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DETERMINATION OF RATIONAL PARAMETERS OF BLAST WELLS DURING PRELIMINARY CREVICE FORMATION IN CAREERS

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ABSTRACT:

Recommended solutions to reduce the width of the zone of residual deformation, set the parameters and delineation of charges for shielding the slit with enhanced protective capacity and selected parameters of blasting in the marginal zone, ensuring the creation of the shielding slit with high protective ability. The dependence of changes in the diameter of a contour well, the linear mass of the contour charge and the distance between contour wells on the physical and mechanical properties of rocks and energy indicators of industrial explosives is established.

KEYWORDS: pit contour, formation of slopes, preliminary crevice formation, contour charge explosion, width of the zone of residual deformations, protective capacity, parameters of explosion in the contour zone of the pit, diameter of the contour well, linear mass of the contour charge, distance between contour wells.

INTRODUCTION:

Methods for calculating the parameters of stable ledges and sides do not fully take into account the diversity of the structure of rock massifs composing the slopes, the dynamic effects of mass explosions on the state of outcrops, changes in the design elements of the sides over time [1-15]. We have not found a complete solution to the problem of determining the optimal height of non-working ledges, berm width, and side alignment in their limit contour for various mining and geological conditions. Until now, when designing, building, reconstructing and operating quarries, the issues of stability of ledges and sides are not always considered in a complex of natural and technological factors.

However, increasing the depth of development and life outside of pit walls, as well as involvement in the operation of fields with complex mining and geological conditions require a robust sustainability of effective structures of boards and their members to increase the completeness of mining, improve the technical and economic performance of enterprises, guarantee the safety of mining operations [8-11].

One of the criteria for determining the number of simultaneously exploding explosives is the value of the seismic hazard measure, in which the residual deformations of the rocks composing the ledges and sides of the quarry are practically excluded [12-15].

FINDINGS:

Since the maximum error of measuring vertical Δh and horizontal Δl deformations under the accepted measurement method is 3 mm, the maximum permissible value of the seismic hazard measure for all cases is determined from the equation:

$$\Delta \boldsymbol{h} = \mathbf{exp}(\boldsymbol{ap} - \boldsymbol{b}). \quad (1)$$

The safe distance for contour ledges from the explosion site to the protected object should be determined using the formula:

$$r_б = K_c \sqrt[3]{Q}, \quad (2)$$

where Q - the mass of simultaneously exploding explosives, kg; Cs- the value inversely proportional to the measure of seismic hazard.

Due to the fact that the rocks on the horizon of the exploding ledge are subject to the greatest deformation, the calculation of the amount of simultaneously exploding explosives should be carried out taking into account the coefficient of Cs corresponding to these conditions. The proximity of coefficient values for vertical and horizontal offsets allows using averaged values with an error of 7-9%.

The numerical values of this coefficient depend on the criteria for the type of displacement, the location of the protected object, the type of rock and the nature of fracturing.

The number of simultaneously exploding explosives in the approach of blasting operations to the limit contour of the quarry is determined by the formula

$Q=(r_б/K_c)^3$,

where Cs - the average coefficient value.

Based on the results of the study of the effect of mass explosions on the deformation of the contour ledges the amount of weakening of the array is determined depending on the number of simultaneously exploding explosives Q and the distance to the explosion site Le:

$$\tau= 0{,}45\cdot10^3 Q/L_e^2 \qquad (4)$$

Since on the limit contour of the quarry τ=1, then for these conditions the dependence (4) will take the form

$$Q = L_e^2/450, \qquad (5)$$

where L_e - the length of the exploding block, m.

Based on the provision of a minimum zone of intense deformation, it is possible to determine, according to the revealed regularities, the optimal specific consumption and quantity of explosives per 1 m of the work front on the basis of dependencies

$$L=Z(q_ф - q_o)^\lambda \rightarrow \min, \qquad (6)$$

$$L=\beta(q_м - q_{м.о})^\varepsilon \rightarrow \min. \qquad (7)$$

the points towards the stationary side, where the displacement does not exceed 3 mm.

In general, the number of simultaneously exploding explosives

$$Q = l_l \cdot h \cdot L_л \cdot q_o, \qquad (8)$$

where l_l – the width of the working tape, m; h - the height of the ledge, m; L_l – the length of the working tape, m; q_o - the optimal specific consumption of explosives, kg/m^3.

Substituting the expression (8) in equation (1), we have

$$\boldsymbol{R = C_s\sqrt[3]{l_l h L_l q_o}}. \qquad (9)$$

$$q_m=l_l\, h\, q, \qquad (10)$$

where q - the specific consumption of explosives.

From here, taking into account the established optimal parameters q_0 and q_{m0}, you can determine the maximum width of the contour tape, which provides the minimum destructibility of the contour array, using the formula

$$l_l = q_{m0}/(hq_0). \qquad (11)$$

The width of the working tape depending on the resistance line along the sole w, the number of rows of wells n and the distance between the rows of wells B:

$$l_l = w+(n-1)B. \qquad (12)$$

Based on this, the width of the contour zone is determined by the converted formula (9):

$$R = C_s\sqrt[3]{[\boldsymbol{w} + (\boldsymbol{n} - \boldsymbol{1})B]\boldsymbol{h}\boldsymbol{L_l}\boldsymbol{q}_o}. \qquad (13)$$

Taking into account the dependencies (6) and (7), we obtain an equation of the form

$$R = A\sqrt[3]{\boldsymbol{L_l}}, \qquad (14)$$

where A - the empirical coefficient (A=11.5-18.0).

Expression (14) allows you to determine the size of the exploding block along the work front at a given distance from the explosion site to the limit contour of the quarry side.

From equation (12) it is possible to determine the number of rows of wells in the exploding block at different heights of the ledge:

$n = (q_{m0} - whq_0)/(hq_0B)+l.$ (15)

The mass of charges in wells is determined taking into account the fracturing of rocks.

