

THE INFLUENCE OF EXTERNAL LOADING AND THE OWN WEIGHT OF THE SOIL ON THE SEISMIC RESISTANCE OF THE FOUNDATIONS OF STRUCTURES

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Abstract:

In this scientific article, the results of research on the influence of external loading and the own weight of loess soil on the seismic resistance of the soil foundations of structures during oscillation are considered. As the results of experimental studies have shown, at the beginning of dynamic (seismic) impacts, the loading and own weight of the soil has a positive effect on increasing their dynamic stability, and in the future their influence will depend on the duration of the oscillation. With prolonged fluctuations, the effect of the soil's own weight and loading on increasing the dynamic stability of the base decreases, i.e. after a violation of the soil structure, the strength characteristics gradually decrease and this will lead to deformation (compaction) of the soil. Sometimes, with prolonged fluctuations in the strength characteristics of the soil, it tends to zero. At such moments (complete liquefaction of the soil), the soil completely loses its strength and stability. In these cases, the loading and own weight of the soil negatively affects the dynamic stability of the soil, i.e. heavy structures can melt into liquefied soil during prolonged earthquakes.

Keywords: *loading, ground weight, critical acceleration, seismic acceleration, liquefaction, loess soil, deformation, seismic resistance, structure, strength characteristics.*

Introduction

Introduction. It is known that the general stability of the soil under dynamic conditions and the development of extreme plastic deformations in the base under the sole of the foundations depends primarily on the critical (threshold) acceleration of the oscillation [1,3,8,9].

If the structure and strength of the moistened loess soil are not disturbed during the oscillation, i.e. when the critical acceleration is greater than the seismic acceleration, the deformation of the soil does not occur. The deformation of the soil during oscillation develops after a violation of the structure and strength of the soil (after overcoming the critical acceleration, when the seismic acceleration is greater than the critical acceleration), i.e. after the soil loses its dynamic stability (into a state of liquefaction) [13,15,17,21].

The seismic resistance of the soil bases depends mainly on the strength characteristics of the soil, the value of the normal stress (both from the own weight of the overlapping horizon and the weight of the loading from the structure), etc. The influence of the strength characteristics of the soil on the seismic resistance of the soil foundations, both in static and dynamic conditions, has been studied by many experts and there is quite a lot of data in this area. Therefore, one of the tasks of our experimental research was to study the effect of external loading and the own weight of the soil on the seismic resistance of the soil foundations of structures. [2,6,7,10,11,12,18,19,20,22].

The research carried out on a vibrating installation with sandy soils by R. Wittman, P.O.Pablo, P.L.Ivanov showed that with an increase without inertial loading, the seismic stability of soils increases.

Experiments conducted with moistened loess soils by A.A.Musaelyan showed that an increase in the static strength of loess soils with an increase in the value of sample loading.

The experiments conducted by H.B.Sid and K.Lee with muddy sands showed an increase in the dynamic stability of soils with an increase in the static stress state. Experiments have also shown a decrease in the role of priming depending on the duration of the earthquake.

P.L.Ivanov noted that the condition caused by the own weight of the stratum is of great importance in ensuring the stability of moistened sands under dynamic influence. Here, the stress state arising in the thickness from its own weight has a beneficial effect on the depth of the zone where the soil loses its stability. The degree of stability of moistened sands at a given depth at a given intensity of dynamic action is determined by the magnitude of the own weight of the sand thickness.

N.N.Maslov established the limited role of the intrinsic weight of a water-saturated sand column in the degree of its dynamic stability.

H.Z.Rasulov noted that the intrinsic weight of the water-saturated soil column, when applied to a dynamic load, has a positive effect, increasing its dynamic stability. Further, with the continuation of the dynamic effect on the thickness of the water-saturated soil, the value of its own weight decreases as a parameter that increases dynamic stability.

It follows that the own weight of water-saturated soils has a positive effect on seismic stability at the time of application of dynamic load, and in the future its effect will depend on the duration of the earthquake.

Materials and methods. In order to study in more depth the effect of external loading and the own weight of the soil on the dynamic stability (deformability) of the foundations of structures, we conducted experimental studies.

Experimental studies were performed on a vibrating installation in laboratory conditions [4,5].

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 Гц. The vibration parameters (frequency, amplitude) created by this experimental vibration installation are close to the parameters of seismic vibrations. For example, the frequency of the devastating Tashkent-Uzbekistan earthquake on April 26, 1966 was 10 Гц [16].

It is known that the critical acceleration of the soil determines its dynamic stability. When the acting external dynamic (seismic) acceleration overcomes the critical acceleration, the dynamic stability of the soil is disrupted, i.e. the soil structure is disrupted (destroyed) and the soil is deformed (compacted) [13,15,17,21,23].

Analysis and results. In our experimental studies, we paid special attention to the behavior of critical acceleration of the soil, as determining the dynamic stability of the soil, at various loads.

As the experimental results show (Table 1), with an increase in external pressure (overload), dynamic stability increases, i.e. critical acceleration. Also, the density of the soil has a positive effect on increasing the dynamic stability of the soil [14,15].

