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FREE OSCILLATIONS OF EARTHQUAKE SOURCE

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Abstract

The purpose of the work is to establish the peculiarities of ground vibrations in the near-field zone. The fact is that the existing ideas about generation and propagation of seismic waves in this zone poorly agree with empirical data. The ground vibrations in this zone during explosions and earthquakes are compared. A method of plotting the level of the day surface as a function of time after the moment of explosion is proposed. As a result of ground motion analysis, it is concluded that stresses in rocks during explosion are released in the form of damped standing waves. The amplitude of such oscillations far exceeds the level of generated volumetric seismic waves. And since the mass of oscillating rocks is much greater than the mass of the near-surface layer of ground, the latter have practically no effect on the spectrum and duration of oscillations. Similar processes in earthquakes differ only in the fact that the stresses in rocks exist before the beginning of movement along the fault. The verification showed that in contrast to the ideas about wave generation and propagation used in normative documents of earthquake-resistant construction, the parameters of vibrations in the near-fault zone do not depend on ground conditions. This fact is noted by many researchers. Consequently, many provisions of building codes should be revised. For example, the ground models used in NERA, STRATA, etc. programs are based on the assumption of passing waves and therefore the use of these programs is inappropriate.

Keywords: magnitude, source, fault, near-field and far-field zones of the earthquake, parameters of seismic ground motion, increment of seismic intensity

I. Introduction

Sometimes, the source of an earthquake is often defined as a rupture in rocks or a system of ruptures that occurred in the Earth and led to an earthquake. This definition corresponds to the fault plane as a model for the source of seismic waves. But energy cannot exist outside a certain volume.

Closer to the truth is the definition of an earthquake source as an area in which part of the deformation energy of rocks is converted into the energy of seismic waves. Even such a definition is too simplified. The processes of wave generation and propagation in the source zone remain unknown. There are no estimates of the shape and size of the source zone. The assumption of the source as a realized accumulated strain energy in some area corresponds to small sizes compared to the estimates of such areas from seismotectonic data.

The same applies to the size of aftershock regions. As early as 1935, Charles Richter spoke about the existence of primary and secondary aftershock zones [1]. It is quite probable that secondary aftershocks occur outside the origin and their appearance is the result of stress relief in the origin zone of the main shock. But how to separate primary and secondary aftershocks is still unknown.

Finally, the empirical data do not correspond to the characteristics of known types of seismic waves. According to empirical data, near the fault the amplitudes on soft ground are no higher than on hard ground [2 - 9].

II. Methods

Observations of explosions provide great assistance in studying the processes of generation and propagation of seismic waves. This method has the following advantages. The relative energy of the source is known. The exact time and location of the source are known. This makes it possible to organize a dense network of geophones near the epicenter.

Employees of the Schmidt Institute of Physics of the Earth (IPE) have studied the records of strong ground motions due to explosions, and came to the conclusion that it is impossible to explain the wave field using known types of seismic waves.

The author tried to consider on the field observations materials, obtained by IPE employees, not the level of oscillations at the geophone locations, as usual, but the levels of the day surface at different moments of time [10].

It was shown that the stresses arising in the environment cause, in addition to the known waves, free oscillations of a certain volume of rocks, surrounding the epicenter. The levels of the day surface at different moments of time for one of the explosions, taken from the above-mentioned work, are shown in Figure 1.

There is shown the vibrations of the day surface (vertical component) during an ejection explosion using dispersed charges with a total weight of one thousand tons. The distance between geophones is 100 m.

The first construction was made 0.35 sec after the explosion. The first arrival of shock waves corresponds to a distance of about 650 m. An oscillatory motion is observed with a maximum at a distance of 400 m and a minimum at a distance of 300 m.

After 0.45 s, we can talk about a formed *P*-wave with the first entry at approximately 820 m. The speed of this wave is about 2 km/sec. The amplitude of the minimum, which was observed after 0.35 sec at a distance of 300 m, took on a negative value (under the previously level).

