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Research of Weakening the Strength of Rock Massives by Explosion Using Surface-Active Substances

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ABSTRACT. In this work, the author conducted a study on the use of surfactants to weaken the strength of the rock mass. The scientific research included five practical series of experiments, with the developed design of drilling and blasting operations. Schemes of the developed design of the borehole charge and graphs of the dependences of the radii of the zones of weakening rock strengths depending on the consumption of the amount of surfactants during these blasting operations are given. The design of the borehole explosive charge was developed using the appropriate surfactant, which allows obtaining positive results on the weakening of the rock mass and thereby reducing the total drilling volume. Granulometric analysis was carried out, showing the effective outcome of surfactants on reducing the average size of blasted rock mass; according to the data obtained during the study, a formula for determining the radius of weakening taking into account the use of surfactants was derived.

KEYWORDS: rock mass, surfactants, well, zone radius, blasting, rock strength.

I. INTRODUCTION

To date, a single workable theory of destruction, like explosion theory, has not been created. However, it is generally accepted that the destruction efficiency is determined by the interconnection and mutual influence of the parameters of the applied technological equipment and the process technology and the properties of the rocks being developed. One of the directions for improving the destruction process is a directed change in the properties and state of the rock mass using surfactants, the action of which is based on the adsorption decrease in the surface energy of bodies. The use of surfactants in the processes of dynamic destruction of a rock mass requires solving a whole range of scientific problems, the most important of which are improving the methodology for choosing the most suitable surface-active medium for specific conditions and developing a system of predictive assessments of the effectiveness of using surfactants in these processes. All of the above determines the relevance of the research.

The determination of the zone of weakening of the rock mass created by explosions of borehole explosive charges using explosives was carried out at the quarries of Zarmitan and Marjanbulak of the Navoi Mining and Metallurgical Combine, the physical and mechanical properties of which are shown in Table. 1. Scientific research included five series of experiments. Although the rock masses were blown up according to the drilling and blasting passport (DBP) for this quarry, the last row of wells was formed according to the developed design [1], which was produced as follows (Fig. 1). In the well 1, a charge was installed from an industrial explosive, divided into sections 2 by gaps 3. Moreover, the volume of the explosive charge section should be four times the volume of the gap.

A filler, a surfactant, was placed in between, which was used as cheap components produced in the Republic of Uzbekistan, namely: cotton soap stock (waste resulting from alkaline refining of vegetable oil) placed in capsules.

Moreover, the length of the gap filled with filler was not more than two well diameters. An intermediate detonator 4 was installed at the bottom of the well, and stemming was carried out at the wellhead 5. The charge was formed in a known manner, first by placing an intermediate detonator, series from 50 to 200 pcs.

II. MATERIALS AND METHODS

In experimental studies, the diameter of the wells was taken to be 105, 125, 150, 200 and 250 mm. The ratio of the specific consumption of the surfactant and explosive solution was 0.1; 0.15; 0.2; 0.25; 0.3 and 0.35. After each series of explosions, the granulometric composition of the blasted rock mass was determined by a known method [2, 3,

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4]. To determine the radius of the zone of weakening of the rock mass created by the explosion of borehole explosive charges using a surfactant solution, the core method and the method of water absorption of rocks have been developed.

According to the core method [5], which is based on the study of the state of the massif using cores drilled in the disturbed and undisturbed massifs, in order to assess the weakening of the strength of the rock mass at various distances depending on the number of blown wells before and after the explosion, core samples were taken from seven wells, alternating explosive charge and filler, clogging was carried out at the wellhead. After charge formation, an intermediate detonator was initiated. The detonation from the explosion of the lower section of the charge passed through the gap filled with surfactants, slowed down, while the surfactants were injected into the interior of the massif, contributing to the formation of zones of weakening of rocks outside the destruction zone, then the next section was detonated, and so on to the wellhead. The indicated parameters of the volumes of the explosive section and the gaps filled with surfactants contributed to a more effective effect of detonation on the massif, which was confirmed by experimental explosions.

