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Abstract

Full Text

CONTINUUM MECHANICS

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SOME EXPERIMENTAL STUDIES ON THE DYNAMICS OF SOFT SOILS

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In paper (^{1}) a model of a continuous medium was proposed, intended for describing the motions of media of the type of soft soils under conditions where these motions cannot be described by the relations of classical elasticity theory. The system of equations of this model includes two functions, one of which characterizes the volumetric deformation of the medium, and the other the properties of the medium under shear deformation. The suitability of the model of paper (^{1}) for describing soil motions must be verified by experiment. The mentioned functions must likewise be constructed experimentally, if this suitability is established. In paper (^{1}) there are certain considerations concerning the arrangement of experiments of this kind. The present paper gives the results of experiments carried out by the authors in accordance with these considerations in the summer of 1959, for the purpose of verifying the basic hypotheses of paper (^{1}) and obtaining certain quantitative characteristics of soils.

Two series of experiments were carried out: the first to verify the qualitative character of the diagram of volumetric compression of the medium, i.e., the first of the functions noted above, and the second to verify the applicability of the plasticity condition of paper (^{1}) and to establish the specific form of the function appearing in this condition—the second of the functions noted above. The experiments were conducted in sandy soil of natural occurrence with a density of 1.5–1.6 g/cm^3 and moisture content of 5–7%. Loads in the soil were produced by explosions of TNT charges placed in it.

1. In paper (^{1}) it is assumed that the curve representing the dependence of the mean compressive stress $p = -\frac{1}{3}(p_{xx} + p_{yy} + p_{zz})$ on the density of the medium is convex upward for small p, then has an inflection point, and further, as p increases, becomes convex downward. From this, as can be shown, it follows rigorously that, when a stress wave from a centrally symmetric explosion propagates, near the center of the explosion it will be a disturbance with a sharply defined leading front—a shock wave; beginning at a certain distance, small disturbances will arise ahead of the shock wave, propagating faster than the shock wave; at some distance the shock wave will disappear altogether, and farther on the disturbance will propagate in

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Fig. 1

Figure 1: Fig. 1

> the form of a continuous wave.* If in the experiments the entire sequence of stages of development of the stress wave with distance from the center of the explosion were observed, this would confirm the initial assumption concerning the qualitative features of the soil-compression curve.

In the experiments of the first series, TNT charges weighing 1.6 kg and more were detonated, and at distances beginning with $20r_z$, where r_z is the charge radius, and farther on through $5r_z$ or $10r_z$, at the same depth, the dependence of $-\sigma_r$ on time was recorded, where σ_r is the stress in the radial direction from the center of the explosion—

High-frequency strain-gauge sensors were used ($f = 10{,}000$ Hz), whose readings were recorded through an 8 ANCh-7 type amplifier on an MPO-2 oscillograph. To monitor the steepness of the shock-wave front, piezoelectric sensors based on barium titanate were used, whose readings were recorded on a cathode-ray oscillograph.

Figure 1 presents typical oscillograms. On the upper recording film, from bottom to top, the traces correspond to distances from the center of 20; 25; 30; $35\,r_3$, and on the lower film—to distances of 40; 45; 50; 60; $70\,r_3$. The time scale is the same for all curves, while the pressure scale is different for different curves

Fig. 1

and, for their quantitative description, each must be deciphered according to the corresponding key. Fig. 1 corresponds to the explosion of a 1.6 kg charge at a depth of 2 m. The first pulse from the left in the records corresponds to the moment of the charge explosion. In the oscillograms shown, the portions of the curves corresponding to steep fronts are somewhat smoothed, which is connected with the resolving power of the apparatus complex with strain-gauge sensors, equal to 0.0078 sec. Control records made with piezoelectric sensors reveal a truly jump-like change of stress in these portions.

The oscillograms clearly show how the disturbance changes its form as the distance from the center of the explosion increases. Up to $30\,r_3$ it arrives with a steep front; farther on, it is replaced by a disturbance with an initial continuous segment, and at a distance of $70\,r_3$ it is already almost completely smoothed. At still greater distances, the oscillograms, not reproduced here, are smooth,

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* The correspondence of the listed types of stress distribution in the wave to the qualitative features of the compression diagram for the case of plane self-similar waves in a nonlinear elastic medium was first discovered by G. I. Barenblatt (2).

