = c.$$

In this case, the straight line will be parallel to the Ox axis.

b) If all the points of the abscissa are equal to the same number, i.e.

$$x_1=x_2=x_3= \dots =x_n=c,$$

then the last equation get the form

$$x = c.$$

In this case, the line will be parallel to the *Oy* axis.

To check the validity of the result, let's look at the examples.

Example 1. For simplicity, consider three points.

Let the points $M_1(x_1; y_1)$, $M_2(x_2; y_2)$, $M_3(x_3; y_3)$ satisfy the conditions of the theorem, i.e. $M_1(1; 3)$, $M_2(3; 6)$, $M_3(5; 9)$.

The difference between the points of abscissa $x_2-x_1=x_3-x_2=1-3=5-3=2$, the difference between the ordinates of points $y_2-y_1=y_3-y_2= 6-3=9-6=3$.

Then, substituting them into equation (2), we get:

$9 - 3 = \frac{3}{2}(5 - 1)$, $6= 3\cdot 2$, $6=6$.

We got the identity, so the equation is correct.

Example 2. In this case, we also consider three points.

Let the points $M_1(x_1; y_1)$, $M_2(x_2; y_2)$, $M_3(x_3; y_3)$ do not satisfy the conditions of the theorem, i.e. $M_1(1; 3)$, $M_2(3; 4)$, $M_3(5; 10)$.

The difference between the points of abscissa $x_2-x_1=x_3-x_2=1-3=5-3=2$, the difference between the ordinates of points $y_2-y_1= 4-3=1$, $y_3-y_2=10-4=6$, in other words, they are not equal. Then

$$10-3=\frac{1}{2}(5 - 1).$$

From this we get $7\neq 2$. due to the inequality of the differences of the ordinate points, these three points do not lie on the same line, which confirms the result of the theorem.

When using NDC to obtain a solid straight line of cracks in the rocks being destroyed, it is very important to determine the location of the holes. Their location and getting cracks in a straight line depends on the structure, strength and degree of extensibility of the developed rocks. After applying the NDC, cracks appear in the rocks. These cracks are formed as a result of chemical and physical reactions of the NDC composition used. Cracks can form in any place of the hole and develop in any direction. As a result, the resulting material may be unusable or some of it may have to be rejected. For this reason, experts in this area are conducting research. Simply put, the formation of these cracks depends on many factors, such as the composition of the applied mixture, the type of rock, the diameter and depth of holes, distances between holes, strength, shatter rocks, etc. In this case, the solution of the problem of obtaining a continuous line as a result of emerging cracks in the use of NDCs becomes a task difficult to solve.

If you use certain methods, you can give direction to these cracks, so that the final result is connected cracks, which eventually form a solid line of cracks between the holes. In the process of solving this problem, a theorem is mathematically modeled and proved, where it is stated that the centers of holes are located in a straight line if the coordinates of these centers satisfy a certain condition.

Theorem. If the following condition is met: distance between points of the coordinate axes $x_1, x_2, \ldots, x_n$ and $y_1, y_2, \ldots y_n$ must be equal, i.e.

$$x_2 - x_1 = x_3 - x_2 = \ldots = x_n - x_{n-1} = a,$$
$$y_2 - y_1 = y_3 - y_2 = \ldots = y_n - y_{n-1} = b,$$

the points $M_1(x_1; y_1)$, $M_2(x_2; y_2)$, …, $M_n(x_n; y_n)$, which are the centers of the holes, lie on the same straight line, given by the equation

$$y - y_1 = \frac{b}{a}(x - x_1).$$

The result of this theorem is confirmed by examples,as well as by experimental data. This theorem is a real version of the solution of this problem.

Below is a mathematical model in the interval version, which solves the problem of the mutual location of holes in the design development for chipping part of the rock from the main mass, without causing damage to the non-project, i.e., not developed part of the rock. The solution of this problem in the interval version, or rather by methods of interval analysis [2], is motivated by the fact that the diameter, depth of the hole, as well as the distance between them can vary in the aisles of a certain interval, depending on many parameters of the developed rocks.

For example, according to [8], the well diameter is $d \in [60; 100]$mm, depth$h \in [6d; 10d]$, the distance between the holes$l = 1000\frac{df}{\sigma}$mmand etc., here$f$ – rock decompression coefficient, σ – coefficient of rock strength. For this reason, naturally, these parameters need to be considered in a certain interval. Consideration of the mathematical model in the interval version guarantees a two-way estimation of these parameters along the lower and upper bounds of the obtained intervals.

