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*working out of condition of dynamic stability loessial  
soils*

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## Introduction

Designing and erecting buildings and structures on moistened (water-saturated) loess soils in seismic regions, ensuring their strength, stability and uninterrupted operation is one of the most complex problems of modern construction practice. High rates of economic development characteristic of many Union republics of the country favor construction in large the scale of multi-storey residential buildings, factories, factories, hydroelectric power stations, which requires consideration of various factors, affecting the strength and stability The structure of these structures during the earth's oscillations.

The wide distribution of forest and loess soils, as a rule, in the high-seismic regions, where intensive construction is currently under way, puts this problem among the most urgent. Given that the cost of building buildings and structures in seismic regions rises on average by more than 4%, further improvement of construction methods in these areas, especially on weak water-saturated loess soils, is of major economic importance.

When performing construction work in a zone of high seismicity, the ground conditions exert a strong influence on the seismic stability of buildings and structures erected on them. As the practice of construction shows, especially dangerous in this respect is the water-saturated loess soils lying at the base of the structures and characterized by residual deformations caused by earthquakes.

The need to take into account ground conditions when designing structures in seismic regions is currently being advanced by construction practice.

The issue of assessing the influence of soil properties in the foundation of structures on the increase in seismic intensity in recent years has increasingly attracted the attention of specialists working in the field of earthquake-resistant construction. The main provisions of seismic micro-zoning of cities and populated areas, dictated by instructional documents, in particular HF and P2-A. 12-69, have many drawbacks caused by the under-account of the ground conditions of concrete construction sites. This circumstance is inevitably associated with a rise in the cost of construction by tens of millions of rubles a year.

Construction practice is known for numerous cases of the formation of sediments and distortions of buildings and structures during earthquakes. At the same time, there has always been a significant role in the damage to structures of uneven sediment. The presence of even small uneven sediments in the ground causes additional stresses in the structures, overvoltage and deformation in separate structural elements, which increases the degree of damage during an earthquake. From what has been said, it follows that the development of issues related to the manifestation of sediments in an earthquake is of considerable interest.

The foregoing causes the relevance of the problems of this study, the purpose of which is to study the regularities in the variation of the strength and deformation properties of loess soils, the emergence of a dynamic head, with the identification of its value at various points in the soil strata, and the establishment of the size of the core within which soil may develop under conditions of oscillation. In the end, all these studies contribute to the identification of the criterion of dynamic (seismic) soil stability - critical acceleration, below which the oscillating strata will retain the static structure of the pile, which is important in ensuring dynamic stability of the soil.

Purpose of the study. The aim of the master's thesis is to develop a method of critical acceleration of soil vibration providing dynamic stability of the oscillating strata.

Objectives of the study:

1. Development of a technique for experimental studies of liquefying wet loess;
2. Conducting dynamic studies on various loess soils with the aim of elucidating changes in soil cohesion and identifying factors that affect progress;
3. Investigation of conditions the emergence of a dynamic head and its changes in time, depending on the composition, state, strength and deformation properties of the soil, and also the parameters of the oscillation;
4. Theoretical substantiation of the revealed regularities and development of the method of dynamic soil stability - critical acceleration with experimental verification of contributing factors on this most important indicator.

The scientific novelty of the work is as follows:

1. Studying the dynamics of changes in the strength and deformation properties of forest loams in the loess strata, depending on the composition and condition of the soils under the influence of dynamic loads of varying intensity on them;
2. Factors influencing the change in the connectivity of the ground and the appearance of a dynamic head under shock conditions have been identified;
3. A calculation method for determining the critical acceleration (criterion for the dynamic stability of the soil structure) for a layer with a horizontal surface is proposed.

The reliability of the obtained results is justified by carrying out studies based on the well-known theory of dynamic disturbance of the wetted loess structure and carrying out experimental work using modern measuring instruments and apparatus.

To be protected:

1. Results of studies to identify factors that affect the change in the plastic connectivity of loess in the process of shaking;

2. Obtained dependences of the dynamic head changes on the depth of the thickness and in the process of oscillations;
3. The method of critical acceleration of the oscillation to assess the dynamic stability of soils in an oscillating stratum.

The practical significance of the work is to develop a criterion for estimating the dynamic stability of the soil structure in the composition of the strata, which makes it possible to ensure the necessary stability of the foundation of structures during shaking.

Publication. The main provisions of the work are published in 8 scientific articles, including in 4 journal articles and 4 - in the proceedings of international conferences.

The volume of work. The thesis consists of an introduction, three chapters, conclusion, a list of used literature, including sources, is written on the page of computer text. The work is illustrated with a picture and tables.

The work was completed in 2017 - 2018. at the department of "hydraulic engineering structures, foundations and foundations" of the Tashkent Engineering and Construction Institute under the direction of Ph.D. Narbaeva S.M.

**Chapter 1. The fundamentals of the theory of Kh. Rasulov**  
**<< The disturbance of the structure of moist forest**  
**under seismic influences >>**

1.1 Initial provisions on the violation of the structure of moisturized forest under shaking.

The violation of the stability of the water-saturated loessial sequence under dynamic influence on it does not appear in all cases and with varying degrees of intensity.

At present, there is no doubt that the intensity of the most dynamic effect plays a significant role in this respect. On the other hand, under certain conditions, the natural state of density-the humidity of soils-can plays an important role.

In the light of our studies confirming the points of view of many researchers, it can be considered established that the degree of disturbance of the structure of water-saturated loess soils during shaking, and hence their dynamic regime is determined by the impact of only a certain part of the dynamic load applied to them.

This load is estimated from the magnitude of the maximum seismic acceleration, it is characteristic of the oscillation arising in this case-  $\alpha_{seis}$

$$\text{As is well known, } - \alpha_{seis} = 4\pi^2 Af^2(1.1)$$

Where A is the amplitude of the oscillations, f is the oscillation frequency.

We denote the active part of the acceleration of the oscillation through the  $\alpha_{calcul}$ . Then we can write:  $\alpha_{calcul} = \alpha_{seism} - \alpha_{kr}(1.2)$

Here  $\alpha_{kr}$  is the magnitude of the critical acceleration, as some limiting acceleration, which extinguishes within the soil strata by forces acting in the resistances and, in the first place, as analysis showed, by the adhesion forces ( $C_w$ ) and internal friction ( $\varphi_w$ ).

Under this condition, the magnitude of the critical acceleration can be regarded as an acceleration in which the loess soil does not go over into a dynamically excited state. For all values of the accelerations  $\alpha_{kr}$ , the resistance of loess soil to a shift in any of its states should be estimated from the formulas corresponding to the static regime, in particular, according to the expression:

$$S_{pw} = P_n * tg\varphi_w + C_w(1.3)$$

Where  $P_n$ - is the normal stress from the weight of the soil lying above the horizon in question and the weight of the structures?

$\varphi_w$ - is the angle of internal friction at moisture w;

$C_w$ - total grip for soil moisture w.

Obviously, the higher the value of the critical acceleration  $\alpha_{kr}$ , the smaller the value of the acceleration  $\alpha_{rec}$ , which determines the dynamic regime of the soil sequence.

However, the foregoing is complicated by the influence on the process of the time factor t, depending on which, under certain conditions, the value of the calculated acceleration  $\alpha_{calcul}$  can increase.

The role of duration shaking in the dynamic stability of cohesive soils in experiments was noted by prof. N.N.Maslow and Y.Y.Velly (1957). Even earlier, in 1951, P.L.Ivanov, who conducted experiments with water-saturated sands, established a linear dependence of the disturbance of soil stability on the duration of the concussion. In particular, they established the functional dependence of the critical acceleration  $\alpha_{kr}$  on the duration of concussion of cohesive soil, that is,  $\alpha_{kr} = f(t)$ . However, the study foreseen by these scientists was only the initial stage of the study of the question and, naturally, the nature of the phenomena as a whole could not be revealed.

The relationship of the critical acceleration to the strength characteristics of the soil is unquestionable. In particular, N.N.Maslov described this dependence in the form:  $\alpha_{kr} = \xi * S_{p*w}(1.4)$

Where  $\xi$  - is some parameter describing the ground facilities and the nature of the dynamic regime.

Substituting the values of  $S_{p*w}$  from the expression (1.3) into the dependence (1.4), we have:  $\alpha_{kr} = \xi(P_n * tg\varphi_w + C_w)(1.5)$

In accordance with expression (1.5), the change in the value of  $\alpha_{kr}$  in seismic conditions can occur due to a partial or complete decrease in the strength

parameters of the loess, such as normal stress ( $P_n$ ), friction angle ( $\varphi_w$ ) and total adhesion ( $C_w$ ), which, under all other conditions to an increase in time in the value of the calculated acceleration.

Thus, the disclosure of nature, the disruption of the stability of cohesive soils reduces to the performance of resistance parameters changing during shaking for their shear.

In accordance with the formulation of the question, seismic impacts applied to connected soils are first of all perceived by the internal connections acting in them. When the seismic acceleration exceeds the critical value inherent in a given soil, these relationships may be violated. The possibility and degree of violation of these relationships are determined by the intensity of the effective design acceleration ( $\alpha_{calcul}$ ) and in relation to the duration of the tremor, moistened by the forest.

The conditions and nature of the violation of these links are as follows. As is known, during the earthquake as a result of the allocation of a huge amount of energy in the source, various seismic waves propagate along the soil. Reaching the earth's surface, seismic waves cause vibrational motions of the upper layers of the soil and thereby render the earths destructive in certain conditions. The nature of seismic waves is the same as that of ordinary sound waves. Spreading in solid, liquid gaseous phases and being absorbed in them, they cause considerable stresses.

The skeleton of clayey soils consists of various minerals, forming a framework system, inside of which there is water. At the same time, under these conditions, the cohesion of the soil, which determines its strength, arises from the gluing ability of water-colloid shells on the surface of the particles. The strength of connectivity, according to the theory of the denisov-rebinger, depends on the degree of concentration of colloidal substances in the water shells of the soil. Due to the presence of montmorillonite colloidal minerals, a mobile structure is created in the soils, and thus the connectivity of these species is weakened.

Stresses ( $S_{seism}$ ), caused in the ground with the absorption of energy as a result of the passage of different seismic waves. Characterized by: first, the transition of mechanical energy into thermal energy, which can transmit high speeds and accelerations to the particles of the ground; Secondly, special actions of seismic waves on groundwater, consisting in violation of the orientation of molecules on water-colloid shells of the soil.

Stresses in soils caused by joint action of these factors can have a destructive effect on the soil structure. In the process of disturbances in the structure of loess in the conditions of concussion, a special role is given to the connectivity of the soil and to changes in its properties and composition. In the process of shaking, the orientation of molecules in the water-colloid shells of the soil is disturbed, and the

physically bound water is converted into free soil, which leads to a weakening, and under certain conditions, to the complete disappearance of the cohesion of the soil.

However, this process is complicated by the appearance of a hydrodynamic effect during shaking, which occurs when the disturbed bonds of soil particles are densified.

As is known, in the transition from particle shaking to motion, their compaction is inevitably accompanied by extrusion of excess water from the soil pores. With an appropriate duration of shaking as a result of disturbance of the internal bonds of the soil, it is obvious that due to the transfer of connected water into free soil, intensive compaction of the particles takes place, which in the pile turns, leads to a sharp hydrodynamic effect. This circumstance is explained by the most intensive weakening of connectivity, for one reason or another, the remaining disturbed.

Under these conditions, the ground particles lose their weight. The contacts between the particles are weakened or completely disappear, which leads to the inhibition of the acquisition of a new soil structure. The entire mass of soil, devoid of bonds, spreads like a liquid, which is observed in individual cases in experiments. In accordance with the position of the "filtration theory" in the water-saturated soil stratum underlain by the waterproof horizon and the plunging state, a certain mode of operation arises. In the case of weakly cohesive soils, this regime is accompanied by the weakening or disappearance of internal bonds in time and the compaction of the broken bonds of particles.

In the conditions of complete water saturation, the thicknesses of the compaction of particles can occur only in the case of outflow of a certain volume of water filling the pores in the ground and excessive for a new state of its density, which leads to the formation of a filtrate syrup with a definite pressure gradient ( $I_z$ ). This gradient is sustained by the dynamic head ( $h_z$ ) arising in the ground when increasing in depth ( $z$ ) and in time ( $t$ ). Thus, in the ground thickness is the acting counter pressure, weighing the ground particles.

Hence the need to take into account the time factor for the prediction of a fall in the strength of moisturized forest under conditions of shaking. This requires taking into account the decrease in the shock resistance as applied to a certain predetermined time, determined by the duration of the possible seismic action.

In accordance with this reduced resistance to moist loess shift during shaking binds to weakening over time and even, in certain circumstances, with the disappearance of the forces of cohesion ( $C_w$ ), causing the structural strength of the soil, as well as the dynamic pressure occurring in the soil column at seal broken structures particles and activating in these conditions the process of disturbing the connectivity of soil particles.

Observations of the behavior of water-saturated loess soils during vibration have shown that the concussion has a particular effect on the magnitude of the cohesion forces. With regard to changes in the internal flow angle loess soil during shaking, it should create a small amount, as evidenced by increased resistance to shear rate values, apparently due to the angle of friction vibration soon after closure.

Q constant angle of internal friction of the vibration soglosuetsya well with statements N.N.Maslova, P.L.Ivanova, T.N.Valisheva, experiments conducted with water-saturated sandy soils. In particular, they noted that the internal friction angle of sandy soils under vibration remains constant, and the change in resistance to shear is determined by the voltage drop across the state on the ground of its own weight or the weight overload in these circumstances.

