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Increasing the Strength Characteristics of Loess Soils Over Time After Vibration

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Abstract: This scientific article presents the results of experimental studies to study changes in the strength characteristics of vibration-compacted moistened loess soils over time. As field experiments have shown, the strength indicators of compacted moistened loess soils using vibratory rollers increase over time after vibration. This has a positive effect on increasing the density and seismic resistance of soils. If the soil moisture exceeds the optimal value, then vibration will not contribute to an increase in the strength characteristics (density) of the soil, but on the contrary will lead to a decrease in the adhesion force and the angle of internal friction. The greatest vibration effect is achieved when soil moisture corresponds to the optimal value.

Keywords: strength characteristics, loess soils, moistened soils, angle of internal friction, adhesion force, vibration, vibration compaction, vibratory roller, soil structure.

Introduction

As is known, when loess soils are exposed to external forces and humidity, their structure is sharply disrupted, strength characteristics are reduced and the soil is deformed, i.e. are compacted, and buildings and structures built on them without special measures to prevent deformation are damaged and can even lead to destruction. Also, the strength characteristics of soils are used to solve important engineering problems, such as calculating the stability of the foundation, establishing the limit of applicability of the theory of linearly deformed bodies, when calculating the settlement of foundations, determining the bearing capacity of piles, etc. The strength characteristics of loess subsidence soils (specific cohesion C and angle of internal friction φ) depend mainly on their degree of density and moisture content. Experiments have established that an increase in the moisture content of loess subsidence soils from the natural state (i.e., from 5-7%) to complete water saturation leads to a decrease in the adhesion value by up to 12-15 times, and the angle of internal friction by up to 1.2 times. The strength characteristics of loess soils, primarily cohesion, increase with increasing structural strength. Adhesion and the angle of internal friction also increase with increasing soil density [1-5].

The strength characteristics of loess soils and their changes under static conditions have been studied by many specialists and currently there is a lot of data on this problem. But insufficient attention has been paid to the issue of changes in the strength characteristics of loess soils when exposed to dynamic loads.

Experimental studies of the influence of vibrations on the coefficient of internal friction of soils were first carried out by G.I. Pokrovsky and his colleagues in laboratory conditions, as well as D.D. Barkan (Russia) on a single-plane cutting device under the influence of vertical vibrations. The results of these experiments showed that the coefficient of internal friction depends on the kinetic energy of vibrations, decreasing with its increase, tending to a certain value that is 25-30% less than the initial value (before vibration).

Preobrazhenskaya and I.A. Savchenko (Russia), S. Murayama and T. Shibata (Japan) tested clays for vibration resistance to shear using two-plane shear devices (the first authors tested soil samples with horizontal vibrations, the other two authors tested them with vertical vibrations). R.G. Badalyan and S.R. Meschyan (Russia, Armenia) developed a miniature vibrator, with the help of which experimental studies were carried out on clay soils [6-10].

The experimental results obtained indicated a significant influence of vibration on the shear resistance of loess soils. Moreover, the influence of vibration on shear resistance will be less, the greater the adhesion of the soil. An increase with decreasing effect of vibrations of the compaction load was also noted.

A decrease in soil shear resistance occurs mainly due to a decrease in the magnitude of adhesion: i.e. loss of structural strength. Proof of this can be the fact of a significant decrease (more than 15 times) in the amount of adhesion during vibration. At the same time, the angle of internal friction during vibration changes slightly [11-17].