Distance between wells in a row, ensuring minimal destruction of the rock mass of the non-working ledge

$a = Q_f/(w\ h\ q_o),$ (16)

where Q_f - the mass of charge in the well, taking into account the natural fracturing of rocks.

Taking into account the values w and q_0 we get

$a = Q_f/K_i,$ (17)

where K_i - the coefficient for various conditions of quarries, equal to 54 to 58.

The maximum specific charge in a group of charges is determined by the transformed equation:

$\beta = Q/L_l = V^2r^2/(\boldsymbol{K_1^2}e^{-0.06\ r}).$ (18)

Given that the speed of permissible rock vibrations in the ledges is 24 sm/s, for the conditions of the quarry we have:

– for rocks with a strength coefficient f=9÷11

$\beta = 0{,}005\ r^2/e^{-0{,}06\ r};$ (19)

– for rocks with a strength coefficient f=11÷13

$\beta = 0{,}0059\ r^2/e^{-0{,}06\ r};$ (20)

– for rocks with a strength coefficient f=13÷16

$\beta = 6{,}0073\ r^2/e^{-0{,}06\ r}.$ (21)

Hence, taking into account the formulas (3), (18) and (19), which determine the specific charges and the amount of simultaneously exploding explosives, the maximum work front for various conditions is found from the expression

$L_l = Q/p.$ (22)

The value p can be used to adjust the number of rows of wells in the contour tape.

The specific consumption of explosives during the development of contour belts, depending on the fracturing and strength of the array, can be determined if the charge value is expressed in terms of volume indicators.

Then

$$\boldsymbol{wahq}_{\text{м}} = \frac{\bar{n}\Delta\rho c^2 da}{4pK_{\text{тр}}}\left[h\sigma_{\text{p}} + (3sin\alpha + hcos\alpha)(\sigma_c sin\alpha + h\gamma\mu)\right]. \quad (23)$$

Where from

$$\boldsymbol{q}_{\text{м}} = \frac{\bar{n}\Delta\rho c^2 d}{4pwhK_{\text{тр}}}\left[h\sigma_{\text{p}} + (3sin\alpha + hcos\alpha)(\sigma_c sin\alpha + h\gamma\mu)\right]. \quad 24)$$

Thus, the recommended decision to reduce the width of the zone of residual deformation, set the parameters and delineation of charges for shielding the slit with enhanced protective capacity and selected parameters of blasting in the marginal zone, ensuring the creation of the shielding slit with high protective ability and the corresponding constraint stresses in the incident wave compression.

Stresses on the walls of a contour well caused by the action of detonation products should not exceed the strength characteristics of rocks under conditions of explosive loading P_s:

$P \leq P_s.$ (25)

The strength characteristics of rocks under explosive loading at the last stage of the explosion can be determined by the dependence [13]

$$\mathrm{P_s} = \sigma_c\left(\frac{\rho_0 c^2}{5\sigma_c}\right)^{1/4} \quad (26)$$

where σ_s – compressive strength, Pa; ρ_0- rock density, kg/m^3; c - the speed of the longitudinal wave in the rock, m/s.

Expression (26) is derived from consideration of the quasi-static expansion of the explosive cavity at the final stage of the explosion, which occurs during contour blasting.

The charge diameter of the contour well is much smaller than the diameter of the charging cavity, so the pressure of the detonation products on the walls of the borehole:

$$\mathrm{P} = \mathrm{P_D}\left(\frac{\mathrm{V_{ch}}}{\mathrm{V_w}}\right)^{\gamma} \quad (27)$$

or

$$\mathrm{P_w} = \mathrm{P_D}\left(\frac{\mathrm{V_{ch}}}{\mathrm{V_w}}\right)^{\gamma}, \quad (28)$$

where P_D - the average pressure of the detonation products after the explosion, Pa; V_{ch}/V_w is the ratio of the volume of the contour charge to the volume of the charging cavity; γ is the adiabatic index of the explosion products (for contour blasting, γ=1.5).

The ratio of the volume of the contour charge to the volume of the charging cavity per 1 m of the well length

$$V_{ch}/V_w = (r_{ch}/r_w)^2, \quad (29)$$

where r_{ch}/r_w - the ratio of the charge radius to the well radius.

Converting (28) we get

$$P_w = P_D\left(\frac{r_{ch}}{r_w}\right)^{2\gamma}. \quad (30)$$

Hence the charge radius of a contour well is defined as

$$r_{ch} = r_w\left(\frac{P_w}{P_D}\right)^{1/3}. \quad (31)$$

Average pressure of detonation products in an explosion

$$P_D = \rho_e D^2/8, \quad (32)$$

ρ_e – the density of explosive, kg/m³; D – explosive detonation speed, m/s.

Substituting the formulas for P_w and P_D in (31), we find the charge radius of the contour well

$$r_{ch} = 0{,}55\,\frac{(\rho_0 c^2)^{7/12}}{(\rho_e D^2)^{1/13}\sigma_c{}^{1/4}}\,r_w \quad (33)$$

or

$$r_{ch} = 0{,}55\,\frac{(\rho_0 c^2)^{1/3}\,(\rho_0 c^2)^{1/4}}{(\rho_e D^2)^{1/3}\sigma_c{}^{1/4}}\,r_w. \quad (34)$$