Subsequently, this position was confirmed in the studies of N.D.Krasnikov, L.R.Stavnitser, V.F.Shiryaev, I.S.Ponomareva, and others.G.N.Zhinkin and I.V.Prokudin conducted laboratory experiments to identify changes in the strength characteristics of clay soils, depending on the amplitude of the oscillations. As a result of the analysis of foreseen experiments, they established changes in clay adhesion. Of the general nature of the change in cohesion, it was possible to distinguish three sections, the first of which was characterized by a change in the cohesion of the soil by up to 5% of initial value, the second part - an intensive decrease in adhesion and in the third segment the adhesion remained practically constant. Changes in the angle of internal friction of the soil also had the same character.

It should be noted that these experiments were carried out under these high-frequency conditions ( $4 \pm 80$  Hz and  $80 \pm 200$  Hz) and with very small oscillation amplitudes (several tens of microns), which simulated the working conditions of the roadbed, which was the focus of attention authors. A sharp change in the value of the angle of internal friction of the soil is apparently due to the influence of a high frequency of the experiment.

On the shear device, the angle of internal friction ( $\varphi_w$ ) and adhesion ( $C_w$ ) of water-saturated loess-like loam before and after vibration was determined. The images from a single monolith were pre-saturated with water. Angles of friction and adhesion were established by the results of a triple replication of the experiment. Simultaneously, three samples were subjected to vibrations of intensity  $1000 \text{ mm}/c^2$ , and then the experiments were repeated with new samples from the same monoliths.

In these experiments, the shock intensity was 500, 1500, 2000, and  $2500 \text{ mm}/c^2$ , respectively. Immediately after vibration, the samples were transferred to a shear device and the friction angle ( $\varphi_w$ ) and the adhesion ( $C_w$ ) were determined.

The results of the study showed approximately 1.5 -3 <the smallest value of the angle  $\varphi$  and 8-10 times less in the adhesion value  $C_w$ (Table 1.1)

**Change in the strength characteristics of soils Table 1.1. during their shaking**

Soils	Initial humidity%	Acceleration of shaking $mm / m^2$	Before the shock		After a shock	
			Angle int. Friction grad	Total adhesion $kgs / sm^2$	Angle int. Friction grad	General adhesion $kgs / sm^2$
№2	28	1600	21	0,28	19,2	0,02
№3	25	1500	22	0,32	18,2	0,045
№4	24	1450	19	0,33	16,3	0,030
№6	27	1600	18	0,12	15,51	0,057
№12	26	1800	20	0,2	17,8	0,005
№17	23	1840	31	0,35	26,8	0,012

In conditions of concussion of weak water-saturated loess soils, the forces of adhesion are strongly affected. The value of the angle of friction for the first approximation can be assumed to be unchanged under dynamic conditions, since the change in the friction angle at shaking is small compared with the general cohesion, which makes it possible to consider it practically constant. However, this issue should be clarified with further development of the problem. At the same time, the conducted experiments testified to the huge role of the active part of the dynamic load in the degree of disturbance of soil stability.

A.A.Musaelyan carried out laboratory studies of the effect of dynamic loads on the magnitude of deformation of loess soils. The soils had a porosity of more than 50% at a humidity of up to 7%, and the tests were carried out at a sample pressure of 0.5 to 0.4  $kgs / cm^2$ . As a result of such experiments it was established that any increase in the dynamic load causes an increase in the deformation of the soil, the degree of variation of which depends on the state of its density.

With the increase in the acceleration of the vibrational motion, as our investigations have shown, the degree of change in the strength characteristics of the soil increases accordingly. These changes, along with the weakening of internal ties, acquire a progressive character due to the hydrodynamic effect of counter pressure, is due to the dynamic pressure (excessive pressure) arising in the earth's thickness during the compaction of disturbances in the particle structures. As is known, the effect of the dynamic head ( $h_z$ ) is to attenuate the value of the normal earth stresses acting in the soil ( $P_n$ ).

The above-mentioned makes it possible to consider the total adhesion ( $C_w$ ) and normal stress ( $P_n$ ), causing the strength of the ground, varying values during the shaking of weakly connected humidified forests under conditions of  $\alpha_{calcul}$ .

This circumstance makes it possible to represent the magnitude of the resistance of humid loess soils to a shift in seismic conditions in the form of:  $S_{pw}^c = [(P_n - \Delta_B h_{z,t}) tg \varphi_w + C_{w,t}]$  (1.6)

In expression (1.6), the term  $C_{w,t}$  shows a decrease in the cohesion of the soil at time  $t$ . Obviously, in the case  $t = 0$ , respectively,  $h_{z,t} = 0$  и  $C_{w,t} = C_w$ .

Then expression (1.6) takes the form:  $S_{pw} = P_n * tg \varphi_w + C_w$ .

Thus, in accordance with the development of the problem of disturbance of the seismic stability of wetlands, the loss of stability of such soils occurs due to a decrease in the resistance to their shear in time. In turn, the decrease in the resistance of such soils to a shift according to the expression (1.6) is associated with the gradual weakening of internal bonds ( $C_w$ ), and also with the emergence under these conditions of the dynamic head  $h_z$ , which changed in time. When the loess ground is shaken, the strength of the soil is changed due to a decrease in the amount of adhesion and normal stress. Hence, when assessing the seismic stability of moist soils, it is necessary in all cases to establish the values of the decrease in the connection  $C_{w,t}$  and the growth of the dynamic head  $h_{z,t}$ , depending on the duration of the expected shock.

When solving the task in general, the development of the corresponding theoretical dependencies primarily required the solution of a number of problems connected with the disclosure of the nature of the weakening of the strength of soils during shaking. First, it was necessary to establish the nature of the deformations of moist loess soils under the influence of dynamic loading; secondly, the transition to a dynamically excited state of soils under their shock was to be studied in more detail, and the factors influencing the process were identified; Thirdly, it was required to establish a definite dependence of the rate of attenuation of bonds on the intensity of concussion, taking into account the time factor, etc.

To this end, it was necessary to conduct research on a vibrating installation to monitor the deformation of moist loess soils under the influence of various shocks of intensity. Simultaneously with the deformation of the soil, observations were made of the pore pressure, which, as follows from (1.6), is of great importance in the discovery of the observed phenomenon. In addition, in all our studies, we were most interested in the change in the magnitude of the cohesion of the soil, which is of decisive importance in the seismic stability of such soils.

## **1.2. On the structural features and nature of internal bonds of wet loess soils.**

Loess soils are a kind of clayey soils that have a macro porous structure in natural occurrence (in a malleable state), which partially or completely disappears with additional moistening as a result of subsidence.

Distinctive features of loess soils in comparison with other varieties of clayey soils are:

- 1) Visible to the naked eye porosity, due to the presence of vertical tubules;
- 2) A significant content of dust particles (more than 50% of particles with a size of 0.05 - 0.005 mm)
- 3) Uniformity of the granulometric composition;
- 4) The content of carbonate salts is of the order of 10: 15%;
- 5) Rapid soaks in the water.

The first and fifth of the marked signs of loess are most characteristic for its natural moisture content.

The skeleton of loess soils consists of sandy, salty and clayey particles (sometimes including lime, etc.) that are different in size and mineralogical composition, and are firmly cemented in a dry state (cement is mainly trivalent actions Fe, Al or divalent Coactions), depending on from the conditions of the environment in which the coagulation occurred and the degree of the variety of primary particles, the skeleton of the soil has a certain macrostructure.

The loose structure of loess, according to LS Berg, is due to the accumulation in it of calcium and magnesium. This provision has recently been confirmed in the studies of a number of specialists.

The presence of a loose structure, naturally, has a great influence on the physico-mechanical properties of loess. In particular, in particular the loose structure of the loess soils, the moisture content of the soil in the natural occurrence significantly depends, the filtration properties of the soil the strength of the bonds, and so on.

A study of the causes of deformation (subsidence) of loess soils carried out by a number of researchers showed that under the influence of Some factors (pressure on the soil of the external load and self-weight of the soil, hydrodynamic pressure during soaking, etc.), the macro porous structure decreases significantly, and disappears completely under the appropriate conditions. This structure is retained only where the soil has water-resistant bonds. It follows that the macro porous structure of loess soils is largely determined by its moisture content.

As shown by our studies conducted on different loess soils on different moisture conditions, the soil moisture, at which the degree of filling of the pores with water is very high, for example, more than 0.8 (where in some cases large pores were practically absent), does not exclude the possibility of deformation of the soil at its concussion. Deformation of loess depends on the state of porosity and strength of bonds, rather than its macro porous structure and moisture. Meanwhile, in these studies, it was noted that a relatively sharp decrease in connectivity with additional

loess wetting led to an increase in its ability to compact. Table 1.2 shows the results of the vibration test of loess-like soils at different degrees of humidity.

Change in porosity of loess soils during shaking Table 1.2.

Name of soil	Acceleration of shaking, $mm / m^2$	The duration of a concussion, s	Soil moisture content, %	Initial porosity, %	Porosity after concussion, %
№1	2200	150	13	48,9	46,4
№1	2200	150	18,7	48,2	47,0
№1	2200	150	23,5	43,6	42,7
№7	1950	120	18,7	49,4	46,3
№7	1950	120	22,5	46,0	42,2
№7	1950	120	27,0	46,5	44,7

Soil moisture content, % As can be seen from the data in the table, the ground subjected to concussion, regardless of the initial moisture state, was densified to some extent. In quantitative terms, the degree of moistening of these soils depends on many factors, such as bond strength, soil porosity and shaking duration.

Deformation of loess soils during shaking is the result of very complex processes occurring in the earth's thickness, which cannot be estimated from individual indicators, for example, by macroporosity or humidity. Under all conditions, the deformation of the loess during shaking proves to be connected with its unstable structure.

As is known, the instability of the structure is determined by the weak connectivity of structural elements characteristic of loess soils.

Despite the long history of studying forest and loess populations, the origin, as well as the mechanism of their deformation, due to their internal connection, remain far from being clarified. This is due to the diversity of genesis, properties and composition, as well as various natural moisture levels of the rocks.

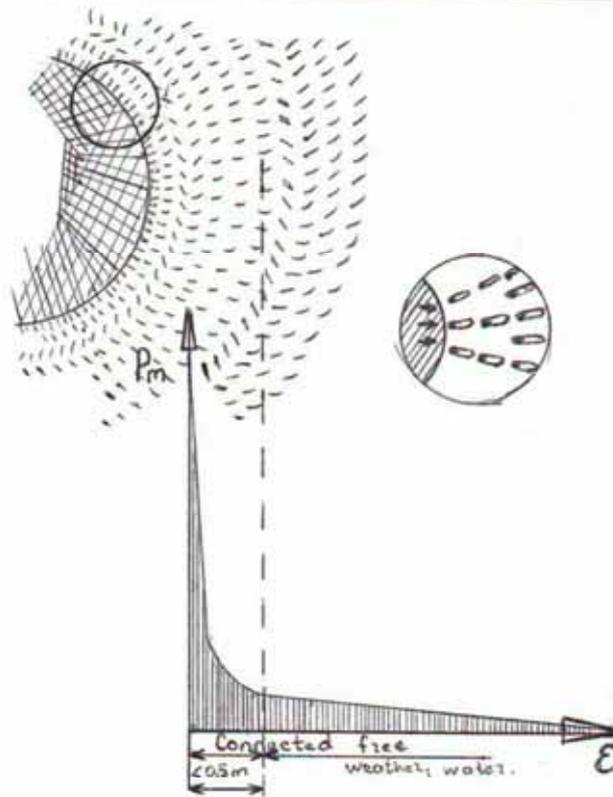
At the present time, specialists offer various theoretical assumptions about the structure of the internal bonds of loess soils.

Thus, V.V.Polynov and S.S.Bystrov (1930) believed that the internal connections of loess soils are caused by various water-soluble salts in the water shells of the particles, encasing them with films and creating a cemented rock. According to K. Terzagi, the destruction of soil bonds occurs as a result of the disappearance of the constrictive action of menisci when moistened. N.Y.Denisov proceeded from the presence of high friction between the particles of the vapor, surrounded by thin films of water, attracted to their surface. In his opinion, the thickening of these films with humidification reduces friction and has a wedging effect on the particles, making it possible to settle more comfortably.

Both the above-mentioned and other hypotheses (V.P.Ananiev, Y.M.Abelev, G.A.Mavlyanov) on the internal relationships of loessial rocks were expressed in studying the nature of the phenomenon of subsidence in the process of moistening inherent in soils in their low-salinity condition.

However, in humid loess soils these bonds have a different nature, which is well described by modern electro kinetic theory.

In violation of the structure of humid loess soils, water shells on the surface of the particles play an important role, informing them, under certain conditions, the necessary looseness. The presence of water shells on particles is known to be associated with electric charges acting on the surface of the particles. According to the electro kinetic theory (Fig.1.1), three types of hydrant shells are formed on the surface of ground particles: 1) internal, that is, immediately adjacent to the surface of the particle. The molecules of water in this layer are attracted to a particle with a huge force, measured by tens of thousands of atmospheres, and therefore it is firmly connected with the particle. With an insignificant distance from the surface of the particle, the electro molecular forces of attraction decrease intensively in connection with the dispersion of the electro kinetic potential, and finally, at a distance from the surface a few microns, the action of the electro molecular forces turns out to be negligible; 2) medium - the diffuse shell is characterized by a relatively weak connection. In this connection, the bonds decrease with the distance from the surface of the particles; 3) the outer shell, located beyond the limits of the attractive force, that is, in the zone where the value of the electro kinetic potential reaches zero. The water in this shell is free. The additional saturation with water of the rock always leads to the swelling of the soil, which is connected with the further thickening of the water shells of the particles. The soil particles in this case leave the zones of molecular attraction, weakening the forces of connectivity between the particles. Thus, the force of attraction of water to the particle depends on the thickness of the water shells, with the increase of which the molecular attraction force decreases. This circumstance indicates a comparatively easy transfer of loess soils saturated with water to a dynamically excited state.



