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CRUSH CRATER AT THE AREA OF HOLES OVER-DRILLING

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ABSTRACT: It had been established that concluding effect of explosion of the oblong cylindrical charge of explosive is determined by dimensions of the maximum cavity, crushing zones and radial clefts. They are calculated for the charge section, where the cylindrical form of the explosive cavity and the pointed zones of destruction is kept.

With approach of the oblong charge considering section to its bottom, because of ever-increasing meaning of rock's strength characteristic in conditions of explosive loading, the cylindrical development of explosive cavity and destruction zones is broken, their dimensions decrease essentially. The numerous «glasses» and safe-kept over-drilled parts of the holes are evidences of the fact that at the level of the charge bottom in average and strong mining rocks destruction doesn't take place at all. As a rule, the cylindrical development of the oblong charge explosion comes to end at the section, whis is situated from its bottom at some distant, determined by rocks base properties, applied explosive and explosion conditions.

DISCUSSION AND NEW OBSERVATION

It had been fixed by practice of blasting operations cohducting that by blasting of the oblong cylindrical charges group at their butt-end (bottom) part some volume of rocks practically was no exposed to destruction. That is why by passing of the underground mining excavations the coefficient of the bore-holes use is 0,8-0,9 of their depth, and at the open-pit mines for providing of the terrace foot normal working-up the holes are over-drilled on the quantity of 0,10-0,20 from the terrace height. Slackening of explosion mechanical effect at the bottom part of the cylindrical charge doesn't find the sufficient theoretical explanation. For explanation of this effect and corresponding parameters of destruction volume lef s consider sequence of explosion development in strong medium. As is known, after detonation of the explosive cylindrical charge along the rocks massif powerful wave of compression spreads, at the front of which rock is strongly crushed (crumbled up). The gaseous products of detonation (GPD), further developing the started process of destruction, widen axis-symmetrically the charge camera. On the expiry of some time the last one achieves its limit state. In other words, the GPD will widen axis-symmetrically until their pressure should fall to the meaning of Po, equals to the strength resistance of medium in conditions of explosion loading [Rodionov et al., 1971; Rakishev, 1983]. During all this time destruction of the rocks massif is going on under the combined influence of the wave processes and GPD: from the crush zope the zone of radial clefts spreads. Since the result effect of explosion is defined by dimensions of the maximum cavity, zones of crush and radial clefts, let's adduce the formulas for their calculation at some distance from the charges butt-ends, where the cylindrical form of the explosion cavity and pointed zones of destruction are kept [Rakishev, 1983].

With a help of some states of mechanics of variable mass and the theory of elasticity for the limit relative radius of the explosion cavity (Tj = *x\ I* ro) the expression has been received:

$$\bar{r}_l = (P_{in} / P_0)^{1/4}, \qquad d)$$

where n is the limit radius of the cavity, ro is the radius of the charge.

The average initial pressure of PD

$$P_{in} = (1/8)(\rho_{exp} D^2), \qquad (2)$$

where $p_{ex}p$ is explosive's density, D is velocity of explosive's detonation.

The strength characteristic of rock in conditions of explosion loading is defined by formula

$$P_0 = \sigma_c(\rho_0 v^2 / \sigma_c)^{1/4}, \qquad (3)$$

where a_c is the limit of compression strength of rock;

po is rock's density, v - velocity of sound in rock.

The radius of crush zone (r_2) in monolithic rocks at the camouflet stage of explosion can be calculated from dependence

$$r_2 = r_l (\rho_0 v^2 / 5\sigma_c)^{1/2} \qquad (4)$$

The radius of the zone of radial clefts (n) is defined from the expression

$$r_1 = r_2 [v / (1+v)] \sigma_c / \sigma_t, \qquad (5)$$

where v is the Pousson's coefficient;

o_t is the limit of rock tensile strength.

The main properties of rocks and relative dimensions of the investigated zones for some typical rocks, calculated by the formulas (1-5), are adduced in the tables 1,2. With this, the Pousson's coefficient has been adopted as equal to 0,3 for all rocks. The meanings of P_{in} correspond to the detonational and energy characteristics of using industrial explosives like ammonites, grammonites, granulotols, alumnatol and their combinations.

As is obvious from the formulas (1-5), by explosion of the oblong cylindrical charge the sought dimensions of destruction zones are intercoordinated full enough with the elastic, strength properties of rocks, with detonational and energy characteristics of applied industrial explosives. That is why the calculations results (tab. 2) coincide closely enough with the experimental data of the data of the mining, buiiainç :- .\;.;;P.;„w^ .. analogous conditions [Repin, 1978]. The adduced dependences are true of the spread in practice case of the charges placing near the free surface.