Consider the following problem: at what location of the holes can you get a solid crack formed between them? To do this, proceed as follows.

Taking into account the given motivation of the interval variant, we take the diameter of the hole d and the coordinates of the center of the holes $M_i(x_i; y_i)$ as an interval value, i.e.

$$\boldsymbol{d} = [\underline{d}, \overline{d}], \boldsymbol{x}_i = [\underline{x_i}, \overline{x_i}] \text{и } \boldsymbol{y}_i = [\underline{y_i}, \overline{y_i}],$$

here $\underline{x_i}$ – is called the lower bound and $\overline{x_i}$– is the upper bound of the interval $\boldsymbol{x}_i$, respectively, which are real numbers.

Further, intervals, according to the generally accepted rules, are indicated in bold, and real numbers in normal font. In the future, all arithmetic operations on interval values will be performed, according to [2], in the full interval arithmetic of Kausher, which is usually denoted *KR*. We denote the interval space and classical interval arithmetic in this space by *IR*.

Let, $* \in \{+,-,\cdot,/\}$, then $* \in KR$ means that the addition, subtraction, multiplication, and division operations are performed in full interval arithmetic *KR*.

Now let's start solving the problem.

Since the considered intervals are located in the positive part of the abscissa and ordinate, these intervals are positive and non-zero-containing intervals. The intersection of the intervals $\boldsymbol{x}_i$ and $\boldsymbol{y}_i$ in R^2 form rectangles containing the point $M_i(x_i; y_i)$, whose sides are $\overline{x_i} - \underline{x_i}$, $\overline{y_i} - \underline{y_i}$, respectively.

We present some characteristics of interval values according to [2], which we will use in further discussions.

The midpoint of the interval $\boldsymbol{a} = [\underline{a}, \ \overline{a}]$ is called the value $\mathrm{mid}(\boldsymbol{a}) = \frac{1}{2}(\underline{a} + \overline{a})$, the width of this interval is called the value $wid(\boldsymbol{a}) = \overline{a} - \underline{a}$.

In the real version of the problem under consideration, the coordinates of the point had to satisfy the condition:

the abscissa of the point $x_2\text{-}x_1 = x_3 - x_2 = \ldots = x_n - x_{n-1} = a$, (*)

ordinates of a point$y_2\text{-}y_1 = y_3 - y_2 = \ldots = y_n - y_{n-1} = b$. (**)

Note that $x_i \in \boldsymbol{x}_i и y_i \in \boldsymbol{y}_i$for all$i$=1, 2, …, n.

Now, using the introduced notation, we will rewrite the equalities (*) and (**) in the following form

$$\mathrm{mid}(\boldsymbol{x}_2) - \mathrm{mid}(\boldsymbol{x}_1) = \mathrm{mid}(\boldsymbol{x}_3) - \mathrm{mid}(\boldsymbol{x}_2) = \cdots = \mathrm{mid}(\boldsymbol{x}_n) - \mathrm{mid}(\boldsymbol{x}_{n-1}) = a, \quad (4)$$

$$\mathrm{mid}(\boldsymbol{y}_2) - \mathrm{mid}(\boldsymbol{y}_1) = \mathrm{mid}(\boldsymbol{y}_3) - \mathrm{mid}(\boldsymbol{y}_2) = \cdots = \mathrm{mid}(y_n) - \mathrm{mid}(y_{n-1}) = b, \quad (5)$$

where a and b are constant numbers.

Then, as in the real case, we require the location of the midpoint of the intervals $\boldsymbol{M_i}$ on a single line, since the midpoint of these intervals, by definition, are real numbers. Then these points lie on a single line and satisfy the equation of the line

$$\frac{x-x_1}{x_2-x_1} = \frac{y-y_1}{y_2-y_1}.$$

Substituting the corresponding interval values for x and y in this equation, we get

$$\frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{\mathrm{mid}(\boldsymbol{x}_2)-\mathrm{mid}(\boldsymbol{x}_1)} = \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{mid}(\boldsymbol{y}_2)-\mathrm{mid}(\boldsymbol{y}_1)}, \ \frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{\mathrm{mid}(\boldsymbol{x}_3)-\mathrm{mid}(\boldsymbol{x}_1)} = \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{mid}(\boldsymbol{y}_3)-\mathrm{mid}(\boldsymbol{y}_1)}, \ldots, \frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{\mathrm{mid}(\boldsymbol{x}_n)-\mathrm{mid}(\boldsymbol{x}_1)} = \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{mid}(\boldsymbol{y}_n)-\mathrm{mid}(\boldsymbol{y}_1)}. \quad (6)$$