**Fig.1.1. Scheme to the electro kinetic theory.**

### **1.3 Factors affecting the weakening of the connectivity**

of water-saturated loess soils during shaking.

An analysis of the experimental data and plant accidents in earthquakes shows that the strength of wet loess soils can be reduced under certain conditions (with strong concussions) and that such soils can go into a dynamically excited state.

Unlike loosely disconnected soils that lack cohesion between particles, loess soils, in particular loess soils of loam and sandy loam, are in the water-saturated state and possess some connectivity forces, which, as our studies have shown, can only be disrupted with time in the conditions of continuing shaking. At the same time, the presence of bonds in loess soils gives them properties that differ from the nature of the disruption of the dynamic stability of disconnected soils, which is confirmed by the cases of stability disturbances in the thickness of soils during strong earthquakes. The most frequent cases of damage to structures were called ground conditions, when their bases are composed of saturated loess soils,

When seismic stability of moisturized forests affected by seismic actions is disturbed, the thickness of such soils undergoes very complex internal

transformations caused by changes in internal bonds and the hydrodynamic effect that occurs when compacting disturbed soil structures.

At the same time, the cases of settling of structures in the liquefied ground, when this occurred only for several tens of seconds of exposure to earthquakes, indicate a possible sharp fall in these conditions of soil strength.

It should be emphasized that the above provisions were confirmed by experiments carried out by us in the laboratory,

Since this question is essentially new in the case of water-saturated loess soils, it is necessary to give due attention to the study of the nature of these phenomena during shaking, in particular the change in internal bonds, which is the main cause of disturbance of soil stability under these conditions.

In the case of concussions of loose cohesive soils (water-saturated lacrosse and loess soils), the phenomenon of soil transition from the plastic state to the flow is observed, which after a certain time, as a result of compaction under the influence of its own weight, applies a new density state. In this case, the time for the transition of the liquefied ground to the compacted state depends on many factors - the mineralogical composition, the particle size, the number of broken bonds, etc. and the rate of compaction depends on the mineralogical composition, the density state-humidity, and the intensity of the concussion. According to A.I. Avgustinik, the relative value of the duration of compaction of liquefied clay masses is 60-200 hours. The study of B.M. Humenskii et al. show that this value, depending on the factors noted above is measured in only minutes. Such a situation is observed in our experiments carried out on water-saturated loamy and loamy loess soils, when the total compaction time was 10 to 120 minutes.

However, in the light of the main task of this problem, we are not interested in the duration of compaction of different loess masses, but in the conditions that determine the transition of such soils to a dynamic excited state. In connection with this, much attention is paid to the factors that cause the stability of loose loess masses to break.

It should be noted that in our initial studies conducted to reveal the nature of the disturbance of the stability of water-saturated loess soils, our results were compared with the data obtained earlier for disconnected soils. However, according to the results of the first experiments, a significant difference in the character of deformation of these two types of soils was revealed. Here immediately arose the question of the role of soil connectivity in the dynamic violation of their structure. The above circumstances dictated the solution of the problem on the basis of studying the physical basis of the observed process and the property of soils.

The investigations were carried out in laboratory conditions on several types of soils of both disturbed and undisturbed structures characterized by the indices given in Table 1.3.

The experiments were carried out on a specially designed vibration device for directional oscillation (Fig. 1.2). The grounds were subjected to a variety of concussions in both frequency and amplitude. In order to obtain comparative indices, the experiments were carried out at a constant value of the oscillation frequency by changing the amplitude or vice versa.

To study soils with a disturbed structure, a technique was adopted, the assumptions of N.N.Maslov in the testing of non-cohesive soils. With reference to the undisturbed soil structure, we used a technique developed by Y.Y.Welley.

In both cases, the vessel where the sample is placed was equipped with appropriate measuring devices.

**Table 1.3 Characteristics of the investigated soils.**

Name of soil	Specific weight, $\text{ts/m}^3$	The bulk weight of the skeleton of the soil is $\text{mc/m}^3$	Volumetric ground weight, $\text{ts/m}^3$	Porosity of the soil, %	Coefficient of porosity	Characteristic humidity		Number of ductility	Internal angle of friction, grad.	Coupling $\text{kgs/cm}^2$	Fraction content, %		
						$w_t$ , %	$w_p$ , %				More than 0.05	0.05 - 0.005	Less than 0.005
Soil №1	2.71	1.42	1.68	47.6	0.908	29.6	20.5	9.1	22	0.987	8.15	82	9.85
soil2	2.68	1.50	1.68	45.5	0.840	26.9	19.0	7.9	26	0.139	10.0	78	12.0
soil3	2.70	1.45	1.77	44.0	0.791	27.6	19.0	8.5	26	0.179	12.9	80.1	7.0
soil4	2.69	1.42	1.69	49.8	0.894	27.2	19.9	7.03	19	0.70	30.24	67.7	2.05
soil5	2.70	1.55	1.74	42.6	0.742	27.8	18.2	9.6	22	0.10	19.35	70.6	10.0

Measurements of the pressure in water resulting from the shaking of the water-saturated soil were made using a pressure sensor with a record of the oscilloscope H-700 readings. The sample was fixed by a clock-type indicator attached to the rod's roots, and the other end to a perforated plate mounted on the surface of the sample. The test soil was shaken for 5 to 10 minutes. Roots and the other end to a perforated plate mounted on the surface of the sample. The test soil was shaken for 5 to 10 minutes.

Analysis of the results of experiments carried out on loess soils moistened to varying degrees showed that the beginning of deformation of the soil during the shaking corresponds to 20 sec. And more since the application of dynamic load on the ground, which is a distinctive feature of cohesive soils from disconnected. A rapidly increasing character of the deformation of the soil during its shaking was noted. This type of deformation is observed in all investigated soils. The intensity

of shock in these cases was measured in the range 1200 - 1800 mm / $\text{sm}^2$ , which does not correspond to the value of critical acceleration, is characteristic of these soils



**Fig.1.2. General view of a vibrating installation with horizontally directed oscillations.**

( $\alpha_{kr} = 450 - 900 \text{ mm} / \text{c}^2$ ). The readings of the pressure sensors are slightly different from those of the indicator. In these experiments, the pressure in the water begins to grow from a certain point after the application of a dynamic load on the ground.

This circumstance allows us to conclude that the structure of loess soils may be disturbed by the application of a dynamic load of intensity  $\alpha > \alpha_{kr}$ . At the same time, the nature of the observed phenomena indicated complex processes occurring under conditions that are obviously connected with changes in the internal connections of the soil.

The studies were carried out on a vibrating plate of the experimental setup simultaneously with four soil samples. For the sample, they were tested according to the above described procedures with the recording of the pressure sensors and soil sediment, and the remaining two were tested by a round-bottomed submerged injection, representing a metal ball 1.0-3.0 cm in diameter (the diameter of the ball was selected depending on the initial state of soil plasticity); which was freely retained by the soil until vibration. To measure the mixing of the ball along the ground, a steel rod with a diameter of 0.6 mm and a length of 30 cm was welded to

it, at the upper end of which the indicator leg was mounted. To maintain the verticality of the ball's displacement along the ground, its rod was passed through the guide hole of the special frame, rigidly attached to the vibrating platform of the installation.

It should be noted that the soil in all four samples had almost the same physical and mechanical properties and was subjected to the same dynamics in terms of intensity, which made it possible to make the correlated conclusions. In many experiments, there was a drop in the balloon, which indicated the beginning of disturbance of the soil structure. At the same time, the deformation of the soil was characterized by a negligible value. Table 1.4 shows the results of a single cycle of experiments conducted with four soil samples. On the basis of these studies, it can be concluded that unlike non-cohesive soils that can compact immediately after a structure failure, water-saturated loess soils undergo simultaneous complex compaction due to disruption of their connectivity under shock conditions. Obviously, this process in water-saturated loess soils is accompanied by a drop in their overall strength, as evidenced by experiments conducted with the ball.

**Table 1.4 Changes in pressure in water, ball deformation and sedimentation of the soil surface in time (shaking intensity  $\alpha = 1900 \text{MM}/\text{C}^2$ ).**

Type of experimental measurement	The duration of a concussion, s								
	8	12	15	20	30	45	50	60	90
Pressure in water mm,	3	6	10	10	16	20	22	24	24
Ball immersion, mm of soil	15	3	5	8	13	20	20	20	20
Surface sediment mm,		2	-	4	-	8	-	-	10

The method of the ball for determining the vibratory viscosity of sandy soils was used by D.D. Barkanov and P.L. Ivanov. As a result of a series of experiments, these scientists have established an increase in the viscosity coefficient with an increase in soil density and a decrease in its size.

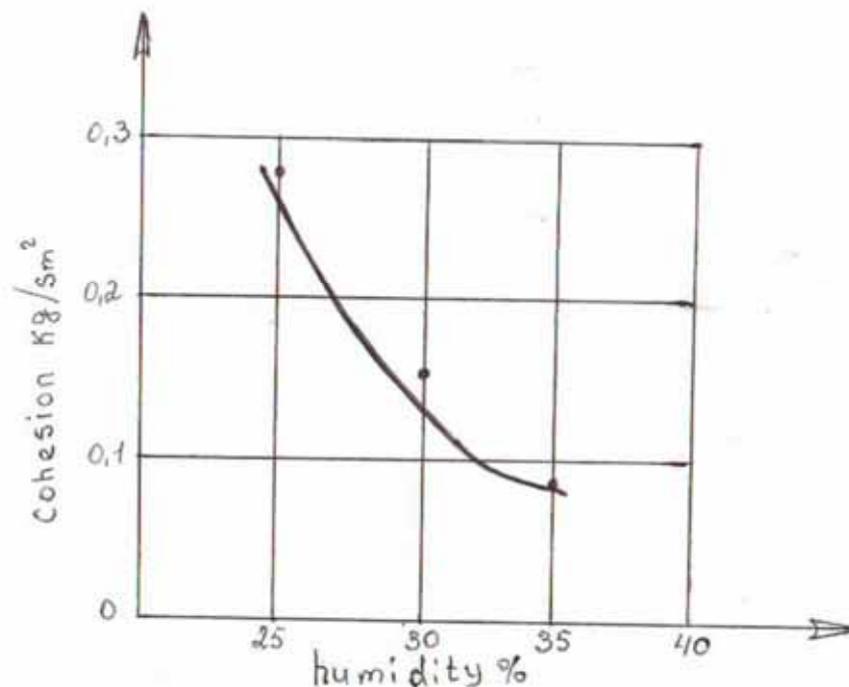
If we assume that the magnitude of the connectivity forces in the soils depends on the moisture content in them, then it can be assumed that the coefficient of vibro-viscosity will also depend on the moisture content of the soil. Experiments conducted by D.D. Barkan with soils of different humidity, showed more than 200-fold increase in the coefficient of vibration of the soil with an increase in the moisture content of sand to 13%. A further increase in humidity caused a sharp decrease in its value.

As follows from these data, the magnitude of the coefficient of vibra-viscosity of the soil is to a large extent determined by the forces of soil coherence. And only after the destruction of internal bonds in such soils begins the process of effective compaction, since the structural strength of cohesive soils under static conditions is ensured in static conditions is primarily provided by the connectivity of rocks and the role of internal friction in soils manifests itself only after the destruction of internal bonds.

It has been established by investigations that the forces of connectivity and viscosity of loess are not constant in time and vary from ground state. The change in time of the force of viscosity and the coefficient of vibra-viscosity can occur both in the direction of increase and decrease, depending on the increase in loess soil.

Studies show that, in addition to the loess soils saturated with water, the connectivity forces decrease, which, in turn, leads to a decrease in the resistance of the soils to shear.

This situation is illustrated by the graph shown in Fig. 1.3, where the dependence of the form  $\sum_w = f(W)$ , obtained from the results of the author's experiments, is shown. As follows from the graph, any increase in soil moisture will entail a decrease in the connection value  $\sum_w$ . Thus, it can be assumed that any weakening of the cohesion of the soil, occurring in the process of shaking, leads to a decrease in the coefficient of vibra-viscosity or vice versa.



**Fig.1.3. The nature of the change in the general cohesion of loess-like soil when moistened**

This makes it possible to use the well-known ball method in experiments to study changes in the viscosity of soils under vibrations. However, this method does not make it possible to judge the quantitative value of the change in the connectivity of the soil, since the viscosity coefficient determined by the ball method in the general case does not equal the numerical value of the connection  $C_w$ . At the same time, the functional coherence of these two indicators makes it possible to use the ball method to determine the nature of the change in the connectivity of the loess in the process of shaking.

Proceeding from the goal in our studies, the ball method was widely used, fixing the depth of its immersion in the ground under very different experimental conditions (acceleration, porosity, etc.).

