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Investigation of the Patterns of Changes in the Structural Strength of Moistened Loess Soils Under Dynamic (Seismic) Influences

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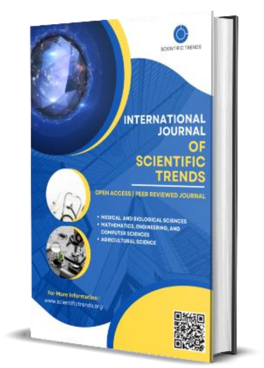

Abstract

This scientific article presents the results of laboratory and field experimental studies on the study of patterns of changes in the structural strengths of moistened loess soils under dynamic influences, depending on various external and internal factors.

Recommendations have been developed for determining the design pressure based on buildings, taking into account changes in the strength characteristics of loess soils under seismic influences.

Keywords: adhesion; connectivity; vibration compaction; angle of internal friction; bulk soil; loess soil; strength characteristics; vibration roller; structural strength; method; seismic subsidence.

Introduction

The study of patterns of changes in the structural strength of weak clay, as well as moistened loess subsidence soils under dynamic (seismic) influences, depending on various internal and external factors, in order to combat the development of plastic zones under the sole of the foundation, certainly represent significant scientific and practical interest.

The construction of buildings and structures on weak, structurally unstable soils (which include moistened loess soils) in seismic areas with ensuring their strength, stability and reliable operation is one of the difficult problems of modern construction.

The above causes the urgency of the problem of the current research, the purpose of which is to study the patterns of changes in the strength and deformation properties of loess soils under dynamic influences, depending on the composition, condition and properties of soils under the influence of various external factors (intensity, parameters and duration of vibration, etc.), to combat the development of plastic zones under the sole of the foundation in seismic conditions.

The analysis of literary sources shows that there is no question in terms of our task in a generalized form. However, the research of the behavior of loess soils in dynamic conditions is devoted to the work of many Russian and foreign scientists.

2. Review of Scientific Literature (Literature Review)

The results of experiments by A.S.Aleshin, A.D.Kozhevnikov, I.G.Mindel, S.I.Lavrusevich, etc. It has been shown that an increase in humidity entails a decrease in the strength of structural bonds and a predisposition of loess rocks to seismic subsidence-compaction during earthquakes, explosions, and production dynamic loads.

N.I.Krieger's research has shown that seismic subsidence depends on the magnitude of seismic energy, the amplitude-frequency spectrum of vibrations, resonant phenomena, the strength of structural bonds in the rock, etc.

As a result of laboratory studies, A.I.Lagoisky found that the following main factors affect the loss of soil strength under dynamic influences: the magnitude of the amplitude of vibrations, the mineralogical composition of soil particles, the content of particles in the soil with a size of less than 0.001 mm, soil moisture.

According to A.A.Musaelyan, the determining factor in the formation of seismic subsidence is a decrease in the strength characteristics of soils.

Studies conducted by M.Y.Abelev and H.G.Gafurov on water-saturated loess soils in stabilometers showed that under dynamic loads, the values of the internal friction angle turned out to be 3-6 degrees lower than during static tests, and the adhesion values decreased by 10-15%.

N.A.Preobrazhenskaya, I.A.Savchenko note the influence of frequency fluctuations in the reduction of soil strength.

A.A.Kagan, Yu.G.Trofimenkov and A.A.Dobrovolsky considering the influence of seismic influences on the strength properties of loess soils come to the conclusion that the decrease in strength occurs due to the adhesion parameters. However, in the studies of other specialists (A.A.Vakhtanova, V.F.Chernyaev, I.P.Bondarev, etc.), it is noted that the angle of internal friction is essential in reducing the strength of soils under dynamic influences.

Rasulov, S.S.Saifiddinov attach great importance to the connectivity of the soil in the loss of strength and the formation of seismic subsidence of loess soil.

There are different opinions on the issues of dynamic disturbance of the soil structure. According to the research of some specialists, in case of violation of the structure of loess soils, amplitude is essential, in others, the frequency of oscillation, etc. However, the issue of the influence of vibration parameters on changes in soil structure has not been sufficiently studied. The study of the effect of oscillation acceleration on the disturbance of the structure of loess soils is insufficient.

In recent years, experts have paid great attention to the study of seismic subsidence of loess under dynamic influences. Many specialists are engaged in the study of seismic subsidence, however, there are different opinions on this issue, especially regarding the causes of this phenomenon and the influence of various factors on the course of the seismic subsidence process.

Despite its relevance, there are still no specific data on the issue of combating seismic subsidence of loess soils, with the exception of some individual works related to the initial stage of research. H.Z.Rasulov developed computational methods for critical acceleration and earthquake-resistant foundations, which are based on a comparison of the oscillation accelerations already known to us: critical and seismic. Experiments conducted by him in the laboratory showed that the magnitude of critical acceleration is associated with the strength characteristics of soils, with the strength of internal bonds, the increase of which in all cases led to an increase in the magnitude of critical accelerations.

It should be noted that in the above works, due attention was also not paid to the issues of studying changes in strength characteristics, the development of plastic and subsidence deformations of loess soils under seismic influences, the development of methods that contribute to the elimination of seismic subsidence deformations and reduce the development of plastic deformations in the subfundament zone.

The analysis of the issue shows that despite a certain amount of work devoted to the study of the influence of dynamic loads on the structural strength of loess soils, the research results still do not make it possible to make sufficiently reliable generalizations and offer quantitative and qualitative recommendations on this issue that could be used in the design of foundations.

The issues of structural strength of loess soils under dynamic influences are insufficiently covered in published works.