Slow addition of the left and right parts of equality (6), respectively, gives

$$\frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{\mathrm{mid}(\boldsymbol{x}_2)-\mathrm{mid}(\boldsymbol{x}_1)} + \frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{\mathrm{mid}(\boldsymbol{x}_3)-\mathrm{mid}(\boldsymbol{x}_1)} + \cdots + \frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{\mathrm{mid}(\boldsymbol{x}_n)-\mathrm{mid}(\boldsymbol{x}_1)} = \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{mid}(\boldsymbol{y}_2)-\mathrm{mid}(\boldsymbol{y}_1)} + + \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{mid}(\boldsymbol{y}_3)-\mathrm{mid}(\boldsymbol{y}_1)} + \cdots + \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{mid}(\boldsymbol{y}_n)-\mathrm{mid}(\boldsymbol{y}_1)}. \quad (7)$$

Byvirtueofequalities (4) and (5), wecanwrite

$$\mathrm{mid}(\boldsymbol{x}_2) - \mathrm{mid}(\boldsymbol{x}_1) = a, \ \ \mathrm{mid}(\boldsymbol{x}_3) - \mathrm{mid}(\boldsymbol{x}_1) = 2a, \ldots, \mathrm{mid}(\boldsymbol{x}_n) - \mathrm{mid}(\boldsymbol{x}_1) = (n-1)a \ u$$

$$\mathrm{mid}(\boldsymbol{y}_2) - \mathrm{mid}(\boldsymbol{y}_1) = b, \mathrm{mid}(\boldsymbol{y}_3) - \mathrm{mid}(\boldsymbol{y}_1) = 2b, \ldots, \mathrm{mid}(y_n) - \mathrm{mid}(y_1) = (n-1)b,$$

Then, using the properties of interval operations [2], we replace the denominators of fractions in the equation (7) with the corresponding numbers. This is possible because the denominators are numbers. Then have

$$\frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{a} + \frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{2\mathrm{a}} + \cdots + \frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{(\mathrm{n}-1)\mathrm{a}} = \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{b}} + \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{2\mathrm{b}} + \cdots + \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{(\mathrm{n}-1)\mathrm{b}} \quad (8)$$

In equality (8), putting the General multipliers in the bracket, we get

$$\frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{a}\left(1 + \frac{\mathbf{1}}{2} + \cdots + \frac{\mathbf{1}}{(\mathrm{n}-1)}\right) = \frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{b}}\left(1 + \frac{\mathbf{1}}{2} + \cdots + \frac{\mathbf{1}}{(\mathrm{n}-1)}\right).$$

Reducing the expressions in parentheses in both parts of the last equality, we have

$$\frac{\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)}{a}=\frac{\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)}{\mathrm{b}}. \quad (9)$$

After performing simple transformations, we rewrite the last equality in the following form

$$\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)=\frac{b}{\mathrm{a}}\left(\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)\right). \quad (10)$$

Equation (10) defines the width of the strip on the plane located in the first quarter of the *Oxy* plane.

This means that the centers of the holes are located inside this band, and the distance between the centers of the holes is constant, i.e. equal, this follows from conditions (4) and (5). the Coordinates of the centers of the holes are located at points

$$M_i(\mathrm{mid}(\boldsymbol{x}_i);\ \mathrm{mid}(\boldsymbol{y}_i)).$$

The direction of the band is determined by the b/a value. The distance between the centers of the holes is defined by the equalities

$$M_{i+1}\left(\mathrm{mid}(\boldsymbol{x}_{i+1});\ \mathrm{mid}(\boldsymbol{y}_{i+1})\right)-M_i\left(\mathrm{mid}(\boldsymbol{x}_i);\ \mathrm{mid}(\boldsymbol{y}_i)\right)=l,\text{где}\ i=1,2,\dots,n-1. \quad (11)$$

Now we determine the width of the resulting band, which is defined by equation (10).