It can be suggested that the process of disturbance of the stability of moistened soils during shaking will be accompanied by a change in soil moisture. However, such an option disappears as illogical and experimentally unconfirmed for cohesive soils. This is because the outflow of water from the soil pores can occur only when the soil is compacted. The soil can be densified also in the event that its structure is disturbed. At the same time, the structural strength of clay soils, as is known, is determined by their internal connection.

Turning to the second possible case of increasing the volume of free water in the pores of the soil, it should be noted that this case is the only possible and well explaining the nature of the phenomenon of reducing the cohesion of soil during a concussion.

A decrease in the cohesion of the soil in the conditions of concussions was noted by many researchers who studied the phenomena of thixotropy of clay soils. Very characteristic in this respect can be considered the statement of B.M. Gumensky. On the basis of his studies, he notes: "by the method of continuous drying it was ascertained that the water in the studied monoliths of hydromica (Leningrad, Lower Cambrian) clays was physically related. On the other hand, it was noted that when vibrating this clay in a vibration shaker, it flowed like a viscous liquid. It follows that the physically connected water under the influence of vibration passes into the free water, which, as shown by the investigation of the same Leningrad and other clays, covers the soil with a thin film from the surface in the cylinder when vibrating (the ground has glossiness). This film disappears (the ground becomes opaque) after the end of the vibration, which, apparently, indicates its transition to a bound state. "

Thus, according to prof. B.M. Gumensky, in the process of concussion of cohesive soils, part (or under certain conditions completely) of bound water in the soil becomes free, thereby increasing the amount of free water in the soil.

Such phenomena have been observed in our studies conducted in the field. On one site, pit excavations = 3.0 m deep in loess-like loam with a moisture content  $W_{pr}=23,2\%$  and bulk density  $\gamma_{gen}= 1,48 \text{ тс}/\text{m}^3$  were excavated. At a distance of 6.0 m from the pits, the soil was prone to frequent impact of a shock weight of 70 kg, falling from a height of 7.5 m to lift the load, a metal derrick with a lifting and dropping device was used.

At the same time, the cargo lifted by the winch and automatically dropped after reaching the upper mark. During the operation of the installation, continuous monitoring of the wall of the pits from the side of the drop of the cargo was made. As a result of 4 to 6 strong impacts on the surface of the soil, water droplets began to appear on the wall, which immediately disappeared when the plant stopped operating. The results of such experiments confirmed the point of view of B.M. Gumensky and a number of other specialists, which testifies to the possibility of the transfer of coherent water in the pores of the soil into a free soil under dynamic conditions.

An analysis of the experiments described above showed that the reduction of connectivity only due to the transformation of connected water into free water occurs under conditions of concussion, which agrees with the initial position of the developed theory.

The weakening of the cohesion of the soil and its transition to a dynamically excited state depends on the state of moisture, water-colloidal minerals, the granulometric composition, the content of various salts, and also the intensity and nature (in frequency and amplitude) of the concussion applied to the ground.

Below we briefly dwell on these factors.

### **1.3.1. Soil moisture.**

The transition of weak clay soils to a dynamically excited state, depending on their moisture content, was studied by A.I. Augustinik, B.M. Gumensky, N.M. Gersevanovym and others in particular, A.I. Augustinik noted that forces violating the structure of the soil depend on its moisture content and increase with the increase of the latter to a certain value, the so-called "optimal", and further increases in humidity lead to an inverse relationship, that is, a decrease in these forces to zero, under a saturated water state clay rocks.

N.M. Gersevanov believed that one of the main conditions for the disruption of the structure is a water-saturated state of soils (ground mass) with the presence of free water in them. Gumensky bases his research comes to the opposite conclusion that for the transition of clay soils to a disturbed state, it is not necessary that they have free water. At the same time, he believed that during the concussion part (or fully) of the bound water in the ground becomes free, and the amount of water formed will be sufficient to transfer the soil to a dynamically excited state.

In order to clarify the role of moisture in the transition of cohesive soils to a dynamically excited state, we conducted field experiments in specially excavated pits using shock mechanisms. Individual cycles in these experiments were described above.

Within a few days, the additional moistening of the experimental site by means of a shock mechanism brought the soil moisture to the value  $W_{pr}=32,6\%$  corresponding to the yield point ( $W_T=34,5\%$ ). Then the experiment was repeated in the previous regime of the drum set. In the same cases, during the first impacts on the ground, water mixed with mud began to flow from the wall of the pit. During subsequent impacts, some destruction of the borehole wall was observed, when the liquefied ground flowed along the plane of the wall, which indicated the acceleration of the process of disturbing the structure of moistened forest with increasing humidity.

The data presented clearly showed the possibility of increasing the degree of transition of wet loess soils to the disturbed state under dynamic loads with increasing soil moisture.

**Table 1.5. Data on the change in humidity of loess-like loam under impact**

Depth of sampling, m	Soil moisture content, %	
	Before the strike	After the strike
0,6	27,7	27,9
1,05	28,0	28,6
2,0	30,2	31,4
2,5	29,9	31,6
3,0	31,2	31,6

In Table. 1.5 shows the soil moisture data obtained as a result of the above-described experiment.

As can be seen from the table, the data obtained indicated the transition of bound water to free water under impact of a shock on the ground, which is evident from the almost constant parameters of soil moisture before and after impact.

The above data once again confirm the underlying development that confirms the transition of wet loess soils to a dynamically excited state due to a change in the thickness of the water shells due to the transition of physically bound water to free water under these conditions.

### **1.3.2 Water-colloidal connectivity.**

Colloidal minerals that form part of the soil affect the degree of disturbance of their structure during shaking. According to the theory of the water-colloidal nature of the cohesion of clay species, developed by N.Ya. Denisov and P.A. Reindeer, the cohesiveness of clayey soils is a consequence of the adhesiveness of

the colloidal shells of the particle surface. The manifestation of connectivity depends on the degree of concentration of the colloidal substance in the water-colloidal shells of the soil. This explains the decrease in soil connectivity as a result of liquefaction of water-colloid shells as a result of hydration during flooding of soils.

The hydration process is accompanied by a thickening of the water shells on the particles, which leads to an increase in the distance between them and to a weakening of the manifestation of intermolecular forces and, consequently, the very cohesion of the soil.

The property of soils containing clay particles is largely determined also by the group to which their colloids belong. The relationship between the composition of colloidal-dispersed minerals of the soil and the violation of their structure was examined by B.M. Gumensky. To determine the effect of vibration on the properties of montmorillonite, kaolinite hydromic clay, soil vibration was carried out at a frequency of 4000 rpm with vibration amplitude of 1.0 mm. On the basis of these experiments, B.M. Gumensky made the following conclusions: at the initial moisture content of clays, when they were vibrating for 15 minutes, the structure of hydro mica clay (seal 12.5%) showed the greatest strength, the structure of kaolinite (14.6%) and the smallest - montmorillonite clay, compacted by 35.4%. Explanation of the greater consolidation of montmorillonite clay should be sought in the content of more diffuse water in it than in hydromic and kaolinite clays.

In minerals from the montmorillonite group, the ability to transform them into a dynamically excited state is more pronounced than that of minerals from hydro micas or kaolinite groups, which indicates a breakdown in the structure of soils, depending on the structure of the crystal lattices. These data also indicate an increase in the ability of soils, in the colloidal shells of which there are montmorillonite minerals, to pass into a dynamically excited state.

### **1.3.3. Grading.**

When considering the problems associated with a structure failure during a concussion, a certain value is given to the particle size. To clarify the role of particle size in the possibility of their transition to a dynamically excited state, we carried out a series of experiments with various soils, the characteristics of which were carried out in Table 1.3.

As it is seen from the data of the table, the soils presented for testing were characterized by different physical properties (by specific gravity  $\gamma_{rem}$ , granulometric composition, etc.).

The main parameter to be measured in experiments was the fixation of the beginning of the immersion of the ball ( $d = 16 \text{ mm}$ ), mounted on the surface of

the test sample. As was noted above, the immersion of a ball in the ground during the process of vibration resulted from the weakening of the connection due to the transition of the ground to a dynamically excited state. The results are summarized in Table 1.6.

**Table 1.6 Dependence of immersion of a ball in a ground from a shock**

Name of soil	Acceleration of vibration $\text{mm}/\text{c}^2$	Ball immersion, mm
Soil №5	1300	14.0
Soil №6	1150	12.5
Soil №7	1480	10.0
Soil №8	1740	18.5

As a result of these experiments, the following conclusion can be drawn.

The transition of cohesive soils to a dynamically excited state does not depend on the particle size and mineralogical composition of the soil, but is determined by the intensity and duration of the concussion. Such a conclusion was obtained by P.L. Ivanov for sandy soils and, as follows from our studies, it preserves the importance for cohesive soils. So, in the corresponding state, it was possible to break the structure of any soils having particles of any size. The residence time in the destroyed state also depends on the mineralogical composition and particle size, in the disturbed state. The role of the mineralogical composition in the acceleration or inhibition of the process of disturbing the soil structure is quite obvious, which, it seems to us, does not require additional clarification.

#### **1.3.4. Different salts.**

The question of the effect of salts present in loess soils on the transition to a dynamically excited state is of some interest. In the presence of data explaining the effect of salts on the process of weakening of soil connections, it would be possible to develop technical measures aimed at accelerating or inhibiting the process of disturbance of the structure of these soils.

In the literature on this question, almost no data are available. At the same time, it can be assumed that an increase in the composition of hydrant shells of particles of limited substances will contribute to weakening of internal bonds of the soil. From this point of view, it is quite obvious that the dynamic stability of loess-like water-saturated soils containing an excess of colloidal organic substances is quite evident.

#### **1.3.5. Intensity and nature of concussion.**

At the present time in the field of the dynamics of disjointed soils indisputably established phenomena the question of what any disjointed soil in any of its states can be translated into a dynamically excited state. There is only the question of the necessary magnitude (intensity) of the applied dynamic load. This situation

generally remains valid in the case of loess soils. However, in this case, as noted above, along with the intensity, the duration of the tremor will play a certain role in disturbing the dynamic stability of the less. In our studies, we focused on this issue in view of its exceptional importance. The results of numerous experiments made it possible to establish a directly proportional dependence of the immersion of the ball in the ground on the intensity of the shock.

Thus, for  $\alpha = 360 \text{ MM}/c^2 l = 4.0 \text{ MM}$

$\alpha = 800 \text{ MM}/c^2 \quad l = 8,5 \text{ MM}$

$\alpha = 1400 \text{ MM}/c^2 \quad l = 20,0 \text{ MM}$

$\alpha = 2500 \text{ MM}/c^2 l = 30,0 \text{ MM}$

Thus, the intensity of concussion plays an important role in weakening the strength of the soil.

The main purpose of the studies was to establish the rate of transition of loess soils to a dynamically excited state, depending on the intensity of the shock. A number of experiments with various types of soils (sandy loam, loam, clay) were carried out in this direction. The essence of these experiments was concluded, as in other experiments, in observing (in time) the immersion of the ball in the test soil dipped in the sample. The sample in this form was subjected to very different in intensity dynamic effects.

In Fig. 1.4 as an example, the graph of the dependence of the immersion velocity of a ball as a function of  $v = f(\alpha)$  is given. The velocity of the ball's immersion into the ground increases linearly with increasing intensity. Measured by acceleration  $\alpha$ .

This circumstance is important from the point of view of assessing the stability of the soil under shock conditions, since these experiments showed that the dependence of the magnitude and velocity of the ball displacement (proportional to the magnitude and rate of weakening of the soil strength under these conditions) on the value applied to the soil of the design seismic load with accuracy sufficient for practical purposes can be taken as linear. However, this character of the dependence  $l = f(\alpha)$  is observed up to a certain value of acceleration, the so-called limiting value, above which the immersion of the ball into the ground acquires a progressively increasing form.