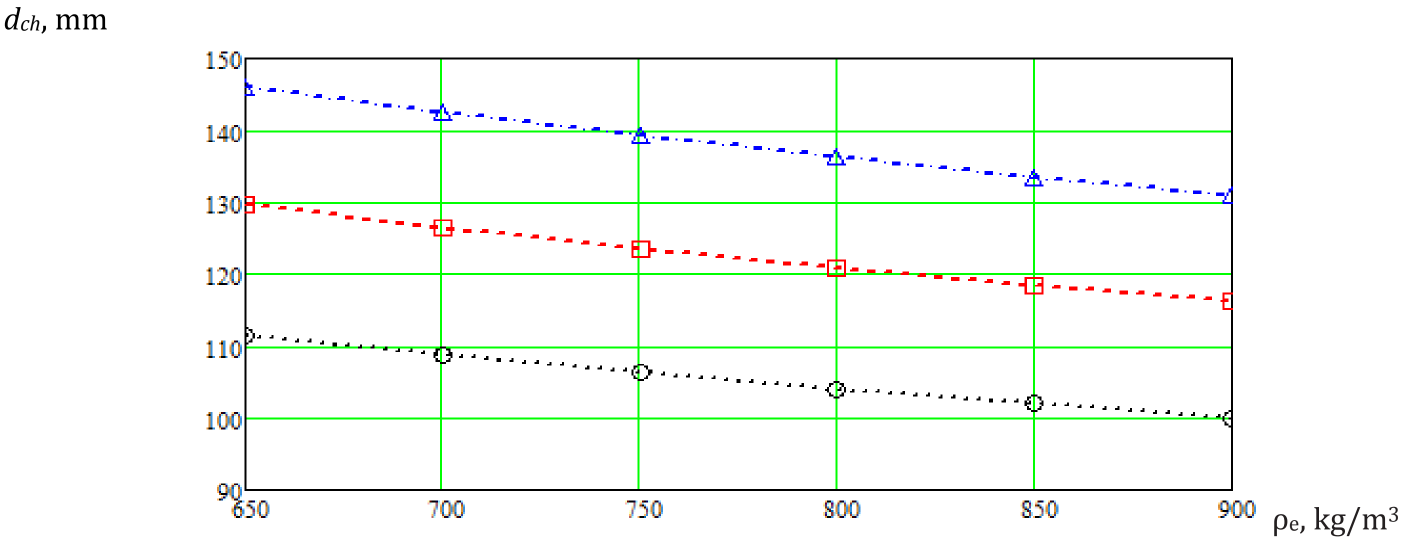
In expression (34), the second factor is the cubic root of the ratio of the acoustic stiffness of the rock and the explosives. The greater this ratio, the less energy of the explosion passes into the rock and the greater the charge radius of the contour well. The third factor is the coefficient of dynamism. This value shows how many times the strength characteristic of the medium increases under explosive loading conditions.

The charge diameter of a contour well is determined from the dependence

$$d_{ch} = 0{,}55\,\frac{(\rho_0 c^2)^{7/12}}{(\rho_e D^2)^{1/3}\sigma_c{}^{1/4}}\,d_w. \quad (35)$$

RESULT OF STUDY:

Figure 1-4 shows the dependence of the diameter of the exploding contour charge on the density of explosives, the compressive strength of rocks, the velocity of the longitudinal wave in the exploding rock, and the rate of detonation of explosives in various rocks.

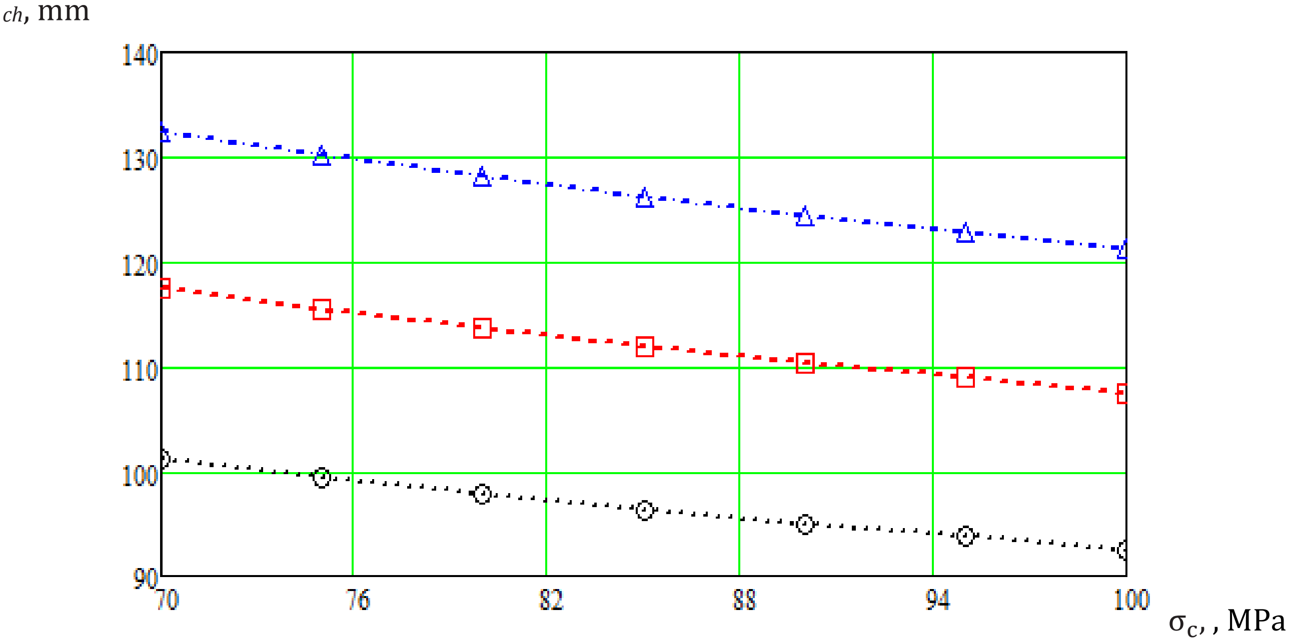


o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 1. Change in the diameter of the explosive charge d_{ch} from the density of the explosives ρ_e in various rocks

