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DETERMINATION OF THE GROUND VIBRATION WAVELENGTH BY EARTHQUAKE FREQUENCY

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Abstract. The study of the earthquake phenomenon has recently been of interest in connection with the increasing frequency of earthquakes. Seismic microzoning evaluates the influence of local engineering-geological conditions of a construction site on the parameters that determine the nature of the destruction of buildings and structures under specific soil conditions. These parameters include the intensity, the form of recording and the spectrum of vibrations of the upper part of the soil section during possible earthquakes. Since in some cases resonant effects can occur in soils (significant amplification of oscillations at specific frequencies) even under favorable (in terms of seismic rigidity) site conditions, the seismic safety of buildings or structures built on it is not guaranteed.In earthquake-resistant construction, it is necessary to know the magnitude of the intensity of vibrations, the values of maximum accelerations and the distribution of seismic effects in frequency. The soils on which structures stand affect the vibrations of these structures. When calculating the structure-foundation oscillatory system for all modes, the forecast of its resonant frequencies and peak displacement amplitudes, considered as limiting - the most unfavorable conditions for the operation of the structure, is of great importance. In the spectrum of a seismic wave, there are fluctuations with frequencies close to the natural frequency of a number of structures, which for different modes often ranges from fractions to a few hertz (characteristic periods from 0.2 to 2 s). At resonance, stresses increase at the contact of the foundation with the soil, and in the structure of the structure, the probability of its destruction increases. For the first time, the formation oscillation is described in the work, the frequency of oscillations from the wavelength is determined. The equation of oscillation of an elastic body is taken as a basis. The case of functions periodic in X and an arbitrary variable in height and depth is considered.
Keywords: wavelength, seismic effect, elastic soil, inertial forces, oscillation period, angular frequency

Introduction. The resonant amplification of pendulum oscillations is especially dangerous when the center of gravity of the structure is significantly removed from its fulcrum, which is typical for bridge supports, pipes and high-rise buildings. The seismic effect is determined by three parameters: 1. amplitude level; 2. prevailing period; 3. duration of fluctuations. The duration of vibrations can be critical to the stability of structures short-term high acceleration loads may not be dangerous for many of them. The longest period of the Earth's oscillations is about 1.5 hours. The periods of oscillations of the Earth's layers during earthquakes are of the order of a fraction of a second. Therefore, it can be assumed that earthquakes are independent of the Earth's vibrations. In the work under study, the reservoir is considered independently of the Earth's oscillations. Estimated values of ground displacement parameters during earthquakes (table 1).

Table 1.

Earthquake intensity in points (MSK-64 scale)	Ground displacement acceleration, sm/s^2	Ground displacement speed, sm/s	Horizontal ground displacement, mm
VI	30-60	3-6	1,5-3
VII	61-120	6,1-12	3,1-6
VIII	121-240	12,1-24	6,1-12
IX	241-480	24,1-48	12,1-24

Methods. A layer of earth with a thickness of $\boldsymbol{y_0}$ is considered, there are no stresses on the surface, $\boldsymbol{\sigma_{xy} = 0}$ and и $\boldsymbol{\sigma_{yy} = 0}$; at the base $\boldsymbol{v = 0}$ and $\boldsymbol{\sigma_{xy} = 0}$, i.e. there is no vertical displacement and the ground slides freely in the horizontal direction (Fig. 1)

Horizontal ground slip. Solutions of wave equations in polar coordinates r, θ are found

$$a^2\Delta\varphi - \frac{\partial^2\varphi}{\partial t^2} = 0$$
$$b^2\Delta\psi - \frac{\partial^2\psi}{\partial t^2} = 0 \qquad (1)$$

under boundary conditions on the surface of cylindrical inclusion

$$U(t) = H(t)\,V_0 \qquad (2)$$

in the form of

$$u_t = \frac{2r_0V_0\sqrt{ab}}{\pi}\Big(\frac{1}{ab}(A_1(a,b) - \frac{a+b}{r_0\mu}\int_{\frac{r-r_0}{a}}^{t} A_1(a,b)\ \mu\ d\tau) + $$
$$+\frac{1}{br\mu}\int_{\frac{r-r_0}{a}}^{t} A_2(a,b)\ \mu\ d\tau) + \frac{2}{ar_0\mu}\cdot\int_{\frac{r-r_0}{a}}^{t} A_3(a,b)\ \mu\ d\tau + \frac{2}{r_0\,r}(A_4(a,b) -$$
$$-\frac{a+b}{r_0\mu}\int_{\frac{r-r_0}{a}}^{t} A_4(a,b)\ \mu\ d\tau) - \frac{1}{ar\mu}\int_{\frac{r-r_0}{b}}^{t} A_2(b,a)\ \mu\ d\tau - \frac{2}{r_0\,r}(A_4(b,a) -$$
$$-\frac{a+b}{r_0\mu}\int_{\frac{r-r_0}{b}}^{t} A_4(b,a)\ \mu\ d\tau)\Big) \qquad (3)$$