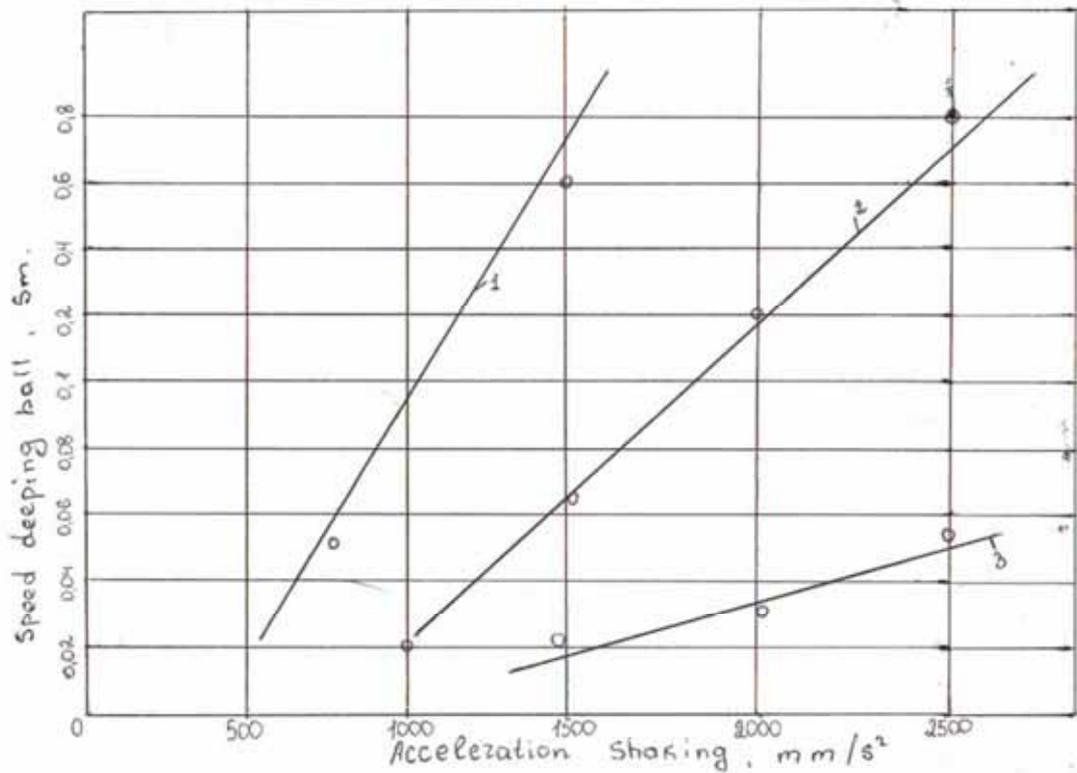


Fig.1.4. The graph of the dependence of the immersion rate of the ball in the ground on the intensity of the shock: 1- ground number 7; 2- soil number 16; 3- soil number 1 ( $P=1,0\text{kg}/\text{CM}^2$ )

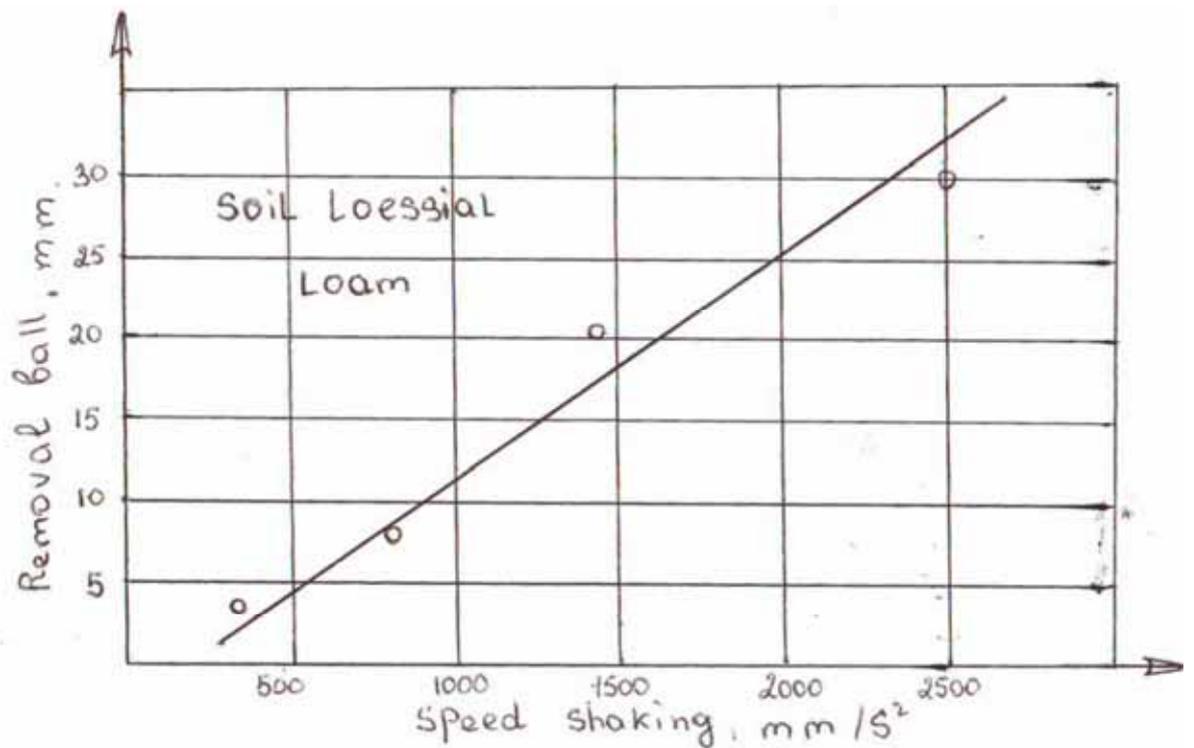


Fig.1.5. The nature of the immersion of the ball in the ground, depending on the acceleration of shocks.

The graph, compiled from the results of the experiments (Fig. 1.5), shows how the depth of immersion of a ball mounted on a sample of a water-saturated loess-like loam under various shocks was measured. In these experiments, samples of the same loess-like loam monolith were tested, which for a certain time were previously saturated in a highly humid environment, these samples were shaken one by one with varying intensity of vibration. In this case, each time the same ball was placed on the surface of the sample, and the value of its immersion in the ground was measured with a concussion.

As can be seen from the graph, the degree of destruction of the structure (connectivity) of moist loess-like loam, which could be judged from the size of the immersion of the ball in the ground, actually increases with increasing active acceleration on the soil ( $\alpha_{calcul}$ ). However, in many experiments carried out with balls, the ball was immersed in the ground and with constant values of acceleration of the shock.

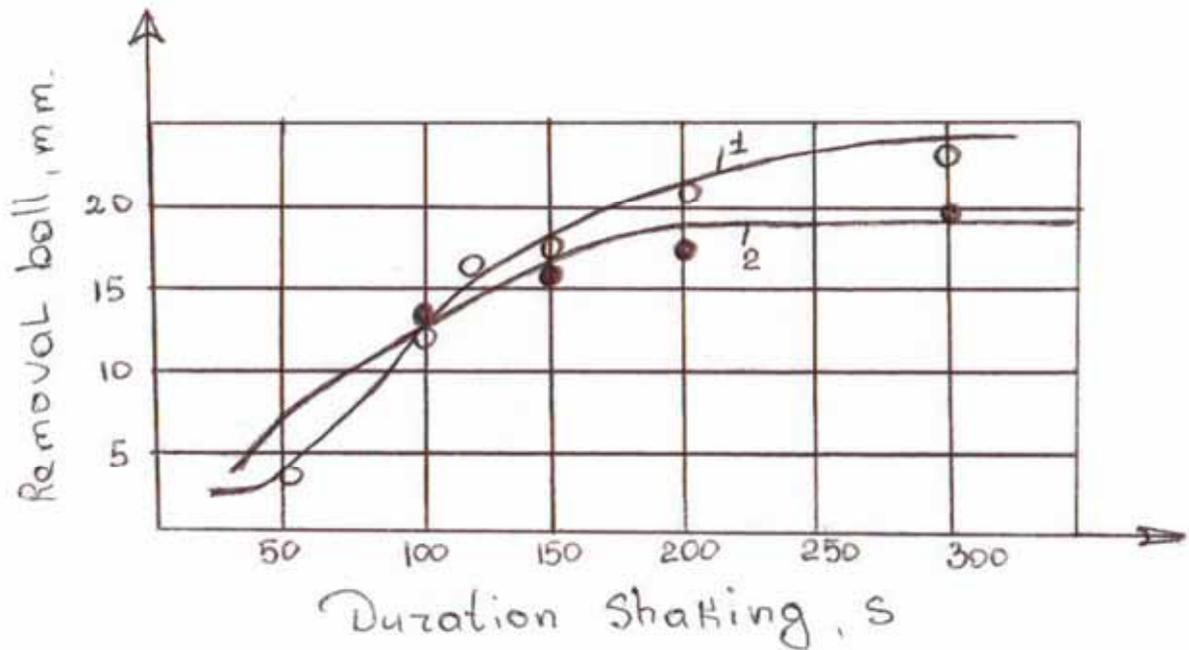
We turn to Fig. 1.6, where the graph of the dependence  $l=f(t)$  for  $\alpha = const$  is given. As follows from the graph, along with the magnitude of the calculated acceleration, the duration of its action is of great importance. Depending on this, the degree of disturbance of the structure (connectivity) of the soil also increases. This confirms our starting position, taken as the basis for investigating the gradual nature of the loess connectivity in concussion.

At the same time, the role of the frequency (period) and amplitude of concussions in the degree of weakening of the internal bonds of cohesive soils seems to be obvious. In this plan, further research is needed. However, it should be noted that the oscillation frequency is of great importance in the process under consideration.

#### **1.4. The role and nature of the dynamic pressure that occurs when compaction of moisturized forests.**

##### **1.4.1. On the value of the coefficient of dynamic compaction.**

In accordance with the initial position of the theoretical development of the problem of disturbance of the dynamic stability of moist (water-saturated) loess soils, the latter are densified as a result of the disruption of connectivity, which determines the structural strength of these soils. In such a case, the effect of further



**Fig.1.6. The nature of the immersion of the ball in the ground (1 - ground number 12, 2 - ground number 2) with a prolonged shaking  $\alpha = 2200 \text{ mm/c}^2$  weakening of the shear resistance is found by decreasing the role of the normal stress due to the weighing action of the counter pressure acting in the soil stratum.**

It requires a more detailed study of the phenomenon of densification of loess moist soils at their varying degrees of concussion.

According to the aforementioned "filtration theory", the main factor estimating the rate of soil compaction in the appropriate dynamic modes is the dynamic compaction factor  $v_n$ , calculated by the expression:

$$v_n = \frac{dn}{dt} \quad (1.7)$$

The coefficient of dynamic compaction is a dynamic characteristic indicative of soil compaction. The dimension of this exponent, taking into account expression (1.7), is the inverse of time ( $t - 1$ ).

According to studies conducted at different times by different scientists, the value of  $v_n$  is determined by many factors, in particular: 1) the granulometric composition of the soil and, in particular, the degree of its homogeneity; 2) the particle roundness; 3) the initial porosity of the soil; 4) the intensity of the dynamic impact; 5) the magnitude of the external load and 6) the duration of the dynamic impact.

According to N.N. oil, the value of the coefficient  $v_n$  increases with the homogeneity of the soil, the degree of pellet rolling, the strength and intensity of the soil, and for cohesive soils - with an increase in the duration of the shaking.

At the same time, the last factor (that is, the duration of the shock), taking into account the specific features of the cohesive soils, was very important in the value of the coefficient  $v_n$  for our analysis, and much attention was paid to studies carried out with loess soils. As is known, the coefficient of dynamic compaction  $v_n$  for disconnected soils has values only then, then the condition  $\alpha > \alpha_{kr}$  is observed. For all other values, the value of the dynamic compression coefficient  $v_n$  is zero, which indicates the static state of the investigated soil. Otherwise, there is soil compaction with the corresponding compaction factor  $v_n$ .

However, as our studies have shown, the coefficient of dynamic compaction has a rather complex form with respect to cohesive (loess) soils. In this case, the value of the coefficient  $v_n$  is significantly affected by the magnitude of the loess connectivity, the breaking of which is directly explained by the strength of these bonds.

In the light of the materials considered, the destruction of the strength of these bonds is determined not only by the intensity of the shock, but also to a large extent by the state of moisture, the water-colloidal minerals contained in the water shells, the content of various salts, which in combination requires a violation of the duration of the concussion.

An analysis of the studies carried out on a vibration installation with soils (see Table 1.3) showed that the time required for the disruption of the cohesion of these soils during a concussion with an intensity of  $\alpha = 200 \div 1800 \text{ mm/c}^2$  varied within 10-60 s, depending on the strength condition of the soil.

In Fig. 1.7, as an example, the results of numerous experiments on the determination of the porosity of lumps compacted during shaking are given for different duration and intensity of the dynamic impact on them. The determination of porosity in these cases was made by measuring the lowering of the loess surface.

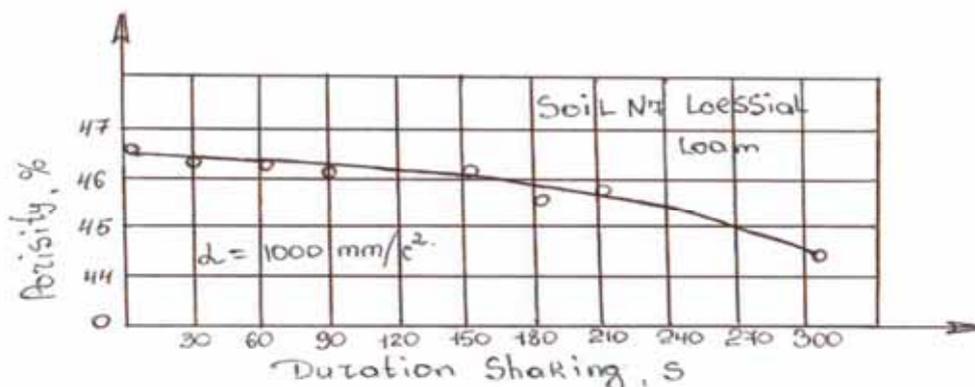


Fig.1.7. Change in the porosity of loess-like sandy loam upon shock.

According to the change in the porosity of the loess under the influence of the dynamic load, the calculation was made in the form

$$v_n = \frac{\Delta n}{\Delta t} (1.8)$$

Where:  $\Delta n$  - changes in soil porosity in fractions of a unit

$\Delta t$  - is the time interval.

This definition of the coefficient of dynamic compaction  $v_n$ , the index of the degree of deformability of the ground by a link with the establishment of the value of  $v_n$  directly from the experiment.

In each specific case, for given values of the loess moisture density, as well as the nature of the dynamic load intensity, the variation in the porosity of the loess is monitored, if possible, over a short period of time.

Taking into account the specific feature of wetted loess during shaking, the value of  $v_n$  was determined by us at the time of the greatest degree of compaction.

