Methods for calculating the parameters of drilling and blasting operations based on the primary determination of the zones of destruction of the rock mass

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Abstract: The article considers the dependences of determining the parameters of the destruction zones of the rock mass by explosive charges, proposed by V.N. Mosinets, N.P. Gorbachev, M.F. Drukovanny, V.N. Tyupin, B.N. Kutuzov and A.P. Andrievsky and others. These dependences allow determining the location of the boreholes in the face, taking into account the physical and mechanical characteristics of the destroyed massif and the characteristics of the explosive used.

Key words: drilling and blasting (BVR), explosive, fracture zone, collapse zone, fracture radius, borehole, face, mine working.

1. Introduction

Methods, the calculation of which is based on determining the parameters of the zones of destruction of the rock mass by explosive charges, are fundamentally different. The calculation carried out on the basis makes it possible to determine the location of the boreholes in the face, taking into account the physical and mechanical characteristics of the destroyed massif and the characteristics of the explosive used.

2. Results and discussion

V.N. Mosinets and N.P. Gorbachev were among the first who proposed formulas for determining the destruction zones.

Collapse zone radius:

\[ R_{tr} = \sqrt{\frac{C_S}{C_P}} \times \sqrt[3]{q}, m. \]

Fracturing zone radius:

\[ R_{fr} = \frac{C_P}{C_S} \times \sqrt[3]{q}, m. \]
\[ R_{TR} = \sqrt{\frac{c_p}{c_s}} \cdot 3 \sqrt{q}, m. \]

\[ R_{UD} = \frac{\sqrt{c_p}}{10} \cdot 3 \sqrt{q}, m. \]

\[ R_{CM} = r_{sh} \left( \frac{p_b}{-\left(\frac{ka}{\alpha}\right) + (c_j + \frac{ka}{\alpha}) + \frac{2\alpha}{L(1+\alpha)}} \right) \frac{1}{2\beta} \cdot \sqrt{L}, m, \]

\[ L = \frac{E}{\sigma_{cj} (1+0.14\sigma_{ras})}, \]

\[ R_{TR} = \frac{(\sigma_{cj})}{\sigma_{ras}} \cdot R_{CM}, m. \]

\[ r_{PR} = \left( \frac{P_N}{P_C} \right)^{\frac{1}{4}}, \]

\[ P_N = \left( \frac{1}{8} \rho \cdot D^2 \right), \]

\[ P_C = \sigma_{cj} \cdot \left( \frac{\gamma c^2}{5 + \sigma_{cj}} \right)^{\frac{1}{4}}, \]

\[ R_{TR} = R_{CM} \cdot \frac{v}{1+v} \cdot \frac{\sigma_{cj}}{\sigma_{ras}} , m. \]

\[ R_{TR} = 55d_{sh} \cdot \frac{\rho \cdot c}{\sqrt{f}}, m. \]
The nomogram was built on the basis of experimental data obtained during the explosion of ammonite T-19. If ammonite №6 is used, then the radius of the crack formation zone, determined from the nomogram, should be multiplied by a factor of 1.10.

When using more powerful explosives and mechanized charging of wells to the full cross section, it is recommended to determine the radius of the fracturing zone by the empirical dependence:

\[ R_{RT} = (271 + 4K_{zap} + 42d_{ckv} + 33Q - 20\sigma_{raz}) \times 10^{-3}, m. \]

Where \( K_{zap} \) — coefficient of loading (filling in cross section) of the well with explosive; \( d_{ckv} \) — borehole diameter, mm; \( Q \) — the heat of the charge explosion, MDj; \( \sigma_{raz} \) — rock tensile strength, MPa.

In turn, the heat of explosion is defined as:

\[ Q = q \times P = \frac{\pi d_3^2}{4} \times L_3 \times \rho \times MDj, \]

Where \( q \) — heat of explosion, MDj/kg; \( P \) — charge mass, kg; \( d_3 \) — charge diameter, mm; \( L_3 \) — the optimal length of the charge involved in the formation of a zone of radial cracks in the section perpendicular to the axis of the cylindrical elongated charge; \( \rho \) — patronage density, kg/m³.
\[
R_{TR} = \frac{\sqrt{\pi}}{8} \ast \frac{D + \gamma \cdot d_3 + c \cdot v \ast \sqrt{d_e \cdot d_e^{-1}}}{(\sigma + \pi + (1 + F^{-1}) + \mu \cdot K \cdot p + (1 - \nu) + F^-)},
\]

\[
d_k = \frac{\gamma - K}{\nu}.
\]

\[
\gamma = \frac{\sqrt{\pi}}{8} \ast \frac{D + \gamma \cdot d_3 + c \cdot v \ast \sqrt{d_e \cdot d_e^{-1}}}{(\sigma + \pi + (1 + F^{-1}) + \mu \cdot K \cdot p + (1 - \nu) + F^-)},
\]

\[
a_{VR} = R_{TR} \sqrt{\frac{d_{xp}}{d_k}} = 0.32 R_{TR}
\]

\[
a_o = \sqrt{2} \ast R_{TR} \left( 2 - \frac{h}{\pi W} \right)^{0.5} = 1.82 R_{TR},
\]

\[
a_o = R_{TR} \sqrt{\frac{d_y}{d_k}} = 0.7 R_{TR}
\]

\[
N_{ct} = (S_V - S_{VR}) \ast S_p^{-1} = (S_V - 2.4a^2) \ast (K_y \pi R_{TR}^2)^{-1}
\]