After approximately 0.75 sec, the ground surface becomes close to the original one. Seismic body waves disappear beyond the considered range of distances. Fluctuations at distances of 600 m and 700 m have practically ceased. But the free vibrations of rocks do not stop.

After 0.9 sec, the amplitude at the same distance of 300 m takes on a maximal positive value.

After 1.5 sec, the amplitude again takes on a maximal negative value.

It can be concluded that the stress resulting from the explosion in the surrounding rocks is "reset" in the form of standing damped oscillations of the medium. Moreover, the amplitude of these oscillations is much higher than the generated traveling seismic waves.

Similar phenomena should occur during earthquakes. The only difference is that during earthquakes, stress in the rocks exists even before movement along the fault begins. The characteristics of seismic vibrations that confirm this hypothesis are considered.

Using empirical material, it is shown that other parameters of oscillations in the focal zone of earthquakes - the predominant period and the duration of oscillations - do not depend on ground conditions. However, seismic intensity on soft ground increases due to a decrease in the bearing capacity of the ground. Previously, only soil liquefaction was usually considered such a factor. However, there is a method for vibrating piles to significant depths (up to 70 m) without the liquefaction process. At acceleration amplitudes on the vertical component PGA > 0.1 g, the shear strength of soft ground in the horizontal plane can decrease several times. This phenomenon is also observed for hard ground, but to a weaker extent [11 - 13].