Table. The effect of priming on the dynamic stability (critical acceleration) of the soil

№	Loading, in MPa	Degree of humidity, Sr	Critical acceleration of loess-like soil, α_{kp} в mm /s ²		
			Soil 1 soil density, 1,45 т/м ³	Soil 2 soil density, 1,49 т/м ³	Soil 3 soil density, 1,55 т/м ³
1.	0,1	0,8	500	600	650
2.	0,2	0,8	650	700	750
3.	0,3	0,8	800	850	900
4.	0,4	0,8	950	1000	1050

The table illustrates the dependence of α_{kp} on external loading. As the table data show, the critical acceleration increases with increasing overload, 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 500-650 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.

Critical acceleration is closely related to the effect of normal stresses on the thickness (both from the own weight of the overlapping horizon and the weight of the loading from the structure), and this dependence is linear in nature, and a well-described empirical formula proposed by N.N.Maslov:

$$\alpha_{kp} = \alpha_{kp}^0 + aP_0$$

where, α_{kp}^0 – is the magnitude of the critical acceleration in the absence of an external fits;

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

P_0 – external overload.

As can be seen from this formula, with an increase in inertia-free loading, the critical acceleration, i.e., the dynamic stability of the soil increases.

The dynamic stability of the soil foundations, along with parameters such as the own weight of the overlapping horizon and the weight of the loading from the structure, is also positively affected by the size of the structure's penetration into the ground, which is very important when designing structures, especially in seismic areas. It should be noted here that the occurrence of dynamic pressure during prolonged fluctuations in the zones bordering the foundation, above the base of the foundation, reduces the effect of deepening and dynamic stability. And the role of priming as a parameter that increases the dynamic stability of the soil decreases with depth.

The decrease in the value of the soil's own weight confirms the process occurring in a water-saturated soil column under conditions of dynamic impact on it: a gradual violation of the soil structure during shaking; a shift of soil grains downwards under the influence of its own weight in conditions of violation of interparticle contacts; the occurrence in the thickness and the consistent increase of excessive pressures (dynamic pressure) in time to the maximum possible values for a given horizon; the phenomenon of layered liquefaction.

Taking into account the above, it can be noted that the own weight of water-saturated soils positively affects the critical acceleration at the time of application of dynamic load, and in the future its effect will depend on the duration of the shaking.

As noted above, with prolonged fluctuations, the soil turns into a liquefied state [13-15]. During liquefaction, the soil completely loses its strength and stability. The loading and own weight of the soil as a factor that increases dynamic stability in these conditions negatively affects the dynamic stability of the soil, i.e. heavy structures can melt into liquefied soil during prolonged earthquakes.

During the 10-point earthquakes (according to the international scale MSK-64) of 1936 in India, most of the structures were completely submerged in liquefied soil and disappeared. These structures were built on heavily moistened soils with a capacity of hundreds of meters

During the 1964 Niigata (Japan) earthquake (magnitude 7.5 on the Richter scale), more than 300 buildings of the city tilted by 30° and sank into liquefied soil, in places up to 5 m. According to B.N. Faulconer, during the earthquake of more than 20, mostly heavy concrete and reinforced concrete structures sank into the ground by more than 2 m. The thickness of the soils under the city reached up to 200 m and are represented by modern alluvial sandy deposits, sometimes mixed with very homogeneous silty soils. The groundwater level in places reached up to the surface of the earth.

Conclusions and recommendations. Studying the influence of external loading and the own weight of loess soil on the dynamic stability of the foundations of structures during oscillation, we came to the following conclusion:

1. At the beginning of dynamic (seismic) impacts, the own weight of the thickness of moistened (water-saturated) soils has a positive effect on increasing their dynamic stability. However, with prolonged fluctuations, a decrease in the value of its own weight is observed due to the weighing of soil particles by back pressure. With prolonged fluctuations, the dynamic pressure increases proportionally and the soil becomes liquefied. With complete liquefaction, the soil will not have the slightest resistance to dynamic (seismic) load. In such cases, the role of the soil's own weight will be reduced to zero. It follows that the own weight of moistened (water-saturated) loess soils has a positive effect on stability at the time of application of dynamic load, and in the future its effect will depend on the duration of the oscillation.
2. 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 overcoming the critical acceleration by the active dynamic (seismic) acceleration. When the critical acceleration is greater than the seismic acceleration, the loess soil retains its structure, and when the critical acceleration is less than the seismic acceleration, the structure of loess soils is disrupted and the soil gradually turns into a liquefied state.
3. The deepening of structures will entail an increase in its seismic stability. However, it should be noted that the occurrence of dynamic pressure in the zones bordering the foundation, above its sole, can immediately reduce the effect of deepening the foundation. The role of priming as a factor that increases the dynamic stability of the soil decreases with depth.
4. The seismic resistance of the soil increases linearly with the value of normal overload stresses.

5. As noted above, with prolonged fluctuations, the soil turns into a liquefied state (during liquefaction, the soil completely loses its strength and stability) and loading under these conditions negatively affects the dynamic stability of the soil, i.e. heavy structures can melt into liquefied soil during prolonged earthquakes.
6. The obtained results on the study of the influence of external loading and the own weight of the soil on the seismic resistance of the foundations of structures can be taken into account in the design and construction of buildings and structures on loess and other connected soils, especially in seismic areas.

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