This is equivalent to determining the width of the intervals

$$\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)\ \ \boldsymbol{u}\ \boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1).$$

Define the width of the interval

$$\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1).$$

By definition and the interval width property

$$wid\left(\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)\right)=wid(\boldsymbol{x})+wid\left(\mathrm{mid}(\boldsymbol{x}_1)\right)=wid(\boldsymbol{x})+\mathrm{mid}(\boldsymbol{x}_1)=\overline{x}-\underline{x}+\frac{1}{2}(\overline{x}_1+\underline{x}_1)=\left(\overline{x}+\frac{1}{2}\overline{x}_1\right)-\left(\underline{x}-\frac{1}{2}\underline{x}_1\right). \quad (12)$$

Similarly, we get the result for the interval$\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)$:

$$wid\left(\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)\right)=(\overline{y}+\frac{1}{2}\overline{y}_1)-(\underline{y}-\frac{1}{2}\underline{y}_1). \quad (13)$$

From equality (12) and (13) it is visible, what is the width of the resulting band given by formula (10).

A consequence. Because we want to find strip with minimum width, then the equation (10) the expressions $\boldsymbol{x}-\mathrm{mid}(\boldsymbol{x}_1)$ and $\boldsymbol{y}-\mathrm{mid}(\boldsymbol{y}_1)$, without violating the generality, we may replace $wid(\boldsymbol{x})$and$wid(\boldsymbol{y})$, which is common and convenient to use in practical tasks. Then get

$$wid(\boldsymbol{y})=\frac{b}{\mathrm{a}}wid(\boldsymbol{x}). \quad (14)$$

If we put $wid(\boldsymbol{x})=minx_i$and $wid(\boldsymbol{y})=miny_i$ for all i=1, 2,..., n, then equality (14) takes the form

$$\min_i y_i=\frac{b}{\mathrm{a}}\min_i x_i. \quad (15)$$

Equality (15) is of practical value, because engineers work with real numbers, not intervals, and this equality is given by the band with the smallest width. Figure 1 shows the definition of the band width and the location of the hole centers for three points.

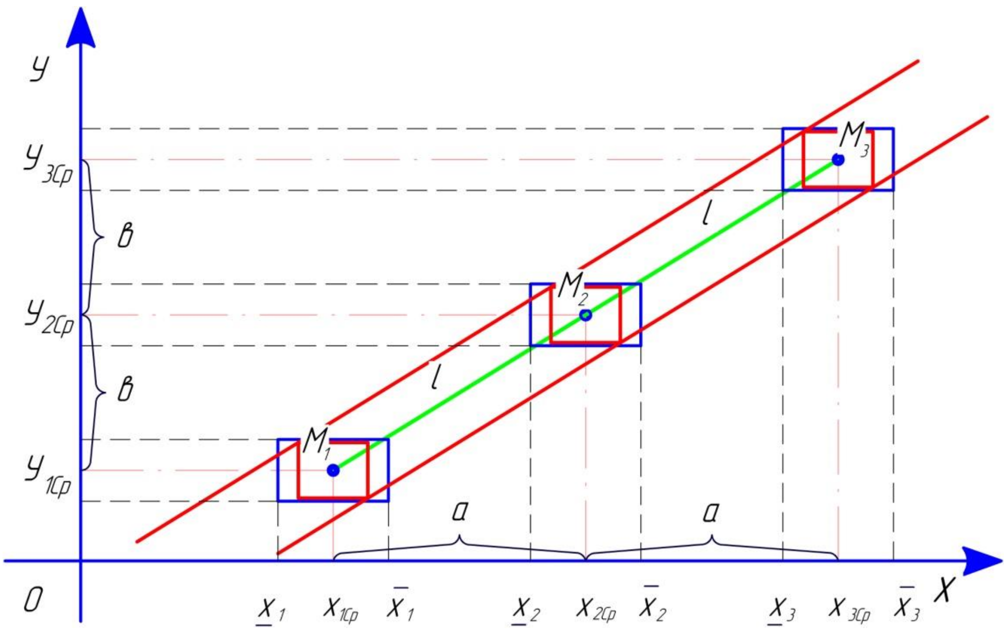

Fig. 1. Image of the strip and location of the hole centers

It is known that the smallest area of a rectangle is equal to the area of the square obtained from this rectangle with the smaller side.