As can be seen from this definition of  $v_n$ , its magnitude is directly related to the porosity of the ground and the condition of its change in time, just as in disconnected soils.

**Table 1.7. Change in the porosity of loess soils over time**  
( $\alpha = 2000 - 2500 \text{ MM/C}^2$ )

Name of soil	The duration of a concussion, min							
	1	2	3	4	5	6	7	8
Soil №7 (n=46,5%)	46,35	46,1	45,5	45,2	44,5	-	-	-
Soil №10 (n=54,2)	53,8	53,5	53,0	52,4	51,4	50,3	50,0	49,2

When determining the values of the coefficient  $v_n$  by the above method, we tried to compare them with the data obtained earlier for disconnected soils. However, the results of such comparisons revealed some differences in the nature of deformation of these two types of soils.

In Table. 1.8 the values of the coefficient  $v_n$  for loess and disconnected soils are given.

As follows from the data of the table, the value of  $v_n$  for loess soils is somewhat less than for sand, which indicates the beneficial role of connectivity with a dynamic decrease in the strength of loess. However, this question also concerns the degree of deformation (compaction) of these soils. If we take into account the weakening or disappearance of the loess connectivity, which, as is known, occurs

even before its deformation appears, then the drop in the strength of the loess can be much higher than sand in certain conditions.

At the same time, the value of the coefficient  $v_n$  for close values of the soil porosity turns out to be sharply different for different forest loses (Fig. 1.8). Obviously, the strength of the bonds of loess soils is of great importance, depending on which the degree of their compaction changes.

To fully solve the problem of determining the role of the coefficient of dynamic compaction in the plan in question, for further use of its value, it was necessary to evaluate those or other factors affecting the value of  $v_n$ . A series of experiments was conducted to determine the coefficient of dynamic compaction  $v_n$  with respect to various conditions.

The initial data obtained from the experiment are given in Table 1.9. With increasing loess density, the value of  $v_n$  decreases accordingly. With increasing porosity of the soil, the value of  $v_n$  increases sharply. This indicates that, in the loose state, even a cohesive soil (loess) is able to transition to a dynamically excited state in layers with very high power due to an intense decrease in the normal stress. **Table 1.8. The value of the coefficient of dynamic compaction for loess and sandy soils at  $\alpha - 2000 \div 2500 \text{ MM}/\text{C}^2$**

Soil	The coefficient of dynamic compaction with porosity n, %							
	40	41	42	43	44	45	46	47
Sand №1	0,0001	-	0,00035	0,00055	0,0013	0,0034	-	-
Sand №3	-	0,0004	0,00045	0,0006	0,00075	0,0010	-	-
Soil (loess) 1	-	-	-	-	0,000001	0,00002	0,0000	0,000
Soil (loess) 3	-	-	-	0,000018	0,000027	0,00009	3	06
Soil (loess) 7	-	-	-	-	0,000010	0,00003	-	-
							0,0000	0,000
							57	09

In accordance with our study, the cohesion of loose humid loess species is characterized by a small value and can be violated relatively easily and quickly with a concussion, thus ensuring intensive compaction of the soil. In Fig. 1.8 gives the data for determining the coefficient of dynamic compaction  $v_n$ , taking into account the porosity of different loess soils. The soils No. 1,3 and 5 with broken

structure were tested, but each of the tested soils is characterized by its strictly defined dependence  $v_n = f(n)$ .

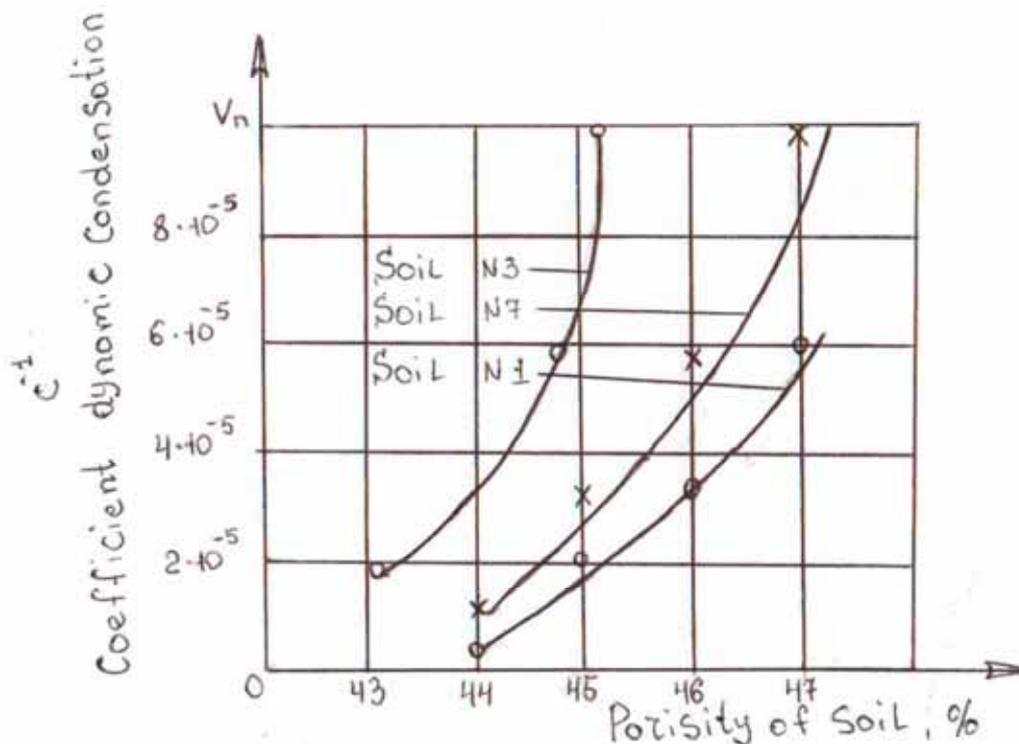


Fig.1.8 The nature of the change in the coefficient of dynamic compaction  $v_n$  from porosity for loess like soils.

Note that for maximum porosity the soils have an extremely high value of  $v_n$ . As can be seen from Fig. 1.8, with a certain increase in density (decrease in porosity), the value of  $v_n$  decreases sharply.

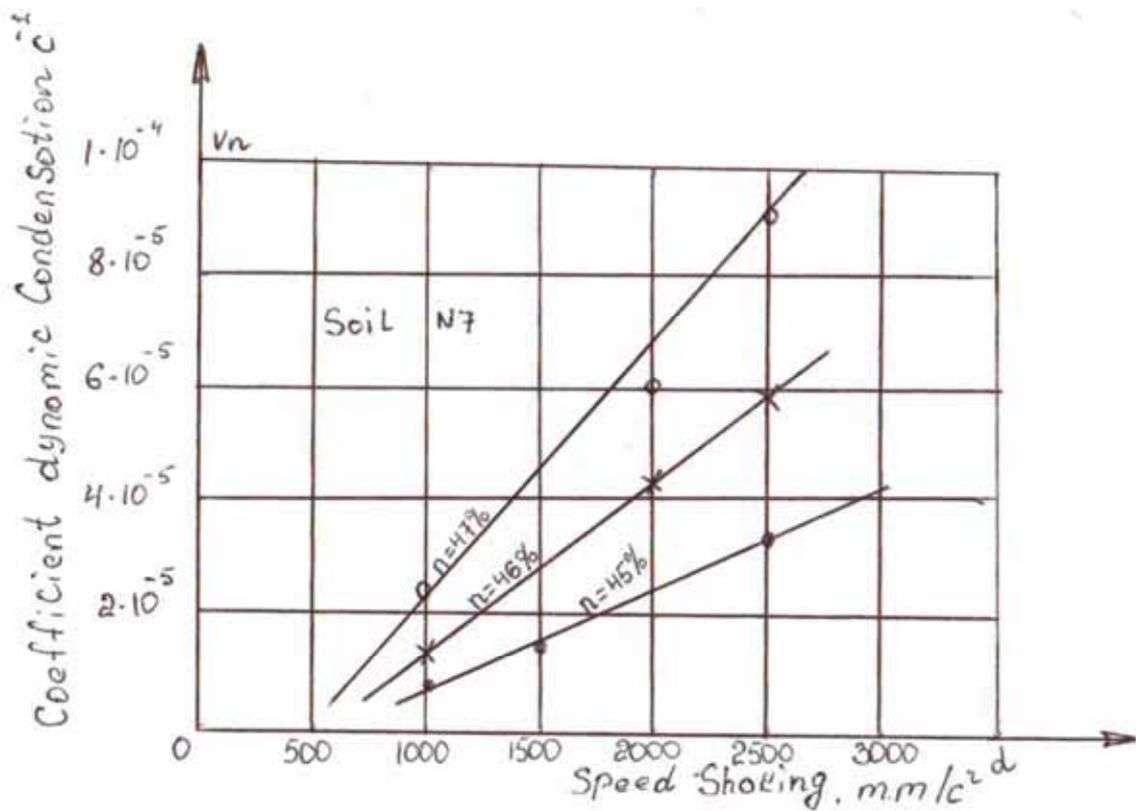
The study of the influence of the shock intensity on the coefficient of dynamic compaction  $v_n$  acquires a very important value in these conditions. In this sense, graphs of the type  $v_n = f(\alpha)$  for some varieties of investigated soils are of undoubted interest. From rice 1.9 it follows that  $v_n$  is related to the acceleration of the oscillatory motion  $\alpha$  by a linear dependence. As the acceleration increases, the values of  $v_n$  increase accordingly.

As can be seen, the curves of the dependence of  $v_n$  on seismic acceleration are very similar in character. However, as expected, the value of  $v_n$  with identical accelerations for different soils is different.

At the same time, an analysis of the conducted studies showed a difference in the value of  $v_n$ , even for, however, that de-soil, depending on the state of humidity. For cohesive soils of the same density, the value of  $v_n$  depends on the nature of the cohesion.

**Table 1.9. Values of the coefficient of dynamic compaction for loess-like sandy loam.**

Acceleration	Porosity n, %			
	44	45	46	47
1000	-	0.000005	0.000012	0.000020
1500	-	0.000011	0.000019	0.000032
2500	0.00001	0.00003	0.000057	0.000090



**Fig.1.9. Dependence of the coefficient of dynamic compaction  $v_n$  on the acceleration of the oscillation  $\alpha$  for loess like soil.**

So, for low-moisture (dry) woods, the value of  $v_n$  is determined to a greater extent by the strength of the bonds, the density of the soil and the intensity of the shock. For wetlands, this dependence acquires a somewhat complex form. Here, first of all, the factors that determine the strength of the bonds, which depend on the duration of the concussion, lead to a decrease in the value of  $v_n$  for these soils.

Consequently, the coefficient of dynamic compaction  $v_n$  is a dynamic characteristic of the ground and in each particular case is subject to experimental

determination. The values of the coefficient of dynamic compaction  $v_n$  obtained in this way were used as a basis for further research.

#### **1.4.2. Dynamic pressure $h_z$ as a weighting factor.**

As a result of experiments carried out with water-saturated ( $G = 0.92 - 0.96$ ) loess like soils, it was found that the dynamic head  $h_z$ , the emerging character. The onset of dynamic pressure in the conditions of our experience with respect to many of the investigated soils corresponds to 10 to 20 s after application of the dynamic load to the soil. The immersion of the ball into the ground simultaneously with the appearance of a dynamic head testified to the beginning of the weakening of the internal bonds of the soil under these conditions.

However, in decreasing the overall strength of the soil, as our studies have shown, a certain role is played by the weighing effect of the counter pressure ( $\Delta_b h_z$ ), which occurs during the compaction of disturbed soil particles.

Analysis of the data of numerous experiments made it possible to compile the following scheme of processes that continuously flowed to varying degrees during the shaking of loose ( $G > 0.8$ ) loosely loosely connected (loess) soils: a) the gradual weakening of internal bonds having a water-colloidal nature, which the experiments carried out with ball loading testified;

b) the formation of a filtration flow with rising currents (dynamic head) as a result of densification of the broken bonds of particles, which could be observed from the value of the dynamic head emerging during the experiment;

c) The increasing character of the fall in the overall strength of the soil due to the simultaneous weakening of the bonds and the weighing effect of the dynamic head  $h_z$ .

As follows from this scheme, the value of the dynamic head should be very important as a factor involved in the reduction of the total strength of the ground in the process of concussion.

As is known from the literature, in the transition from concussion of particles to their motion, compaction is inevitably accompanied by extrusion of excess water from the soil pores. With an appropriate shaking time as a result of disturbance of the internal bonds of the soil, such compaction of particles leads to a sharp hydrodynamic effect. Under such conditions, a certain mode of operation arises in the water-saturated soil stratum subjected to concussion. With reference to cohesive soils, this regime is accompanied by the weakening or disappearance of internal bonds in time and simultaneous consolidation of the broken bonds of particles.

Under conditions of complete water saturation, the thicknesses of the compaction of particles can take place in the event of outflow of a certain volume of water filling the pores in the ground and a new state of its density that leads to

the formation of a filtration flow with the gradient of the pressure  $I_z$ . This gradient is maintained by the dynamic headers  $h_z$ , which rise in the depth of the soil during the shaking, increasing in depth  $z$  and in time  $t$ . Thus, the counter pressure weighing the soil particles appears to be active in the soil stratum.