Physico-mechanical and elastic properties of the studied rocks

Rock	Density $\rho \cdot 10^3$, кг/м^3	Porosity П, %	Velocity of Elongated Waves		Ultimate Compressive Strength		Ultimate Tensile Strength		Dynamic Modulus	
			C_p, м/с	the coefficient of variation, %	σ_{cm}, MPa	the coefficient of variation, %	σ_r, MPa	the coefficient of variation, %	E_d, MPa	the coefficient of variation, %
Slate-coalified granite	2,81	3,91	5000	10,3	120	12,5	15	13,2	6,86	7,8
Mica Quartz Slate	2,67	4,59	4500	8,2	85	10,3	12	14,3	5,14	7,6
Quartz-sulfide ore	2,69	4,52	4700	6,3	91	11,6	14	6,1	5,73	3,8
Granitosyenite shale-sericite	2,71	4,21	4900	5,2	100	8,7	14	3,9	6,33	5,0
Granosienites	2,56	7,71	4100	7,7	76	6,3	11	4,7	4,11	8,9
Carbon	2,17	12,6	3800	5,7	72	5,3	8	6,4	2,93	6,2

The proposed new design of the borehole charge ensured the weakening of the rock mass, which makes it possible to increase the grid of wells during subsequent explosions, thereby reducing the volume of drilling. The number of blasted wells each time was 3 m from the free surface inland to a depth of 20 m (Fig. 2).

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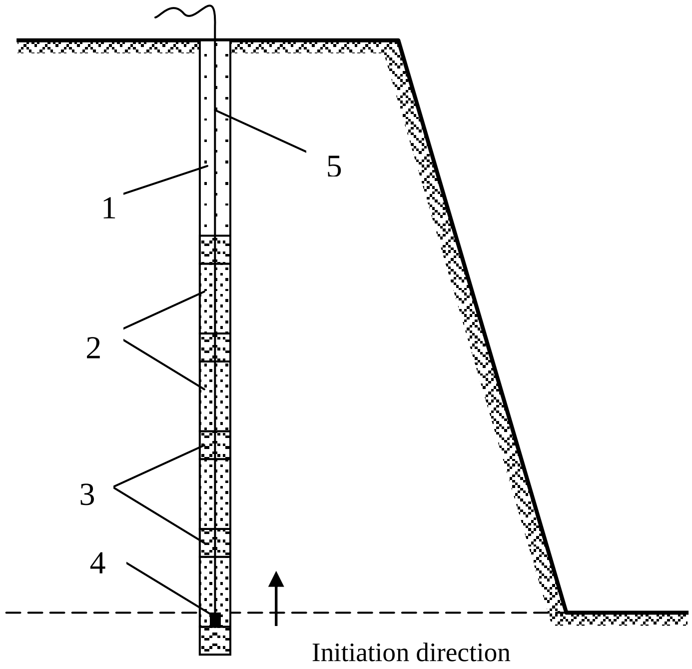

Fig. 1. The design of the borehole charge of explosives using surfactants:
1-well; sections from the explosive charge; 3-interstices filled with surfactants in capsules; 4-intermediate detonator; 5-stemming.

