RESULTS OF EXPERIMENTAL RESEARCH ON STUDYING THE DEPENDENCE OF THE CRITICAL ACCELERATION OF GROUND VIBRATIONS FROM VARIOUS FACTORS UNDER CONVERSATION CONDITIONS

Khakimov Gayrat Akramovich
Abduraimova Khadicha Rakhmonkulovna
PhD, Associated professor at department "Design building and structures", Tashkent University of Architecture and Civil Engineering, Tashkent, Uzbekistan
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Abstrakt. This article gives the concept of the critical acceleration of loess soil, presents the results of experimental studies on the dependence of the critical acceleration of vibration of moistened loess soil on various internal (composition, condition and properties of soil) and external (vibration intensity and its parameters, external loading) factors under conditions concussions.

Keywords: critical acceleration, seismic acceleration, liquefaction, loess soil, seismic stability, deformation, density, structure, connectivity, strength characteristics, humidity, loading.

Introduction. It is known that each type of soil, depending on its composition, condition and properties, has its own critical acceleration of vibration of soil particles. Most authors call the critical acceleration α_{cr} such an acceleration of vibration of soil particles, upon reaching which the soil is in a state of limiting equilibrium and a slight excess of the acceleration over the critical one is sufficient for the water-saturated soil to go into a state of loss of its dynamic stability, i.e. into a state of liquefaction. As a result of liquefaction, a drop in the structural strength of the soil occurs and the development of significant plastic deformations both in the soils located in the zones bordering the foundation and in the sub-foundation zone of the foundation, leading to unacceptable deformations of the structure itself.

It follows that the value of the critical acceleration can be considered as a certain threshold acceleration at which the loess soil retains its static structure and strength, at the same time above which a violation of the structure (liquefaction) and the process of plastic deformation of the soil begin.

Results and Discussion. To assess the possibility of dynamic disturbance of the structure of sandy soils, critical acceleration was used by N.N. Maslov, D.D. Barkan, O.A. Savinov (Russia), and abroad this indicator was often taken as a characteristic of the dynamic stability of sandy soils by E. Bazant, H.B. Sid, R. Whitman, P. Ortigoza de Pablo and others.

To assess the seismic stability of moistened clayey and loess foundations, critical acceleration was used by Yu.A. Vellim (Russia), H.Z. Rasulov (Uzbekistan), etc.

Yu.Ya. Welly, studying the critical acceleration for cohesive soils, established the important role of the duration of forced vibration, necessary for the weakening and destruction of the bonds of these soils under vibration conditions. As a critical acceleration for cohesive soils, he proposes to accept such an acceleration of oscillatory motion, under the influence of which for 5 minutes. cohesive soil remains at rest.

We, under the guidance of prof. H.Z. Rasulov also conducted research to determine the critical acceleration for subsiding loess soils, which established the main and sometimes decisive role of soil cohesion in the duration required for the destruction of its structure to occur. Depending on the strength of the bonds, the required duration of disturbance of the soil structure at a certain intensity of shaking is established. Analysis of our experimental data shows that soil deformation (disturbance of soil structure) during the vibration process in many cases begins after 5-30 seconds. or more from the moment a dynamic load is applied to the soil, which is a characteristic feature for cohesive soils. This is explained by the fact that when loess soil, which has some cohesion between particles, is shaken, the dynamic load is perceived primarily by these connections, the complete destruction of which requires a certain time. The nature of the change in connectivity over time obviously depends on the physical and chemical phenomena in the soil that occur during the vibration process. This circumstance confirms the previously made conclusion about the absence of soil deformation if the adhesion forces are not violated during vibrations, i.e. when the critical acceleration is greater than the seismic acceleration. Apparently, in the experiments of Yu.Ya. Valley, clayey soils with a sufficiently high cohesion value were used, the destruction of which required time within 5 minutes.

The overall stability of the soil under dynamic conditions and the development of extreme plastic deformations in the base under the base of the foundations depends primarily on α_{cr}, i.e. on the critical acceleration of vibration. Therefore, one of the tasks of experimental research was to study the influence of various factors on the value of critical acceleration.

