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THEORETICAL AND EXPERIMENTAL EVALUATION OF A STATIC METHOD OF ROCK DESTRUCTION USING NON-EXPLOSIVE DESTRUCTIVE MIXTURE FROM LOCAL RAW MATERIALS

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
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
Ravshanova Muhabbat Husniddinovna,
Senior Lecturer, Department of Mining, Navoi State Mining Institute.
190, avenue Galaba, Navoi, Uzbekistan, 210100
NomdorovRustamUralovich
https://orcid.org/0000-0001-8609-1414
Assistant teacher of department of Mining and Geodesy,
Karshi Engineering and Economics Institute.
225, avenue Mustakillik, Karshi, Uzbekistan, 180100.
rustamnomdorov@mail.ru

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ABSTRACT

To provide scientific justification and develop a static method of rock destruction using NDM from local raw materials for use at open-pit mining facilities

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 NDM, mathematical modeling of creating high internal pressure in boreholes using NDM, mathematical programming methods, as well as methods of mathematical statistics and correlation analysis of test results using modern computer technology.

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

Introduction. Purpose of the work is amathematical model has been developed for creating high internal pressure in boreholes using NDM, 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 NDMs 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 NDM, which allows for an even separation of the rock mass;a method for studying the new composition of non-explosive destructive mixture has been developed and the physical and mechanical parameters of the rocks of the Zarmitan Deposit have been established.

Practical implicationsisanew composition of NDM has been developed using components from local raw materials that are safe for storage, transportation and use, which allows destroying objects in the immediate vicinity of engineering structures, in localities, etc. while ensuring the safety of objects and complete safety for the environment;a method has been developed for separating monoliths from the massif using a new NDM composition, which makes it possible to split monolithic blocks soundlessly, reduce the labor intensity of the work performed, ensure environmental protection, reduce the cost of production and energy intensity of mining operations, and improve the safety of their conduct.

Findings. In the world, the universal and practically the only method of destruction of hard rocks in the development of mineral deposits is drilling and blasting using the energy of the explosion [1, 2]. This method, in terms of productivity and deadlines, remains the leading one for the next 30-40 years, until new methods of breaking hard rocks using large capacities are invented [3-4]. The main disadvantages of the drilling and blasting method are insufficient provision of complete safety of blasting operations, interruption of mining operations and downtime due to airing of blasting objects, a large amount of auxiliary work, insufficient use of the explosion energy in rocks of different strength, the release of a huge amount of dust and poisonous gaseous products, the danger of storage explosives (explosives), etc. These shortcomings force the development of cheap and promising methods of destruction of hard rocks. As a promising direction for solving this problem is the use of the static method of destruction of various rocks using non-explosive destructive mixtures (NDM) [5].

To date, more than 120 different mixtures and compositions of NDM are known all over the world, the main disadvantages of which are their importability, the complexity of obtaining the composition, the use of rare and expensive substances as additives, a long time of destruction (12-24 h), a limiting temperature regime of operation, limited conditions of use, dependence on climatic and temperature conditions (for example, it does not work in winter) [5] . In this regard, there is a need for research on the development of cheap and high-quality NDMs using components from local raw materials and less time of destruction of rocks.

To date, a number of scientific and practical works have been carried out in the Republic aimed at creating new types of NDMs using components from local raw materials, reducing the time of destruction and simultaneously eliminating the phenomenon of spontaneous release of NDMs from boreholes and wells, studies of the kinetics of NDM self- expansion based on inorganic compounds [6-20] . Analysis of works devoted to the problems of fracture shows that the Griffiths- Irwin theory is most widely used in engineering calculations, which does not require a large amount of experimental data for calculation and satisfactorily describes fracture due to the growth of a single crack. This gives grounds to choose its position as the basic one for solving the problems of destruction of rocks using NDMs.

The main advantages of NDMs are the absence of dynamic impact on the destroyed object, emission of harmful gases, sound and other vibrations. To implement the method, the purchase of expensive special equipment or devices is not required, the method can be implemented near transport and electrical equipment, while eliminating the possibility of their damage due to the lack of scattering of parts of the destroyed object.

Currently, many methods of non-explosive destruction are known, but their industrial use is restrained by the lack of equipment, low reliability, high energy intensity, dangerous impact on humans, and high cost. All these drawbacks force us to look for ways to create cheap and promising methods for breaking solid rocks.