With approaching of the oblong charge considered section to its bottom because of the still-increasing meaning of Po the cylindrical development of the explosion cavity and destruction zones is broken, their dimensions decrease considerably. At the level of the charge bottom in average and strong mining rocks destruction doesn't take place at all, the numerous «glasses» and safe-kept over-drilled parts of the holes are evidences of this fact. In other words, at the action area of the charge of over-drilling the effect takes place, characteristic for explosion of the oblong charge near the daylight surface.

By explosion of the point charge in massif with one free surface, as is known, the cone-shaped destruction (fig. 1) is formed, which have been accepted to call «destruction crater» or «explosion crater». The shape and dimensions of the forming crater depend on the properties of blasting medium, blasting characteristics of the explosive and value of deepening. The crater is characterized by the following parameters: depth of the charge lay or the shortest distance from the charge center to the nearest free surface (h); the radius of the charge explosion effect (r); the angle of half-spread of the crater (a); the indice of explosion effect n = r/h = tga.

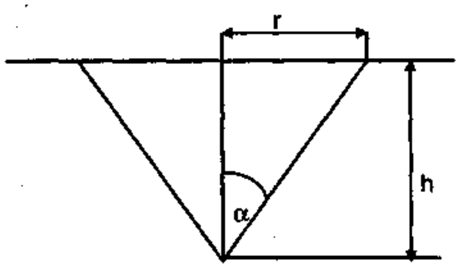

Figure 1. The elements of the explosion crater.

In contrast to explosion in massif with one free surface, at the area of holes (bore-holes) over-drilling the indice of explosion effect in strong rocky rocks will be less than 1. The

Table 1. The main properties of mining rocks.

Rocks (their indexes)	Rocks density, kg/m^3	Velocity of sound, m/sec	The limits of strength of		Po MO^2, MPa
			compression	tensility	
Granodiorite-porphyries without signs of quartzina, primary (K-1)	2720	5200	157.0	15.7	7.63
Secondary quartzites from: effusive porphyries, strong(K-2)	2770	5200	133.4	15.2	6.6
granodiorite-porphyries, temperate-quartzized (K-5)	2740	4550	71.6	9.3	3.87
Coarse-grained limestone (A-2)	2820	4350	175.6	16.2	7.50
Marblized limestone (A-3)	2820	3820	158.9	12.3	6.48
Diorite-porphyrite of Akzhal (A-4)	2720	5700	107.9	10.3	5.90
Diorite-porphyrite of Sayak (C-2)	2900	4920	251.1	21.1	10.4
Tufa-sandstone (C-3)	2700	4640	243.3	20.6	9.76
Granodiorite of Sayak (C-6)	2730	4960	189.3	16.2	7.52
Massive limestone (C-9)	2820	3860	145.2	12.7	6.10

Table 2. The relative radii of the cavity, zones of crush and of radial clefts.

Rocks indexes	By PMO^2, MPa								
	20.0			27.0			33.5		
	n	T_2	**n**	"ri	T_2	ri	**n**	T_2	n
(K-1)	1.27	12.1	29.0	1.37	3.0	31.2	1.44	13.7	32.8
(K-2)	1.32	14.0	28.4	1.42	15.0	30.5	1T50	15r9	32.3-
(K-5)	1.51	19.0	37.6	1.62	20.4	40.4	1.72	21.6	42.8
(A-2)	1.27	9.9	24.7	1.37	10.7	26.6	1.44	11.2	27.9
(A-3)	1.32	9.5	28.5	1.42	10.2	30.6	.1.50	10.9	32.7
(A-4)	1.36	17.4	42.1	1.48	19.0	46.0	1.55	19.3	47.9
(C-2)	1.18	8.9	24.7	1.28	9.6	26.6	1.35	10.1	28.0
(C-3)	1.20	8.3	22.6	1.29	8.9	24.2	1.36	9.9	26.9
(C-6)	1.27	10.7	28.9	1.37	11.5	31.1	1.44	12.1	32.7
(C-9)	1.34	10.2	26.5	1.46	11.1	28.9	1.53	11.7	30.4

holes (bore-holes) over-drilling (l_{ov}) plays the role of the charge lay depth, and the radius of the crush zone (r_2) - the role of the radius of the explosion crater (fig. 2).

It should be noted, that forming of the destruction crater is the universal result of influence upon strong medium of mechanical loads of different physical nature. So, for example, by influence of water jet of big pressure upon mining rock the destruction crater forms too, Its dimensions depend on the rocks properties, value of percussion pressure, other parameters of jet and conditions of interaction.