Among them there are internal: composition, condition and properties of soils and external: vibration intensity and its parameters (duration, frequency, amplitude), external loading.

Let us consider the results of experimental studies to study the dependence of the critical acceleration of vibration on various factors under shaking conditions.

1. Critical acceleration and moisture content of loess soil. During the experiment, the test soil samples were given different moisture levels by artificially soaking them. With a humidity of less than 10%, even with vibration accelerations of 5000 mm/s2, which exceeds the values of the maximum seismic vibration accelerations under a 9-point seismic impact, the soil structure was not disrupted, and the soil did not experience any vertical deformations. When the humidity reached 18-20%, there was a sharp decrease in the critical acceleration value. This is explained by the weakening of the cohesion (decrease in strength) of rocks with increasing humidity. It is known that additional saturation of rock with water is always accompanied by swelling of the soil, associated with thickening of the water shells of particles. At the same time, soil particles move away from each other, leaving the zones of molecular attraction, weakening the cohesion forces between the particles. The force of attraction of water to a particle depends, in turn, on the thickness of the water shells, with an increase in which the force of molecular attraction decreases. This circumstance indicates a relatively slight disturbance of the structure of loess soils and a decrease in the value of critical acceleration with increasing humidity. This decrease continues until the humidity level Sr = 0.8 and then the value of the critical acceleration tends to a constant value, which can be clearly seen from the graph shown in Fig. 1.

It follows that the loss of dynamic stability of the studied soils occurs most intensively in the humidity range from optimal to water saturation.

2. Critical acceleration and loading. Research by N.N. Maslova, P.L. Ivanova, V.A. Ershova, Kh.B. Sida, H.Z. Rasulov et al. found that critical acceleration is closely related to the

IBAST | Volume 3, Issue 10, October

effect of normal stresses on the thickness, and this dependence is linear, and is well described by the empirical formula proposed by N.N. Maslov:

$$\alpha_{\text{кр}} = \alpha^{\text{o}}_{\text{кр}} + \text{aP}_{\text{o}}$$

where, $\alpha^{\text{o}}_{\text{кр}}$– the value of critical acceleration in the absence of external load;

a – coefficient depending on the strength characteristics of the soil;

aP_{o} – external loading.

Figure 2 graphically illustrates the dependence of $\alpha_{\text{кр}}$ on external load. As graphs of this kind show, as the load increases, the critical acceleration increases, i.e. there is a linear relationship between them.

With an increase in pressure from 0.1 to 0.4 MPa on identical twin soil samples, the critical acceleration increased from 500-700 mm/s2 to 950-1050 mm/s2, i.e. more than 1.5 times. With increasing load, the range of critical accelerations decreases, tending to a constant value, which is apparently due to an increase in soil density during compaction.

3. Critical acceleration and soil density. Figure 3 shows a graph of the dependence of the critical acceleration $\alpha_{\text{кр}}$ on the density of dry loess-like soil in the form $\alpha_{\text{кр}} = \varphi(\rho_d)$. For a loam sample having 18 percent moisture and load P= 0,075 MPa at dry soil density $\rho_{d=}$1,40 t/m3, critical acceleration is approximately 1000 mm/s2; at $\rho_{d=}$1,45 т/м3 acceleration is equal to 1250 мм/с2, and when $\rho_{d=}$1,60 t/m3 acceleration is 3000 mm/s2, etc.

Thus, we can conclude that with an increase in the density of dry soil, other things being equal, the value of the critical acceleration increases. This is apparently due to an increase in soil cohesion with increasing density, since cohesion in loose, moistened loess varieties is characterized by a small value and can be relatively easily and quickly broken by shaking, thereby ensuring intensive compaction of the soil, and to break the cohesion of dense soils it is required high intensity of oscillatory movement.

The results obtained indicate that the critical acceleration is not constant and depends on the density.