Methodology and results. In order to deeply study the impact of vibration on the strength characteristics of loess soils, we conducted field studies. Special field experiments were carried out with loess loams at the construction site. To conduct experimental studies in the field, a vibrating machine, a trailed vibrating roller SVAW-12, manufactured in Germany, was mainly used. Trailed vibratory rollers, made in Germany, have three modifications depending on the type of drum, differing in weight. The SVAW-12 vibratory roller is characterized by the following technical indicators: diameter - 2.0 m, width - 2.0 m, weight - 12 tons, operating speed - 1.5-5.0 km/h, specific static pressure - 59 kg/cm2 , exciter force - 36 t, vibration frequency up to 25 Hz. To conduct the experiment, three maps were prepared, characterized by soils with varying degrees of moisture. A vibration machine operated on each card, creating different intensity and duration of vibration. Then, after 3-7 days after the vibration, soil samples were taken from places that were exposed to vibration and their physical and mechanical properties were determined.

Determination of the shear resistance of loess soils was carried out using a single-plane cut device model GGP-30 (Russia). The experiments were carried out at vertical pressures of 0.1; 0.2; 0.3 MPa.

In order to clarify the role of the time factor on changes in the strength characteristics of loess soils after 50-60 days after vibration, physical and mechanical characteristics were determined on samples taken from vibration sites.

From the data in Fig. 1,2 it is clear that the increase in the angle of internal friction of the soil by 2-3.5° degrees within 3-7 days after the vibration.

Experiments carried out on samples 50-60 days after vibration showed an increase in the angle of internal friction (than 3-7 days after vibration) by 1.0-1.5°, and in some cases by 2.0°.

The issue related to changes in the magnitude of soil adhesion during vibration is considered in a completely different way (Fig. 3, 4). Thus, 3-7 days after vibration, the magnitude of the adhesion force decreased by 40-50% relative to the initial value. Over time, after the vibration occurs, an increase in the adhesion force of the soil is observed. This is evidenced by experiments conducted on soil samples taken from vibration sites 50-60 days after vibration. According to the data, the increase in soil adhesion forces during this period is 40-50% in relation to the initial value or 80-100% in relation to the value obtained 3-7 days after vibration. The decrease in soil moisture 50-60 days after vibration is approximately 4%.

As follows from the above analysis of the experimental results, the vibration process has a significant impact on changes in the strength characteristics of soils. This influence especially affects the adhesion force of the soil, the C value increases several times. During the

vibration process, a sharp decrease in adhesion force is observed, which is apparently associated with a violation of the soil structure and its compaction. And then, upon completion of the compaction process, there is a gradual increase in the magnitude of connectivity up to 1.5-2.0 times. This circumstance is also related to the moisture state of the soil.

