ON THE QUESTION OF THE SEISMIC EFFECT OF POWERFUL EXPLOSIONS

1969

SovietRxiv

Abstract

Full Text

GEOPHYSICS

V. M. SHAMIN

ON THE QUESTION OF THE SEISMIC EFFECT OF POWERFUL EXPLOSIONS

(Presented by Academician M. A. Sadovskii, 3 X 1968)

The seismic effect of explosions on buildings and structures is understood as damage caused by ground vibrations propagating from the explosion source. To assess the seismic effect in the USSR, the maximum mass velocity of ground vibrations at the surface is used (1). The critical velocity, above which initial damage in the form of cracks in plaster occurs, is usually taken for low-rise brick buildings to be 10 cm/sec. For the proper use of this criterion it is necessary to bear in mind that it was established on the basis of a study of the seismic effect of explosions of relatively small and usually distributed charges of explosives, totaling several tens or hundreds of tons and emplaced at shallow depth. Because of this, the radius of the seismically hazardous zone is relatively small, and the conditions of occurrence of soils at great depth have very little effect. The pattern of seismic vibrations is then sufficiently simple and consists of an onset phase, made up of the incident longitudinal wave and reflected longitudinal and transverse waves, and the main phase—the surface wave. The vibrations, especially in the first phase, decay rather rapidly; their duration is short and amounts, for each phase, to only a few periods.

Recently the scale of the use of explosions in the national economy has greatly increased, and the weights of the explosive charges have also increased considerably. It would be natural to expect that the mechanism of the seismic effect should thereby change as well. The first and important indication of this was a substantial decrease in the critical vibration velocity. As an example one may cite the description given in the USA of the seismic effect produced by an underground nuclear explosion with a yield of 5 kt at a depth of 825 m (2). After the explosion, a large number of complaints were received about the appearance of cracks in buildings where the mass velocities of ground vibrations were far below the critical velocity adopted as 10 cm/sec. Thus, for example, in a town 36 km from the epicenter of the explosion, where the expected and subsequently measured vibration velocity was only 0.5 cm/sec, about 200 complaints were received. A characteristic feature of the ground vibrations recorded there was their great duration, reaching 90 sec.

In considering the general pattern of seismic vibrations in powerful explosions in comparison with that described above, one should single out the circumstance that the radius of the seismically hazardous zone increases greatly not only

Fig. 1

Figure 1: Fig. 1

along the surface but also in depth, and the geological structure of the soils, especially the thickness and structure of individual layers, begins to play a decisive role. In addition to the comparatively rapidly attenuating primary waves listed above, emitted by the explosion source, secondary waves arise in individual soil layers, reflected from interfaces; owing to multiple reflection, these waves are distinguished by a long duration of vibration.

Apparently, it is here above all that one should seek the reason for such a strong increase in the seismic action at a mass velocity that is negligible by previous notions.

In order to estimate this factor, let us carry out an elementary dynamic calculation. The expression for seismic vibrations of the ground may be represented, as is often done, in the form of a damped harmonic oscillation:

$$x_0 = a_0 \exp(-\varepsilon_0 t) \sin \omega t. \tag{1}$$

Let the damping of the ground vibrations to a value of 5% of the initial amplitude a_0 occur over n periods; then

$$\varepsilon_0 = 12/(4n+1)T, \tag{2}$$

where T is the period of the oscillations.

Fig. 1

The calculation scheme for ordinary buildings may be taken in the form of a cantilever, the base of which undergoes oscillations according to law (1). Under any refinement of this scheme, the main role will be played by oscillations in the fundamental (lowest) mode, and therefore one may use the simplest system with one degree of freedom in the form of a mass concentrated at the end of the cantilever, to which any more complex scheme can always be reduced. The oscillations of a system with one degree of freedom, taking into account the damping of external and natural oscillations, are considered in (3), from which we borrow the necessary calculation formulas.

The maximum displacement of the mass (the end of the cantilever) in the case of resonance is described by the approximate expression

$$x_m \simeq \frac{a_0 \omega}{2(\varepsilon_0 - \varepsilon)} \left[\exp\left(-\frac{\ln \varepsilon/\varepsilon_0}{1 - \varepsilon/\varepsilon_0} \right) - \exp\left(-\frac{\ln \varepsilon/\varepsilon_0}{\varepsilon_0/\varepsilon - 1} \right) \right]. \tag{3}$$

For low-rise brick buildings, according to the data given in (3), the average value of the damping coefficient will be

$$\varepsilon = 0.3/T. \tag{4}$$

Figure 1 shows the values, calculated from (3), of the maximum relative displacements of the mass x_m/a_0 as a function of n.

For a very long duration of ground oscillations, $n \to \infty$ and $\varepsilon_0 \to 0$. Then for the established forced oscillations we obtain

$$x_m \simeq 10.47a_0. \tag{5}$$

Thus, the maximum displacement of the end of the cantilever is proportional to $a_0\omega$—the maximum mass velocity of the ground—and also depends very substantially on the duration of the oscillations of the base. Hence it follows that the value of the critical velocity of 10 cm/sec, established earlier for rapidly damped ground oscillations, must be significantly reduced when the duration of these oscillations is increased.

Institute of Physics of the Earth
named after O. Yu. Schmidt
Academy of Sciences of the USSR

Received
29 IX 1968

CITED LITERATURE

1. M. A. Sadovskii, *Simplest methods for determining the seismic hazard of mass explosions*, 1946.
2. D. V. Power, Bull. Seismol. Soc. Am., **56**, 6, 1413 (1966).
3. I. L. Korchinskii et al., *Fundamentals of designing buildings in seismic regions*, 1961.

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

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.