TRENCH FORMATION IN GROUP EXPLOSIONS WITH LINEAR CHARGE DISTRIBUTION

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Using the laboratory-modeling method developed at the All-Russian Scientific-Research Institute of Engineering Physics, group explosions for the creation of long trenches (canals) are investigated. The minimum canal cross section and its other dimensions are obtained as a function of the basic parameters of the explosion. Conditions for the creation of canals with minimum fluctuation of the profile over the trench length are found, criteria of economic efficiency are derived, and a method is given for choosing the explosion parameters so as to create a canal of specified cross section with minimum expenditure of explosives. The results of the model experiments are compared with the trench dimensions in the Baggi (USA) and T-II (Russia) nuclear explosions.

This work is a continuation of the investigation in [1, 2] of underground explosions that remove the earth from a particular site (similarity issues, method of laboratory modeling, experiments to solve particular problems). The laboratory-modeling method described in [2] was developed at a Russian research facility, the All-Russian Scientific-Research Institute of Engineering Physics, in the years when the use of large explosions to solve various economic problems, for example, to create large canals within Russia, was under discussion. For this reason, the method has been used in investigating group explosions with a linear charge distribution. Data on the effect of such group explosions with various charge distributions are discussed in the present work. Criteria of economic efficiency are derived, and a method of selecting the charge-distribution parameters to yield a channel of specified cross section with minimum expenditure of explosives is outlined. The modeling results are compared with data on the Baggi and T-II group explosions.

FORMULATION OF THE EXPERIMENTS

The modeling stand described in [2] is shown in Fig. 1. On account of the large size (3 x 1.1 x 0.6 m) of the volume with sand or other soil simulator in the vacuum chamber, experiments with the simultaneous explosion of five linearly distributed charges may be conducted. This is sufficient to obtain information on long canals. The energy obtained in the explosion of a single charge is equivalent to 0.2 g of explosive. The pressure in the chamber is reduced to $P_0 = 130$ Pa, which corresponds to full-scale explosions of power 2-10 kton in various soils, according to the formula $P_0/\rho_0 g V_{\text{max}}^{1/3} = \text{const}$ ($V_{\text{max}}$ is the maximum crater volume with a single explosion; $\rho_0$ is the soil density). However, with the appropriate choice of $P_0$, weaker full-scale explosions (hundreds or even tens of tons) and much more powerful explosions may be modeled [2].

In [2], an artificial medium yielding a crater similar in shape to that obtained in soil was chosen: pressed sand with added vacuum oil. Working with this medium is more difficult than working with dry sand. However, explosions in dry sand yield shallower cavities: if the volume is the same, they are 1.2 times broader and 1.5 times less deep than in real soil [2]. At the same time, the dependence of the cavity volume on the depth of the explosion $h$ in dimensionless units — $V/V_{\text{max}} = f(h/V_{\text{max}}^{1/3})$ — is in fairly good agreement in the two cases.

Since the factors 1.2 and 1.5 are fairly stable, predictions may be made on the basis of microexplosions in sand if appropriate corrections are made. Since the aim is not to model explosions in specific soils (but only to obtain general laws), modeling is conducted in dry sand here. Note that real canals may also be shallow if they are cut in gravelly areas or in swampy regions of a river watershed.
Five charges of identical power $E_0$ are placed at a depth $h$ under a horizontal surface at intervals of $l$. The dimensionless parameters $\bar{h} = h/V_{\text{max}}^{1/3}$ and $\bar{l} = l/V_{\text{max}}^{1/3}$ are varied. The density of the sand $\rho_0 = 1.45 \pm 0.5 \text{ g/cm}^3$; the angle of natural inclination $\varphi = 33^\circ$. Because of the unavoidable fluctuation in the energy of the individual microcharges and other factors, $V_{\text{max}}$ varies from 2500 to 3000 cm$^3$; the values used in the calculations are $V_{\text{max}} = 2750 \text{ cm}^3$, $V_{\text{max}}^{1/3} = 0.14 \text{ m})$. The sand is periodically renewed, sifted, and winnowed to remove impurities and dust generated in the explosions. Its granulometric composition is monitored periodically.

EXPERIMENTAL RESULTS

The basic cavity parameters considered are the shape and size of the trench cross section, which determine the water capacity of the canal and its navigational properties. In most cases, the longitudinal profile of the trench is somewhat undulatory (Fig. 2). As a rule, the maximum cross section $S_{\text{max}}$ is above the charge location, and the minimum cross section $S_{\text{min}}$ is found halfway between the charges; the cross sections and linear dimensions are measured to (or across) the level of the initial surface.

The basic goals are to establish the dependence $S_{\text{min}}(h, \bar{l})$; to find the conditions in which $S_{\text{max}}$ and $S_{\text{min}}$ are close; to determine the dependence of the minimum transverse dimensions of the trench and the cavity volume corresponding to a single charge on $h$ and $\bar{l}$; to obtain the criteria of economic efficiency; and to find the values of $h$, $l$, and $E_0$ corresponding to the minimum expenditure of explosives in creating the trench (a bar above a symbol denotes a dimensionless quantity).

In the experiments, the depth of the charges varies in the range $h = 4-20 \text{ cm}$ ($h = 0.28-1.4$) in steps of 2 cm, and $l = 4-28 \text{ cm}$ ($\bar{l} = 0.28-2.0$) in steps of 4 cm.

Minimum Cross Section. Curves of $S_{\text{min}}(h)$ at various $h$ are shown in Fig. 3. In the given range of $h$ and $\bar{l}$, $S_{\text{min}}$ increases with decrease in $\bar{l}$ at all $h$, because the interaction between the charges improves as they are moved closer together. The limiting case $\bar{l} = 0$ corresponds to the explosion of a single charge of the aggregate power, when $S_{\text{min}}$ is a maximum. With increase in $\bar{l}$, not only does $S_{\text{min}}$ decrease, but its range of possible values at different explosion depths becomes narrower, i.e., the curves of $S_{\text{min}}(h)$ become less steep. At large $\bar{l}$, individual cavities are obtained ($S_{\text{min}} = 0$). For all $\bar{l}$, $S_{\text{min}}$ is greatest at the value of $h$ optimal for a single explosion ($h_{\text{opt}} = 0.86$).

The fluctuation of the profile along the trench is best characterized by the ratio $S_{\text{min}}/S_{\text{max}}$, which is shown in Fig. 3 for various $h$ and $\bar{l}$. When $\bar{l} = 0.28-1.1$, the curves of $S_{\text{min}}/S_{\text{max}}$ are almost horizontal straight lines at the level $S_{\text{min}}/S_{\text{max}} = 0.93-0.97$ over practically the whole range of $h$. However, for the given parameter range, $S_{\text{min}}$ itself sometimes differs by a factor of 1.5 for the same $\bar{l}$ and up to 2.5 for different $\bar{l}$ (explosions with $l_1 = 4 \text{ cm}$, $h_1 = 16 \text{ cm}$ and with $l_2 = 16 \text{ cm}$, $h_2 = 16 \text{ cm}$). Therefore, the condition $S_{\text{min}}/S_{\text{max}} = 1$ sometimes adopted in practice is inadequate to ensure that the explosions occur in the best way.

With increase in $\bar{l}$, the fluctuation of the longitudinal profile changes rapidly: when $\bar{l} = 2$, $S_{\text{min}}/S_{\text{max}} = 0.5-0.6$. Irregularity of the profile is clearly evident after removing the soil layer above the initial surface. If $S_{\text{min}}/S_{\text{max}} = 1$, the fluctuation of the longitudinal profile at the bottom of the trench is slight.