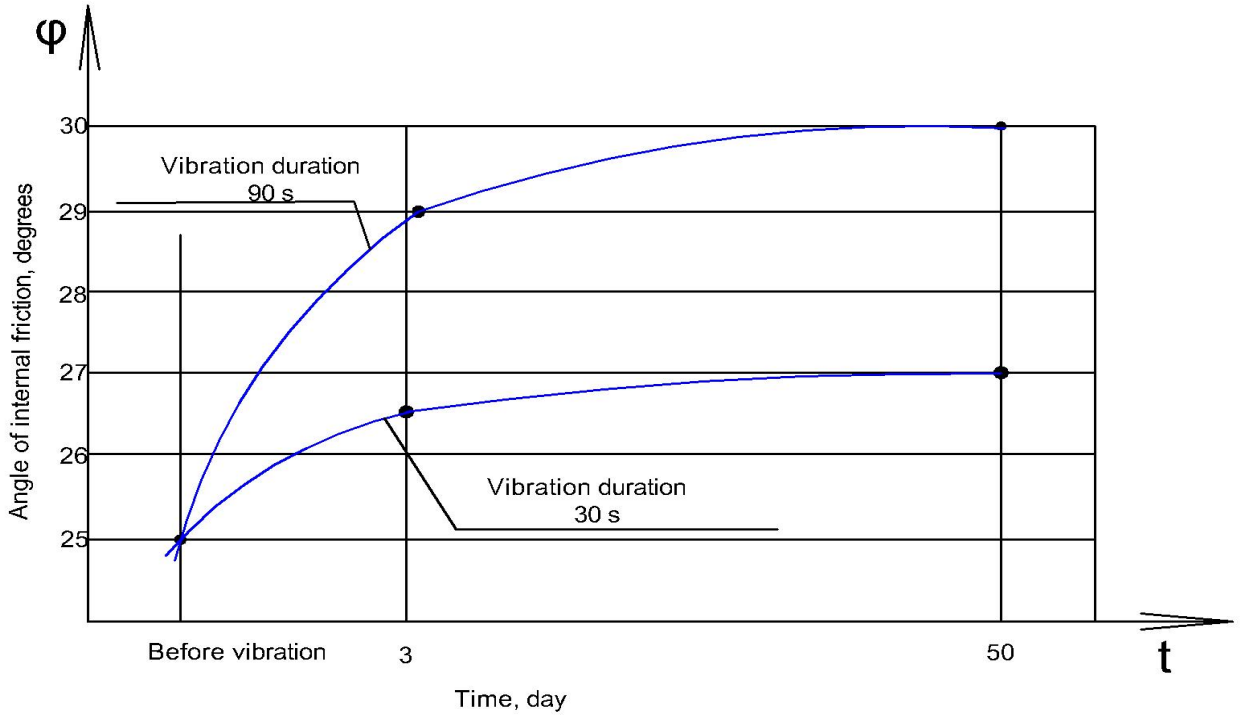

Fig.1 The nature of the increase in the angle of internal friction of loess-like loam with over time. Vibration frequency ŧ = 12.5 Hz

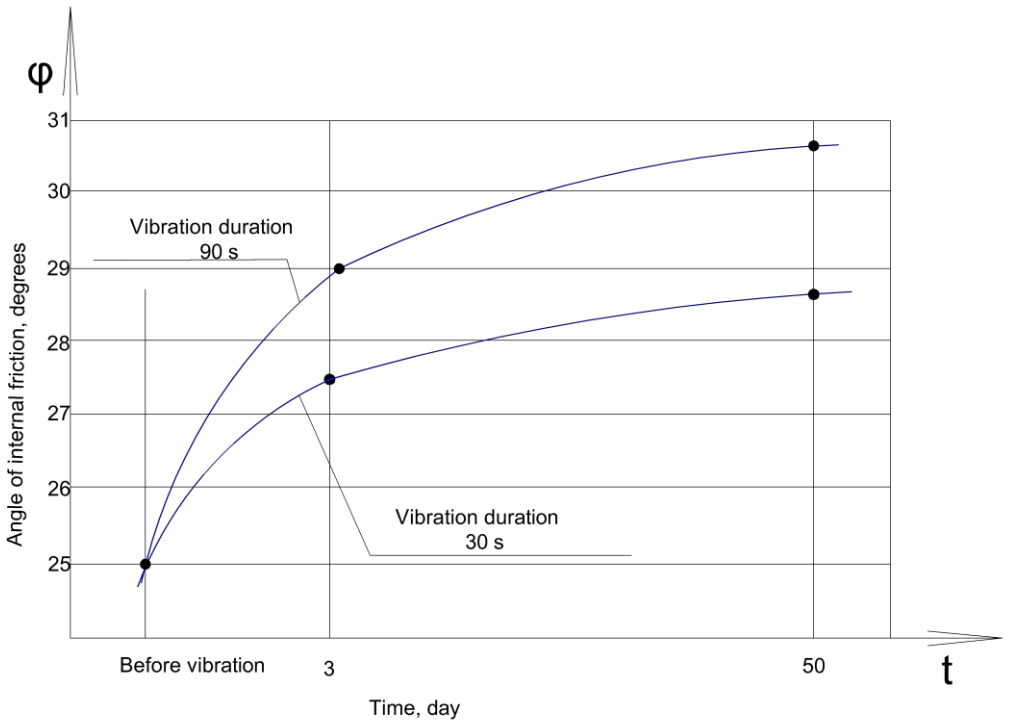

Fig.2 The nature of the increase in the angle of internal friction of vibrated loess-like loam over time. Vibration frequency ŧ = 23.5 Hz.