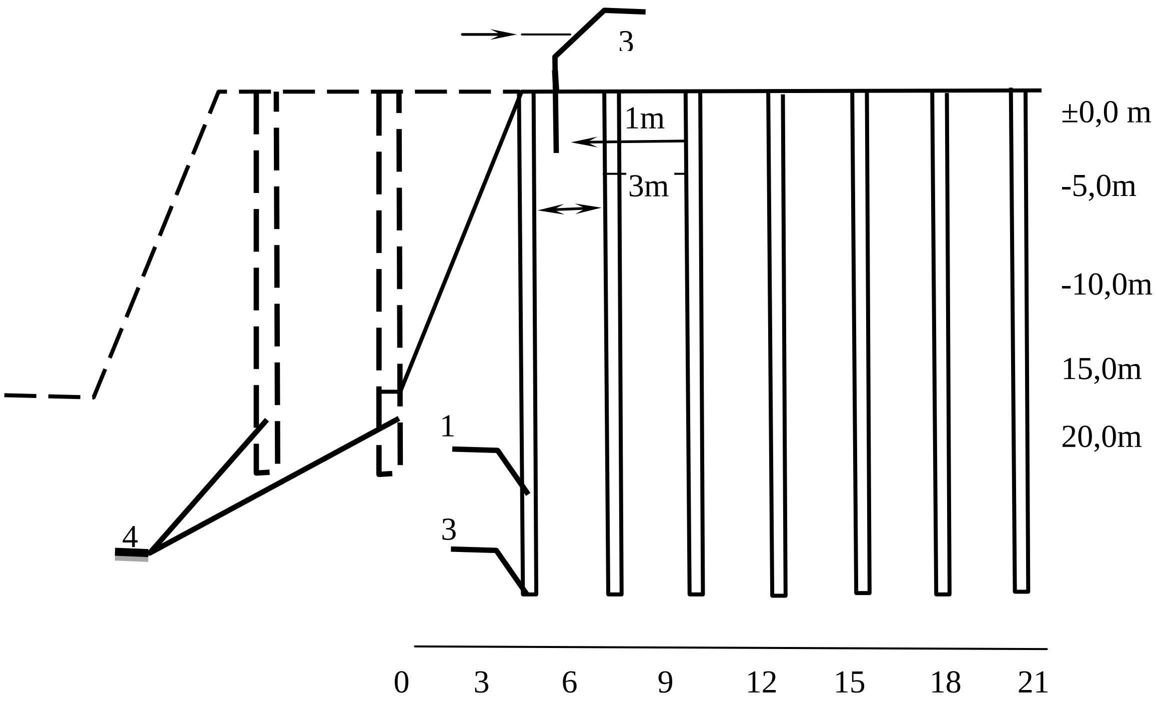

Fig. 2. The scheme for determining the radius of the zone of weakening of the massif: 1-geological wells; 2,3 - geophones; 4 exploded wells.

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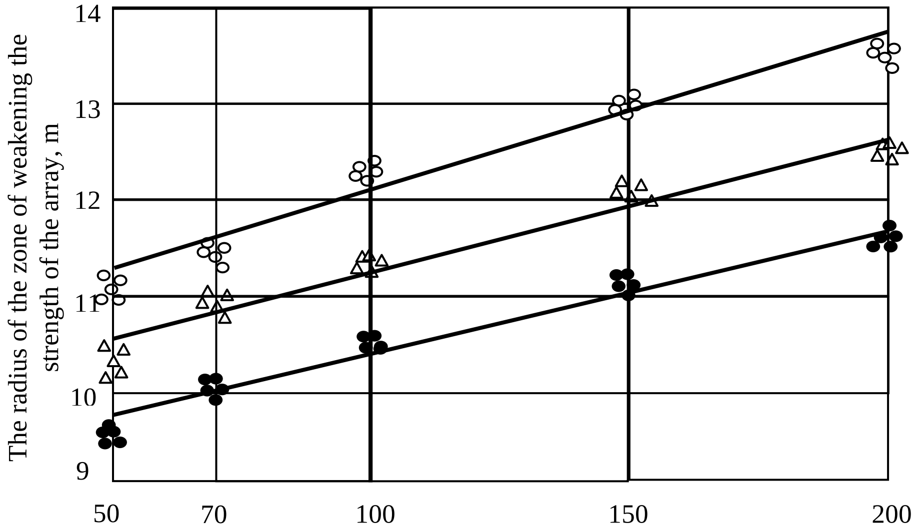
On the selected samples, the strength properties of the rock mass were determined. The difference in the strength of the samples before and after the explosion was used to judge the change in the stability of the rock mass at various distances from the free surface of the ledge.



The number of exploded borehole charges○ – medium blast rocks; Δ - hard blast rock; ● – very hard blast rocks;

Fig. 5. Graph of the change in the radius of the zone of weakening of rock mass strength (relative rock strength equal to 0.8) versus the number of blown borehole charges (diameter 200 mm).

