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INVESTIGATION OF INFLUENCE OF THE LOCAL GROUND CONDITIONS ON THE SEISMIC HAZARD OF A CONSTRUCTION SITE

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Abstract. When studying seismic hazard, it is necessary to evaluate the local effect of earthquakes. The main factors that determine the parameters of surface vibrations during earthquakes include local effects associated with the response of the soil, the effects of surface topography and the topography of internal boundaries (heterogeneities, inclusions, sedimentary basins, etc.). At present, methods for reliable estimation of these effects have been developed in seismology. Knowledge of the probabilistic parameters of surface vibrations is necessary to calculate the reaction spectra, dynamic stresses and deformations that can cause destruction of buildings, to assess the possibility of soil liquefaction. The article examines the influence of local soil conditions on the seismicity of a construction site during an earthquake. To assess the seismic stability of structures erected on a layered foundation, it is necessary to investigate the influence of local soil conditions on surface vibrations during an earthquake. The influence of local soil conditions on the change in the characteristics of vibrations of the surface of the construction site of a structure during an earthquake is the result of a complex process of the passage of seismic waves. The resulting seismic effect of the construction site is affected by the parameters of the initial seismic load and the characteristics of the soil layers underlying the base. Under certain ground conditions, dynamic amplification or attenuation can occur in the form of a change in the amount of peak acceleration or the duration of oscillations. The layers of the underlying soil are capable of changing the frequency characteristics of the oscillations of the seismic wave coming to them. The result of such changes may be an increase in oscillations in certain frequency ranges, which may coincide with the natural frequencies of the erected structure, which leads to resonance effects.
Keywords: vibration spectra, soil conditions, frequency range, seismic oscillations, earthquake-resistant construction

Introduction. Analysis of earthquake consequences shows that ground conditions affect damage to buildings and structures in seismic areas, with the physical and mechanical properties of soils, which characterize the ability of a given soil to perceive and transmit seismic waves excited by an earthquake, being of primary importance. The causes of the influence of ground conditions on the destructive effects of earthquakes are related to the dynamic characteristics of soils in the surface layers of the Earth, located on the bedrock of deeper layers, as well as the bearing capacity of soils themselves. As studies show, the presence of weaker soils over dense rocks leads to an increase in the intensity of vibrations at the surface.

Methods. The use of data on the frequency characteristics of the soil layer at the base of buildings and structures is necessary to ensure high seismic resistance and minimize the cost of seismic protection measures. In seismic microzoning, to determine the vibration frequencies of the main types of buildings, structures and structures (Table 1) and the maximum vibration spectra during strong earthquakes [1,2], the frequency range from 0.05 Hz to 20 Hz is studied.

Table 1. Approximate values of natural oscillation frequencies [3]

Building type	*Dominant frequency (Hz)*
Single storey buildings	10
3-4 storey buildings	2
Tall buildings (10÷20 floors)	0,5 ÷ 1,0
High rise buildings	0,17

The amplitude-frequency characteristic of the soil stratum under the construction site can be obtained instrumentally using records of earthquakes or microseisms.

In areas with low seismicity, registration of earthquake oscillations is not always possible, therefore, seismic observations at the construction site are carried out using microseismic registration. The registration of high-frequency microseisms gives approximate values of the frequency response of the soil stratum, therefore, in this case, only the increase in seismic intensity is estimated in points of the macroseismic scale.

Engineering-geological and seismological data on the structure, physical and mechanical properties of the soil stratum of the construction site make it possible to build seismo-geological models and calculate the frequency characteristics of the soil base of the construction site under study using the Thompson-Haskell matrix method [4].