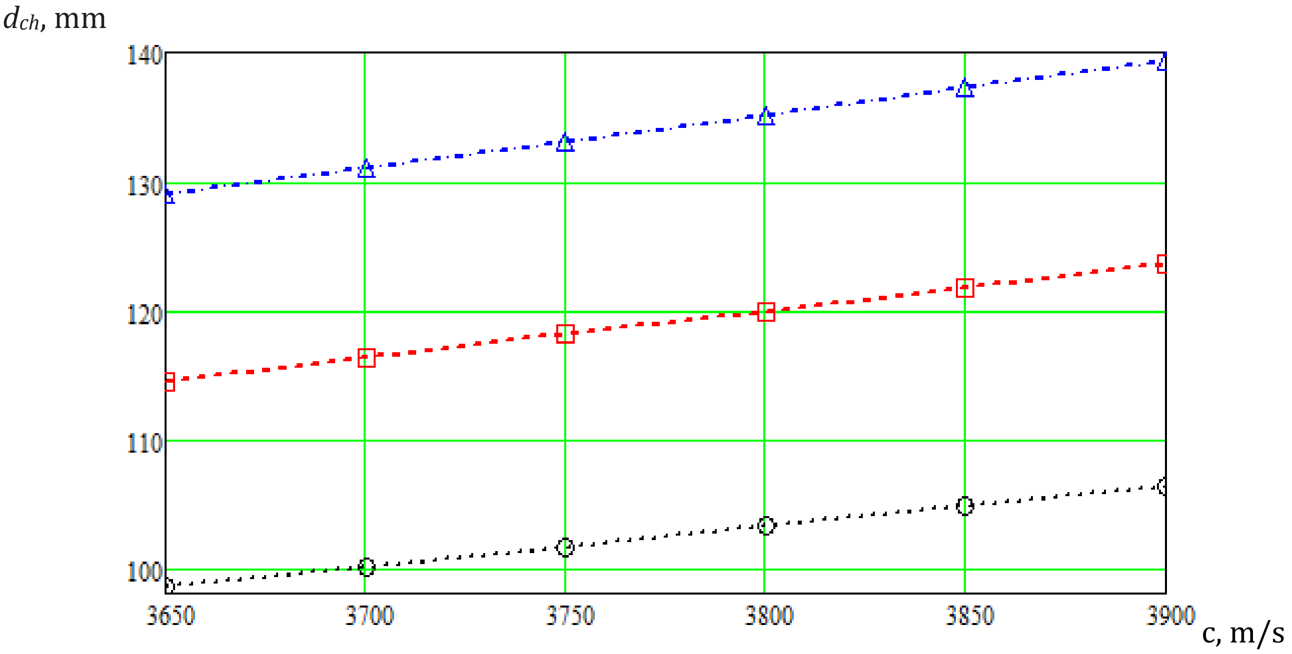
The obtained dependences show that with an increase in the density of the explosive, the compressive strength of rocks and the detonation rate of the explosive, the diameter of the explosive charge in various rocks decreases, and with an increase in the velocity of the longitudinal wave in the exploding rock – increases.

Thus, the change in the diameter of a contour well depending on the density of the explosive charge, the density of rocks, the compressive strength of rocks, the speed of the longitudinal wave in the exploding rock and the rate of detonation of industrial explosives is established.



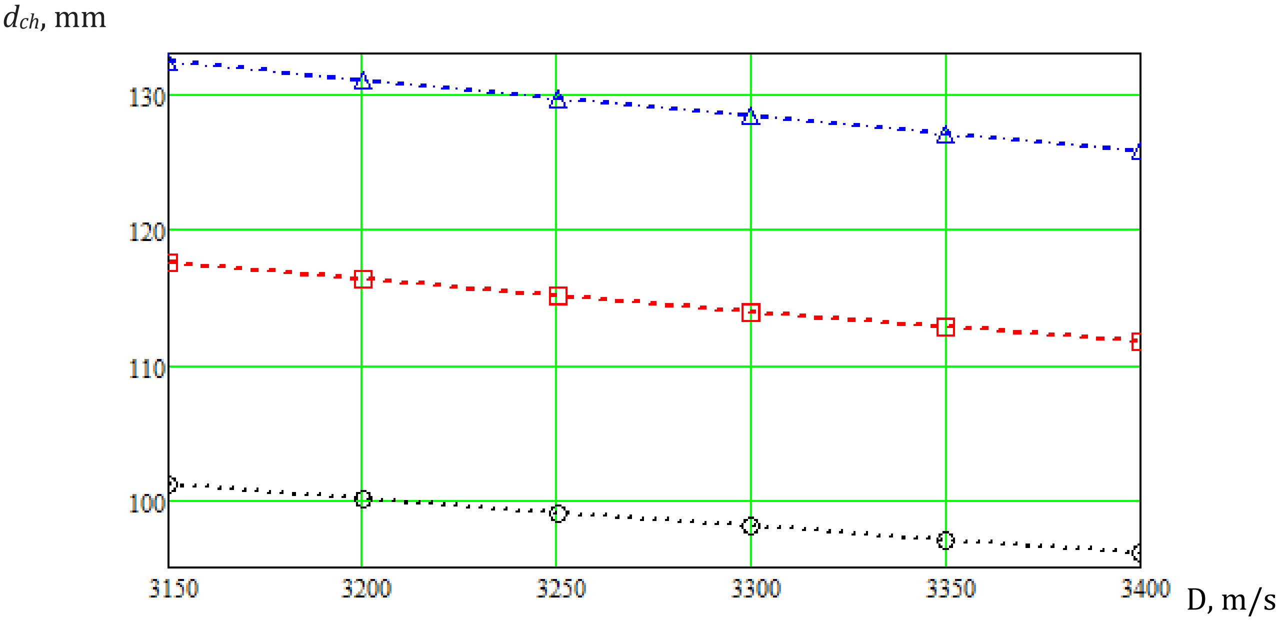
o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 2. Change in the diameter of the explosive charge d_{ch} from the compressive strength of rocks σ_c in various rocks



o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 3. Change in the diameter of the explosive charge d_{ch} from the velocity of the longitudinal wave C in various rocks



o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 4. Change in the diameter of the explosive d_{ch} charge from the explosive D detonation rate in various rocks