Fig. 2 and Fig. 3: experimental plots of T versus p.

Figure 2: Fig. 2 and Fig. 3: experimental plots of T versus p.

gently sloping lines.

Thus we see that the expected picture was fully confirmed by the experiment, which indicates that the soil compression curve indeed possesses the properties noted above.

2. In the second series of experiments, by detonating concentrated and elongated charges, centrally symmetric and cylindrically symmetric stress fields were created, and substantially different principal stresses (two in the first case and three in the second) were measured at different distances from the center or axis of symmetry. The stresses, as in the first series, were measured by strain-gauge sensors, which were installed in boreholes 140 mm in diameter, oriented along the principal planes, and tightly tamped, which ensured their good contact with the soil. Under conditions of central symmetry, explosions of charges weighing 1.6 kg were carried out at depths of 2 m ($35\,r_3$) and 1 m ($17.5\,r_3$); in the first case the sensors were installed in the hemisphere above the charge, and in the second—in the lower hemisphere at distances of 20 and $30\,r_3$. According to these arrangements, 22 experiments were carried out, from which about 150 paired pressure records were obtained at points of the soil mass located differently with respect to the center of the explosion. Under conditions

for cylindrical symmetry, explosions were carried out with charges 10 m long and a linear weight of 2 kg/m at depths of 1.7 and 2 m. The sensors were installed oriented along the three principal planes near a plane equally distant from the ends of the charge, at the same depth as the charge, at distances of 1.7-2 m from it. Detonation of the charge was performed simultaneously along its entire length. The number of experiments with cylindrical symmetry was, naturally, smaller.

These experiments showed that, in the range of stresses accessible to us for measurements (up to 15 kg/cm^2), the components of the stress tensor

Fig. 2. Experiments at a depth of 1 m. Points of the same shape correspond to a fixed distance from the center

Fig. 3. Experiments at a depth of 2 m. a —central symmetry, b —cylindrical symmetry

in the blast wave, under substantially different conditions of central and cylindrical symmetry, are related to one another by a certain same relation—the plasticity condition—and made it possible to establish the concrete form of this relation. Part of the results of processing the experimental data is presented in Figs. 2 and 3, where the abscissa axis gives the mean pressure p, and the ordinate axis gives the square root of the second invariant of the stress-deviator tensor $T = \sqrt{I_2}$. The points correspond to different instants of time at a given distance, as well as to different distances from the center of the explosion. These figures show that the plasticity condition constructed from the experimental results for depths of 1 m (Fig. 2) and 2 m (Fig. 3) is the same and coincides for the cases of central and cylindrical symmetry. In the range studied, for the soil investigated it has the form

$$\sqrt{I_2} = kp + b,$$

where $k = 1.9$, $b = 0.4$ kg/cm^2.

Thus, the second series of experiments also confirmed the acceptability of the corresponding hypothesis of paper [1] and made it possible to establish the specific form of the plasticity condition for sandy soil.

3. Let us also note the following. The structure of the relations in the model of paper [1] is such that, when explosions are carried out under geometrically similar conditions for similar charges of the same explosive at similar distances, according to this model identical stresses should occur at similar instants of time. In our experiments, when changing the weight of the charge (concentrated), we observed conditions of similarity in the placement of the charge and the gauges in the soil, and the measurement results agree with the prediction, although the change in geometric scale in our experiments was insignificant (the charge weight varied from 1.6 to 43.2 kg, i.e., r_3 varied by a factor of 3). For a more complete verification of the similarity principle, experiments with a substantial change in the geometric scale of the phenomenon (and, consequently, in the charge weight) are necessary.

In processing the experimental data we estimated the measurement errors. The magnitude of this error in measuring pressures did not exceed 5–10%.

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REFERENCES CITED

[1] S. S. Grigoryan, DAN, **124**, No. 2 (1959).
[2] G. I. Barenblatt, *Prikl. matem. i mekh.*, **17**, issue 4 (1953).

Note: Figure translations are in progress. See original paper for figures.

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