Using the method of rock permeability, wells (surfactants) were poured into wells located at various distances from the explosion, and the scale of the zone of mass attenuation was determined by the rate of decrease in the liquid level before and after explosive loads.

In fig. Figure 5 shows a graph of the change in the radius of the zone of weakening the strength of the massif of medium -, difficult - and very difficult to explode rocks (with a relative tensile strength of rocks of 0.8) versus the number of exploded well charges (with a well diameter of 200 mm), which shows that an increase in the number of explosive blasting charges of explosives increases the radius of the zone of weakening of the rock mass.

Fig. 6 shows a graph of the change in the zone of weakening of rocks in the depth of the massif after the explosion of borehole explosive charges with diameters of 150 and 200 mm, established by the method of rock water absorption.

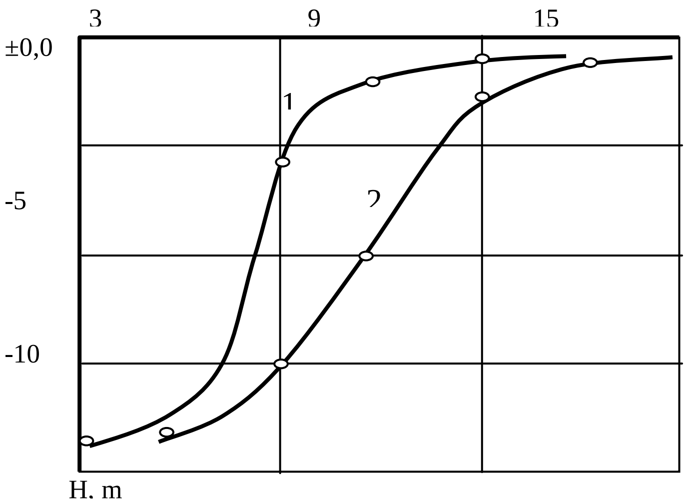


Fig. 6. Schedule of changes in the contour of the zone of weakening of rocks in the depths of the massif after an explosion of borehole explosive charges: 1-well diameter 150mm; 2-well diameter 200mm.

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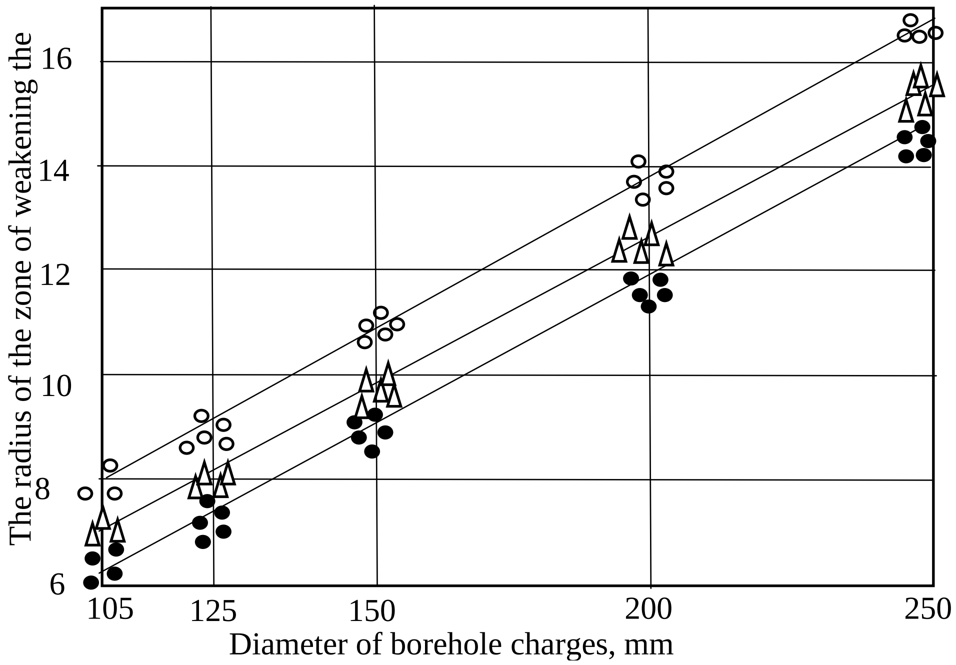

Fig. 7. Schedule changes in the radius of the zone of weakening of the strength of the rock mass from the diameter of the borehole charges of explosives:○ - medium-blown rocks; ● - hard to explode rocks; Δ - very difficult to explode rocks.