When using NDMs to obtain a solid straight line of cracks in fractured rocks, it is very important to determine the location of the holes. Their location and the formation of cracks in a straight line depends on the structure, strength and degree of extensibility of the mined rocks. Cracks appear in rocks after applying NDMs. These cracks are formed as a result of chemical and physical reactions of the applied NDM composition. Cracks can form in an arbitrary place in the hole and develop in any direction.

The formation of a slot as a result of the action of tangential stresses σ_θ at point A, located in the plane of the slot at an equal distance from adjacent holes (Fig. 1). It has been established that a significant role in the mechanism of the gap formation is played by radial stresses from neighboring holes, which are geometrically folded in a plane that intersects the gap perpendicular to it at a distance from neighboring charges. These stresses also create tensile forces in the plane of the slot, and it is necessary to know the energy consumption for the expansion of the slot walls after the formation of the main crack.

Gap arises in the array under the action of the tensile stresses σ_θ at the point A and the symmetric directed to different sides of tensile stresses at the points C and C_1, formed as a result of addition of the geometric radial compression stress σ_r in these points (Fig. 1).

As a result of the analytical and theoretical studies, a formula has been developed for determining the effective distance between boreholes when using NDMs, which makes it possible to ensure an even separation of the rock mass:

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

where d_c - well diameter, m; P (t) - compressive stress caused by the action of the NDM at the wall of the contour well, MPa; μ - Poisson's ratio; σ'_p is the ultimate tensile strength of the rock taking into account the structural weakening coefficient for the given massif, MPa; σ_h - additional stresses required to move the walls of the contour slot by some value h_w, and its opening, MPa.

In the scientific laboratory of the Navoi State Mining Institute, experiments were carried out to find the optimal formulation of the NDM composition, which would accelerate the hydration process without additional heat release and provide high pressure for 5-8 hours after using the composition.

NDM was selected for destruction of rocks, concrete, reinforced concrete, masonry, and also as an expanding additive for the production of backfill materials.

As a result of the studies, the following approximate chemical composition of the expanding non-explosive mixture was selected:

CaO - 9-90%;
Mg - 0 97 -1.66%;
Fe_2O_3 - 3 , 4 -7%;
SO_3 - 0.33-0.65%;
Al_2O_3 -1 , 34 %;
SiO_2 - 2%;
Na_2O_2 - 4%.