Next, we denote by p the width of the strip and by C the side of the square obtained from the rectangle $\boldsymbol{x}_i \cdot \mathbf{y}_\mathrm{i}$. The side of a square is defined by the following equation

$$c = \begin{cases} \min\limits_i x_i\,, & if\ \min\limits_i x_i \le \min\limits_i y_i \\ \min\limits_i y_i\,, & if\ else. \ \ i = 1, 2, \dots, n. \end{cases}$$

In this case, the bandwidth ρ will be equal to

$$\rho = \sqrt{2}\mathrm{c}, \tag{16}$$

if the lane is sloped and

$$\rho = \mathrm{c}, \tag{17}$$

if the bar is horizontal or vertical.

In this case, the hole, as a circle, is inscribed in a square with side c, so for the diameter of the hole there is an inequality

$$d < \rho.$$

Thus, the derivation of equation (10) and, as a consequence, equation (14) and equality (15) are the solution of the problem. Equalities (16) and (17) determine the width of the received band. As a result of obtaining these equations, the following theorem was proved.

Theorem. If the conditions (4) and (5) are met for the intervals $\boldsymbol{x}_i, \boldsymbol{y}_i \in IR$, i=1, 2, …, n, then the

1) coordinates of the points of the center of the holes are located along the band defined by (10), and the smallest width of this band is set by (16) or (17);

2) the distance between the holes is determined by the equation (11).

Consider the formation of a contour gap as a result of the action of tangential stresses σ_θ at a point a located in the plane of the gap at an equal distance from neighboring holes (Fig. 2) [9-11, 19, 20]. A significant role in the mechanism of gap formation is played by radial stresses from neighboring holes that are geometrically formed in a plane that intersects the contour gap perpendicular to it at a distance from neighboring charges. These stresses also create tensile forces in the plane of the gap and it is necessary to know the energy consumption for the expansion of the walls of the gap after the formation of the main crack.

The gap occurs in the array under the action of tensile stresses σ_θ at point A and symmetrical, directed in different directions of tensile stresses at points *C* and *C₁*, formed in the result of the geometric addition of a radial compressive stress σr at these points (Fig. 2).

Write the condition for the formation of a contoured gap as the ratio of the stress causing her education, and stresses that prevent this (Fig. 3):

$$\sigma_R \geq \sigma'_p + \sigma_h, \tag{18}$$

where σ_R is the total tensile stress at point A acting perpendicular to the plane of the holes, MPa;

σ'_p – the ultimate tensile strength of the rock with the structural attenuation coefficient for this massif, MPa;

σ_h – additional stresses required to move the walls of the contour gap by a certain amount of h_b, and its opening, MPa.