The graph shows that near the free surface of the ledge, with a relatively large fracture, the water (liquid) level drops faster. With increasing distance deep into the massif, the radius of the zone of weakening of rock strength decreases, as indicated by a decrease in water filtration both with distance from the free surface of the ledge, and along the depth of the wells. With increasing diameter of blown downhole charges, the contour and radius of the zone of weakening of rock strength increase (Fig. 6, curve 2).

III. RESULTS AND DISCUSSION

A graph of the change in the radius of the zone of weakening the strength of the rock mass from the diameter of the blown borehole charges is shown in Fig. 7. As can be seen from the graph, with an increase in the diameter of the charge from 105 to 250 mm after blasting 50 borehole charges (with a relative rock uniaxial tensile strength of 0.8), the radius of the zone of weakening of strength in all studied rocks intensively increases. For all studied rocks, with an increase in the number of simultaneously blasting borehole explosive charges, the rock mass weakening zone increases and for each well diameter there is a number of simultaneously blown wells in which the rock mass weakening zone equals the distance between the rows of wells and between the wells in a row. This number of simultaneously blown up wells is called critical. An increase in the number of simultaneously exploded borehole explosive charges above a critical one provides the prerequisites for increasing the distance between the rows of wells and the wells in the row.So, for medium-blown rocks, the critical amount of explosive charges is 50, hard-blown - 70, and for very hard-blown rocks - 100 wells. Moreover, as follows from the results of the studies, in order to effectively use the effect of weakening the strength of the rock mass beyond the fracture circuit in order to increase the grid of wells, the explosion of the next group of wells must be carried out until microcracks in the weakened zone of the rock mass become macrocracks.

The granulometric compositions of blasted rocks were determined depending on the change in the ratio of the specific consumption of a surfactant and explosive solution, the results of which are shown in Fig. 8.

The dependences obtained show that with an increase in the ratio of the specific consumption of surfactants and explosives to 0.15, the average size of the blasted rock mass decreases. A further increase in the ratio of the flow rate of the surfactant and explosive solution (more than 0.15) is accompanied by an increase in the average size of the blasted rock mass.

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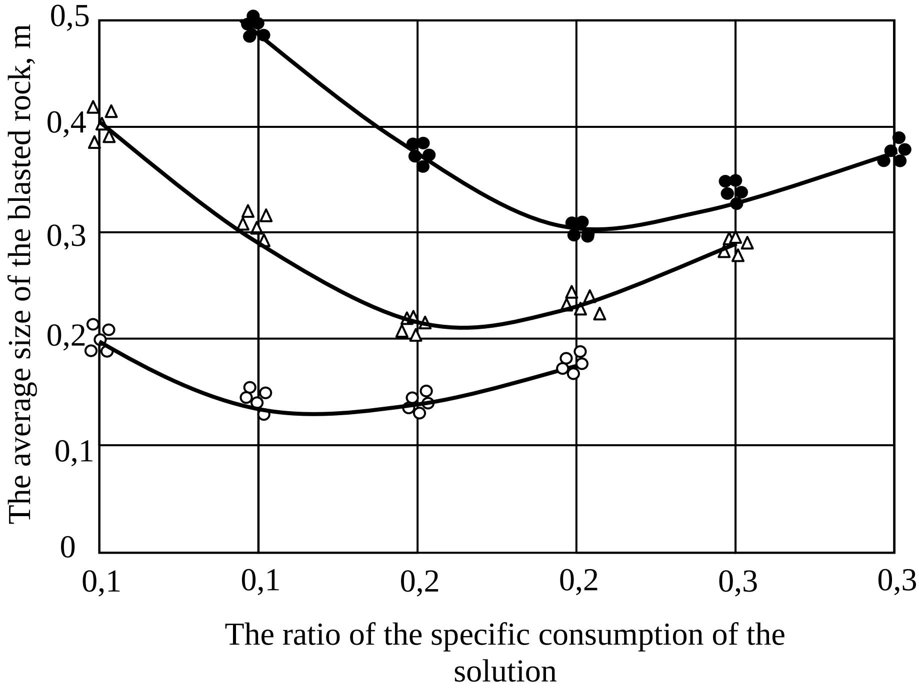

Fig. 8. The graph of the size of the blasted rock depending on the change in the ratio of the specific consumption of a solution of surfactant and explosives:○ - medium-blown rocks; ● - hard to explode rocks; ∆ - very difficult to explode rocks.

A statistical analysis of the results shows that the change in the average size of the blasted rock mass depending on the change in the ratio of the specific consumption of surfactants and explosives is characterized by a parabolic type and is determined by empirical equations: - for medium-blown rocks:

$$lcp = 9q'^2 - 3{,}25q' + 0{,}432,\ m,$$

Where *lcp*– average size of blasted rock mass, m. The correlation coefficient for this equation is 0,89±0,093. - for hard-to-explode rocks:

$$lcp = 12q'^2 - 5{,}36q' + 0{,}82,\ m$$

The correlation coefficient for this equation is 0,92±0,076.

- for very hard exploded rocks:

$$lcp = 12{,}86q'^2 - 7{,}01q' + 1{,}26,\ m.$$

IV. CONCLUSION

The correlation coefficient for this equation is 0,94±0,085. A generalized statistical analysis of the results shows that the radius of the zone of weakening of the rock mass strength during the explosion of borehole explosive charges using a surfactant solution depends on the number of exploded borehole charges, their diameter, the ratio of the specific consumption of a surfactant and explosive solution, as well as the rock category for explosivity and is characterized by an empirical equation of the form:

$$R_{осл} = 4{,}3k\frac{q_{пав}}{q_{вв}}\left(1 - \frac{142{,}85\left(1 - \delta_p'/\delta_P\right)}{n + 60}\right)\cdot \bar{r}_з,\ m$$

where k - coefficient taking into account the rock mass according to explosivity (for medium-, hard- and very hard-to-blast rocks, thus k=130, k=140 и k=150); $q_{пав}$ - specific consumption of surfactant solution; $q_{вв}$ - specific consumption of explosives; n - the number of exploded borehole charges; r3 is the reduced distance from the radius of the explosive charge. The correlation coefficient for this equation is 0,77±0,085. In this way:

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1. The design of the borehole explosive charge using a surfactant solution has been developed, which allows to weaken the rock mass, which makes it possible to increase the network of wells in subsequent explosions, thereby reducing the amount of drilling.

2. A comprehensive methodology has been developed for determining the radius of the zone of weakening of the rock mass strength created by the explosion of borehole explosive charges using a surfactant solution in an industrial environment.

3. It was established that with an increase in the number of explosive borehole charges blasted and their diameter, the radius of the zone of attenuation of the array increases. A critical amount of borehole explosive charges using a surfactant solution has been established, in the explosion of which the use of the zone of weakening the strength of the array is effective. For medium-blasted rocks, the critical number of charges is 50, hard-blown - 70, and for very hard-blown rocks -100 wells.

4. The granulometric compositions of blasted rocks were determined depending on the change in the ratio of the specific consumption of a surfactant and explosive solution. It is established that with an increase in the ratio of the specific consumption of surfactants and explosives to 0.15, the average size of the blasted rock mass decreases. A further increase in the ratio of the flow rate of the surfactant and explosive solution (more than 0.15) is accompanied by an increase in the average size of the blasted rock mass.

5. A formula is derived for determining the radius of the zone of weakening of the strength of a rock mass during the explosion of borehole explosive charges using a surfactant solution.

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