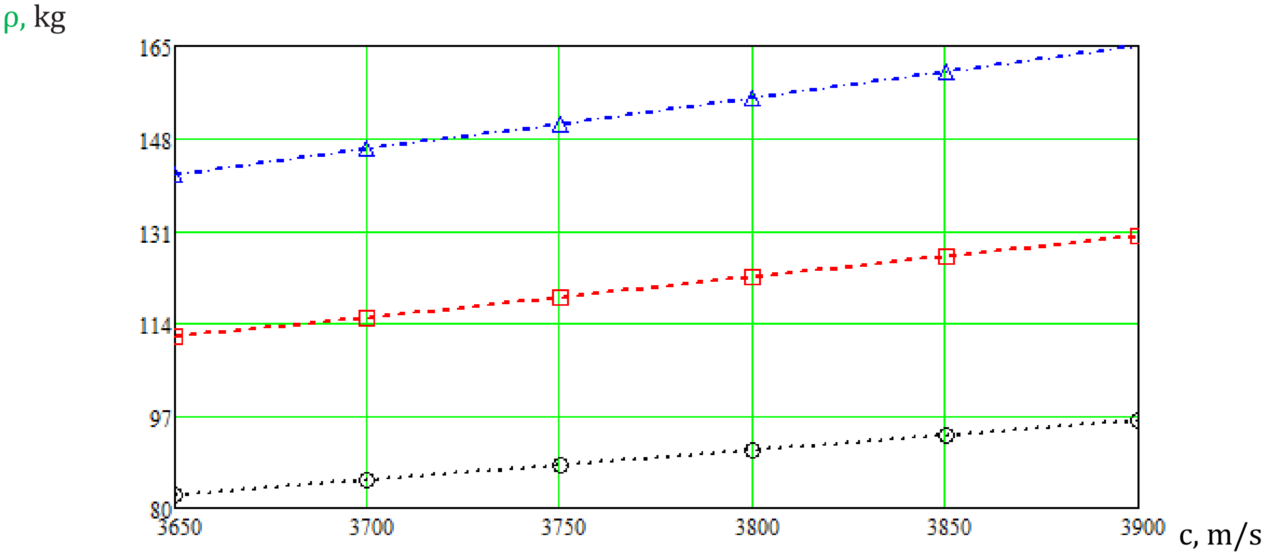
The linear mass of the contour borehole charge is determined by the formula

$$\rho = \pi {r_{ch}}^2 \rho_e. \quad (36)$$

Converting this expression, we get

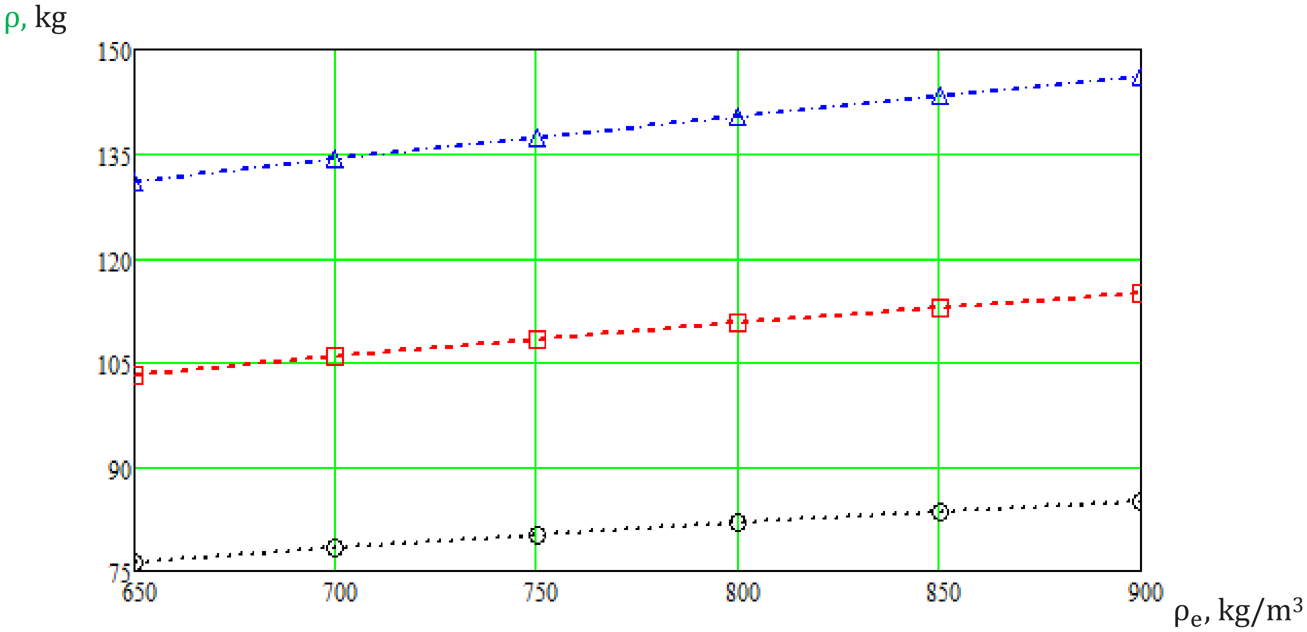
$$\rho = 3{,}8 \cdot 10^{-5} \frac{(\rho_0 c^2)^{7/6}}{(\rho_e)^{1/3} D^{4/3} (\sigma_c)^{1/2}} {r_w}^2 \quad (37)$$

In Fig. 5-9 shows the variation of the linear mass of the charge contour of the hole from the density of the blowing rock, the speed of longitudinal waves in blowing rock, the density and speed of detonation of explosives, the tensile strength of rocks in compression and radius of contour wells in various rocks.