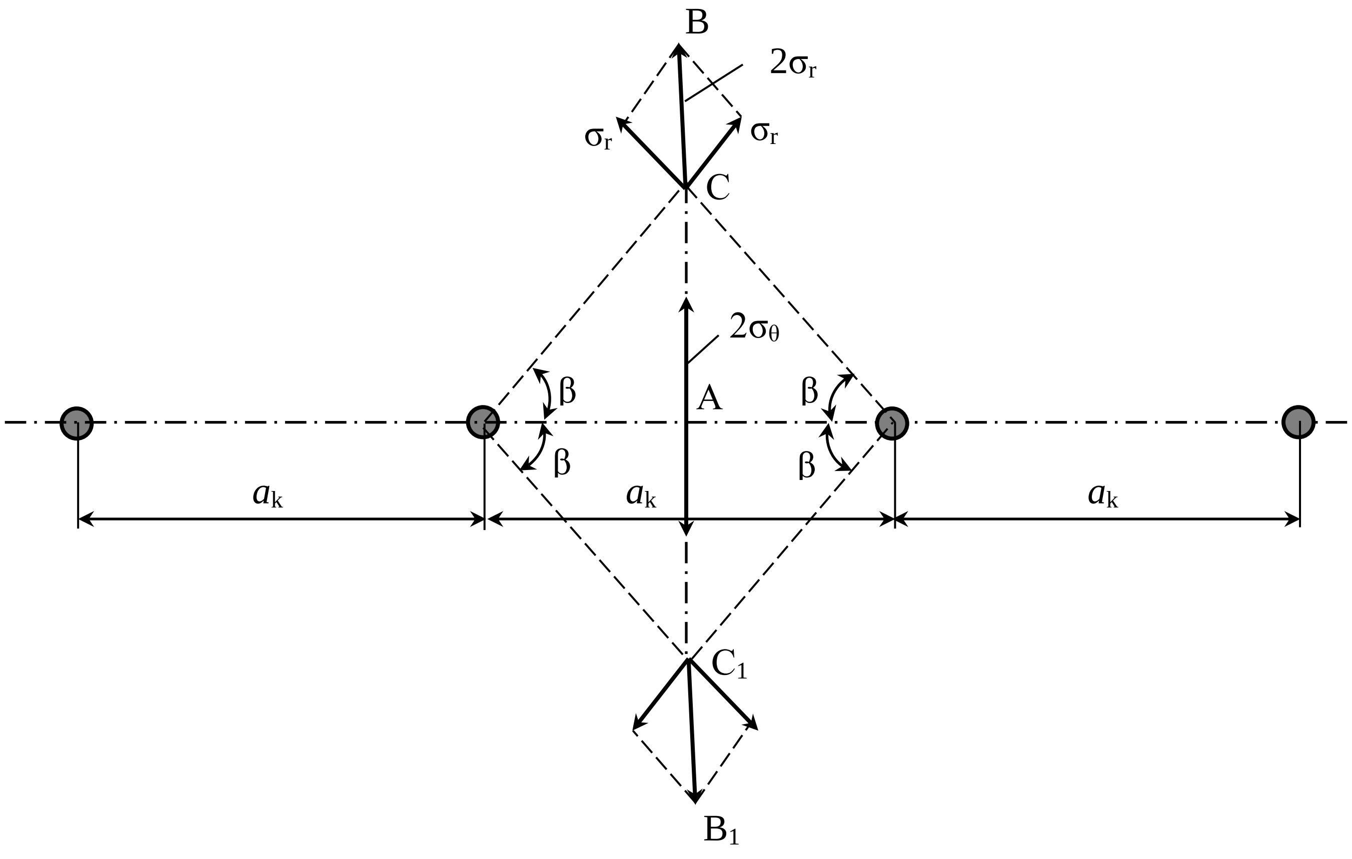

Fig. 2. Diagram for calculating the distance between holes with NDC

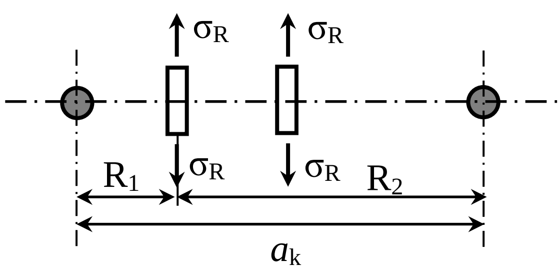

Fig. 3. Scheme for determining the origin of a tensile crack

Taking the value of the compressive stresses caused by the action of the NDC at the contour hole wall equal to P (t), we can write the value of the radial compressive stresses at points C and C_1 as

$$\sigma_r = P(t)\cdot K_{sa}, \text{ MPa}, \tag{19}$$

where $K_{sa}$is a coefficient that characterizes the degree of stress attenuation with increasing distance from the hole axis.

In the first approximation, we can assume that

$$K_{sa} = \left(\frac{d_c}{R}\right)^{n_3}, \tag{20}$$

where d_c- the hole diameter, m;

R - the distance from the hole axis to the considered point in the array, m;

n_3- an indicator of the degree of stress attenuation with the distance of the calculated point from the hole axis.

Then the value of the radial compressive stresses at points C and C_1 can be set by the formula

$$\sigma_r = P(t)\left(\frac{d_c \cos\beta}{a_k}\right)^{1,5}, \text{ MPa}, \tag{21}$$

where a_k- the distance between contour holes, m;

β-acute angle between the plane of contour holes and the direction from the nearest holes to points C and C_1, deg.

Taking into account the dependence $\sigma_\theta = f(\sigma_r)$, it is possible to determine the tangential stresses σ_θ caused by the action of the NDC at point A by the expression:

$$\sigma_\theta = P(t)\left(\frac{d_c}{a_k}\right)^{1,5}\frac{\mu}{1-\mu}, \text{ MPa}. \tag{22}$$

where μ- the Poisson's ratio.

