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I. L. ZELMANOV, O. S. KOLKOV, A. M. TIKHOMIROV, A. F. SHATSUKHEVICH

THE INFLUENCE OF GAS-FORMING SUBSTANCES IN THE SOURCE OF AN ELECTRIC EXPLOSION ON THE MOTION OF WEAKLY COHESIVE SOIL

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1. The study of a camouflet explosion in weakly cohesive soil has been carried out by a number of authors ($^{1-3}$). We have carried out work on studying the possibility of modeling an explosion by means of a powerful spark discharge. A spark-discharge installation developed at the Institute of Physics of the Earth, Academy of Sciences of the USSR (^{4}), was used. The discharge occurred on a massive brass plate, at the end of a coaxial discharger 22 mm in diameter. The magnitude of the energy varied from 2.5 to 28 kJ and was recorded in each experiment. The duration of energy release was about 50 μsec. The explosion was carried out in dry river sand with a bulk density of 1.55 g/cm^3. In the work the mass velocity of the soil was measured as a function of time at various distances from the center of the explosion.

An induction method was used, which in principle consists of the following. With the aid of an external source, a constant inhomogeneous magnetic field is created in the soil. The sensors, which are flat coils of copper wire in an epoxy-resin frame, are placed in the soil and during the explosion move together with it. The signal from the sensor, depending on the velocity of its motion and on the configuration of the field, is recorded on a cathode oscilloscope. The time resolution of the recording system was ensured by a rise time of a rectangular pulse of no more than 5 μsec. The oscillograms were processed up to the moment when waves reflected from the free surface and the walls of the basin reached the sensor. The results were compared with the results of analogous experiments with a chemical explosive (e.v.) (PETN with a specific heat of explosion of 1400 kcal/kg) by introducing the reduced distance $R^0 = R/C^{1/3}$ and time $t^0 = t/C^{1/3}$, where R is the distance from the center of the explosion in meters, t is the time from the instant of explosion in seconds, C is the weight of the charge recalculated to TNT with a specific heat of explosion of 1000

Figure 1

Figure 1: Figure 1

kcal/kg, and in the case of an electric explosion, the weight of a TNT charge equivalent to it in released energy. Spherically symmetric motion was studied. In an electric explosion and in an explosive explosion on a plate (“half-space”), twice the value was attributed to the energy. The results of experiments with explosives confirm the validity of such an assumption.

2. Comparison of the results obtained for the electric explosion and the explosion of an explosive showed that in both cases the motion of the soil possesses a number of common features. The front of the blast wave, being close to a shock wave near the explosion, acquires an increasingly smooth character as it propagates. The distribution of velocity behind the front in Eulerian coordinates differs substantially from the distribution that would occur in the case of incompressibility of the soil, both for the electric explosion and for the explosion of an explosive. This distribution can be approximately described by a power dependence of the form $U = A(t)R^{n(t)}$, where $n = 1.5 \div 1.8$ in the range considered. This indicates a decrease in the density of the soil behind the wave front. The density values themselves in both cases fall below the initial value $\rho_0 =$

$= 1.55$ g/cm^3, reaching 0.7—0.8 ρ_0. This makes it possible to suppose that models which assume only shear deformations behind the compression-wave front ($^{5-8}$) do not reflect the actual mechanism of the phenomenon.

However, despite the similarity of the general character of the wave patterns, it proved impossible to establish a quantitative correspondence between the HE explosion and the electric explosion.

In comparing different sources of explosion, this is usually done by introducing the TNT equivalent, i.e., such a constant multiplier to the weight of the HE charge that the patterns of motion in the reduced coordinates R^0 and t^0 coincide for both sources. This is possible only if the dependences of the parameters by which the TNT equivalent is introduced on time and distance are, to within a constant multiplier, expressed in both cases by identical laws. For the electric explosion and the HE explosion this is not the case either for the maximum mass velocity, by which the TNT equivalent is most often introduced, or for motion behind the front.