As shown by the studies for sandy soils, the dynamic head  $h_z$  for a certain layer of ground, determined by the density ( $n = const$ ) and characterized by the value of the filtration coefficient ( $K_\phi$ ), depends, in addition to the inherent properties of the soil ( $H=const$ ) granulometric composition, density, roundness, etc.), on the acceleration of the oscillatory motion as a whole, as well as on the amplitude and period of motion.

For cohesive soils, the dynamic head  $h_z$ , in addition, must depend on the degree of disruption of the soil connectivity.

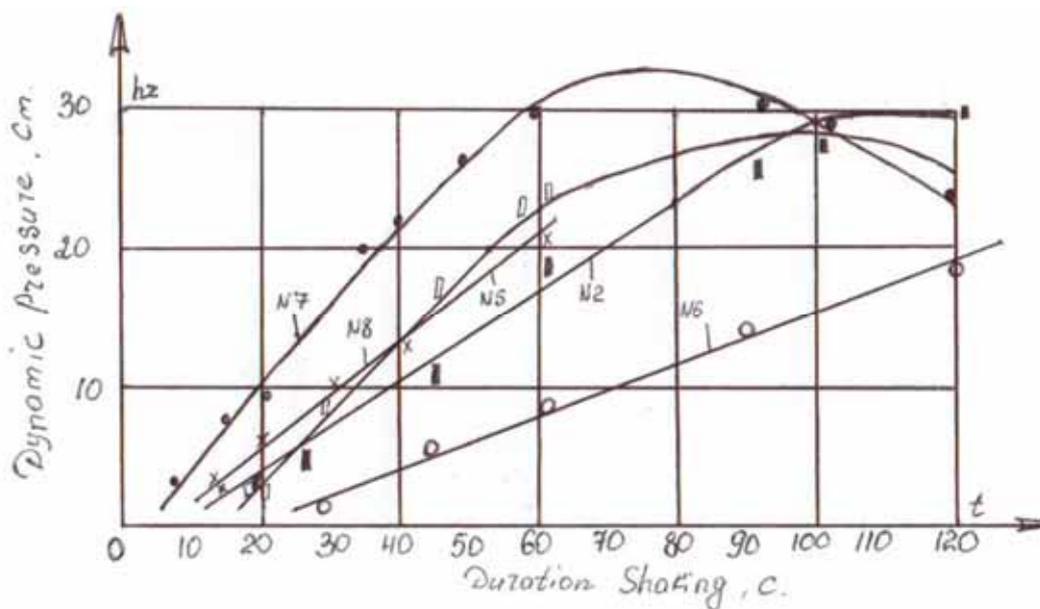
Turning to the presentation of the studies carried out in this direction, we note that all experiments were performed on heavily moistened loose loess soils, as a disturbed loess structure, a  $20 \times 20 \times 40$  vibratory tray was used, into which the soil was loosely filled. In the case when the soil was tested with a broken structure, the sample had a size of  $d = 16$  and  $20$  cm, and additional saturation of the sample with water was carried out by maintaining it for a certain time in a humid environment. Let us recall that in our experiments the dynamic head was recorded with a pressure transducer with the recording of the process by the oscilloscope  $H = 700$ . The use of electrical sensors made it possible to more clearly study the process of changing dynamic heads in time. In the initial experiments, the process was recorded according to the program from the moment the dynamic load was applied to the soil and until it was completely densified. According to the results of the decoding of the oscillograms, it was revealed that the main process of structure destruction under the accepted operating conditions takes place in many cases within 2 to 5 minutes.

Taking into account these provisions, in subsequent experiments the recording process was carried out continuously from the moment of application of the load on the soil to 3 minutes, and the one with which it was recorded in 2 to 3 minutes. Each cycle of the experiment was considered complete, when the soil surface reached a roughly constant level. The dynamic regime was also applied differently in different cycles of the experiment.

The main experiments were carried out according to the following schemes:

- 1) At constant values of density - humidity and variable value of intensity of dynamic impact;
- 2) At constant values of the intensity of dynamic impact, humidity and variable value of sample density.

When measuring pressure in water using pressure sensors, one could observe a pattern common to all soils subjected to qualitative analysis and differing only quantitatively for different conditions. The graph (Fig. 1.10) shows the recording data of the change in dynamic pressure in time for some varieties of investigated loess. The loess soil was shaken with an intensity determined by an acceleration of  $2200\text{--}2500 \text{ mm/c}^2$ . As can be seen from the dependence  $h_z = f(t)$ , in order for the dynamic head on the considered horizon to reach the maximum possible value at a certain shaking intensity, sometime interval is required, measured in several tens of minutes. In this sense, the graph of the dependence  $h_z = f(t)$ , shown in Fig. 1.11, which gives the result of similar studies with water-saturated sandy soil. From the comparison of Fig. 1.10 and 1.11 it follows that in the plan under consideration these essentially different in the property and composition (loess and sand) soils are characterized by some common feature. In particular, the character of growth of dynamic heads on a constant horizon has the same form. At the same time, as can be seen from the graphs, there are some differences in the character of the change in dynamic heads in these soils.



**Fig.1.10. Dependence of the form  $h_z = f(t)$  for the investigated loess soils. (the growth of dynamic heads was measured at a depth  $z = 30 \text{ cm}$ ). The curves indicate the groups N2,5,6,7,8.**

First, the time of increase in the dynamic head to its maximum value for loess soils is measured in a relatively large range than for sand; secondly, the onset of the appearance of dynamic heads in loess soils does not coincide with the beginning of the coordinate system, which characterizes the specific feature of cohesive soils. Obviously, that time interval, for which the value  $h_z = 0$ , indicates the time necessary to disrupt the connectivity of the ground.

The magnitude of this segment (see Figure 1.10) under identical shake conditions turns out to be different for different forest loses, which, apparently, is explained by the strength of these bonds. The soil No. 6 (loess-like loam), which was subjected to a shaking with a broken structure, was characterized by a rather high strength of the bonds ( $1,10 \text{ kgs/sm}^2$ ), for violation of which it was necessary to shake for approximately  $30 \alpha \sim 2500 \text{ mm/c}^2$ . This circumstance once again testifies to the role of the strength of the internal bonds of the soil in the dynamic violation of its structure. At a depth of 30 cm, where the measurement was made, the dynamic head gradually increases in time from the moment of breaking the bonds. When the value reaches 30 cm, the increase in dynamic head stops and in the future it remains either constant until a certain time, or the process of lowering the value of  $h_z$  begins. Obviously, the process of reducing the value of  $h_z$  is associated with the degree of acquisition of contacts by particles and the restoration of connectivity.

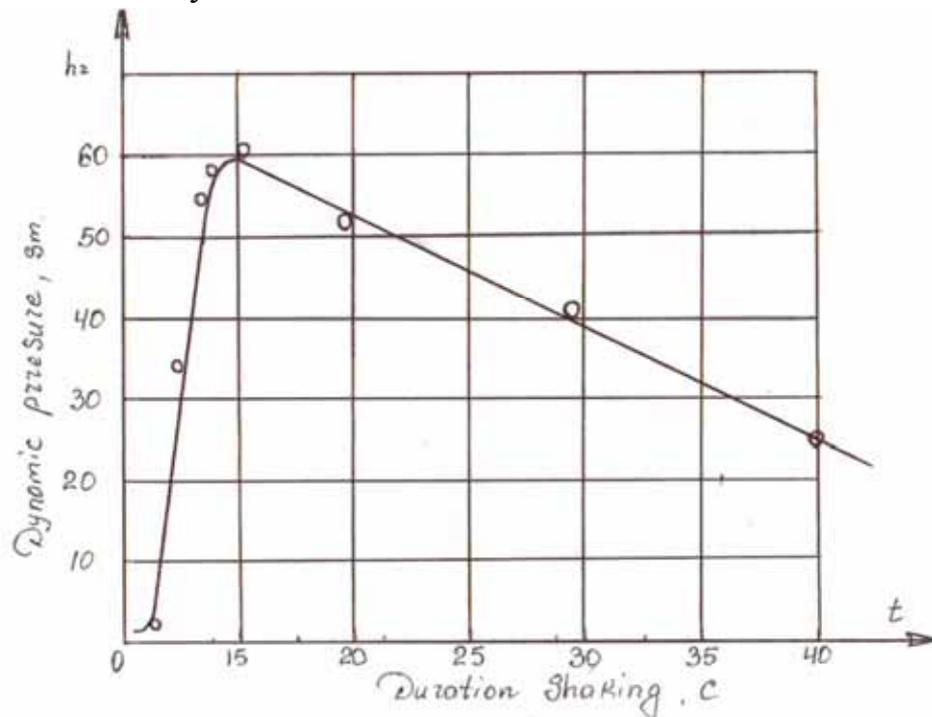


Fig.1.11. The nature of the change in dynamic head  $h_z$  at a constant horizon for sandy soil.

## **Chapter 2. The role of the time factor in the weakening of the strength of moisturized forests under shaking**

### **2.1 General Information.**

A large (in certain conditions decisive) value in the degree of seismic stability of loess soils has a duration of dynamic impact on them. The role of the time factor  $t$  in the seismic stability of sandy soils was noted in the studies and conclusions of many authors.

At the same time, this factor is of considerable importance in connection with cohesive soils. Back in the fifties, N.N. Maslov and Yu.Ya.Velli, who conducted experiments with the uncharged clays, noted that in the disturbance of the stability of the soil, the duration of the tremor plays an important role. In particular, Yu.Ya.Velley noted that the magnitude of the critical acceleration applied to cohesive soils should in all cases be determined taking into account the duration of the expected concussion. In carrying out even initial studies to study the nature of disturbances in the stability of moisturized forests, we encountered certain specific features of cohesive soils:

The process of condensation of water-saturated loess in all experiments did not begin immediately with the observance of the conditions  $\alpha > \alpha_{kr}$ , it took some time to manifest it;

The intensity of compaction at the initial moments of the application to the ground of the dynamic load was characterized by a relatively low value;

The occurrence and growth of dynamic head in loess soils was always longer than in sand.

Thus, it may be considered very important to take into account the time factor, along with the intensity of the shock in the estimation of seismic resistance of cohesive soils.

In accordance with the initial position of the development of the problem, the role of the time factor in the violation of the dynamic strength of moisturized forests results from the presence of a connectivity in them, the destruction of which required the duration of the concussion under the conditions  $\alpha > \alpha_{kr}$ . This circumstance made it possible to set the time required for the destruction of the soil structure and the manifestation of its corresponding deformation as a function of the strength of the bonds.

The instability of the structure of loess soils is determined by the characteristic weak connection of structural elements characteristic of them. The strength of bonds, as is known, depends on the composition and water resistance of the aggregating substance. The ability to soften and dissolve in water the natural cementing substance that causes the connectivity between the loess particles determines the nature of these bonds. The nature of the connectivity of loess soils

is established by the physico-mechanical nature of the bonds, their water resistance and mechanical strength.

## 2.2 Change in soil strength during shaking.

As the practice of construction shows, loose loess soils, which have a connection between the grains not only in dry and low-moisture, but also in a completely water-saturated state, are characterized by high compressibility. The features of deformation of loose loess soils during their shaking are determined to a greater extent by the specificity of their structure.

Suppose the ground has a loose build and has cohesive forces. The loss of stability of the structure of such a soil is possible if the adhesion forces between its individual particles are violated under the influence of pressure on the contacts of the particles in the process of shaking. To break the structure of loess soils, the following basic conditions are necessary:

1. The loose buildup of soil particles, in which the porosity of the soil  $n_{begin}$  the beginning of the shock, causing a disturbance of its structure, would be more porosity of the soil.  $n_{end}$  The impact of this factor, i.e.  $n_{begin} > n_{end}$ ;
2. The intensity of the shock, expressed in the form of acceleration, should be able to disrupt the adhesion forces between the particles;
3. The duration of the concussion must satisfy the condition. An analysis of these conditions shows that in the case where the adhesion forces between the soil particles are not violated by the actual shocks, the deformation of the soil does not appear. Deformation of the soil is not manifested and with concussions lasting a few seconds

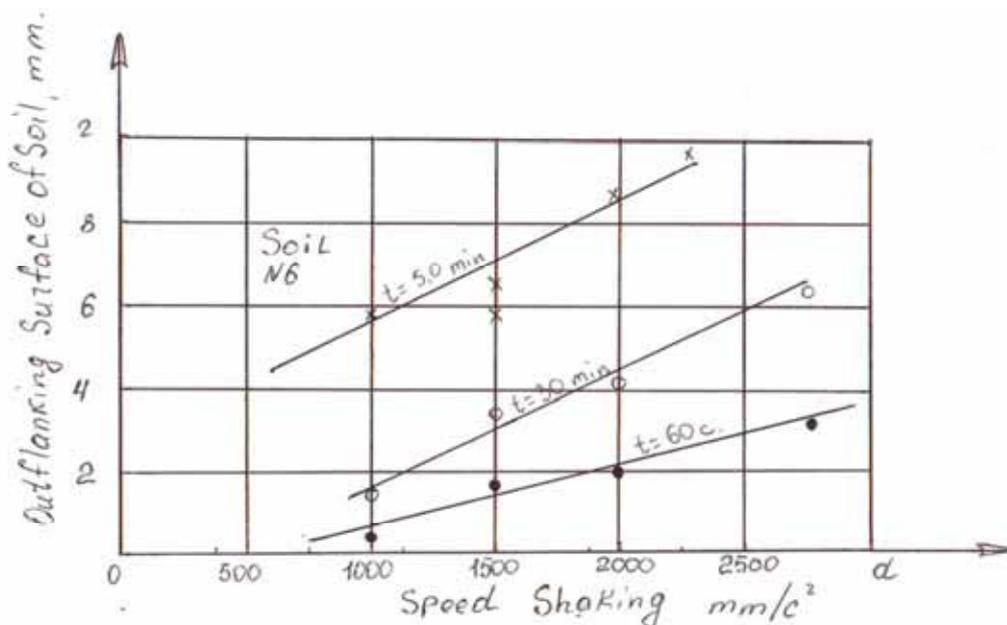


Fig.2.1. Dependence of the final value of the precipitation of the loess-like loam surface on acceleration for different shaking times.