Then, according to the calculation scheme in Fig. 2, the total tensile stresses at point A will be:

$$\sigma_R = 2P(t)\left(\frac{d_c}{a_k}\right)^{1,5}\left(2\cos^{1,5}\beta \sin\beta + \frac{\mu}{1-\mu}\right), \text{ MPa}. \tag{23}$$

The positions of points C and C_1 are determined from the condition for reaching the maximum value σ_R. Analysis of the function $\sigma_R = f(\beta)$ [10] shows that the largest value $\sigma_R = f(\beta)$ corresponds to at β=45°. At the same time

$$\sigma_R = 2P(t)\left(\frac{d_c}{a_k}\right)^{1,5}\left(0,85 + \frac{\mu}{1-\mu}\right). \tag{24}$$

By replacing $\sigma_R = \sigma'_p + \sigma_h$ and performing the corresponding transformations, we obtain a formula for determining the effective distance between contour holes with NDC:

Произведя замену $\sigma_R = \sigma'_p + \sigma_h$ и выполнив соответствующие преобразования, получим формулу определения эффективного расстояния между контурными шпурами с НРС:

$$a_k = 0,17 d_c \left(\frac{P(t)\left(0,85 + \frac{\mu}{1-\mu}\right)}{\sigma'_p + \sigma_h}\right)^{2/3}, \text{ m}. \tag{25}$$

Thus, a formula has been developed for determining the effective distance between contour holes when using NDC, which allows for an even separation of the rock mass.

Conclusions

1. A mathematical model has been developed for creating high internal pressure in boreholes using NDC, which makes it possible to obtain a smooth separation of rocks in the massif.

2. The problem of obtaining a continuous straight line of cracks when using NDC in rocks is considered. An intervalversion of the mathematical model and an algorithm for solving this problem are substantiated and obtained, and a theorem is proved and an interval band with a limited width is shown where the centers of the holes should be located.

3. A formula has been developed for determining the effective distance between contour holes when using NDC, which allows for an even separation of the rock mass.

REFERENCES

[1] A.s. 1251611 SSSR, MPK YE21 S37/00. Sposobnapravlennogoformirovaniyatreshin v massive tverdoysredi/ YE.M. Garsuev, A.A. Xripko, A.I. Shtompel; zayavitelStaxanovskiy filial Kommunarskogogorno-metallurgicheskogoinstitutaMinvuza USSR. zayavl. 25.12.1984; opubl. 25.10.86.

[2] Sredstvonevzrivchatoyerazrushayusheye (NRS-1). Texnicheskiyeusloviya TU21-53-22-87. – Izd. Yanvar 1987. M.: MPSM SSSR, 1987. – 37 s.

[3] ZairovSh.Sh., UrinovSh.R., RavshanovaM.Kh., Nomdorov R.U. Physical and technical assessment of the stability of the sides of the quarries, taking into account the technology of drilling and blasting operations. - Monograph. - Bukhoro: publishing house "Bukhoro", 2020. - 175 p.

[4] Zairov Sh., Ravshanova M., Karimov Sh. Scientific and technical fundamentals for explosive destruction of the mass composed of rocks with different hardness // Mining of Mineral Deposits. National Mining University, 2017. Volume 11. Issue 2. - p. 46-51.

[5] Zairov Sh., Ravshanova M., Karimov Sh. Intensification of technological processes in drilling and blasting operations during open-cut mining in Kyzylkum region // Mining of Mineral Deposits. National Mining University , 2018. Volume 12. Issue 1. - p. 54-60.

[6] NorovYu.D., ZairovSh.Sh., RavshanovaM.Kh. Development of a non-explosive destructive composition using components from local raw materials // GornyVestnik of Uzbekistan. - Navoi, 2018. - No. 4. - S. 136-139 .

