EUROPEAN JOURNAL OF LIFE SAFETY AND STABILITY (EJLSS)
ISSN2660-9630
www.ejlss.indexedresearch.org Volume 18, 2022 ||

Determination of the Radius of Cracking Zones in a Rock Mass by Explosions of Charges

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Abstract: *The paper presents graphs of the maximum radius of crack formation within a rock mass relative to the explosive charge radius, explosion conditions, mass acoustic stiffness, Poisson's ratio, and radial directional stresses occurring during compression.*

Keywords: *blasting, radial stress in compression, Poisson coefficient, the energy absorption coefficient, Sadovsky's formula, the maximum radius of crack formation.*

Date of Submission: 15-5-2022 ***Date of Acceptance: 18-6-2022***

During mass blasting, not only a part of the rock massif is eroded, but also its physical-mechanical and mining-technological properties change, resulting in zones of weakening within the massif [1].

Experiments on rock and ore samples have shown that the strength of limestone and magnetite ore samples after a single charge blast is 38.6 and 40.8%, respectively, relative to the initial state [2].

Studies in the granite massif have shown a decrease in the strength of rocks, an increase in their porosity and water absorption under the influence of loads applied during an explosion.

Subsequent [3] studies have examined various variants of the directional effect of blast energy on the internal structure of a rock. Changes in the microstructure of ores and their strength characteristics due to changes in the load applied to the rock mass during the explosion and the impact of the explosion in the appropriate direction were studied. In rock samples, their explosive strength was found to be 23-57% relative to the initial state [4,5].

To describe the process of decomposition of a rock mass under the influence of detonation products, we consider a hydrodynamic scheme of the formation of cracks in the rock mass as a result of the explosion of an explosive camouflage well charge.

To determine the amount of fracture in the rock mass under the influence of the explosion, we determine the radius of formation of cracks within the rock mass based on the methodology presented in the work [6,7]. In this case, we assume that the radius of cracks in the array is determined by the explosion of a cylindrical camouflage charge of diameter d_o-explosive.

According to the theory of the law of elasticity, the radius of cracking in a rock mass depends on the value of the tangential stress in the elongation occurring in the rock mass and is determined by the following empirical formula:

$$\sigma_{pac} = \frac{\mu \cdot \sigma_{сж}}{(1-\mu)}, \quad (1)$$

There: $\sigma_{сж}$ - radial stress in compression, MPa; m- Poisson coefficient.

The stress in the radial direction of compression at the front of the detonation wave and the displacement of the rock mass are correlated as follows:

$$\sigma_{сж} = \frac{U \cdot \rho \cdot C_p}{g}, \quad (2)$$

There: $\rho \cdot C_p$ - acoustic stiffness of the rock mass, $1.5 \cdot 10^5$-$15 \cdot 10^5$ kg/m$^2 \cdot$s; g-acceleration of free fall (9.81 m/s^2).

The shear rate of the rock massif is determined by the academic M.A. It is determined by Sadovsky's formula:

$$U = A \cdot \left(\frac{\sqrt[3]{Q}}{R_{mp}}\right)^m, \quad (3)$$

There: A - is the coefficient taking into account the explosion conditions, the value of which is assumed to be in the range of 200 ÷ 250;

Q - mass of explosive charge, kg;

R_{mp} - is the distance from the center of charge to the point under study, m;

m - is the energy absorption coefficient for the cylindrical camouflage charge of the explosive, m = 2.

Putting $Q = 2\pi R_0^3$ in formula (3), it can be expressed as follows:

$$U = 3.54 \left(\frac{R_0}{R_{mp}}\right)^m. \quad (4)$$

By placing U, ssj in the equation and solving it with respect to R, we obtain the following empirical formula:

$$R_{mp} = R_0 \sqrt{\frac{3.5 A \rho C_p \mu}{\sigma_{pac}(1-\mu)}}. \quad (5)$$

The area of fracture formation within the rock massif is determined by the condition that the maximum radius $\sigma_{pac} = [\sigma_{pac}]$ is as follows:

$$R_{mp} = R_0 \sqrt{\frac{3.5 A \rho C_p \mu}{[\sigma_{pac}] \cdot (1-\mu)}}. \quad (6)$$

The graph of the dependence of the maximum radius of formation of cracks within the rock mass on the radius of the explosive charge is shown in Figure 1.