Thus, the principal element of the crush crater - the holes over-drilling - fixes the position of the oblong charge section from the hole bottom, where cylindrical development of explosion comes to an end. The last one, as in a general case, is predetermined by results of interaction of PD with surrounding massif. The radius of the crush crater, as the mafor result

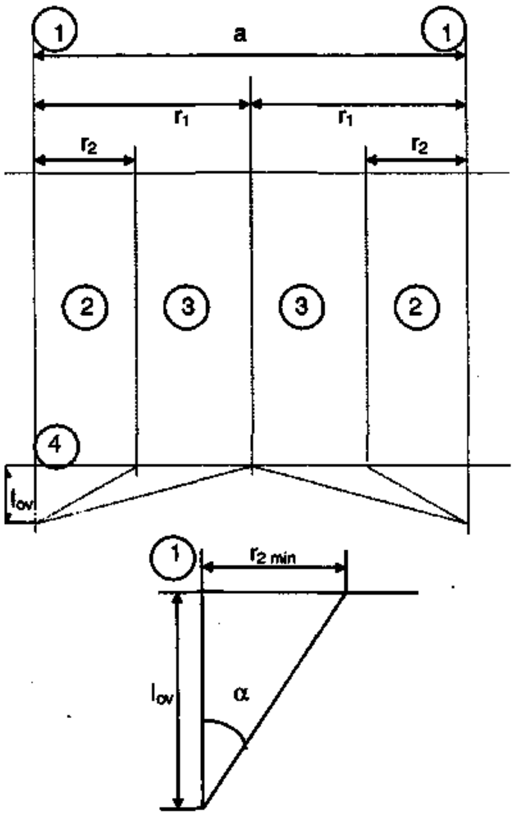

Figure 2. The scheme of destruction of the rocks massif in the bottom part of explosive's charge: 1 - the charge axis; 2 - the crush zone; 3 - the zone of radial clefts; 4 - the terrace foot.

of the cylindrical charge explosion, is the main determining parameter here. Besides the elastic, strength properties of rocks, it depends also on the energy, detonational characteristics of explosive. That is why, for providing of needed shatter at the project mark it is enough to achieve the minimum necessary value of r_2 min, because exceeding of this limit at the expense of the more powerful explosive application only intensifies cylindrical development of the destruction zones.

In one's turn, the sought value of r_2 min, must correspond to the minimum value of the limit relative radius of the cavity *T* - the integral characteristic of the destroying effect of explosive's blast. Analysis of the practice data of the open-pit mining exploitations shows that the quality working of the terrace foot is achieved by"n> 1,3 [Rakishev, 1983]. There fore, the minimum necessary meaning r_2 min can be calculated by the formula (4) under condition of providing of IT« 1,3.

For holes over-drilling value determination at the base of the afore-cited computations let's join the ends of the found radii of the crush zone with the axial point of the hole bottom (fig. 2).

Since the minimum necessary radius of crush can be defined, the value of hole over-drilling is calculated from the dependence:

$$l_{ov} = r_{2\,min}\,\mathrm{ctg}\alpha \qquad (6)$$

As the calculations and their comparison with the data of industrial explosions show, the angles of half-spread of the crush craters equal to 48-52° for the easily-blasting rocks (K -5, A-4), equal to 35-39° for the average blasting ones (K-1, K-2) and equal to 23-27° for the hard-blasting rocks. Not without interest to note, that the angles of the crush crater forming incline to horizon (n/2 - a) coincide with the angles of stable slopes of terrace boards, built from these rocks.

The calculated holes over-drilling in the considered rocks is (12-14) r_0, (15-18) r_0 and (19-22) r_0 correspondingly, which reffects satisfactorily their real state. By these meanings of over-drilling the normal working of the terrace foot is provided. By drilling of the underground mining excavations the sought section, where cylindrical development of the oblong charge explosion comes to an end, determines the project contour of cutting of the rocks outlined volume.

CONCLUSIONS

1. By blasting of the oblong cylindrical charge of explosive in rocks massif the dimensions of the explosion cavity, zones of crush and of radial clefts/are predetermined by the elastic, strength properties of rocks, the detonational and energy charactestics of applied explosive and conditions of blasting.
2. Cylindrical development of the cavity, the destruction zones comes to an end at the section of charge, standing from its bottom at a distance I, defining by the initial data of

explosion. This distance equals to the value of the holes over-drilling.

3. At the area of the holes over-drilling the destroyed volume of rock is the cone-crater of crush. Its radius equals to the minimum necessary for given rocks value of r_2 min, and the height equals to the hole over-drilling. The angle of half-spread of the crater is different for different rocks and has the largest value in the less strong rocks.

4. The value of the hole over-drilling is determined by the value of r_2 mm. multiplied at cotangent of the angle of half-spread of the crush crater.

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