4. Critical acceleration and self-weight of the soil. Many experts, in particular P.L. Ivanov, N.N. Maslov, V.A. Florin, A.A. Nichiporovich (Russia), Kh.Z. Rasulov, Yu.N. Chastoedov (Uzbekistan) and others studied the effect of the own weight of the strata on the stability of soils. Conducting a study with non-cohesive soils P.L. Ivanov noted that the initial tense state, i.e. the state caused by the own weight of the strata is more important in ensuring the stability of water-saturated sand masses under dynamic influence. The state of stress that arises in the thickness from its own weight has a beneficial effect on the depth of the zone where the soil loses its stability. Taking into account the results of the above studies by P.L. Ivanov came to the conclusion that the degree of stability of water-saturated sandy soils at a given depth for a given intensity of dynamic impact is determined by the value of the soil's own weight.

N.N. Maslov (Russia) established the limited role of the own weight of a water-saturated sand mass in the degree of its dynamic stability.

H.Z. Rasulov (Uzbekistan) conducted numerous experiments with various sandy soils in order to study the influence of the soil's own weight on the value of the critical acceleration. He noted that the own weight of a layer of water-saturated soil when applying a dynamic load has a positive effect, increasing its dynamic stability. But in the process of dynamic impact on the thickness of water-saturated soil, the value of its own weight decreases, as a factor that increases dynamic stability. A decrease in the value of the soil's own weight confirms the process occurring in the water-saturated soil mass under conditions of dynamic influence on it: gradual disruption of the soil structure during shaking; downward shift of soil grains under the influence of their own weight in conditions of disruption of interparticle contacts; the occurrence in the thickness and a consistent increase in excess pressure (dynamic pressure) over time to the maximum possible values for a given horizon; time-consistent deepening of the core with a simultaneous decrease in the critical acceleration value in the lower horizons, i.e. the phenomenon of layer-by-layer liquefaction.

Taking into account the above, it can be noted that the own weight of water-saturated soils has a positive effect on the critical acceleration at the moment of application of a dynamic load, and in the future its influence will depend on the duration of the shock.

5. Critical acceleration and speed of propagation of seismic waves. As shown by a survey of the consequences of many destructive earthquakes within the same seismic zone, the amount and nature of damage to buildings and structures are different on different soils, which is largely explained by the difference in the nature of vibrations due to a significant difference in the speed of wave propagation. Oscillations caused by an earthquake and the speed of their waves depend largely on the elastic properties of the medium through which the waves propagate.

Under dynamic (seismic) conditions, ground tremors are affected by various vibrations. For soils, the most dangerous vibrations are considered to be horizontal vibrations, which can arise from longitudinal and transverse waves, but more often the most intense vibrations are from a direct horizontally polarized transverse wave. With a longitudinal wave, soil particles oscillate in the direction of wave propagation, and with a transverse wave, soil particles oscillate perpendicular to the direction of wave propagation.

Many experts, in particular N.D. Krasnikov (Russia) notes that the speed of wave propagation in soils depends on their condition, which is very important especially in relation to moist loess soils.

All other things being equal, with an increase in soil moisture, the speed of seismic waves increases, and the strength characteristics of the soil decrease, and this will lead to a sharp decrease in the value of the critical acceleration.

Research by N.D. Krasnikov also showed that the velocity of seismic waves significantly depends on the stressed state of the soil, i.e. with increasing pressure on the ground, the speed of propagation of seismic waves increases.