3. Materials and Methods

The goals and objectives of the research predetermined the research methodology. Experimental studies were performed in laboratory and field conditions with comparable parameters.

The laboratory experiment was carried out on a vibration installation of the TASHPI design. 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 Hz.

Vibrations are transmitted by means of a crank mechanism from a soldered-current electromotor. 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 1-12 Hz and oscillation amplitudes of 0.2-5.0 mm, with corresponding oscillation accelerations from 200 to 8000 mm/s2, which is within the limits of seismic accelerations of oscillation from 5 to 10 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.

In order to clarify the quantitative changes in the strength parameters of loess-like soil depending on humidity under static conditions, a series of laboratory shear experiments was carried out.In accordance with the task of determining the strength characteristics of the studied soils, the shift was carried out slowly under conditions of complete consolidation at a given humidity.The obtained results on the study of the strength characteristics of loess-like soils show, that with an increase in soil moisture, the strength characteristics decrease according to a certain pattern.The highest values of the adhesion force and the angle of internal friction correspond to the minimum soil moisture, and the minimum values correspond to their water-saturated state.

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 soil connectivity under experimental conditions.

In order to compare with the results of experimental laboratory studies, as well as to develop recommendations for vibration compaction of loess soils lying at the base of structures and in the lateral zones of the foundation, special field experiments were conducted.

A vibrating machine (SVAW-12 trailer vibrating roller, manufactured in Germany) was used to conduct experimental studies in the field.

The performed studies have shown that loess subsidence soils at the base of buildings and structures, being saturated with water under appropriate conditions (seismic, vibration, shock and other dynamic influences), easily lose their stability, while contributing to the development of plastic deformation at the base of structures with loss of their overall stability.

4. Results and Discussion

The results of laboratory experimental studies conducted on moistened loess soils showed:

- the possibility of reducing the magnitude of the critical acceleration with an increase in soil moisture and a decrease in the role of loading in the oscillation process;
- the development of loess deformation from the intensity of the oscillation. Moreover, high-frequency vibrations play a significant role in the process;
- soil deformation also increases with increasing duration of dynamic action;
- reduction of the strength parameters of the soil (angle of internal friction and adhesion) during oscillations with acceleration exceeding the critical value. At the same time, the change in the strength of connectivity is particularly noted, which is intense in the process of vibrations (as our

experimental studies have shown in heavily wet loess soils, the strength of connectivity may decrease to 5-10 times or more, and the angle of internal friction may decrease by only 5-6 ^0, i.e. by 15-20%);

- change in the adhesion of moistened loess soils during fluctuations depending on their density-humidity, intensity, duration and parameters of dynamic action.

Experiments conducted in the field confirmed the results of laboratory studies in terms of disruption of the structure of moistened loess soils and the possibility, at the same time, of the development of plastic deformations during vibration.

Many field experiments with thickness vibration have shown an increase in soil density with an increase in the duration and intensity (frequency) of vibration.

Our field studies also showed an intensive increase in strength characteristics over time (after vibration) (the strength of connectivity increases twofold, and the internal friction coal increases by 2-3^0) and the density of pre-vibrated moistened loess soils. A particularly great effect is achieved when high-frequency vibrations are applied to the soil.

When recommending compaction of weak, subsident loess soils in seismic areas, it should be borne in mind that the strength characteristics of compacted soils with vibration methods are much different from compacted soils with other static methods.In addition, during vibration compaction, 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 values of the friction angle and the connectivity of the soil; the magnitude of the critical acceleration of the soil increases. The method of vibration compaction using vibrating machines is the most effective for increasing the strength of bulk soils, when filling them in small layers. However, as our field studies have shown, vibration compaction can also be used for compaction of soil and undisturbed structure.

5. Conclusions

1. Among the physico-geological processes in seismic areas, the greatest danger to buildings and structures is seismic subsidence (seismic subsidence) loess rocks. Any additional moistening of the base of structures erected on such loess, subsidence soils, under seismic influences, can lead to seismic subsidence.
2. Seismic impacts can also cause a violation of the dynamic stability of soils filled in areas bordering foundations, which often causes a weakening of the bearing capacity of the foundation itself.
3. A decrease in the strength characteristics (angle of internal friction and connectivity) of moistened loess soils causes the development of zones of plastic deformation under the sole of the foundation.
4. Uneven deformations of structures erected on moistened loess soils, in most cases, are associated with a weakening of soil strength and a decrease in the overall stability of the foundations during earthquakes.
5. When designing foundations in seismic areas, it is important to determine the expected additional deformation, taking into account the possible duration and intensity of an earthquake and changes in the strength characteristics of soils under these conditions.

6. The conclusions noted above indicate to a certain extent that the calculation of the foundations of structures erected in seismic areas according to the first limit state, which does not take into account seismic deformation of soils, is insufficient.
7. The sedimentation of the soil of the foundations, manifested during earthquakes, is often the determining factor in the degree of destruction of structures in these conditions.
8. The calculated pressure value will be lower in seismic conditions than in static ones, due to the weakening of connectivity, the angle of internal friction of the soil and the reduction of the role of sinking. In this regard, the calculated pressure on the base should be set taking into account the duration and intensity of the impact of the seismic load.
9. The method developed by us for determining the design pressure on the base proceeds from the condition that the average pressure from a structure erected in seismic areas should not exceed its calculated value, determined taking into account changes in the strength characteristics of soils during earthquakes. Obviously, in this case, when calculating the bases for deformations, additional seismic sedimentation of structures will be taken into account.
10.In accordance with our proposed method, the calculated pressure on the base in seismic conditions is determined by the numerical value of the change in the stress state, connectivity, angle of internal friction and others that occur in the soil thickness during its compaction (deformation).

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