where: φ and ψ - potential functions, described waves the transferring volume expansion and rotation; magnitudes $a = \sqrt{\frac{\lambda+2\mu}{\rho}}$ and $b = \sqrt{\frac{\mu}{\rho}}$ are determine the velocity of propagation of waves of expansion and waves of rotation;λ и μ - constants of Lama; ρ - density of medium; Δ - Laplacian; V_0 – constant speed of cylindrical inclusion; $H(t)$- Hevisayd's unit function, determined by a formula

$$H(t) = \begin{cases} 1,\ t > 0 \\ 0,\ t < 0 \end{cases} \qquad (4)$$

Results. For simplicity, a two-dimensional problem for an elastic soil is considered. The equations of motion are

$$\rho\frac{\partial^2 u}{\partial t^2} = (\lambda + 2\mu)\nabla^2 u \qquad (5)$$
$$\rho\frac{\partial^2 v}{\partial t^2} = (\lambda + 2\mu)\nabla^2 v \qquad (6)$$

where ρ – soil density, λ, μ – Lame's constants, t - time, u, v – displacements in horizontal and vertical directions. $\nabla^2 = \frac{\partial}{\partial x^2} + \frac{\partial}{\partial y^2}$, λ *and* μ are considered permanent.

Assuming that there is an oscillatory motion with an angular frequency and a standing wave length l, we have

$$u = Usin\omega tcos\frac{2\pi}{l}x \qquad (7)$$

and

$$v = Vsin\omega tsin\frac{2\pi}{l}x \qquad (8)$$

where u *and* v – fuction of y.

Substituting (7) and (8) in (5) and (6), we obtain

$$-\rho\omega^2 U = (\lambda + 2\mu)\left[-\left(\frac{2\pi}{l}\right)^2 U + U^{II}\right] \qquad (9)$$

$$-\rho\omega^2 V \quad = (\lambda + 2\mu)\left[-\left(\frac{2\pi}{l}\right)^2 V + V^{\parallel}\right] \tag{10}$$

Solving equations (9) and (10) relatively to u and v, we obtain

$$u = c_1 sin\Omega y + c_2 cos\Omega y \tag{11}$$
$$V = D_1 sin\Omega y + D_2 cos\Omega y$$

where

$$\Omega\sqrt{\frac{\rho\omega^2}{\lambda+2\mu} - \left(\frac{2\pi}{l}\right)^2}$$

Shear stress

$$\sigma_{xy} = \mu\varepsilon_{xy} = \mu\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right) = \mu\left(\frac{2\pi}{l}V + u'\right) sin\omega t cos\frac{2\pi}{l}x \tag{14}$$

Satisfying the conditions at the lower bound: $y = 0, v = 0, \sigma_{xy} = 0$, we get

$$D_2 = 0; \quad c_1 = 0 \tag{15}$$

On the upper border $y = y_0$, $\sigma_{xy} = 0, \sigma_{yy} = 0$, we get

$$\sigma_{xy}\Big|_{y=y_0} = \mu(D_1 \sin\Omega y_0 - \Omega c_2 sin\Omega y_0) sin\omega t cos\frac{2\pi}{l}x = 0$$

or

$$\frac{2\pi}{l}D_1 - \Omega C_2 = 0 \tag{16}$$

From (11) and (15) expressions

$$U = c_2 cos\Omega y_0$$
$$V = D_1 sin\Omega y_0 \tag{17}$$

Further

$$\sigma_{yy} = \lambda\Delta + 2\mu\varepsilon_{yy} = \lambda\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + 2\mu\frac{\partial v}{\partial y} = \left[\lambda\left(-\frac{2\pi}{l}U + V'\right) + 2\mu V'\right] sin\omega t cos\frac{2\pi}{e}x$$
$$= \left[-\frac{2\pi}{l}\lambda c_2 cos\Omega y_0 + (\lambda + 2\mu)\Omega D_1 cos\Omega y_0\right] sin\omega t cos\frac{2\pi}{e}x - \frac{2\pi}{l}\lambda c_2 + (\lambda + 2\mu)\Omega D_1$$
$$= 0 \tag{18}$$

From (16) and (18) expressions

$$\omega^2 = \frac{2(\lambda+\mu)}{\rho} \tag{19}$$

where ν – frequency

$$\nu = \frac{\omega}{2\pi}$$

Conclusions. In this paper, for the first time, the formation oscillation was presented, the frequency of oscillations from the wavelength was determined. The layer of earth under the construction site acts as a filter: at some frequencies, the soil layer transmits vibrations almost unchanged, while at others it amplifies or absorbs vibrations. When designing earthquake-resistant buildings and structures, it is important not to allow the maxima of the frequency response of the soil layer to coincide with the natural frequencies of buildings and structures. To determine the amplitude-frequency characteristic of the soil stratum, frequencies corresponding to resonant forces are considered. The frequencies to which the resonant amplifications correspond can be determined from the amplitude-frequency characteristic of the soil stratum. In this case, it is desirable to consider a wide frequency range from 0.05 to 20 Hz. This range is of the greatest interest in seismic microzoning, since it contains the vibration frequencies of the main types of buildings, structures and their critical structures, as well as the maxima of the vibration spectra during strong earthquakes.

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