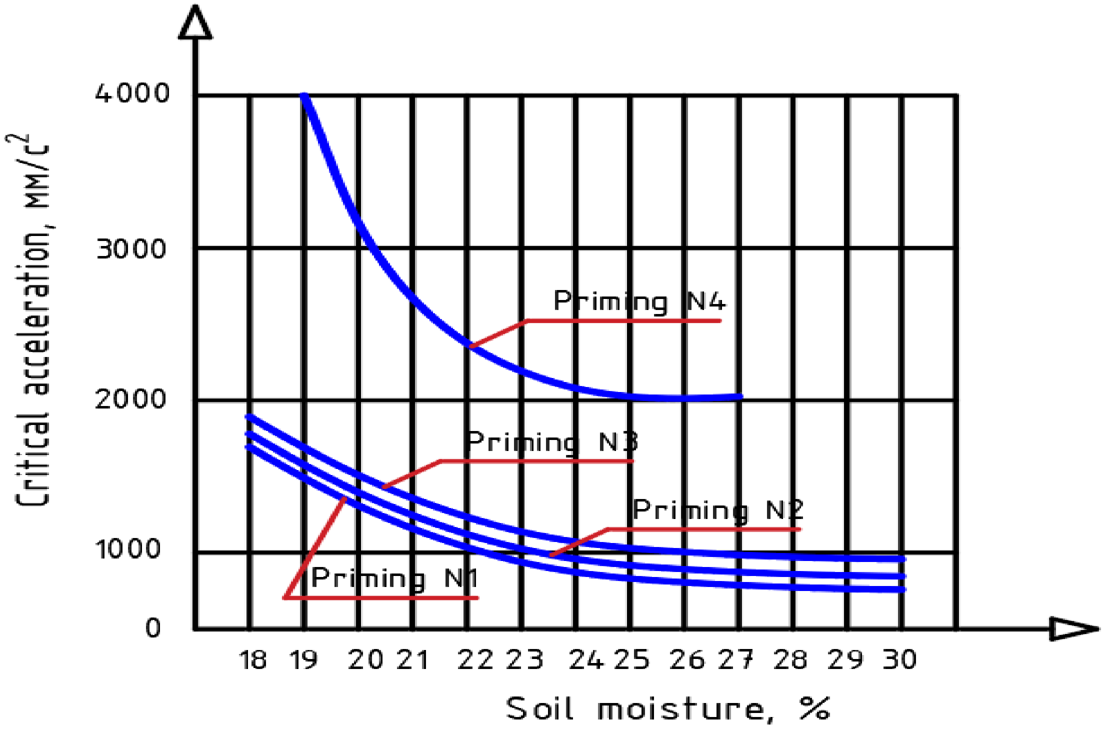

Fig. 1 Change in critical accelerations of loess-like soils with increasing humidity (at P = 0.3 MPa)

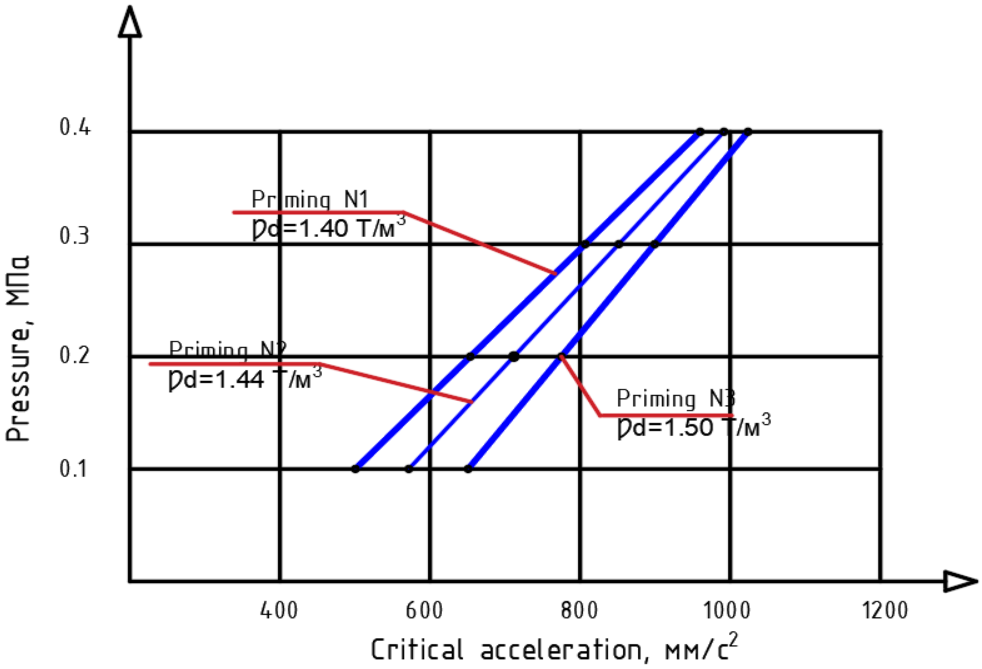

Fig.2 Dependence of the critical acceleration of loess-like soil on pressure. The experiments were carried out with soil moisture Sr ≥ 0.8