The determined graphical correlation shows that when the charge radius is increased from 0.012 m to 0.021 m, the radius of cracks formed within the rock massif also increases from 0.75m to 3.20m, respectively.

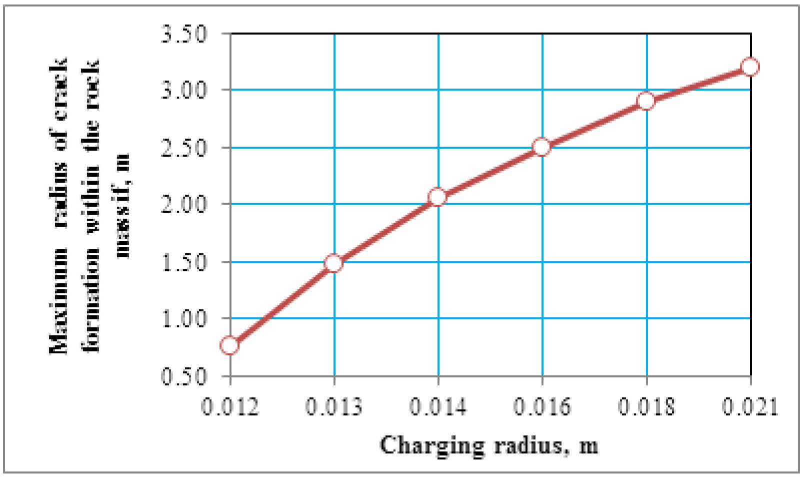

Figure 1. Graph of dependence of the maximum radius of cracks in the rock mass on the radius of the explosive charge

This graphical relationship obtained is described by the law of parabola.

The graph of the dependence of the maximum radius of crack formation within the rock mass on the blasting conditions is shown in Figure 2.

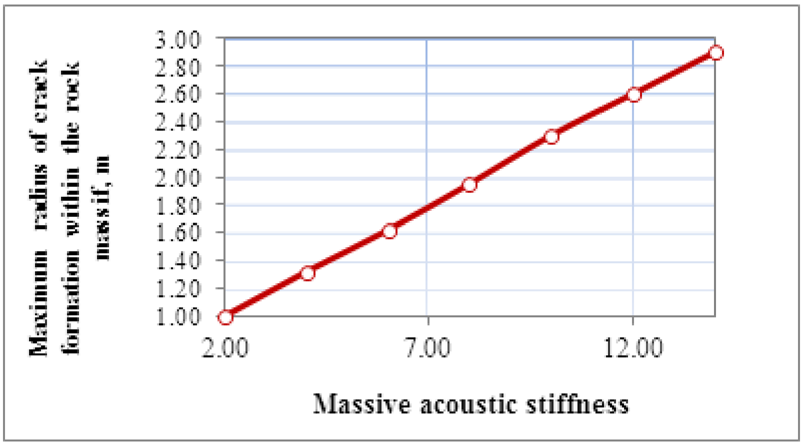

Figure 2. Graph of the dependence of the maximum radius of formation of cracks within the rock mass on the blasting conditions

The study found that the maximum radius of the fracture zone within the rock mass increases from 0.75 m to 3.10 m when the value of the coefficient taking into account the blasting conditions is increased from 200 to 250.

This graphical relationship obtained is described by the law of parabola.

The graph of the dependence of the maximum radius of formation of cracks within the rock mass on the mass acoustic stiffness is shown in Figure 3.

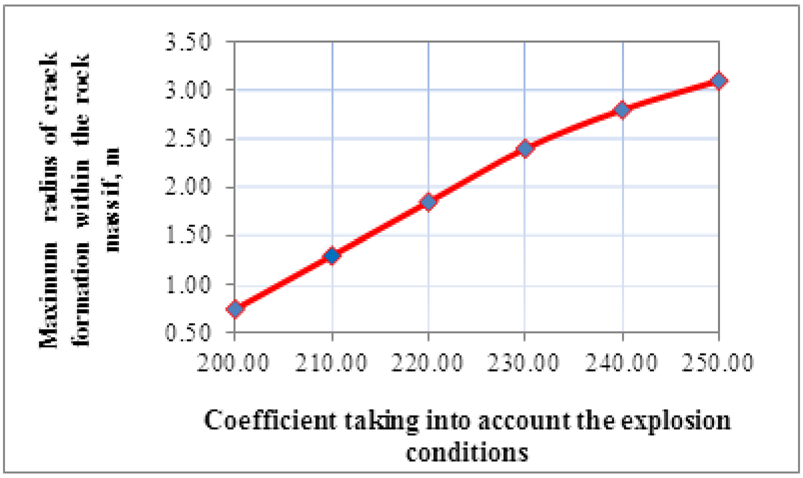

Figure 3. Graph of dependence of mass acoustic stiffness of maximum radius of cracks formation within a rock massif

