The Influence of the Frequency of Dynamic Action on the Violation of the Structure and Compaction of Loess Soils

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A B S T R A C T

This scientific article presents mainly the results of experimental studies on the influence of the frequency of dynamic (seismic) vibrations on the violation of the structure and deformability (compactness) of moistened loess soils. The research conducted by us and other specialists showed that with an increase in the intensity (accelerations) of vibrations, the strength characteristics of moistened loess and other weak cohesive soils decrease (mainly due to a decrease in connectivity) and this leads to an increase in deformation (compaction) of the soil. It should be noted here that the most significant influence on the destruction of the structure and the increase in compaction of the soil is played by the frequency of vibrations. Analyses of the consequences of many devastating earthquakes show that high-frequency earthquakes are the most dangerous for moistened loess and other subsidence soils, from the point of view of violation of dynamic stability.

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Introduction: Violation of stability, i.e. deformation of loess soils under dynamic (seismic) influence on them is a very complex process occurring in the soil thickness, which cannot be estimated by individual indicators. Internal factors play a significant role in this case: the state of density-humidity of the soil, the presence of colloidal minerals, granulometric composition, angle of internal friction, connectivity forces, etc.[1,7-10,15-16,18,23,24]. On the other hand, external factors may also be important in certain conditions: the amount of external loading, duration, intensity and nature of the dynamic effect [6,9,14]. Among these factors, special importance is attached to the intensity and nature (in frequency and amplitude) of the dynamic effect in the degree of deformability (compaction) of loess soils [2,3,13,19-22].

A decrease in the seismic resistance of soils with an increase in the intensity of dynamic vibrations, i.e. acceleration of vibrations, is certain. However, it is necessary to highlight the most significant influence of the oscillation frequency on the seismic resistance of soils. As construction practice and analysis of the consequences of devastating earthquakes show, high-frequency earthquakes are the most dangerous for the foundations of structures (from the point of view of violation of dynamic stability). For example, the frequency of the devastating Gazli-Uzbekistan earthquake of 1976 was 16 Гц, and the Tashkent-Uzbekistan earthquake of 1966 was 10 Гц, etc. [7,8].

In accordance with the task, a series of experiments on samples of loess-like soil was performed to study the dependence of the violation of the structure and deformability (compactability) of moistened loess soils on the nature of dynamic vibrations (in frequency and amplitude).

Materials and methods. The laboratory experiment was carried out on a vibration installation specially designed for this purpose. The vibration system allows you to reproduce harmonic horizontally forced vibrations with an amplitude from 0.1 to 6.0 mm and a frequency of 1-12 Гц. [4,5].

The vibrations are transmitted using a crank mechanism from a DC electric motor. Compression devices with a tested soil sample are rigidly attached to the vibrating plate, to which the specified vibration effects are transmitted. A load from a given vertical pressure can be applied to the surface of the tested soil sample within a wide range.

The main experiments were carried out at frequencies of 2-12 Гц and oscillation amplitudes of 0.1-3.0 mm, with corresponding oscillation accelerations from 800 mm/s², which is within the seismic acceleration range of 7 points (according to the international scale MSK-64).

Loess soils of undisturbed structure were studied. The drawdown tests were carried out using the single curve method according to the generally accepted methodology, first in static conditions, then in dynamic ones. Or two twin samples were tested in parallel under static and dynamic conditions.

The change in the vibration mode in these experiments was achieved due to the oscillation frequency at a constant amplitude value. The recorded parameter in the case under consideration was the connectivity of the soil before and after the experiment.

The connectivity of loess soils, as one of the determining factors of the structural strength of soils, was determined on the described vibration installation by the ball test method developed by N.A.Tsytovich. For this purpose, experimental studies have been conducted with various loess soils of undisturbed structure to study the factors influencing the disruption of the connectivity of moistened loess during oscillation.The experiments were carried out according to the following method: two samples were taken from a single monolith and after preliminary compaction at a given load, the initial value of adhesion was determined on one of them; The second sample was subjected to dynamic action while maintaining the same static load, and after the cessation of shaking, a new value of connectivity was determined. All experiments were carried out three times. The immersion of the ball into the ground and its velocity during fluctuations showed a decrease in the amount of connectivity (structural disturbance, decreased strength and compactness) of the soil under experimental conditions.

Analysis and results (Results and Discussion). Let's consider the results of the experiments (Table 1). So, at the frequency f=2Гц the initial connectivity of the soil C_w(H)=0.05 МПа decreased to C_w(K)=0.025 МПа; by f =4 Гц accordingly: C_w (H)=0.05 МПа on C_w (K) =0.015 МПа; by f =6 Гц - C_w (H)=0.05 МПа on C_w (K)=0.010 МПа; by f=8 Гц - C_w (H)=0.05 МПа on C_w (K) = 0.005 МПа; by f=10 Гц - C_w (H)=0.05 МПа on C_w (K) = 0.002 МПа; by f=12 Гц - C_w (H)=0.05 МПа on

C_w (K)=0.0005 МПа (here, C_w(H)-the connectivity of the soil to vibration, C_w(K)- soil connectivity after vibration).

