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Problems of Design and Construction of Buildings and Structures in Seismic Areas, on Weak Moistened Clay and Subsidence Loess Bases

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Abstract
This article presents the features of the design and construction of buildings and structures on weak clay and subsident loess soils in seismic areas. A recommendation is given on vibration compaction of weak moistened clay and subsident loess soils of the foundations of buildings and structures, as well as bulk soils filled up around the foundation in seismically active areas.

Keywords: Weak clay soil, subsident loess soil, bulk soil, seismic areas, earthquakes, precipitation and subsidence, vibration method, seismic deformation, acceleration, strength characteristics of soils, foundations.

Introduction

As is known, the greatest difficulties arise in the construction of residential, public and industrial buildings and structures on subsident loess, weak water-saturated clay, swelling, saline, permafrost and bulk soils. The territories where such soils are common belong to difficult soil conditions. Soils common in seismic areas also relate to difficult ground conditions.

A significant part of the territory of the CIS (15 former Soviet republics) is located in difficult ground conditions. Such territories include areas of distribution of weak clay and subsident loess soils, in particular the territories of the Central Asian Republics, where the complexity of soil conditions is aggravated by high seismicity and the possibility of their humidification during land urbanization. These conditions necessitate the use of such construction techniques that would ensure high reliability and durability of buildings and structures.

As is known, the design and construction of buildings on weak clay and subsident loess soils in seismically active areas with ensuring their strength, stability and reliable operation is one of the difficult problems of modern construction.

The study of the causes of deformations of buildings erected on weak clay and subsident loess soils under seismic influence shows that uneven subsidence of the foundation and deformations of erected structures occur even with minimal pressure on the ground, and the nature of the deformation of the structure depends on ground conditions and the intensity of seismic activity. A typical example of this is the consequences of the Ghazli (Uzbekistan) 1976,1984. and Verninsky (Almaty, Kazakhstan) earthquakes of 1887, 1911, when not only 2-storey panel and brick houses were completely destroyed, but also lighter ones, including wooden structures, i.e. buildings and structures were damaged regardless of the specific pressure transmitted to the base and the power of the active (compressible) zones.

Thus, in the presence of weak clay and subsident loess soils capable of transitioning into a dynamically disturbed state, it is not always possible to ensure the strength and stability of buildings by calculating their foundations according to the first limit state, i.e. by bearing capacity.

Methods and Results

In this regard, it becomes necessary to develop a new design principle based on the conditions of joint work of the entire structure as a whole with the foundation, i.e. taking into account the strength characteristics of the foundation soils, the specifics of the work of the building structure. It is known that the density of the soil is of exceptional importance in ensuring the seismic stability of the base. Recall that an increase in soil density leads to an increase in the value of the critical acceleration α_c (it is known that each type of soil, depending on its composition, condition and properties, has its own critical acceleration of vibrations of soil particles. Most authors call the critical acceleration α_c such an acceleration of the vibration of soil particles, at which the soil is in a state of extreme equilibrium and a slight excess of acceleration against the critical one is sufficient for the water-saturated soil to pass into a state of loss of its dynamic stability, i.e. into a state of liquefaction. As a result of liquefaction, the structural strength of the soil decreases and significant plastic deformations develop both in the soils lying in the zones bordering the foundation and in the basement zone of the foundation, leading to unacceptable deformations of the structure itself.) and thus, to limit the power of the active zone z down to zero (no dynamic

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effect). Thus, with an increase in the density of the soil, its strength characteristics (angle of friction and adhesion) increase sharply. From here, the full significance becomes clear, as a protective measure aimed at increasing the density of clay and loess soils at the base of the structure and, first of all, in the lateral zones bordering the structure, which in this sense are the most dangerous. Let us note here that individual cases from the practice of construction strongly confirm this conclusion.

Turn to the formula: $P(t) = \frac{\pi\gamma_w\left\{H-I(t)\frac{z}{2}+\frac{C_w(K)+[C_w(H)-C_w(K)]l^{-\mu t}}{\gamma_w tg\varphi_w}\right\}}{1+K_c l^{-wt}\left(ctg\varphi+\varphi-\frac{\pi}{2}\right)}+\gamma_w H\ldots$

As follows from this expression, the decrease in the bearing capacity of the foundation in seismic conditions primarily depends on the drop in the value of H (the height of the bulk soil around the foundation, lying above the base of the foundation) during oscillation. This fall, in accordance with the noted provisions, confirmed by laboratory and field experiments, is associated with the compaction of bulk soil lying above the base of the foundation.

Soil compaction, which takes place under conditions $\alpha_s > \alpha_c$ (where, α_c, α_s are, respectively, the values of the critical and seismic accelerations of vibrations of soil particles), its water saturation is associated with the occurrence of back pressure $\gamma_w \mathrm{I}(t)\frac{z}{2}$ acting within the core zone z.

This back pressure in the process of compaction of the soil is supported by a dynamic pressure gradient varying over time t. In some cases, with strong fluctuations in the soil and weak ground conditions, the amount of back pressure may be equal to the natural weight of the thickness, i.e. $\gamma_w H$, then the phenomenon of complete liquefaction may occur. In conditions of liquefaction, the role of the depth of the foundation is reduced to zero, with all the consequences that follow from this.