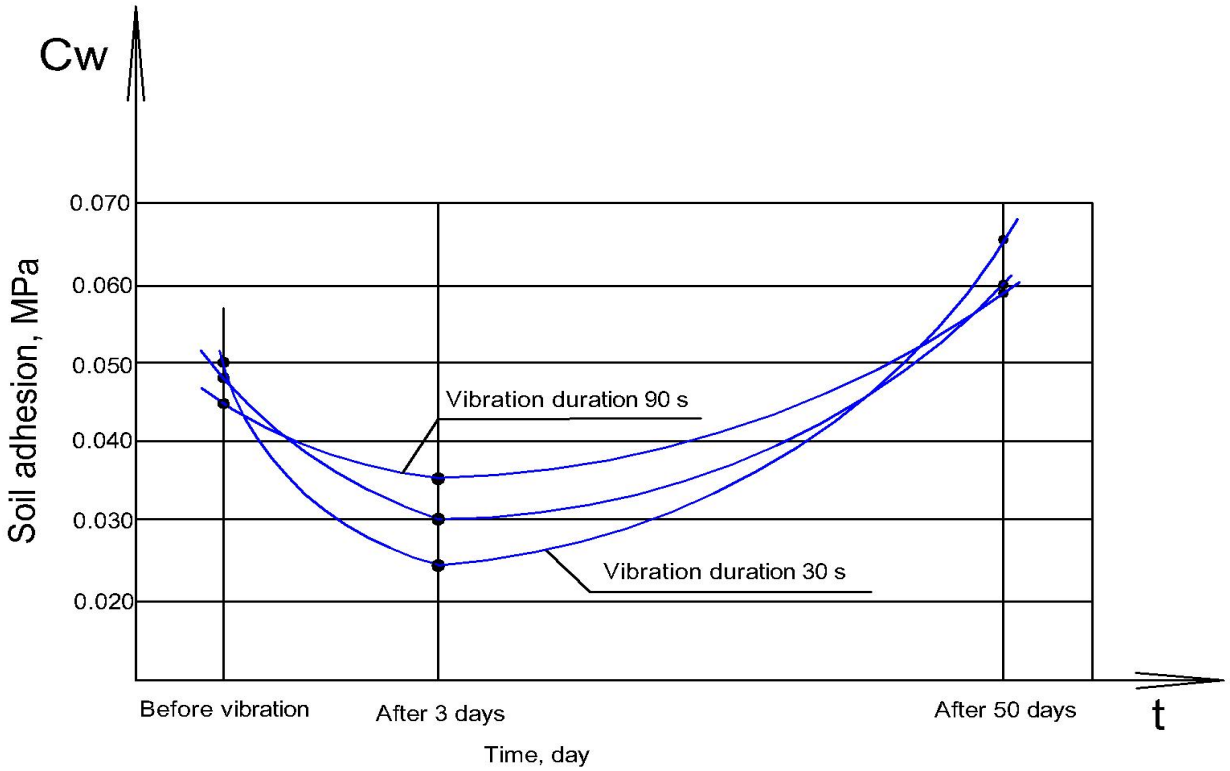

Fig.3 The nature of changes in soil cohesion over time.

Vibration frequency ŧ = 12.5 Hz.