It is noted that at higher vibration frequencies 12 Гц (high-frequency earthquakes) the value of connectivity of water-saturated loess soil decreases to zero even with a 7-point earthquake (on an international scale MSK-64).

The author also conducted experiments to clarify the role of the oscillation frequency in changing the deformation of loess soil. On the table.2 shows the dependence of soil deformation on the oscillation frequency. The experiments were performed on four varieties of loess-like soil with the following parameters: acceleration 2000 mm/s², loading P=0,3 МПа, the amplitude A=0,1-3 mm, degree of humidity Sr=0,8. As follows from the performed experiments, the deformability of the soil exposed to the study depends on the oscillation frequency. With an increase in the frequency of dynamic oscillation from 2 to 12 Гц the deformability of moistened loess soil increases up to 2-3 times. It follows that the effect of dynamic action on the deformability of the soil is more effective if, all other things being equal, this effect is characterized by a high frequency.

The given example clearly indicates a violation of the structure of the moistened loess soil during oscillation and subsequent compaction, and at the same time, a transition to a liquefied state is possible.

As follows from the performed experiments (Table.1,2) the deformability of the soil confirmed by the study depends on the frequency of oscillation. The effect of dynamic action on the deformability of the soil turns out to be more effective if, all other things being equal, this effect is characterized by a high frequency. [1-3,13,19-21].

The change in the connectivity of moistened loess soil at different frequencies of dynamic action.

Table 1

№	Vibration frequency f, Гц	Connectivity before vibration C_w(H), МПа	Connectivity after vibrationC_w (K), МПа
1	2	3	4
1.	2	0,05	0,025
2.	4	0,05	0,015
3.	6	0,05	0,010
4.	8	0,05	0,005
5.	10	0,05	0,002
6.	12	0,05	0,0005

The change in the amount of deformation of moistened loess soil at different frequencies of dynamic action.

Table 2

№	Name of the soil	Density of dry soil, in кg/sm^3	Soil deformation, in mm/m, at frequencies					
			2	4	6	8	10	12
1.	Супесь	1,45	21	34	45	52	55	57
2.	Супесь	1,46	20	32	42	50	52	54
3.	Суглинок	1,52	18	26	32	35	37	38
4.	Супесь	1,58	9	16	21	24	26	28

Conclusions and recommendations. The results of experimental studies conducted by us and some other experts on the influence of the frequency of dynamic (seismic) vibrations on the violation of the structure and deformability (compactness) of moistened loess soils have shown the following:

1. With the destruction of the soil structure during oscillation, the strength and stability of the foundation soils decrease and this will lead to uneven deformations of structures. These deformations of the foundations during earthquakes in most cases determine the degree of destruction of structures.
2. Disruption of the structure and liquefaction of moistened loess soil under seismic influences does not occur in all cases, but only after overcoming some critical (threshold) acceleration determined by the structural strength of the soil by the current seismic acceleration.
3. Experiments have shown the development of deformation of moistened loess soils from the intensity of vibration. Moreover, high-frequency vibrations play a significant role in the process. High-frequency vibrations increase the ability of the soil to move into a dynamically disturbed state. It follows from this, and as construction practice shows, as well as analysis of the consequences of many destructive earthquakes, that high-frequency earthquakes are the most dangerous for the foundations of buildings and structures (from the point of view of violation of dynamic stability).
4. The dynamic stability of moistened loess soils decreases with the impact of high-frequency earthquakes of sufficient duration on them.
5. As the results of our experimental studies have shown, at the same accelerations of dynamic vibrations, the destruction of the structure and liquefaction of moistened loess soil occurs mainly due

to an increase in the frequency of vibrations. With an increase in the frequency of dynamic vibrations, the strength characteristics of moistened loess soil decrease proportionally. Also, with an increase in the frequency of dynamic vibrations, the deformation (compaction) of loess soil increases.

6. From the above, it can be noted that in highly seismic areas, when compacting soils with a vibrating machine, special attention should be paid to the vibration frequency. As our experimental studies have shown, high-frequency vibrations have a positive effect on increasing the density and strength characteristics of soils.
7. The obtained results on the study of the influence of the intensity of dynamic action and its parameters (in frequency and amplitude) on the development of soil deformation can be taken into account when recommending vibration compaction of soils, as well as when designing and constructing buildings and structures on moistened loess soils in seismic areas.

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