[7] Zairov, S.S., Makhmudov, D.R., Urinov, S.R. Theoretical and experimental research of explosive rupture of rocks with muck piles of different geometry. GornyiZhurnal, 2018, No.9, pp.46-50. DOI: 10.17580/gzh.2018.09.05, http://www.scopus.com/inward/record.url?eid=2-s2.0-85055940732&partnerID=MN8TOARS

[8] Zairov S.S., Urinov S.R., Nomdorov R.U. Ensuring Wall Stability in the Course of Blasting at Open Pits of Kyzyl Kum Region. Gornyenaukiitekhnologii = Mining Science and Technology (Russia). 2020;5(3):235-252. https://doi.org/10.17073/2500-0632-2020-3-235-252

[9] Zairov, Sh.Sh.; Urinov, Sh.R.; Tukhtashev, A.B.; and Borovkov, Y.A. (2020) "Laboratory study of parameters of contour blasting in the formation of slopes of the sides of the career," Technical science and innovation: Vol. 2020 :Iss. 3 , Article 14. Available at: https://uzjournals.edu.uz/btstu/vol2020/iss3/14

[10] ZairovSh.Sh., UrinovSh.R., Nomdorov R.U. Modelling and determination of rational parameters of blast wells during preliminary crevice formation in

careers // International peer-reviewed scientific and technical journal "Chemical Technology. Control and Management", 2020, No 5-6. https://uzjournals.edu.uz/ijctcm/

[11] ЗаировШ.Ш., УриновШ.Р., РавшановаМ.Х.Обеспечение устойчивости бортов карьеров при ведении взрывных работ. - Монография. - LAPLAMBERTAcademicPublishing. - Germany, 2020. - 175 с.

[12] Ивановский Д.С., Насиров У.Ф., Заиров Ш.Ш., Уринов Ш.Р. Перемещение разнопрочных горных пород энергией взрыва // Монография. – LAPLAMBERTAcademicPublishing. – Germany, 2020. – 116 с.

[13] ZairovSh.Sh., UrinovSh.R., TuxtashevA.B. Teoreticheskoyeobosnovaniyemetodovotsenkiustoychivostiotkosovtreshinovatixporod // Nauchno-prakticheskiyelektronniyjurnal «TESNika». – Nukus, 2020. - №2. – S. 50-55. https://www.elibrary.ru/item.asp?id=43420025 .

[14] TuxtashevA.B..UrinovSh.R., ZairovSh.Sh. Razrabotkametodaformirovaniyakonstruksiiiraschetaustoychivostibortovglubokixkaryerov // Nauchno-prakticheskiyelektronniyjurnal «TESNika». – Nukus, 2020. - №2. – S. 56-58. https://www.elibrary.ru/item.asp?id=43420027

[15] UrinovSh.R., Nomdorov R.U., Djumaniyazov D.D. Issledovaniyefaktorov, vliyayushixnaustoychivostbortovkaryera // Journal of advances in engineering technology ISSN:2181-1431. https://www.elibrary.ru/item.asp?id=44136895

[16] Norov Yu. D., Umarov F. Ya., UrinovSh.R., Makhmudov D.R., ZairovSh.Sh. Theoretical studies of the parameters of the retaining wall in various forms of a compressed medium from an exploded rock mass // "Izvestiyavuzov. Mining journal", No. 4, 2018. pp. 64-71. ISSN 0536-1028. DOI: 10.21440/0536-1028-2018-4-64-71

[17] NorovYu.D., Bibik I.P., UrinovSh.R., ZairovSh.Sh. Increase of efficiency of crushing of rocks of different durability in difficult mountain geological conditions // The magazine "Suchenresourcerecovery technology hricovavirobnictva", 2012. - Issue 2(10). pp 48-52.

[18] UrinovSheraliRaufovich , "Theoretical and experimental evaluation of the contour explosion method for preparing slopes in careers", JournalNX - A Multidisciplinary Peer Reviewed Journal, Volume 6, Issue 11, ISSN : 2581-4230, Page No. 461-467 . https://journalnx.com/papers/20152085-contour-explosion-method.pdf

[19] UrinovSheraliRaufovich , "Determination of rational parameters of blast wells during preliminary crevice formation in careers", JournalNX - A Multidisciplinary Peer Reviewed Journal, Volume 6, Issue 11, ISSN : 2581-4230, Page No. 468-479 . https://journalnx.com/papers/20152086-rational-parameters.pdf

Article in a journal:

[20] UrinovSh.R., SaidovaL.Sh. Theoretical studies of the influence of deep pit parameters on the choice of technological schemes for transporting rock mass // Solid State Technology, Volume: 63 Issue: 6, 2020, pp.429-433. https://www.solidstatetechnology.us/index.php/JSST/article/view/1549