Fig. 1. Copies of oscillograms of mass velocity. **1, 2, 3**—electric explosion without additives in the focus, $R^0 = 0.44$; 0.97; 2.5; **4**—electric explosion, with a moist hemisphere in the focus (mass moisture content 16%, radius 12 mm), $R^0 = 0.97$; **5**—electric explosion, with a 30 g iodine charge in the focus, $R^0 = 2.2$

Fig. 2. Dependence of the maximum mass velocity of the soil on the reduced distance from the explosion center. **1**—HE; **2**—electric explosion without addi-

Figure 2

Figure 2: Figure 2

tives in the focus; **3**—electric explosion, with a moist hemisphere in the focus (mass moisture content 16%, radius 12 mm); **4**—electric explosion with a 30 g iodine charge; **5**—electric explosion with a 2 g iodine charge; **6**—explosion of 5 g of PETN with a 3 g iodine charge

3. The impossibility of introducing a TNT equivalent for the electric explosion indicates that the pattern of soil motion is determined not only by its properties and by the magnitude of the explosion energy, but also by the very character of the explosion source. One of the principal differences between an electric explosion and an HE explosion is that it practically has no intrinsic products, i.e., in a certain approximation it is “massless.”When energy is released in a spark discharge, in addition to high-temperature plasma there probably appear products of evaporation of the soil and of the electrode material. It may be expected that the presence in the focus of an electric explosion of substances that are easily sublimed or decompose into gaseous products will affect the parameters of the waves arising during the explosion.

Experiments were carried out on introducing into the focus of the electric explosion small additives of crystalline iodine (charges from 1.5 to 30 g) and ammonium chloride (15 g). To determine the influence of moisture, hemispheres of aqueous starch gel (water content by weight 80%) and moistened sand were also placed in the focal zone on the end face of the discharger.

···a hemisphere of radius 12 mm and moisture content 16%. The hemispheres were separated from the rest of the sand volume by a thin rubber film.

The general character of the motion (Fig. 1) did not change when additives were introduced into the seat of the electric explosion; however, both the maximum mass velocity and the velocity behind the front at the corresponding distances increased substantially.

Figure 2 gives the results of experiments with the introduction into the seat of the electric explosion of a moist hemisphere and two charges of iodine, and also plots the points of experiments in which crystalline iodine was distributed around the wire charge. For comparison, curves are given for an explosion of a high explosive and for an electric explosion without additives in the seat. As follows from the graph, the value of the maximum mass velocity, compared with the corresponding value for an electric explosion without additives, increased for the moist hemisphere by approximately a factor of 1.7, and for iodine charges of 2 and 30 g by factors of 1.3 and 2.1, respectively. The additives occupied a small volume near the discharger, which excludes explaining the observed effect by a change in the mechanical properties of the soil. The absence of an effect when iodine was distributed around the wire charge of the high explosive also indicates the same. The data obtained do not indicate any change in the degree of attenuation of the maximum mass velocity with distance when additives are introduced into the seat of the electric explosion.

Fig. 3. Effect of the increase in maximum mass velocity when charges of crystalline iodine are introduced into the seat of the electric explosion, as a function of charge mass. Distance from the center of the explosion 180 mm. Energy 9.4 kJ. U_m^* is the value of the maximum mass velocity at the same distance for an electric explosion of the same energy without additives in the seat.

Figure 3 shows the dependence of the maximum velocity at a distance $R^0 = 1.36$ on the mass of the iodine charge introduced into the seat of the electric explosion. A rapid increase in velocity with increasing charge is observed up to approximately 3 g; a further increase of the charge practically does not enhance the effect.

The introduction of gas-forming substances into the seat of the electric explosion also affected the law of variation with time of the mass velocity behind the front. Figure 4 gives the dependences of the mass velocity of the soil behind the wave front on time at a distance of 120 mm from the center of the explosion for an electric explosion with a moist hemisphere in the seat, an electric explosion without additives in the seat, and an explosion of a high explosive, all at the same explosion energy. As follows from these dependences, the effect of the presence of moisture in the seat of the electric explosion is expressed even more sharply behind the wave front than at the front.

Fig. 4. Variation of the mass velocity of the soil behind the wave front with time. Distance from the center of the explosion 120 mm. 1 —explosion of a high explosive; 2 —electric explosion without additives in the seat; 3 —electric explosion, with a moist hemisphere in the seat (mass moisture content 16%, radius 12 mm). Released energy 28 kJ. Time is counted from the moment when the maximum mass velocity is reached.

Similar results were obtained for sal ammoniac and for water bound by starch. The maximum mass velocity when 15 g of sal ammoniac was introduced into the seat increased by approximately a factor of 1.4. In experiments with water bound ···

···with starch, the increase in the maximum mass velocity grows with the mass of the additive, reaching, for an additive of 0.5 t, a value of about 1.7. A further increase of its mass to 4 t produces no noticeable change in the effect.

Schmidt Institute of Physics of the Earth,
Academy of Sciences of the USSR

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