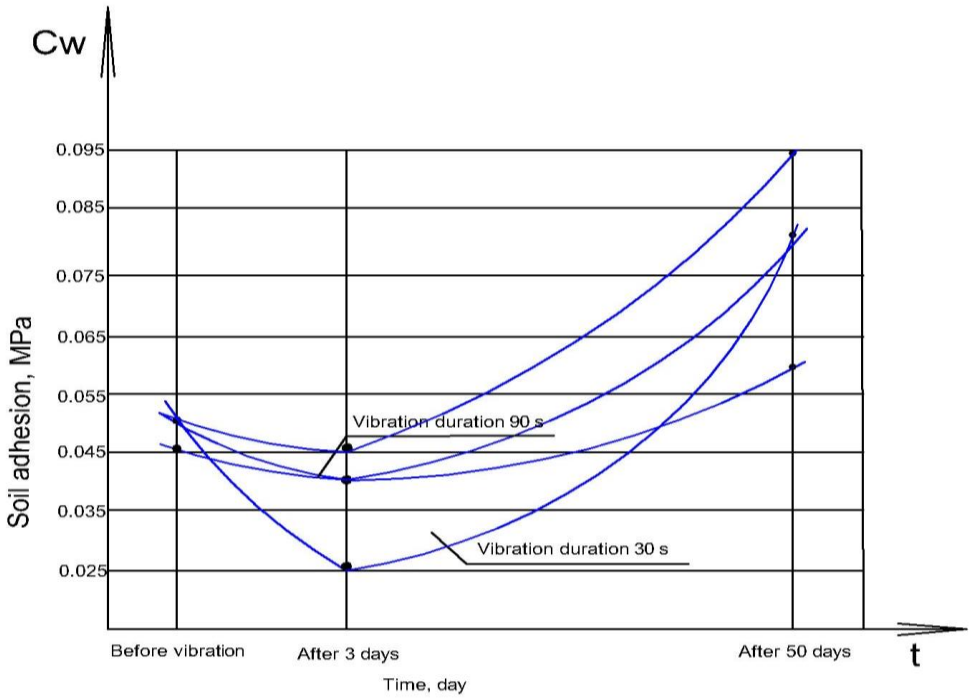

Рис.4 Характер изменения сцепления грунта с течением времени. Частота вибрации ŧ = 23,5 Гц.

As our studies have shown, the greatest effect of vibration compaction is achieved when the soil moisture content corresponds to the optimal value.

With increasing humidity, the values of φ and C can sharply decrease for a short time and

even after the end of vibration these reduced values remain. In this case, the soil will lose most of its strength. For this reason, when compacting loess soils with vibration installations, it is necessary to pay special attention to soil moisture and its optimal value. If during the compaction process the soil moisture exceeds the optimal value, then vibration will not contribute to an increase in soil density, but, on the contrary, will lead to a decrease in the adhesion force and the angle of internal friction of the soil.

Conclusion. Experimental studies conducted in the field on the compaction of moistened loess soils in order to study the further behavior of the strength characteristics of vibration-compacted soils after vibration over time showed:

1. As field experiments have shown, the strength indicators of compacted moistened loess soils using vibratory rollers increase over time after vibration. This has a positive effect on increasing the density and seismic resistance of soils.
2. Research conducted by us in the field has shown that the strength characteristics of compacted loess soils using vibration methods are much different from compacted soils using other static methods, since when compacting soils with vibration, the soil experiences dynamic effects.
3. The increase in seismic resistance of moistened loess soils when using vibration compaction is determined by the following factors: the soil experiences dynamic (seismic) effects even before the construction of the structure; an increase in density is achieved, which leads to an increase in the friction angle and soil cohesion; the magnitude of the critical ground acceleration increases.
4. A decrease in the strength characteristics (angle of internal friction and cohesion) of moistened loess soils causes the development of zones of plastic deformation under the base of the foundation.
5. The greatest effect of vibration compaction is achieved when the soil moisture content corresponds to the optimal value. If the soil moisture exceeds the optimal value, then vibration will not contribute to an increase in soil density, but on the contrary will lead to a decrease in adhesion force and the angle of internal friction.
6. Uneven deformations of structures erected on moist loess soils are in most cases associated with weakening soil strength and a decrease in the overall stability of foundations during earthquakes.
7. The results obtained from studying changes in the strength characteristics of loess soils under dynamic conditions can be taken into account when designing and constructing buildings and structures on moist loess soils in seismic areas.

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