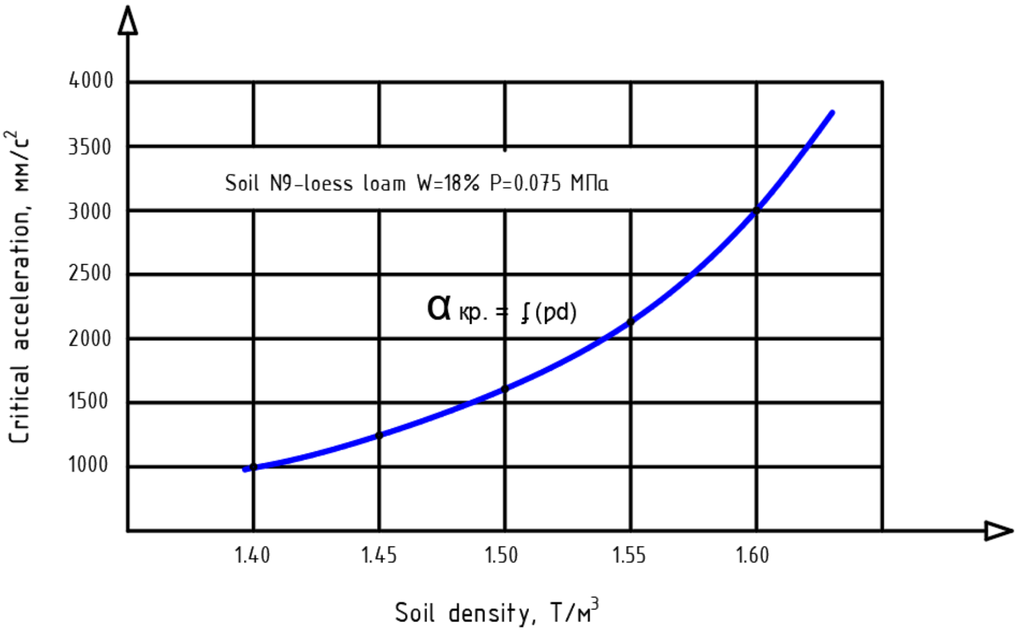

Fig.3 The nature of the change in critical acceleration depending on the density of loess-like soil

Conclusions. The results of experimental studies to study the dependence of the critical acceleration of ground vibration on various factors under shaking conditions showed:

1. Disruption of the structure and liquefaction of moistened loess soils under the influence of dynamic (seismic) forces does not occur in all cases, but only after the critical acceleration has been overcome by the current dynamic (seismic) acceleration. When the critical acceleration is greater than the seismic acceleration, the loess soil retains its structure and can be considered as a quasi-solid body with elastic properties. And when the critical acceleration is less than the seismic acceleration, the structure of loess soils is disrupted and the soil goes into a liquefied state.

2. Possibility of reducing the critical acceleration value with increasing soil moisture during oscillation.

3. Possibility of reducing the value of critical acceleration by decreasing the role of the additional load during the oscillation process.

4. Any deepening of buildings and structures will entail an increase in the value of the critical acceleration and, accordingly, its stability. However, it should be noted that the occurrence of dynamic pressure in the zones bordering the foundation, above its base, can immediately reduce the effect of deepening and the magnitude of the critical acceleration. The role of surcharge as a factor increasing the dynamic stability of the soil decreases with depth.

5. The self-weight of water-saturated soils has a positive effect on the critical acceleration at the moment of application of a dynamic load, and in the future its influence will depend on the duration of the shock.

6. With increasing inertia-free load, the critical acceleration increases. With increasing load, the static strength of soils increases.

7. The speed of wave propagation in soils depends on their condition, which is very important especially in relation to moist loess soils. It follows that to determine the speed of seismic waves, it is necessary to take into account the condition of the soil, as well as the magnitude of the stress acting on the thickness. All other things being equal, with soil

moistening, the speed of seismic waves increases, and the strength characteristics of soils decrease. This circumstance will lead to a sharp decrease in the critical acceleration value.

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