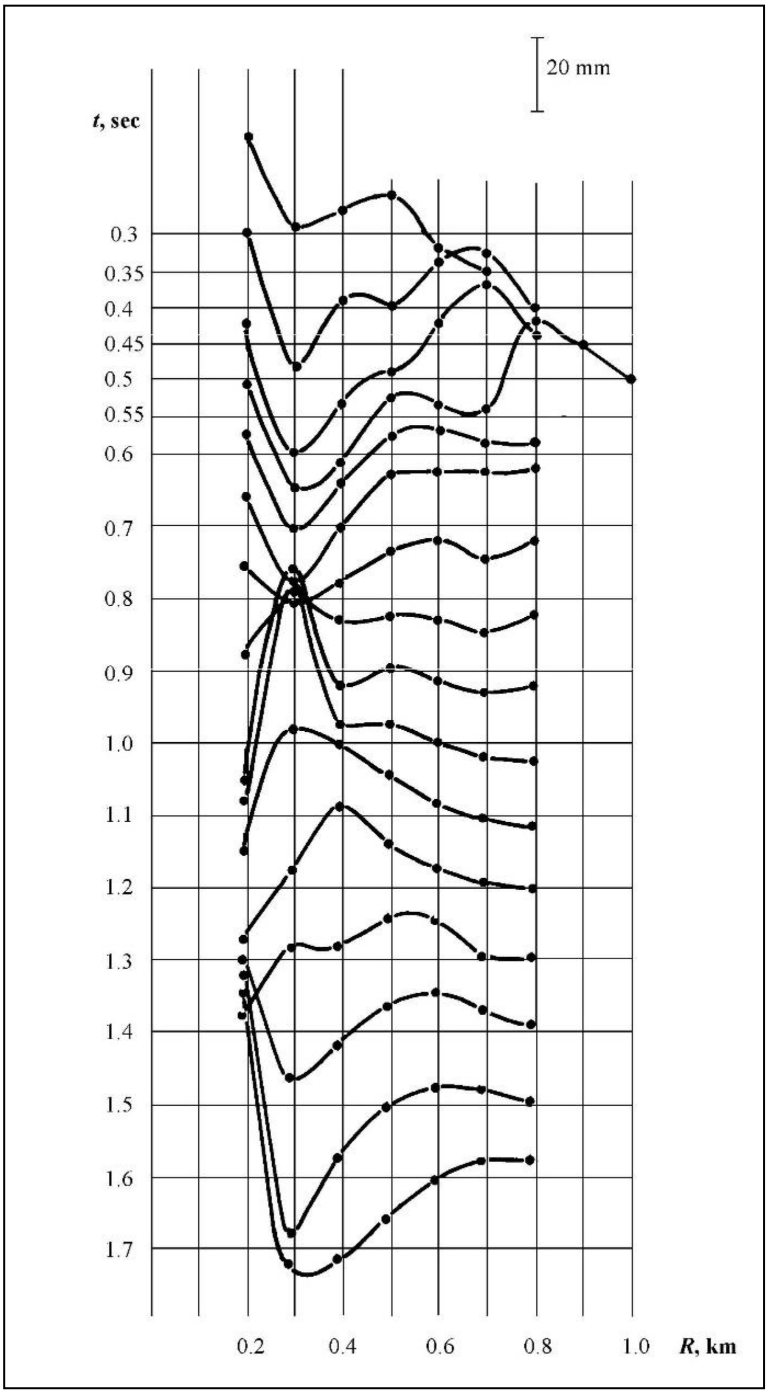

Figure 1: *The levels of day surface for different times for explosion of 1 kt (from [10])*

III. Results

It turned out that the influence of movement along the fault is limited in space. In the engineering range (intensities of 7 – 9 points), three zones were identified in which not only the attenuation laws, but also the dependences of the parameters of seismic ground motion on focal mechanism and ground conditions are different [14].

In the near-field zone the attenuation coefficient is noticeably lower than unity, and in the far-field zone it is much greater than unity. Consequently, seismic wave energy is released in the near-field zone, and this energy is absorbed in the far-field zone. The boundary of the source corresponds to the distance

$$\log R_g = -0.77 + M / 3, \quad (1)$$

where R_g is the shortest distance to the rupture surface,
M – magnitude based on surface waves.

Accordingly, the seismic source has the shape of a parallelepiped with smoothed edges.

Often the natural vibrations of the source are mistaken for a S - wave. In this case, estimates of the hypocentral distance from the difference in arrivals of S- and P - waves will be incorrect.

For some reason, the resonant properties of ground according to the building code is usually determined not on the basis of statistical processing of records obtained on various ground types, but on the basis of models of ground strata such as NERA, STRATA and others. Errors in using such programs are associated with the assumption of passing waves.

Empirical data indicate that the parameters of ground motion in the near-field zone are virtually independent of ground conditions [9, 15]. Thus, the seismic intensity increment in the near-field zone is related to the bearing capacity of the ground.

From the theoretical point of view, the parameters of natural oscillations do not depend on the ground conditions because of the mass of the source rocks is much greater than one of the 30-meter layer on one of the source surfaces. Consequently, seismic intensity increments can be related only to the bearing capacity of the ground. There are known cases when practically undamaged buildings plunged into the ground and tilted strongly. This was attributed to liquefaction of the ground. However, significant ground subsidence can occur without liquefaction. There is a method of vibropiling piles to considerable depths (up to 70 m) and without the liquefaction process.

The influence of ground conditions on the parameters of seismic ground motion is valid only in the far-field zone. Moreover, only half of the increase in seismic intensity is associated with a change in amplitude, and the second half is associated with a change in the duration of oscillations. The last factor, according to empirical data, has the same effect on the damageability of construction objects as the acceleration amplitude. Unfortunately, this factor is not yet taken into account in Russian building codes. In other countries the influence of the duration of oscillations on seismic intensity is accounted for by Arias' formula [16].

Since instrumental estimates of seismic intensity based on accelerations, velocities and displacements generally do not coincide, one can think that the spectral composition of vibrations also affects seismic intensity.

IV. Discussion

Damage to construction objects in the source zone (fault and near-field zones) is related to the free vibrations of the source and is determined only by the magnitude of the earthquake. Parameters of ground motions are independent on ground conditions. Accordingly, it is necessary to develop a system of ground parameters to which the seismic intensity increment refers.

In the far-field zone not amplitude of acceleration only, but all the parameters of ground motion (predominant period and duration of oscillations) depend on ground conditions.

Since instrumental estimates of seismic intensity based on accelerations, velocities and displacements generally do not coincide, one can think that the spectral composition of vibrations also affects seismic intensity [17].

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