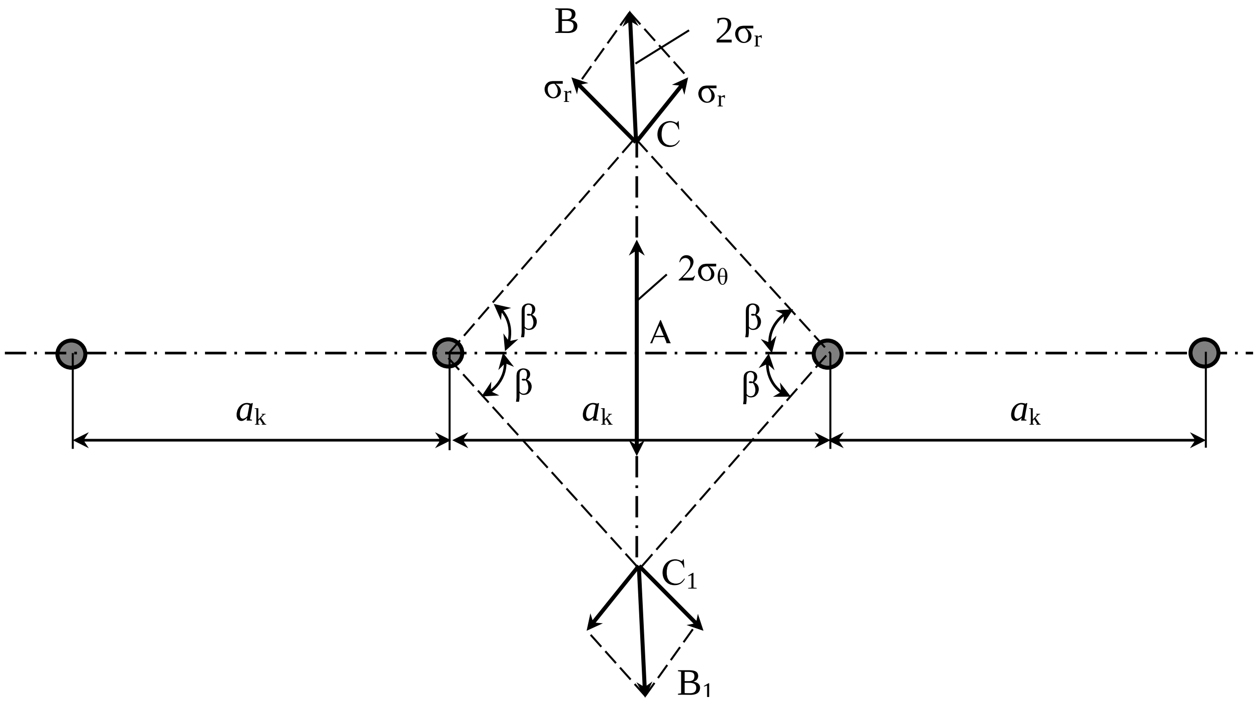


Figure: 1. Scheme for calculating the distance between wells with wells

Was compiled 5 formulations of NDM, in wt . %:

1) calcium chloride - 1.0-10.5; calcium carbonate with a content of the waste and sugar production - 5,0-20,0; quicklime coarse lime - the rest;

2) aluminum powder - 0.25-0.30; glycerin - 3.0-15.1; soda ash - 2.0-9.9; modernized technicallignosulfonate(LSTM-2) - 0.10-2.35; calcium oxide from calcined limestone and gypsum - the rest;

3) potassium permanganate - 1.45-9.5; ethylene glycol - 5.0-21.0; boric acid - 0.25-2.7;

4) urea - 1.8-23.0; glycerin - 2.6-12.8; calcium oxide from fired limestone and gypsum - the rest.

5) The composition of the mixture of NDM-1, developed by Personal And About "In Russian Research Institute of Building Materials and Structures them. PP Budnikov" , the main component (up to 98%) of which is burnt coarse lime. Calcination quicklime produced in special furnaces construction at a temperature exceeding 1400 °C. Boric acid, soda ash, and a chemical substance - sulphate yeast mash (SYM) were used as additives. By powder NDM-1, mixed with water in a ratio of 3: 1, formed a paste which hardens at increased its volume, creating an object to be ruptured in the pressure up to 50 MPa.

Based on the above chemical compositions, the optimal options were selected, in which the chemical mixture can expand to the maximum and lead to the destruction of glass, plaster models, bricks and marble.

To identify the optimal formulations of mixtures of NDM, the data presented in table were used. 1.

In subsequent experimental work, more than 200 experiments were performed with glass penicillin bubbles. Only after obtaining repeated results on the rupture of glass bubbles, were plaster models, bricks and marble blocks pre-drilled in them were used.

Table 1. NDMformulationoptions

NDMcomposition, wt . %				**Self-expansion pressure , MPa, aged**		**The presence of an involuntary release of NDMs from the borehole**
CaO	**Na 2 CO 3**	**LSTM**	**CH 3 COOH**	**12**	**24**	
98.40	1	0.35	0.25	48	58	Ejection
96.35	3	0,4	0.25	40	52	no
92,00	6	1.5	0.5	46	57	no
88,00	nine	2.5	0.5	38	45	no
85.70	eleven	2.8	0.5	thirty	35	no
98.15	1	0.35	0.5	55	69	Ejection
96.10	3	0,4	0.5	44	50	no
91.75	**6**	**1.5**	**0.75**	**48**	**56**	**no**
87.75	nine	2.5	0.75	40	47	no
85.45	eleven	2.8	0.75	32	38	no
97.90	**1**	**0.35**	**0.75**	**65**	**73**	**Ejection**
95.40	**3**	**0,4**	**1,2**	**75**	**82**	**Ejection**
91.30	**6**	**1.5**	**1,2**	**70**	**80**	**Ejection**
87.30	**Nine**	**2.5**	**1,2**	**56**	**65**	**Ejection**
85.10	**Eleven**	**2.8**	**0.75**	**17**	**25**	**no**
Prototype				60	63	Ejection

Also, laboratory tests were carried out in samples of various composite materials and the ultimate strength for uniaxial compression of samples of gypsum block, ceramic bricks, marble and glass was determined. N After obtaining the necessary experimental results performed statistical processing and prepared the corresponding physico-mechanical parameters.

As a result of the research carried out, a method was developed for producing NDMs, which provides for the separate preparation of solid (T) and liquid (L) compositions. A solid composition is obtained by grinding lime (CaO) to a powdery state, mixing the resulting powder with soda ash

(Na_2CO_3), lignosulfonate (LSF) and technical salt (NaCl) at the following ratios, wt . %:

- CaO - 48;
- Na_2CO_3 - 3;
- LSF - 3;
- NaCl - 4.

It turns out a grayish loose mass.

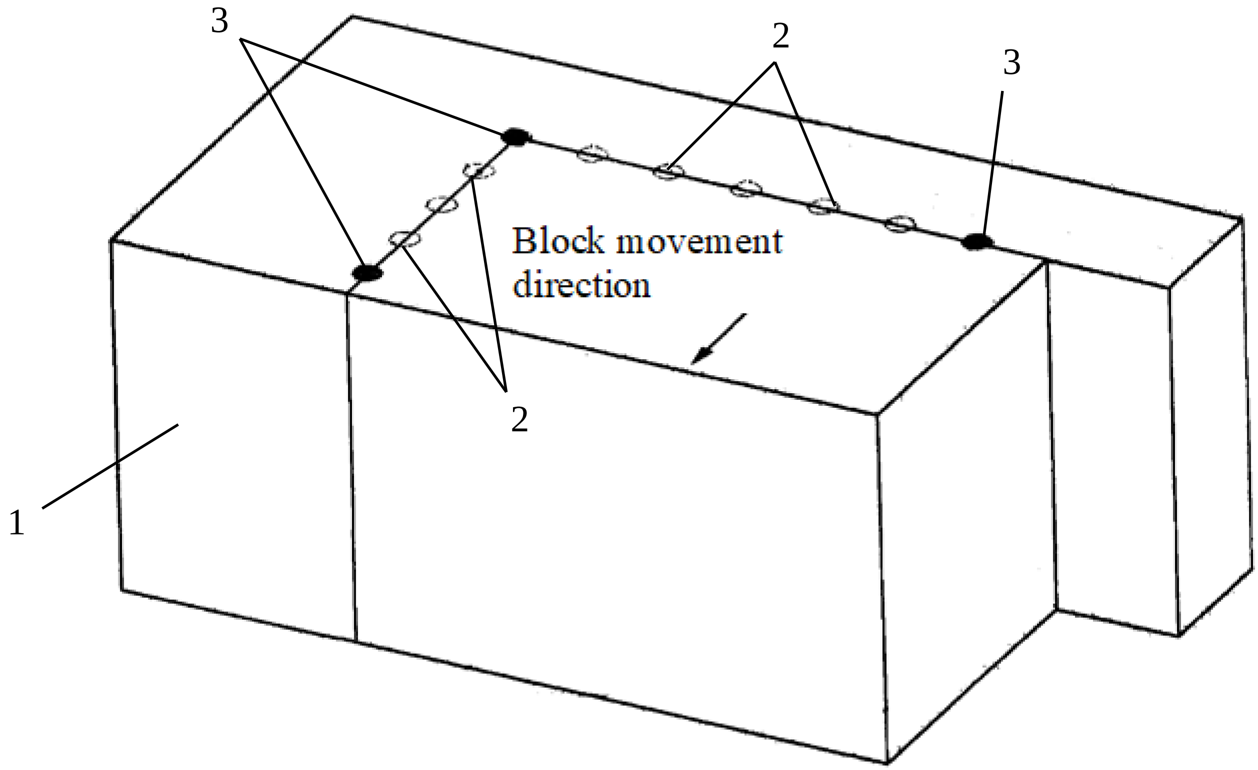
The liquid composition is obtained by mixing liquid soap, water and acetic acid with the following components, mass . %:

- liquid soap - 1.5;
- acetic acid - 1.2.
- water - the rest;

Solid and liquid compositions in the ratio S : W = 3: 1 are mixed until a creamy fluid mass is obtained and, without allowing to solidify, is poured into boreholes or wells. The fracture time of rocks is within 6-8 hours, depending on the ambient temperature.

The developed new composition of the NDM is recommended to be used to separate the monoliths from the rock mass and to split them into appropriate blocks.

A method was developed for separating monoliths from the massif using a new composition of NDMs (Fig. 2).



1 - monolithic block; 2 - drilled boreholes from NDM;
3 - drilled holes with NDMs and installed metal arcuate plates

Figure 2. Method for separating monoliths from massif using a new composition of non-explosive destructive mixture

According to this method, boreholes 2 and 3 with a diameter of 32-43 mm are drilled in a monolithic block - 1 at right angles, and thus the production ledge is formed at an angle of 90 ° to obtain blocks of monoliths of the correct shape and their further use.

