Seismic resistance of loess soils

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Abstract. The article is devoted to the study violation of soil stability loess soils and their transition to a state of liquefaction under strong seismic influences. The research dynamic acceleration was carried out to determine the physical and soil properties structure of cohesive soils. The results of experiments on the study of changes in the resistance to soil shear under conditions of intense vibration are presented. Formulas are given for determining the values of. With prolonged exposure, dynamic loads affect. In order to bring the soil into a liquefied state, the stability of connected soils must be violated. In many cases, it leads to a violation of seismic accelerations in them, the soils may be in a wet state.

1 Introduction

Scientists from Japan [1-3], Russia [4-10], the USA [11-15], Uzbekistan [16-20] and others were at the moment, methods of dynamic liquefaction of sandy soils in a humid state were ready. The authors did not deal with connected soils in dynamic liquefaction, they can be distinguished by their characteristics from sand.

In the article, the authors drew attention to loess soils and dynamic pressures on them, which affects the dynamic load.

The structures of moistened soils and their transitions during fluctuations to a liquefied state, they can be determined using seismic forces. They can be checked out to give maximum seismic acceleration.

Acceleration of oscillations can be written in this form (a_a)

$$a_a = a_s - a_t \tag{1}$$

where aп is the acceleration that resists with different forces, ground adhesion (cw) and friction (φw) [17].

In our experiment, various accelerations were carried out, in which the water-saturated soil was not disturbed by the change. In these cases, the resistance shift was determined in this way τ1.

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$$\tau' = \sigma_{din} tg\varphi_w + c_w \tag{2}$$

Dynamic stress σ_{din}, the weight of the load on the depth of the soil (φ_w), and on the own weight of the soil. In the wet state, soil adhesion and friction angle C_w.

In the dynamic mode of the thickness of the soil, acceleration may be less, it depends on the soil, Acceleration always depends on mechanical properties of the soil with strength characteristics. [16]:

$$\alpha_t = \mu'\left(\sigma_{din} tg\varphi + c_w\right) \tag{3}$$

2 Research method

The problem of shear resistance is the most difficult in the case of concrete soils that differ from bulk (sand, etc.) in that the particles of these soils are interconnected by plastic and partially rigid (cement - crystalline) compounds, while their shear resistance (strength) will mainly be determined by their connectivity (adhesion forces).

The analysis of numerous natural cases of loss of stability with the transition to a liquefied state of such soils during strong earthquakes and experimental research data allowed Rasulov H. Z. to develop a physical theory about the dynamic violation of the structure of moistened cohesive (loess) soils [l7]. This theory is based on possible variations in dynamic conditions of soil shear resistance parameters in the following form:

1. At (ac<aп), the soil retains its natural structure and the change in shear resistance is determined taking into account only the inertia forces caused by fluctuations in the system of foundation structures, which is typical for cases of shaking of dense soils when exposed to relatively weak earthquakes.

разрушается структура грунта и определяется сопротивление сдвигу с учетом переменного напряженного состояния почвенной среды, а также изменяющихся в этих условиях прочностных параметров грунта

At ac>aп, the ground shear resistance was determined first, and at this moment the structure and strength characteristics of the soil are destroyed in the soil, which is typical for cases of fluctuations of weak soils under the influence of intense seismic loads.

This change in relation to dense and dry soils can be reflected, first of all, on the internal friction forces acting in the soil. The latter can also be observed in plastic soils due to changes in density associated with unloading and a possible increase in soil moisture, which naturally leads to a decrease in the number of true angles of internal friction φw and adhesion of rocks cw, which leads to a drop in overall shear resistance, or vice versa.

The internal friction forces in the soil under the conditions under consideration increase (or decrease) almost simultaneously after applying an additional load to the soil (conditionally instantaneous reaction).

Experience shows that all cohesive soils differ in their ability to maintain the density achieved at a higher load to one degree or another during unloading. This is clearly evident in compression experiments conducted in successive loading and unloading cycles. Finally, the unloading branch usually falls below the load branch, and at the same time, under the same loads, the density of the rock was initially at a higher load, and then some unloading was experienced, it happens in all cases higher. However, in different breeds, the nature of the manifestation of this process turns out to be far from the same.

Increment or weakening of the shear resistance of connected soils at the same values of the load change ±Δp turns out to be significantly lower under unloading conditions (-Δp)

compared to the value under load conditions (+Δp). However, the impact of the load is also less significant due to the short duration of the seismic load.

The above circumstance forces, when assessing if we take into account all the parameters, we must prepare the soils for strength characteristics ±Δp in the form of:

$$\tau_c = (\sigma \pm \Delta\sigma) tg\varphi_w + c_w \tag{4}$$

Turning to the second point, we note that seismic impacts applied to moistened cohesive soils are perceived primarily by internal connections acting in them cw. As long as the internal forces are not overcome by the acting seismic pressure (stress), the cohesive soil will behave like a quasi-elastic body with only elastic coupling forces.

