RELATIVE DIMENSIONS OF THE ZONES OF DESTRUCTION CREATED BY EXPLOSIONS

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ABSTRACT: A relation is found between the size of the cavity created by an underground explosion and the zone of destruction of the surrounding porous medium. The relative size of the destruction zone is determined from the density discontinuity and does not depend on the energy density and the size of the charge.

It has been observed that when a charge of any shape is exploded underground the medium surrounding the charge is displaced within a region of essentially restricted size [1]. In accordance with [2–4], it may be asserted that the zone of maximum destruction is bounded and separated from the surrounding undisturbed (more correctly, relatively undeformed) mass by spherical cracks.

The radius R_1 of the zone of spherical spalling may be determined as follows.

Since only a limited volume of the medium is deformed by the energy of the explosion, we will assume that the free volume of the underground cavity is formed as a result of the total elimination or partial reduction of the pore space in the destruction zone. Let the undeformed medium have a porosity n_0, a density ρ_0, and a mineralogical density ρ_* related as follows:

$$n_0 = \frac{\rho_* - \rho_0}{\rho_*}. \qquad (1)$$

Here n_0 is the porosity or pore volume per unit volume of rock, and ρ_* is the mass per unit volume of rock without pores.

After the explosion of a charge occupying a spherical space of radius R_0, the corresponding quantities assumed the values n and ρ, also related by condition (1). It should be stressed that these changes take place only in the zone of spalled condensed medium within a volume characterized by some radius R_1. From the condition of mass conservation in a given volume of the incompressible medium before and after the explosion, we obtain an equation of the form

$$\int\limits_V^{V_1} \rho \, dV = \rho_0 (V_1 - V_0). \qquad (2)$$

Here V_0, V, and V_1 are the volumes of the charge, the underground cavity, and the spall zone, respectively.

In the first approximation, the density in the zone of destruction may be assumed constant $\rho = \rho_2 = 0.5(\rho_0 + \rho_1)$, or linearly dependent on the radius r

$$\rho = \rho_1 - \frac{\rho_1 - \rho_0}{R_1 - R}(r - R), \qquad (3)$$

where ρ_1 is the density at the wall of the cavity.

Then relation (2) becomes

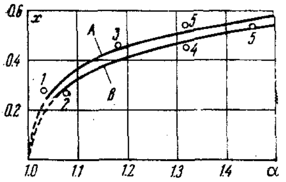
$$\frac{1 - n_2}{1 - n_0} V = V_1 \frac{n_0 - n_2}{1 - n_0} + V_0. \qquad (4)$$

According to [3], on the average for spherical charges in soils $R/R_0 \approx 8.5$; according to [2], for typical soils $V/V_0 \approx 50$, and in the notation employed the inequalities $V_0/V_1 < V_0/V$ and $V_0/V_1 \ll 1$ are obvious. Neglecting the ratio V_0/V_1 in (4), we obtain an expression, independent of the shape and volume of the charge, for

$$\frac{V}{V_1} = \frac{n_0 - n_2}{1 - n_2} = 1 - \frac{\rho_0}{\rho_2}. \qquad (5)$$

With condition (3) relation (2) gives different results for cylindrical and spherical charges. Thus, for very elongated cylindrical charges

$$\frac{R}{R_1} = \frac{\alpha - 1 + \sqrt{9(\alpha - 1)^2 + 12(\alpha - 1)}}{4\alpha + 2} \qquad \left(\alpha = \frac{\rho_1}{\rho_0}\right). \qquad (6)$$



The simplified relation gives

$$\frac{R}{R_1} = \left(\frac{\alpha - 1}{\alpha + 1}\right)^{1/2}. \qquad (7)$$

For explosions with spherical symmetry Eq. (2) with condition (3) gives the density ratio in the form

$$\alpha = \frac{1 + x + x^2 + x^3}{1 + x + x^2 - 3x^3} \qquad \left(x = \frac{R}{R_1}\right). \qquad (8)$$

In analogous form relation (5) gives

$$\alpha = \frac{x^3 + 1}{1 - x^3}. \qquad (9)$$

In Fig. 1 expressions (8) and (9) are represented graphically by curves A and B. Since they are quite similar, the advantage obviously rests with simplified relation (9), which is easily solved for x [see (5)]. Figure 1 also gives the results of experimental underground explosions using both chemical and nuclear charges [1].

	1	2	3	4	5
R m	15 — 16.5	34.5 — 35	5	19	12
R_1 m	45 — 60	120 — 140	11	40	22
ρ_0	2.16	—	1.56	1.8 — 2.2	1.8 — 2.2
ρ_1	—	—	1.84	—	—
n_0	2.7	~8	—	17.4 — 31.4	17.4 — 31.4
n_1	0	0	—	0	0

In the table and the figure the numbers 1, 2, 4, and 5 correspond to the results of the following nuclear explosions conducted in the United States: projects Gnome, Oilsand, Reindeer, and Neptune. Number 3 corresponds to the data of a chemical explosion.

REFERENCES

1. B. I. Nifontov, D. D. Protopopov, I. E. Sitnikov, and A. V. Kulikov, Underground Nuclear Explosions [in Russian], Atomizdat, 1965.

2. F. A. Baum, K. P. Stanyukovich, and B. I. Shekhter, Physics of Explosion [in Russian], Fizmatgiz, 1959.

3. G. I. Pokrovskii and I. S. Federov, Effect of Impact and Explosion in Deformable Media [in Russian], Promstroiizdat, 1957.

4. D. M. Kamyshnikov and Yu. A. Kolodyazhnyi, "Determination of the size of the zone of destruction created by an explosion in rock," Nauchn. tr. Mosk. in-ta radioelektr. i. gorn. elektromekh., no. 37, 1964.

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