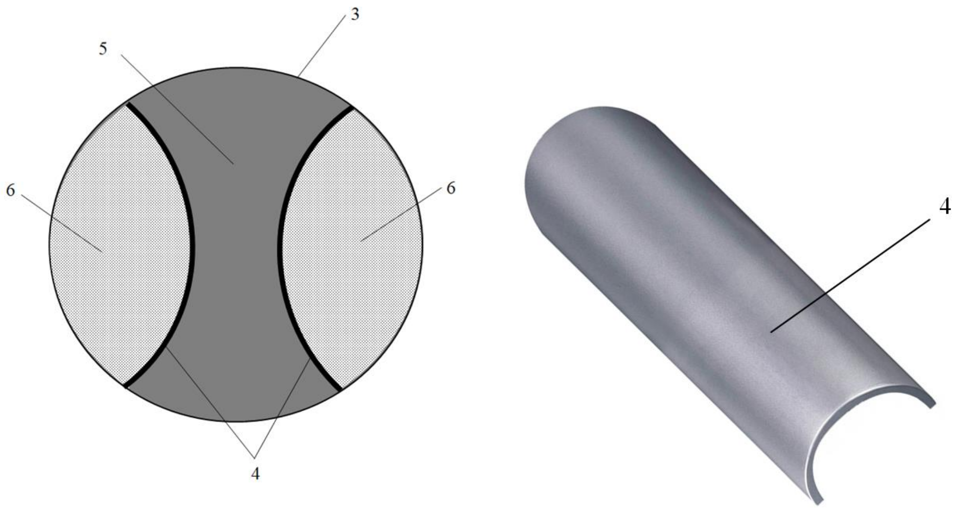
The depth of holes - 2 and 3 depends on the height of the detached monolith and its ability to split. For better formation of cracks in the monolith and more efficient separation of the massif, the depth of the holes should be on average 0.8-0.95 of the height of the object, but not less than six borehole diameters and not more than 1.5 m.

The distance between the holes is determined by the formula (1).

In side boreholes - 3 , a stress concentrator structure is formed, consisting of two arcuate metal plates with an arc height equal to ½ of the borehole radius, and the arc which is directed towards each other in the places of the supposed split plane between adjacent boreholes, the space between the boreholes and the arc sphere is filled with borehole material, and the space between the tops of the arcs and all other wells completely fill the NDM (Fig. 3).

The displacement of the monolith block into the goaf occurs under the influence of a high self-expansion pressure , excluding the involuntary release of the mixture. Thus, the cost of additional rafter work is eliminated and the safety of mining operations is increased.

In an industrial environment, research has established that the use of a new composition and method allows creating high internal pressure in boreholes, contributing to static destruction and rupture of rocks.



3 - Side th contour first hole; 4 - metal arcuate plate;
5 - non-explosive destructive mixture; 6 - stemming material

Figure: 3 . Lateral contour borehole design with arc-shaped metal plates

Thus, the performed theoretical and experimental studies on the development of a new composition of NDMs, the practical implementation of their results in open pit mining made it possible to make a significant contribution to solving an urgent scientific problem - the scientific substantiation and development of a static method of rock destruction using NDMs from local raw materials for use on open pit mining sites.

Conclusion. A mathematical model has been developed for creating high internal pressure in boreholes using NDM, which makes it possible to obtain a smooth separation of rocks in the massif.The problem of obtaining a continuous straight line of cracks when using NDM in rocks is considered. An interval version of the mathematical model and an algorithm for solving this problem are proved and obtained, as well as a theorem is proved and an interval band with a limited width is shown, where the centers of the holes should be located.A formula has been developed for determining the effective distance between contour holes when using NDM, which allows for an even separation of the rock mass.A method for studying the new composition of a non-explosive destructive mixture and rock samples under laboratory conditions has been developed.A method for producing a non – explosive destructive mixture has been developed, including separate preparation of solid and liquid compositions and mixing them to obtain a creamy fluid mass, characterized in that the solid composition is obtained by grinding lime (CaO) to a powdery state, mixing the resulting powder with soda ash (Na_2CO_3), lignosulfonate (LSP) and technical salt (NaCl) at the following ratios, mass %: CaO – 48; Na_2CO_3 – 3; LSF-3; NaCl-4, and the liquid composition is obtained by mixing liquid soap, water and acetic acid with the following components, wt. %: liquid soap – 1.5; acetic acid – 1.2; water – the rest.A method has been developed for separating monoliths from the massif using a new NDM 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.Industrial tests of the new NDM compound have shown that its use makes it possible to create high internal pressure in the boreholes, contributing to static destruction and tearing of rocks.

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