The coupling forces in this case, as in others, mean the resistance of the structural joint to any moving particles connected by them, regardless of the magnitude of the external pressure.

If the seismic force action, expressed in the form of acceleration (ac), exceeds the threshold value (determined taking into account the pressure change inside the fluctuating medium due to the variability of the external load), characteristic of these soils and due to its structural strength, these connections may be broken.

The conditions and soil violations these links can be explained as follows.

During an with various earthquakes, the soils always shift and there is a process of compression. Since soils have solid, liquid, and gaseous phases. At the same time, along with elastic deformations, destruction of the structure and irreversible deformations of the soil are sometimes observed.

It is believed that under the action of a tangential seismic load, the destruction of the structural bonds of the soil (viscoplastic and rigid) will be observed simultaneously. At the same time, special importance is attached to the plastic connectivity (cw) of the soil, changes in its properties and composition. In the process of concussions, the orientation of molecules in the water-colloidal shells of the soil is disrupted, and at the same time physically bound water turns into free water, which leads to a weakening, and in certain conditions to the complete disappearance of cohesive and soil cohesion.

However, this process is complicated by the occurrence of a hydrodynamic effect during shaking, which occurs when the broken bonds of soil particles are compacted.

In conditions of complete water saturation of the thickness, particle compaction can occur only in the case of outflow from the thickness of some excess volume of water in the ground for the new state of its density, which will lead to soil filtration a certain pressure gradient. The latter is supported by the excess pressure (dynamic pressure) arising from the shaking in the soil thickness, increasing in depth (z) and in time (t).

Thus, in conditions of weakening connectivity and the possibility of compaction in the soil thickness, back pressure arises, weighing soil particles. This circumstance contributes to the most intensive weakening of all the possibilities of the soil, which remains undisturbed for one reason or another. Contacts between particles weaken or completely disappear, which leads to inhibition of the acquisition of new internal connections. The entire mass of soil, devoid of bonds, can acquire the properties of a liquid, which is sometimes observed in experimental studies.

Summing up, it can be assumed that under the conditions of concussions in a connected ground, quite complex phenomena arise that are subject to complex accounting for their quantitative prediction. As a rule, the above is associated with a drop in the strength of soils during vibration. Hence, it became necessary you should always pay attention to the soils decrease in strength (shear resistance) of such soils in relation to a given time, taking into account the duration of a possible seismic impact, under the influence of which the process of weakening connectivity (cw) and a gradual increase in dynamic pressure (h) can develop.

This makes it possible to represent the value:

$$\tau_c = \left[(\sigma \pm \Delta\sigma) - \gamma_w h_t\right] tg\varphi_w + c_{w,t} \tag{5}$$

According to expression (5), the decrease in shear resistance of water-saturated soils under seismic influences is characterized by a weakening in time of connectivity (cw) and the stress state at a constant angle of internal friction.

To determine the change in dynamic pressure (h) depending on the duration of the oscillation (t), a dependence of the form is proposed

$$h(z,t) = \frac{v_o}{k_f}\left(H_z - \frac{z^2}{2}\right)\left(e^{-\mu} - e^{\lambda}\right) \tag{6}$$

The amount of soil connectivity under these conditions:

$$c_w(t) = c_w(k) + \left[c_w(n) - c_w(k)\right]e^{-\mu} \tag{7}$$

In expressions (6) and (7): vo is speed detection soil, determined by experiment in the form: $\frac{dn}{dt}$,

n is soil porosity; kf is the filtration coefficient: H is ground thickness; z thickness horizon under consideration; μ - some parameter depending on the properties and condition of the soil, determined experimentally; cw(n), cw(k) are the initial and final values of the soil connectivity.

3 Research and discussion

As an example, all experiments were conducted in the laboratory to identify the role of factors affecting the liquefaction of water-saturated loess soils under the influence of oscillatory movements with different intensity are illustrated below.

The change in the density of the soil in the process of fluctuations exceeding the critical value all the results were shown in the first figure the study on sandy loam soil is given.