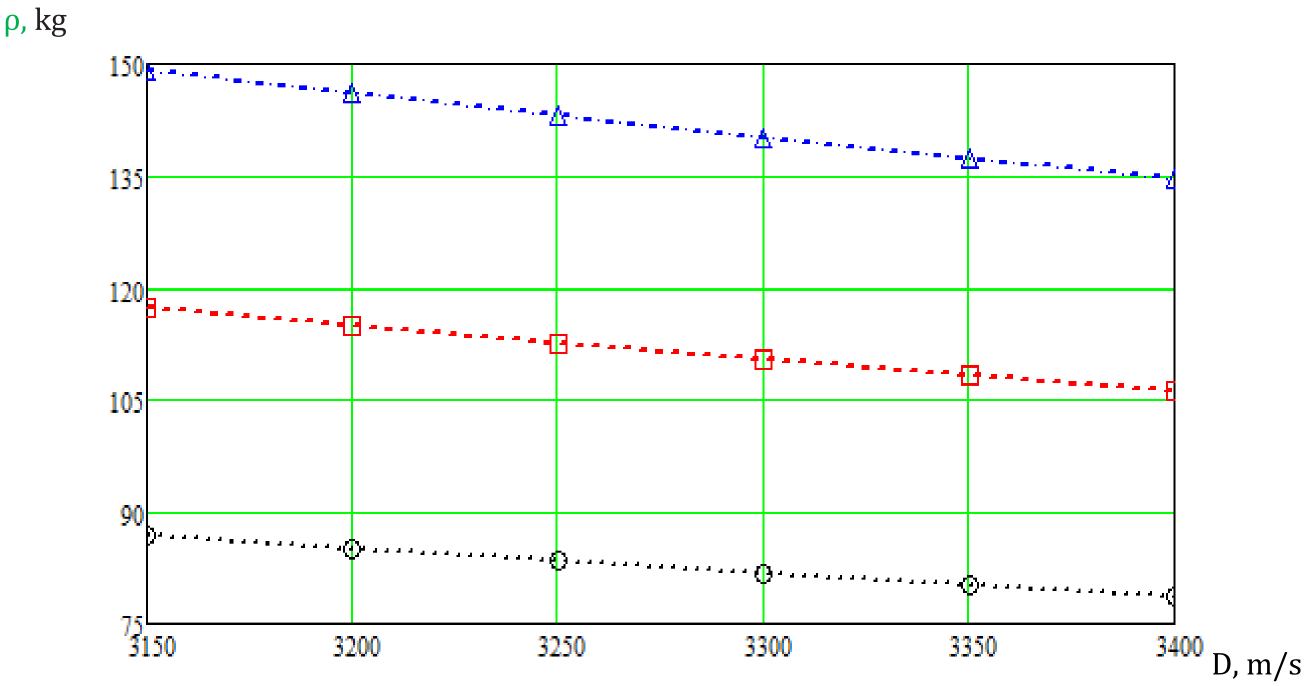
o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 5. Change in the linear mass of the charge of a contour well ρ from the velocity of the longitudinal wave in the rock c in various rocks



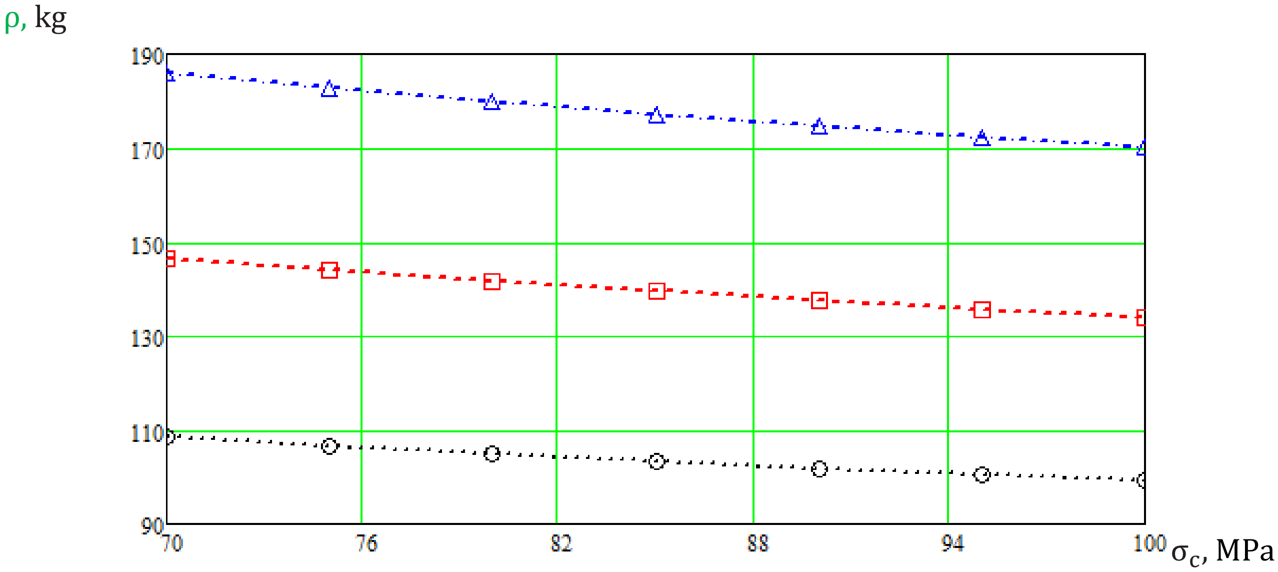
o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 6. Change in the linear mass of the charge of the contour well ρ from the density of the explosive substance ρ_e in various rocks