Studies have shown that when the acoustic hardness of a rock mass increases from 2.00 to 14.00, the maximum radius of the fracture zone within the rock mass increases from 1.0 m to 2.90 m.

The graph of the dependence of the maximum radius of formation of cracks within the rock massif on the Poisson's ratio is given in Figure 4. The obtained dependence is described by the law of parabola.

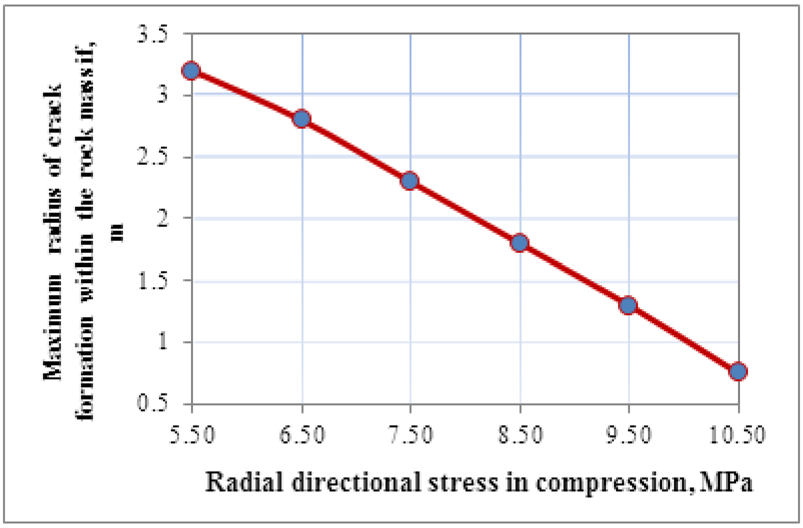

Figure 4. Graph of the dependence of the maximum radius of formation of cracks in the rock mass on the Poisson's ratio

Studies show that when the Poisson's coefficient is increased from 0.22 to 0.32, the maximum radius of the fracture zone within the rock mass also increases from 1.0 m to 3.30 m, respectively.

Figure 5 shows the graph of the stress in the radial direction during compression of the maximum radius of crack formation within the rock massif.

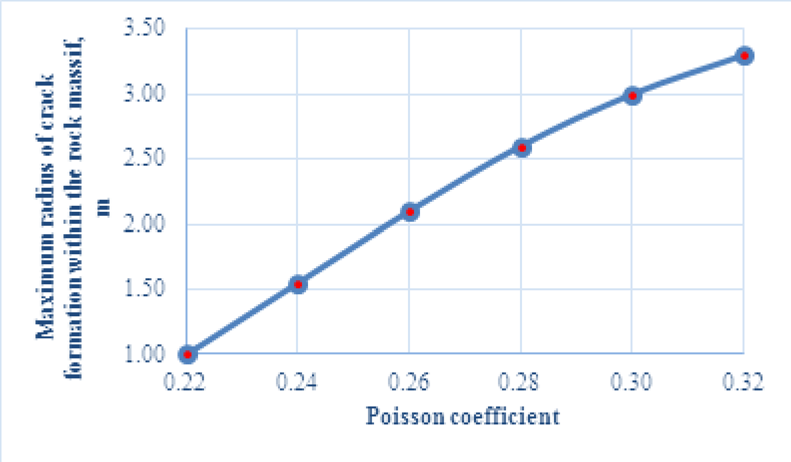

Figure 5. Graph of radial directional stresses occurring during compression of the maximum radius of crack formation within a rock massif

Studies have shown that when the value of the radial stress during elongation increases from 5.50 to 10.50, the maximum radius of the fracture zone within the rock mass decreases from 3.20 m to 0.75 m, respectively.

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