\[
S_{VR} = \frac{S_V}{S_p}
\]

\[
K_y = \frac{S_V}{S_p}
\]

\[
Q_{OB} = q_{vv} \ast S_v \ast l_{sh}
\]

\[
Q_1 = Q_{OB} \ast N_{OB}^{-1}
\]

\[
q_{vv} = \frac{(\pi \ast D \ast \gamma)^2}{2 A_{IP} \ast \gamma \ast F} \ast \left( \frac{n^* + 1}{16} \right) \ast \frac{d_3}{h} + \frac{\mu}{2 A_{ID}} \ast \left( \frac{W^* r}{1 - \nu} \right) \ast \ln \left( \frac{2W^*}{d_3} \right) + K_r
\]
Where А — full perfect bang job; 𝑛* — the number of interacting charges in the group (𝑛* = 1 with fire blasting; 𝑛* = 𝑣 - 1 with electric).

The radius of the fracture zone in the work is proposed to be determined as:

$$R_{TR} = r_3 \left( \frac{P_b}{2\sigma_{ras}} \right)^{\frac{1}{2}}, m$$

Where $$r_3$$ — charge radius.

B.N. Kutuzov and A.P. Andrievsky proposed their own method for determining the size of destruction zones [10-19].

The radius of the crush zone is determined by the expression:

$$R_{CM} = d_{sh} \sqrt{\frac{\rho * D^2}{8 * \sigma_{cj}}}, m$$

Where $$d_{sh}$$ — bore hole diameter, m; $$\rho$$ — explosive density, kg/m³; $$D$$ — detonation velocity, m/s; $$\sigma_{cj}$$ — compressive strength of rocks, Pa.

The radius of the cracking zone that forms around the hole in a monolithic rock mass when it is explosively loaded with elongated charges is determined by the following relationship:

$$R_{TR} = 0.7 * R_{CM} * \sqrt{\frac{\rho * D^2 * d_{sh}}{8 * \tau_{cr} * R_{CM}}}, m$$

Where $$\tau_{cr}$$ — ultimate shear strength of the massif being destroyed (for most rocks $$\tau_{cr}$$ not exceed 20 MPa).

Approximately $$\tau_{cr}$$ can be defined as (0.1 - 0.02) * 8 * $$\sigma_{cj}$$, Pa; $$D$$ — detonation velocity, m/s; $$\rho$$ — density of explosives, kg/m³; $$\sigma_{cj}$$ — compressive strength of rocks, Pa.

The radius of the cracking zone that forms around a hole in a fractured massif when it is explosively loaded with elongated charges is calculated by the expression:

$$R_{TR} = 0.7 * R_{CM} * \sqrt{\frac{\rho * D^2 * d_{sh}}{8 * \tau_{cr} * R_{CM} * K_{c}}}, m$$

Where $$K_{c}$$ — coefficient of structural weakening of the rock of the fractured massif, calculated by the formula:

$$K_{c} = \frac{\frac{1}{0.97 + 0.13 \frac{R_{TR}}{l_{m}}}}{}$$

$$l_{m}$$ — average distance between cracks, m

$$\tau_{cr}$$ — ultimate shear strength of the massif being destroyed (for most rocks $$\tau_{cr}$$ not exceed 20 MPa).

$$\tau_{cr}$$ can be defined as (0.1 - 0.02) * 8 * $$\sigma_{cj}$$, Pa; $$D$$ — detonation velocity, m/s; $$\rho$$ — density of explosives, kg/m³; $$\sigma_{cj}$$ — compressive strength of rocks, Pa.

The maximum value of the line of least resistance of the blast hole charge is determined by the following formulas.

- For monolithic array:
  $$W = \cos \alpha * R_{TR}, m$$

- For fractured massif:
  $$W = \cos \alpha * R_{TKT}, m$$

3. Conclusions

Based on the analysis of the previously given methods for calculating the destruction zones, it can be noted that they all work under certain conditions. In addition, a number of techniques are applicable only to monolithic arrays [20-29].

Nevertheless, it can be concluded that the design and direct conduct of blasting operations in the construction of horizontal and inclined mine workings can be carried out both according to already established methods, and according to relatively recently proposed...
The most workable at present seems to be the method of B.N. Kutuzov and A.P. Andrievsky. It allows to carry out a complex construction of the BVR passport according to the calculated destruction zones. However, the disadvantages of this technique are that it assumes the use of only a wedge stepped cut, the use of which when drilling with self-propelled drilling rigs (SBU) is very difficult. In addition, when calculating the parameters of drilling and blasting in soft rocks, under certain conditions, not entirely correct results were obtained.

The conducted analysis showed that the work on determining the rational parameters of drilling and blasting is complicated by the fact that it is necessary to take into account the whole variety of mining-geological and mining-technical conditions for driving mine workings. Any developed methodology for determining the rational parameters of drilling and blasting should be considered both from the point of view of the efficiency of the use of resources, and from the point of view of the safety and economics of the enterprise. It is quite obvious that it is difficult for specialists of mining enterprises to orientate themselves in all the variety of proposed methods. It is necessary that they take into account the full range of specific conditions and factors under which the construction of mine workings is carried out. Accordingly, there is a need to conduct a comprehensive analysis of the conduct of blasting operations, taking into account the whole variety of conditions inherent in specific construction sites of mine workings.

4. References:


