11 WCEE
Published by Elsevier Science Ltd 1996
Paper No. 1591. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

NON-LINEAR GROUND MOTIONS AT INTENSIVE DYNAMIC LOADS

V.A. Pavlenov, V.V. Chechelnitsky

Laboratory of Engineering Se1smology, Institute of the Earth's Crust, SB of RAS, 128, Lermontova str., 664033, Irkutsk, Russia

ABSTRACT

Special works were done in the Irkutsk region, Russia, to study non-linear ground motion with the help of explosions. The explosions were performed in loamy grounds, in foreholes 2 m deep, and charges weights varied from 0.4 to 8 kg exsloisive.

KEYWORDS

Explosive, non-linear ground motion, stress, deformation.

The present-day develpment of new geophysical methods of study of the Earth has resulted in a new concept of geophysical medium (Nikolaev, 1987). This concept reduces to the following postulates: 1) geophysical medium is inhomogeneous and not transparrent; 2) geophysical medium is non-linear, i.e. the principle of superposition does not work; 3) the entrails are active, i.e. they absorb and radiate acoustic, electromagnetic and electric energy; 4) geophysical medium is not three- but four-dimensional, i.e. it varies in time, especially its stressed state; 5) a complex interaction of geophysical fields produces different effects, such as seismoelectric, seismodeformational etc.

. These new ideas of properties and parameters of geophysical fields have to be additionally thought over and to undergo special experiments. Imperfect geophysical equipment, analogue seismometers in particular, does not provide a reliable record of non-linear effects associated with disturbances of the main principles of linearity - superposition and proportionality of seismic waves - in actual mediums

The most acceptable way of study of non-linear properties of the medium is the record of a seismic phenomenon near the focus at a gradual increase of its power. The majority of the present-day investigations have been conducted in accordance with the theory of non-linear motions and wave propagations based on Hooke's law. The theory of linear motions leans upon the notion of an infinitely small motion or an infinetely small deformation; at the expansion of the elastic energy in a power series, the strain tenzors deprive of the members of the third order and more. If the members of the third order and more are taken into account in the expansion of the elastic energy in a power series, then non-harmonic effects originate. Such type of non-linearity is called "geometrical". Another type of non-linearity, arbitrarily called "physical", is more frequent and actually realized at the record of strong seismic waves or at the study of motions in the near zone of seismic explosions. The problem of ground motions at intensive dynamic and especially seismic loads is still poorly studied, which is due both to rather numerous experimental data for all the variety of grounds and lack of a common theory for non-linear ground motions.

The first who investigated the effects of physical non-linearity in a small zone of explosion were Gvozdev and Kuznetsov (1967), and Nikolaev (1967). The studies of non-linear processes in grounds with the help of explosions, conducted by the investigators from Moscow (Vasilyev et al., 1981) and Alma-Ata (Sinyaev & Pikanovsky, 1981), are also widely known. The experience of the measurement of residual deformations in soft dry grounds (loams, sandy loams) was accumulated and summarized. The residual deformations of shear, formed at high intensity seismic waves' propagation through the ground, were approximately assessed on the basis of these experiments. The assessments and comparisons, rather important for engineering seismology, were obtained with the help of the so called "skeleton curve" of $\tau - \gamma$ loads, where τ is a shear stress and γ is a shear strain. The observed "skeleton curves" were then scaled according to seismic intensity by the relationship between intensity and velocity of the motions (an experimental relationship between particle velocity and earthquake intensity according to the seismic scale). Inspite of the exceptional importance of these experiments, they have, to our mind, the material drawback that such kinematic parameters of ground motions as amount, velocity and acceleration were not simultaneously recorded with stresses and strains from explosions.

Such experiments with the grounds in their natural state were conducted in Ust-Kut of the Irkutsk region and within Irkutsk. There were two participants of these works: the Institute of the Earth's Crust SB RAS and the Institute of Seismology of Kazakhstan. 52 explosions were done in the boreholes at a depth of 2 m in breakstone and loamy grounds within Ust-Kut. The weight of charges was fixed - 2 kg of ES (explosive substance). (Explosive substance - tolite). The sites of motion records were on the ground surface in a distance range of 1,5 to 10,8 m from a borehole mouth. The main components of strain tenzor - ε_r, y,z(t) - and those of stress tenzor, and amount, velocity and acceleration of ground motions were at the same time recorded. The observations were done by the same method within Irkutsk, but the grounds under explosions were somewhat different from those within Ust-Kut and represented by sandy loams and loams. Besides, the weight of charges varied in this case from 0,4 to 8,0 kg ES, and the distance from a borehole mouth to tenzometric and seismic instruments varied from 1,5 to 12 m.

After the processing of the obtained oscillograms, the non-linear ground motions acquired the following parameters: radial stresses in grounds varied from $1{,}2\cdot10^5$ n/m^2 to $0{,}13\cdot10^5$ n/m^2, and radial strains varied from 10^{-3} to 10^{-2} in a distance range of 2,00 m$\cdot$kg$^{--1/3}$ to 8,7 m$\cdot$kg$^{-1/3}$.

The amount of motions at these experiments varied for a radial component from 17 mm to 0,3 mm, and the velocities of motions - from 119 sm/s to 10 sm/s. The accelerations were recorded in a distance range of 2,25 m$\cdot$kg$^{-1/3}$ to 3,55 m$\cdot$kg$^{-1/3}$, and varied from 1,0 g to 8,3 g. If to use the MSK-64 scale formally, then the intensity will vary from 8 to 11 according to the velocity of motions, and from 10 to more according to the accelerations. One have to mind that the frequencies varied from 2,6 to 18 Hz for the maximum amounts, from 7,8 to 15,6 Hz for velocities, and from 12 to 40 Hz for accelerations. The processing of the obtained field data on explosions allowed to distinguish the zones of residual and elastic deformations and to compare them with the maximum amounts. The elastic deformation zones were determined on the following formulas:

$$lgR_n = -1{,}2 + 0{,}4lgE \qquad (1)$$

where R_n is the radius of the radiator and E is a seismic energy of the radiator (Aptikaev, 1969);

$$r_0 = 0{,}053\ \sqrt[3]{C} \qquad (2)$$

where r_0 is the radius of charge (m) and C is the weight of charge (kg) (Krasnikov, 1970).
The radius of the non-elastic zone was determined as $6R_n$ or (30-100) r_0.
The residual deformations were computed on Graizer's empirical formula (1989):

$$lg\,A_0 = 2{,}0 - 3{,}3\,lg\frac{R}{\sqrt[3]{C}} \qquad (3)$$

where A_0 is a residual deformation in mm, C is the weight of charge in kg, and r is the distance in m.

When the fixed-weight charges (2 kg ES) were explosed, the residual deformations acquired the following values: 10 mm for a distance of 2,0 $m \cdot kg^{-1/3}$ from the borehole mouth and 0,1 mm for a distance of 8,7 $m \cdot kg^{-1/3}$.

Thus, the conducted investigations resulted in the obtaining of new experimental data on the parameters of ground motions at strong seismic loads in the near zone of explosion. These data go beyond the habitual ideas of the linear motions and require vbnvsome further investigations.

References

Aptikaev, F.F. (1969). - Seismic motions at earthquakes and explosions. - Nauka, Moscow, 104 pp. (in Russian).

Graizer, V.M. (1989). - Seismic data on residual deformations at explosions and earthquakes. - Dokl. Akad. Nauk SSSR, 306, 4, 822-825 (in Russian).

Gvozdev, A.V. & Kuznetsov, V.V. (1967). - Ground splittings observed at seismic survey. - Izv. Akad. Nauk SSSR, Ser. Fizika Zemli, 5, 21-28 (in Russian).

Krasnikov, N.D. (1970). - Dynamic properties of grounds and methods of their determination. - Stroyizdat, Moscow, 170 pp. (in Russian).

Nikolaev, A.V. (1967). - Seismic properties of loose grounds. - Izv. AN SSSR, Ser. Fizika Zemli, 2, 23-31 (in Russian).

Nikolaev, A.V. (1987). - The problems of non-linear seismics. - Nauka, Moscow, 281 pp. (in Russian).

Sinyaev, A.Ya. & Pikanovsky, V.A. (1981). - Methods and results of the measurements of dynamic stresses and strains in grounds. - Izv.AN SSSR, Ser. Fizika Zemli, 6, 43-48 (in Russian).

Vasilyev, Yu.I., Gvozdev, A.A., Ivanova, L.A. et al. (1981). - Residual deformations of soft ground at explosions and earthquakes. - Izv. AN SSSR, Ser. Fizika Zemli, 11, 17-26 (in Russian).