o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

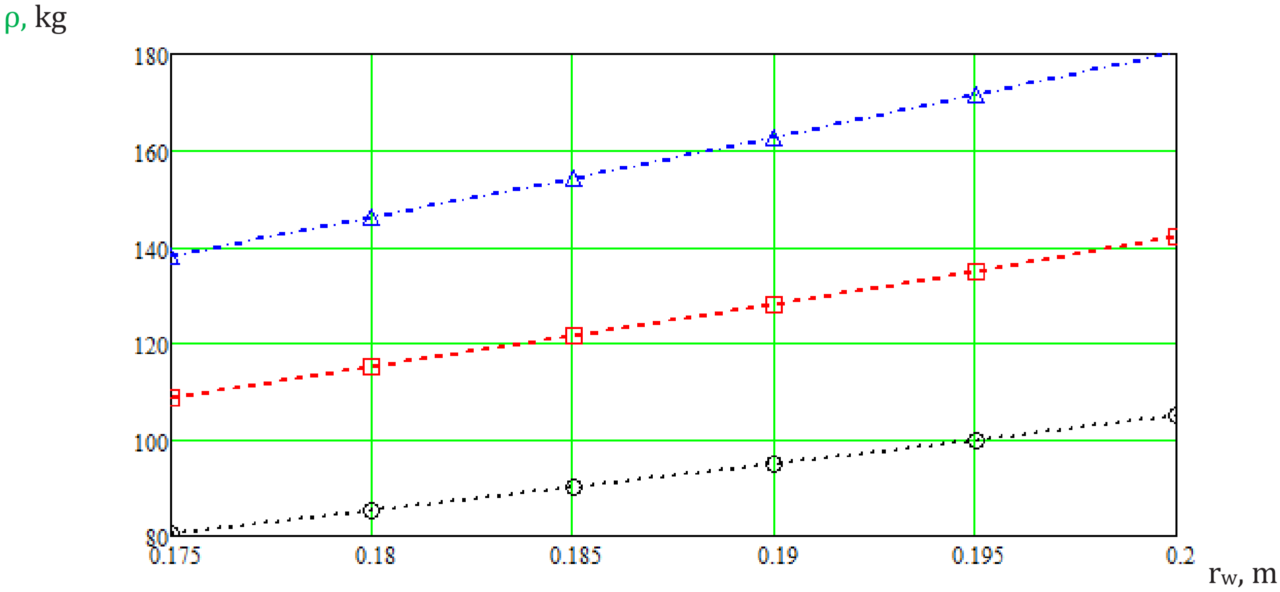
Fig. 7. Change in the linear mass of the charge of a contour well ρ depends on the rate of detonation of the industrial explosive *D* in various rocks



o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 8. Change in the linear mass of the contour well charge ρ from the compressive strength of rocks σ_c in various rocks

The obtained dependences show that when the velocity of the longitudinal wave in the rock increases, the density of the explosive substance and the radius of the contour well, the linear mass of the charge of the contour well increases, and when increases the detonation rate of industrial explosives and the compressive strength of rocks, it decreases.



o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 9. Change in the linear mass of the contour well charge ρ from the radius of the contour well r_c in various rocks

Thus, the dependences of changes in the linear mass of the contour charge on the velocity of the longitudinal wave in the rock, the density of the explosive, the radius of the contour well, the detonation rate of industrial explosives and the compressive strength of rocks are established.

The change in tangential stresses during a well explosion with radius r_w and distance r is determined from the dependence

$$\sigma_\theta = P\left(\frac{r_w}{r}\right)^2. \tag{38}$$

According to (3.25) P ≤ P_w, then

$$\sigma_\theta = \left(\frac{\rho_0 c^2 \sigma_c^3}{5}\right)^{1/4}\left(\frac{r_w}{r}\right)^2. \tag{39}$$

The formation of a crack along the line connecting contour wells is possible if there are tangential stresses $\sigma_\theta \geq \sigma_t/2$ at the point located at half the distance between the wells r = a/2

$$\sigma_s/2 = \left(\frac{\rho_0 c^2 \sigma_c^3}{5}\right)^{1/4}\left(\frac{2r_w}{a}\right)^2. \tag{40}$$

Hence, the distance between contour wells in the pre-crevice method is determined from the dependence

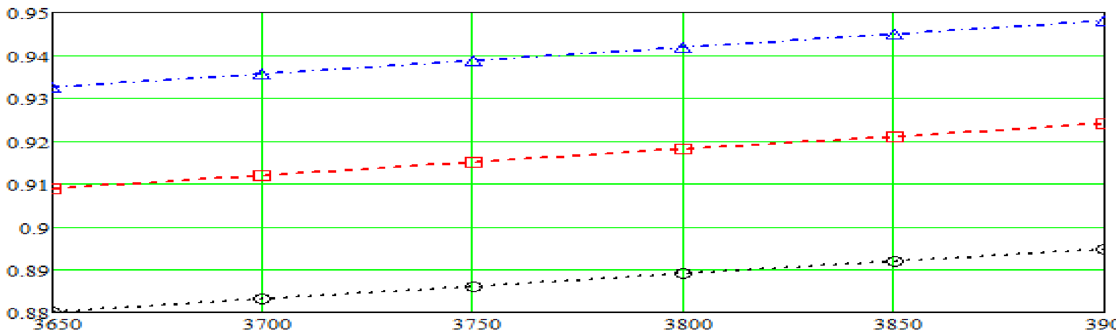
$$a = 0{,}128\, r_w \left(\frac{\rho_0 c^2 \sigma_c^3}{5\sigma_s^3}\right)^{1/8} \tag{41}$$

or

$$a = 0{,}064\, d_b \left(\frac{\rho_0 c^2 \sigma_c^3}{5\sigma_s^3}\right)^{1/8}. \tag{42}$$

Fig. 10-13 shows the dependence of the distance between contour wells on the speed of the longitudinal wave in rocks, the strength limit of rocks for compression and stretching, as well as the radius of contour wells in various rocks

a, m

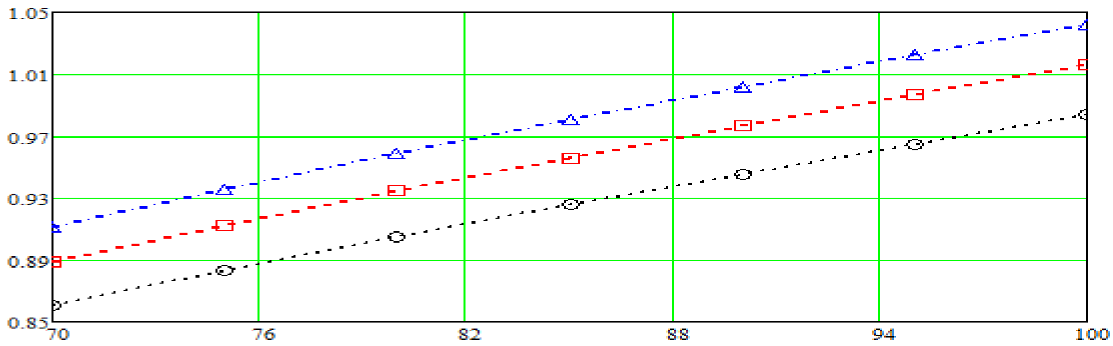


c, m/s

o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 10. Variation of the distance between contour wells *a* from the velocity of the longitudinal wave *c* in various rocks