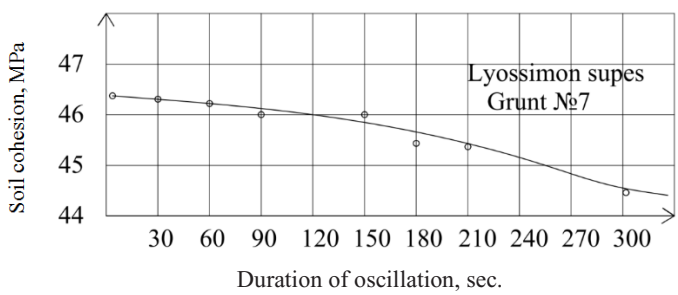

Fig. 1. Change in soil porosity during dynamic oscillation

As noted above, the process of compaction of the soil during concussions is accompanied by a simultaneous decrease in the plastic connectivity of the soil, you can look at the second and third figure

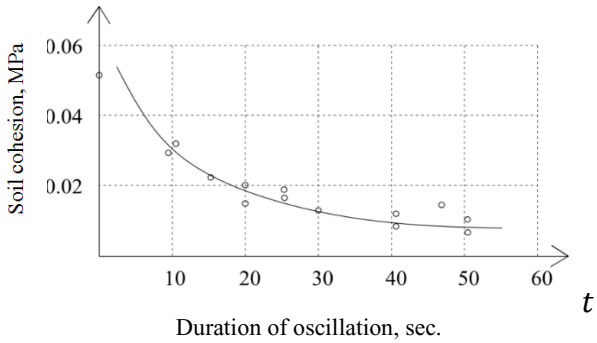

Fig.2. Change in the plastic connectivity of loess soil in the state of liquefaction with acceleration $\alpha_c = 2500\ mm/s^2$

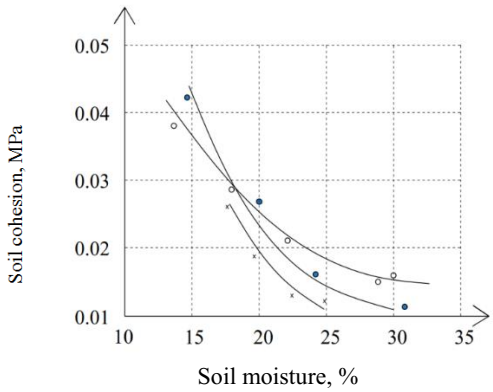

Fig.3. Change of soil connectivity (destroyed structure) depending on humidity at ac intensity = 1600 mm/s^2

In accordance with the above, any decrease in soil adhesion and the beginning of thickening occurs when the intensity of the impacting vibration exceeds the value of the critical (threshold) acceleration characteristic of this soil, causing its natural strength, the state of density and humidity of a particular soil.

Under the conditions under consideration, a dynamic pressure arises in the water in the thickness, which weighs the soil particles, lead to soil liquefaction.

In turn, the dynamic pressure gradually reduces the critical acceleration, which indicates the expansion of the liquefaction zone more and more horizons of the thickness (Fig. 4.).

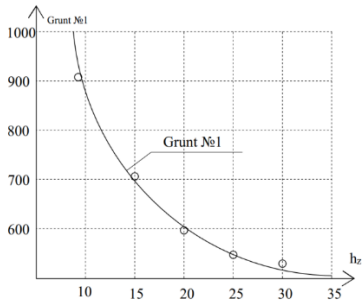

Fig. 4. Influence of dynamic pressure on the value of critical acceleration.

The change in dynamic pressure in thickness and oscillation is indicated in Figure 5-6.

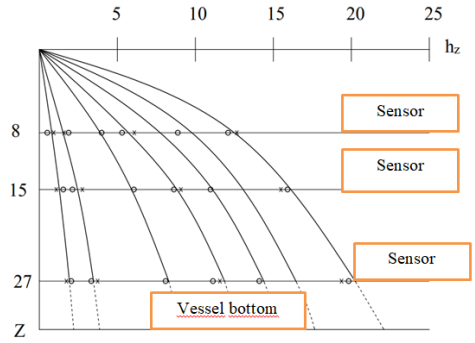

Fig. 5. Change of dynamic pressure in depth.

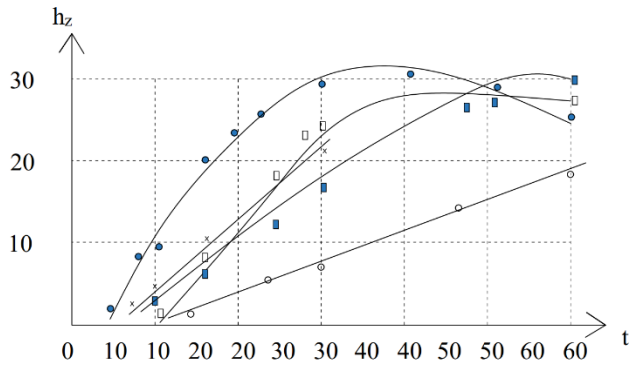

Fig.6. Change in dynamic pressure during oscillation.

4 Conclusion

1.The structural state and change of soils in chemical and physical results, which varies from the soil compacted particles in which the filtration pressure acts.
2. In soils, if there is no connectivity, there is a direct influence from the soil moisture, they have minerals, salt content, dynamic loads in their composition.
3. The liquefied state of the soil is affected by its speed and the intense nature of the soil.
4. We should always study the dynamic pressure of the soil in which it can lead to liquefaction if they have seismic zones.

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