In the practice of seismic microzoning, the mechanisms of linear transformations of seismic waves in the near-surface soil layer, which lead to increased oscillations and resonance phenomena, have been sufficiently studied. To model the behavior of the soil stratum under seismic impacts, a linear or non-linear approach is used. During an intense earthquake, the proportionality between stresses and strains is violated, a saturation phenomenon occurs, when the stress increases more slowly than at lower strains, therefore these phenomena cannot be described by the linear theory of elasticity. The stress value at which the proportionality of the dependence between stresses and strains disappears is the threshold of elasticity. The elasticity threshold for different categories of soils is different [5] and is determined by the absorption of seismic energy by soils [6]. Therefore, to analyze the response of soil to seismic impacts, considerable attention has recently been paid to nonlinear approaches [5,6,7,10-11]. Under high-intensity seismic impacts, the nonlinear approach to the response of the soil stratum will depend on the magnitude of seismic deformations [12, 13]. An incorrect approach to modeling the response of soil to seismic effects from earthquakes will lead to inaccurate values of the resonant frequencies of the soil stratum, which during an earthquake can lead to the destruction of the building due to resonance effects not taken into account in the design.

In the world practice of earthquake-resistant construction, equivalent linear modeling of the soil response to seismic actions is widely used [5], where the soil is considered as a linear viscoelastic material, and its nonlinear properties are taken into account by introducing the dependences of the shear modulus and absorption coefficient on the amplitude of shear deformation. Such dependences are selected for each layer of the soil stratum model separately for the data obtained as a result of laboratory or field studies [2,5].

Conclusions. Analyzing real records of strong earthquakes, as well as the results of numerical simulation [12], we can conclude: Nonlinearity of the response of the near-surface ground strata leads to changes in the spectral composition of seismic vibrations, and to changes in the amplification of seismic vibrations [12].

At high intensity of oscillations nonlinear absorption mechanisms begin to operate, which lead to attenuation of oscillations at high frequencies, but do not attenuate at the same time low-frequency oscillations. Changes in the spectral composition of oscillations at the surface, associated with the nonlinearity of the response of the ground strata, manifest themselves in a shift of the resonance frequencies to the low-frequency region. The amplification of seismic oscillations at the surface decreases due to the nonlinearity of the ground response compared to the linear response in dry soils (when groundwater is at a depth of 10 m or more). In water-saturated soils (when the water table is less than 10 m deep), this enhancement is less noticeable.

When modeling the response of soils to seismic effects, for soils of category I according to the classification of the Building Code AzDTN 2.3-1 "Construction in seismic areas", a linear dependence between stresses and strains may be used. For soils of category II, a linear dependence on intensity of 8 points may be assumed. And for soils of categories III and IV - non-linearity should be taken into account starting from 6-7 points.

Soils of the construction site are classified upon their seismic characteristics to I, II, III and IV classes (Table 1).

Table 1.

Category of Soil	Soils	The velocity of seismic wave, V, m/s	N_{spt} Stroke quantity	Calculated resistance of soil Ro,kqq/cm²
I	All type of solid rocks, sand rock, Soils (with net mass>2,2t/m³) which 70 % broken from rock pieces and 30% consist of sand clay mixture	>800	- -	>10,0
II	I class soil, but detrited, with emptiness in its structuture; Less damp or damp, with big or medium density, Big or small grainy sands, Pebbly sands with consistency coefficient il<0,5; porosity coefficient e<0,9 Hard clays	500÷800	>50	3,0÷10,0
III	Damp, small grainy, sands with small density, consistency coefficient il<0,5 porosity coefficient e<0,9 half solid clays	200÷500	15÷50	1,5÷3,0
IV	Fine sands, sandy soils not depending from density of grain and saturated with water; dusty clays with consistency coefficient il<0,5;	<200	<15	<1,5

Linear modeling in seismic microzonation of construction sites is recommended only for soils of categories I and II. And for soils of categories III and IV, their possible nonlinear behavior should be taken into account. It should be taken into account that the accumulation of seismic energy (resonance effects) significantly depends on the duration of seismic oscillations, i.e., in local earthquakes, resonance effects are less dangerous than in strong subcrustal earthquakes.

To ensure high seismic resistance and minimize the cost of seismic protection measures, it is necessary to use data on the frequency characteristics of the ground strata at the base of buildings and structures to exclude the coincidence of natural periods of seismic vibrations, reinforced by local ground conditions with natural periods of buildings and structures vibration.

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