a, m

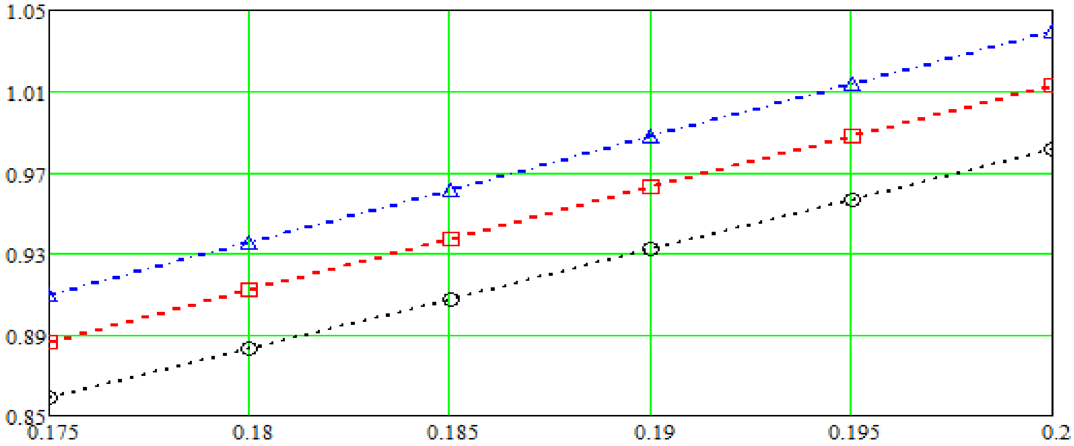


σ_c, MPa

o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 11. Variation of the distance between contour wells *a* from the compressive strength limit of rocks σ_c in various rocks

a, m

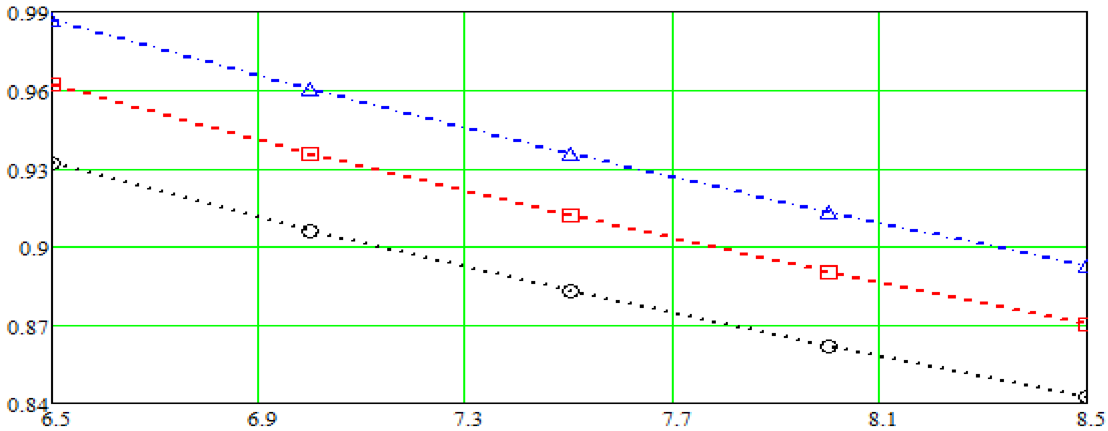


rw, m

o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 12. Variation of the distance between contour wells *a* from their radius r_w in various rocks

a, m



σ_s, MPa

o - soft rocks; □ - medium-strength rocks; Δ - strong rocks

Fig. 13. Variation of the distance between contour wells *a* from the tensile strength of rocks σ_s in various rocks

The obtained dependences show that when the longitudinal wave velocity in the rock increases, the compressive strength of rocks and the radius of contour wells increases, the distance between contour wells increases, and when the tensile strength of rocks increases, it decreases.

Thus, the dependence of the change in the distance between contour wells on the speed of the longitudinal wave in the rock, the density of the explosive substance, the strength limit of rocks for compression and stretching, as well as the radius of contour wells is established.

CONCLUSIONS:

1. Recommended solutions for reducing the width of the zone of residual deformations, the parameters of contouring charges are set to create a shielding gap with increased protective capacity and the parameters of explosion in the contact zone are selected, which ensure the creation of a shielding gap with an increased protective capacity and the corresponding limitation of stresses in the incident compression wave.
2. Established that the changes diameter of a contour well depending on the density of the explosive charge, the density of rocks, the compressive strength of rocks, the speed of the

longitudinal wave in the exploding rock and the speed of detonation of industrial explosives. When the density of the explosive increases, the compressive strength of rocks and the detonation rate of the explosive increases, the diameter of the explosive charge in various rocks decreases, and when the longitudinal wave speed increases in the exploding rock – increases.

3. Established that the changes of dependence of the linear mass of the contour charge on the velocity of the longitudinal wave in the rock, the density of the explosive, the radius of the contour well, the detonation rate of industrial explosives and the compressive strength of rocks. When the velocity of the longitudinal wave in the rock increases, the density of the explosive substance and the radius of the contour well, the linear mass of the charge of the contour well increases, and when the detonation rate of industrial explosives and the compressive strength of rocks increases, it decreases.

4. Established that the changes of dependence of the distance between contour wells on the speed of the longitudinal wave in the rock, the density of the explosive substance, the strength limit of rocks for compression and stretching, as well as the radius of contour wells. When the longitudinal wave velocity in the rock increases, the compressive strength of rocks and the radius of contour wells increases, the distance between contour wells increases, and when the tensile strength of rocks increases, it decreases.

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