It should be noted that in practice, the most common case is partial liquefaction of the stratum, leading to unloading of soils lying below the foundation base. This circumstance, associated with a decrease in the strength characteristics of soils over time (primarily connectivity with the soil), leads to a weakening of the bearing capacity of the base. This can lead to the expansion of plastic deformation zones and its gradual penetration into the base area.With sufficient duration of dynamic action, this penetration can cover the entire base area and lead to the extraction of soil from under the sole of the foundation (Fig.1).

This case, which often leads to an accident of structures, requires a very careful approach to the design and construction of structures on weak moistened clay and subsident loess soils in seismic areas.

The requirement to prevent the process of compaction and the development of plastic zones at the base of structures is obviously achieved by creating the condition a$\alpha_c > \alpha_s$ at all points of the soil massif.

Critical acceleration α_c. in the concept of Prof. H.Z.Rasulova (Uzbekistan) is generally associated with the strength characteristics of the soil in the following form

$$\alpha_c = \frac{2\pi g\left(\sigma_{\text{дин}} tg\varphi_w + C_w\right)}{\gamma_w T_{\text{п}} \upsilon_{\text{сд}} sin 2\pi \frac{z}{\lambda_b}}$$

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where,

g - acceleration of gravity;

φ_w -the angle of internal friction of the soil at humidity w ;

c_w- soil adhesion (connectivity) corresponding to humidity w ;

γ_w - density of wet soil;

T - is the period of oscillation;

υ_{sw}- velocity of transverse seismic waves;

Z - -is the depth of the horizon under consideration;

λ_b −is the wavelength.

According to the formula, the magnitude of the critical acceleration in real conditions can be increased by increasing the strength characteristics of the soil φ and C

.

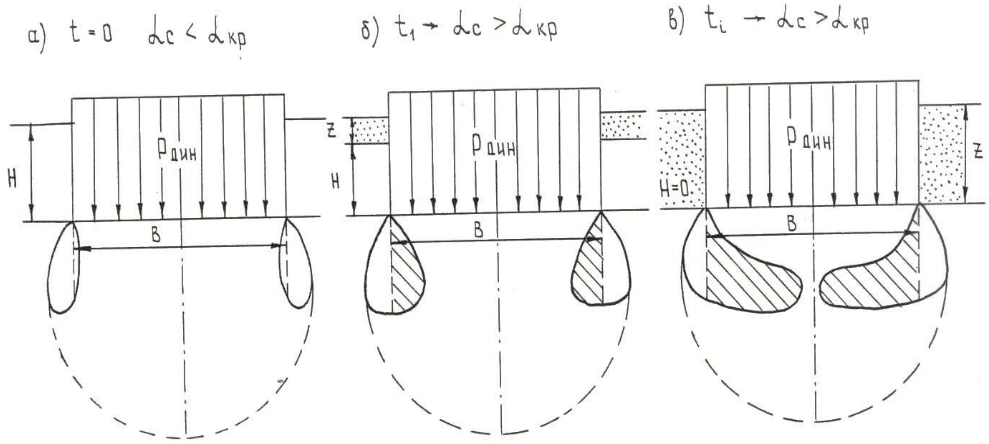

Fig.1 The nature of the development of the zone of plastic deformation at the base of the foundation during soil fluctuations under conditions of $\alpha_s > \alpha_c$

(where, α_c, α_s are, respectively, the values of the critical and seismic accelerations of vibrations of soil particles)

Construction activities that contribute to improving the strength characteristics of the soil are very diverse. The most common and often used measures in the practice of construction include: - mechanical compaction of soils throughout the thickness of weak soil; -chemical fixation of soils, aimed at increasing the amount of adhesion c; - thermal treatment of soil, increasing the strength of connectivity; - drainage of groundwater using various drainage devices; - artificial compaction of the thickness by using various dynamic influences (explosion, vibration, etc.).

In accordance with the direction of our research, among the noted measures, the last one is the most appropriate, i.e. vibration compaction of the thickness of weak soil. It is known that vibration compaction of soils by rollers is widely used in the practice of hydraulic engineering and road construction.

Conclusions

In our view, and as confirmed by the conducted research, the increase in seismic resistance of moistened clay and subsidence loess soils when using vibration compaction is due to the following factors:

- the soil experiences dynamic 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 φ and the connectivity Cw;
- the magnitude of the critical acceleration increases. α_c

The method of compaction of soils using vibratory rollers is an effective and accelerated method of preparing the foundations of buildings and structures on weak clay soils, it is also 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.

In this regard, recommendations have been developed on vibration compaction of the foundations of buildings and structures, as well as on vibration compaction of bulk soil laid to fill the pit around the foundation.

In conclusion, it should be noted that in the conditions of Uzbekistan, where additional deformations in clay and loess bases, as well as bulk soils filled in around the foundations of buildings and structures, under seismic influences, the method of compaction of soils using vibratory rollers is the most reliable and economical way to prepare the foundations. The cost of 1 m^3 of compacted soil is 2-3 times cheaper compared to surface methods of compacting soils with heavy ramming. It must be said that when calculating the economic efficiency of the soil compaction method using vibratory rollers, options for preparing the bases should be considered to ensure the complete elimination of the subsidence properties of loess soils

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