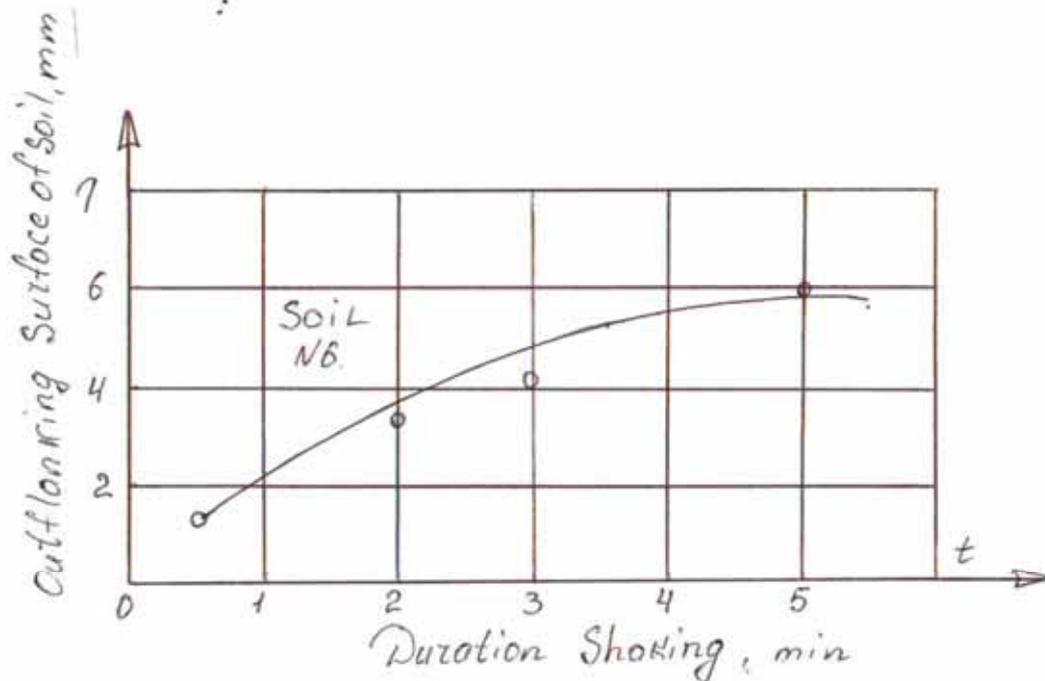


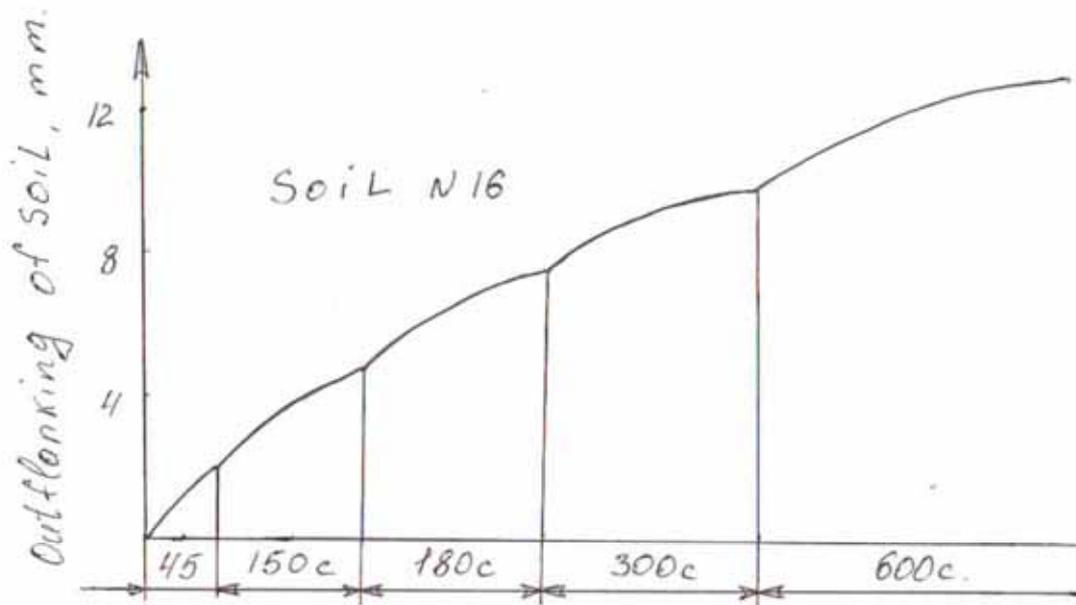
Fig.2.2. The change in the sediment size of the surface of loess-like loam with different shaking times ( $\alpha = 1500/c^2$ )

In nature there may be cases when in different zones of the soil massif the forces of cohesion between the particles are determined by different strengths of cement. Obviously, with concussion the deformation of the particles will not be the same in different places, and the soil structure will remain where the bond strengths are the most durable and are due to the presence of more rigid cements, which is observed in kind.

In Fig. 2.1 and 2.2 show the results of testing loess-like soil by vibration. Soil number 6 of almost identical condition before the experiment on the vibrating table was subjected to preliminary soaking for 7-8 days. At the same time, the adhesion forces decreased to  $0,050 \text{ kgs/cm}^2$  and the porosity was 44.4%. Then these samples were subjected to vibration duration of 60s, 2min, and 5min, respectively. Acceleration of the vibrational motion in these experiments was taken on the order of  $1500 \text{ mm/c}^2$ . Graphs of the dependence of the precipitate on the intensity of concussion  $\eta = f(\alpha)$  and on the time  $\eta = f(t)$  made it possible to establish the following. Despite the fact that the soils subjected to the study were characterized by the same physico-mechanical characteristics, the deformation effect as a result of shaking of different duration was different. Deformation of the soil increases depending on the duration of the shock, which is very important from a practical point of view. This conclusion is due to the fact that when shaking a loess soil, which has some connectivity between the particles, the dynamic load is perceived

by these links, which requires for a complete violation of a certain period of time. The nature of the change in the connections in time is evidently due to the physic mechanical phenomena occurring in the ground in the process of concussion.

The role of the time factor in violation of the cohesion of loess soils can be clearly demonstrated from Fig. 2.3, where loess loam with undisturbed structure was subjected to a shock ( $\alpha=2000 \text{ mm/c}^2$ ). The vibration was carried out five times with constant intensity. And each time after the cessation of concussions in the course of 30 minutes, the sediments were altered. Each subsequent concussion had a duration of 45 seconds, 150 seconds, 3 minutes, 5 minutes, and 10 minutes. The amount of deformation of the soil after each subsequent shock was of an increasing nature. It is interesting to note that the applied constant load along with the disturbance of the soil structure led to an additional compaction.



**Fig.2.3. The nature of the increase in precipitation for different shaking times ( $\alpha = 2000/c^2$ )**

It could be assumed that in this experiment briefly the temporary dynamic loads applied to the ground were able to break only the weakest bonds of the soil, which led to some of its deformation, and subsequent relatively long shocks had already produced a rather large effect in the disturbance of soil cohesion under these conditions.

Thus, as a result of the experiments, one can draw a conclusion about the decisive role of the time factor in the seismic disruption of the connectivity of water-saturated soils. To substantiate this conclusion, a series of experiments was carried out in which the soils were characterized by the same data in terms of their

physico-mechanical conditions and intensity. In these experiments, the variable parameter was the time factor, that is, the duration of the tremor.

It is interesting to note that the soil, compacted by about 5 mm with an acceleration shaking of the order of  $1000 \text{ mm}/\text{c}^2$  for 3 minutes, was practically not deformed at an acceleration  $\alpha = 1600 \text{ mm}/\text{c}^2$  applied for 40 seconds. Thus, the disturbance of the dynamic stability of loess soils turns out to be dependent on the strength of structural bonds.

At the same time, the greater or lesser resistance of soils to the applied dynamic load depends on the strength indices, such as the friction angle  $\phi_w$  and the greater adhesion  $C_w$ .

The forces of internal friction in soils occur when normal compressive stresses act on them and are determined by the degree of roughness of the surface of the constituent particles. With respect to cohesive soils, the question of internal friction is much more complicated and requires consideration in conjunction with other types of internal bonds that determine the strength of these soils, for example, the common  $C_w$  couplings. The values of the angle of friction and adhesion in cohesive soils depend, first of all, on the state of humidity and decrease with increasing latter. In Fig. 2.4 is a graph of the variation of the angle of internal friction of loess soil, depending on the state of its moisture content. With a soil moisture content of 15-20%, a slight change in the friction angle (about 2-3%) is observed, and as the loess is further moistened, the angle of internal friction sharply decreases.

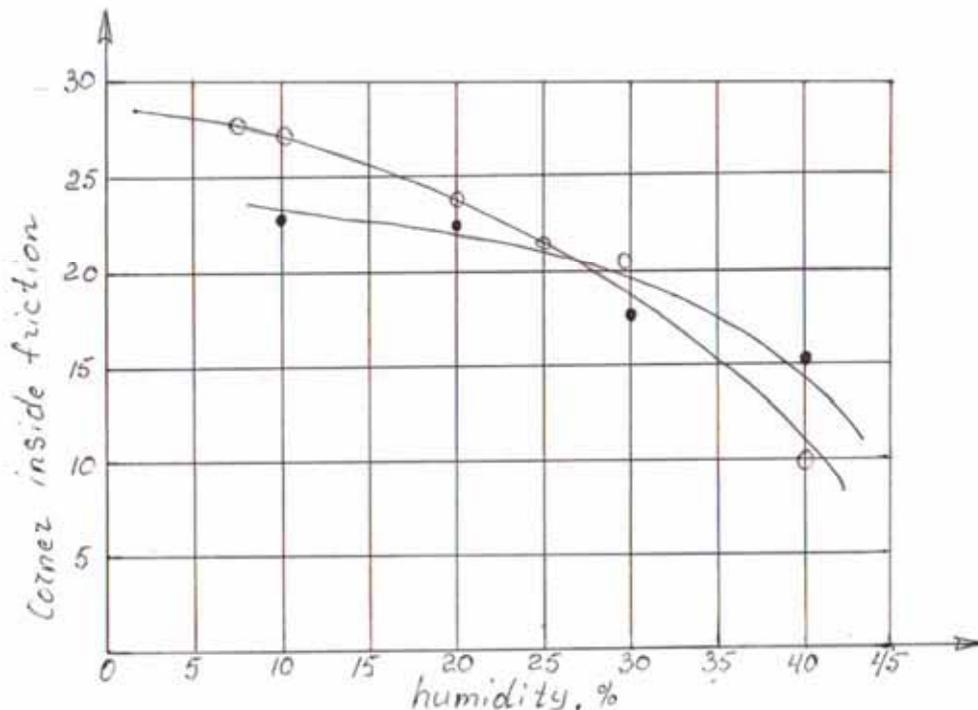


Fig.2.4. Change in the angle of internal friction of loess like soil, depending on the state of moisture: 1 - soil number 16, 2 - soil number 5.

Obviously, this situation is a consequence of the thickening of the hydrate shells on the particles with water overgrown with progressive deterioration and a decrease in the number of contacts between the particles. This circumstance makes it possible to assume that a decrease in the strength of water-saturated clay soils results in a decrease in the angle of internal friction.

However, experimental confirmation of such a conclusion seems almost impossible in connection with the manifestation, in these conditions, of the role of soil connectivity. The fact is that with the entrainment of the distance between the particles as a result of the thickening of the water shells, the effects of molecular bonds are weakened. In this case, simultaneously with the angle of internal friction, the connectivity of the rock also decreases (Figure 2.5), which makes it difficult to quantify a factor (angle of friction or connectivity). In the light of such a representation, it is expedient to evaluate the strength of loess soils taking into account the state of their moisture content, on which the angle of friction and adhesion depend.

The transition to dynamic testing of cohesive soils, which have a cohesion and a lower filtration capacity, makes it necessary to take into account the peculiarity of these factors. It should be noted that the weakening of bonds in a concussion of one degree or another takes place in all cohesive soils, especially in weak water-saturated loess soils. However, proceeding from specific conditions, the transition of soils to a dynamically excited state can manifest itself to such an insignificant degree that accounting for them during calculations will be practically impractical.

The question of the fall in strength of loess soils associated with the transition to a dynamically excited state loses its significance to the greater extent, the greater the strength of the soil and the less its strength and duration of shaking.

Our studies and analysis of natural observations have shown that the fall in the strength of soils can reach a significant development in time with accelerations of seismic shaking ( $\alpha_{seism}$ ) exceeding the values of critical acceleration ( $\alpha_{kr}$ ), that is, under the condition  $\alpha_{seism} > \alpha_{kr}$ , which confirms the essential role of strength (resistance) of the soil in its seismic stability.

As the practice of construction shows, the soils, depending on the composition and state of the natural occurrence, as well as a number of other factors, are characterized by different strength characteristics.

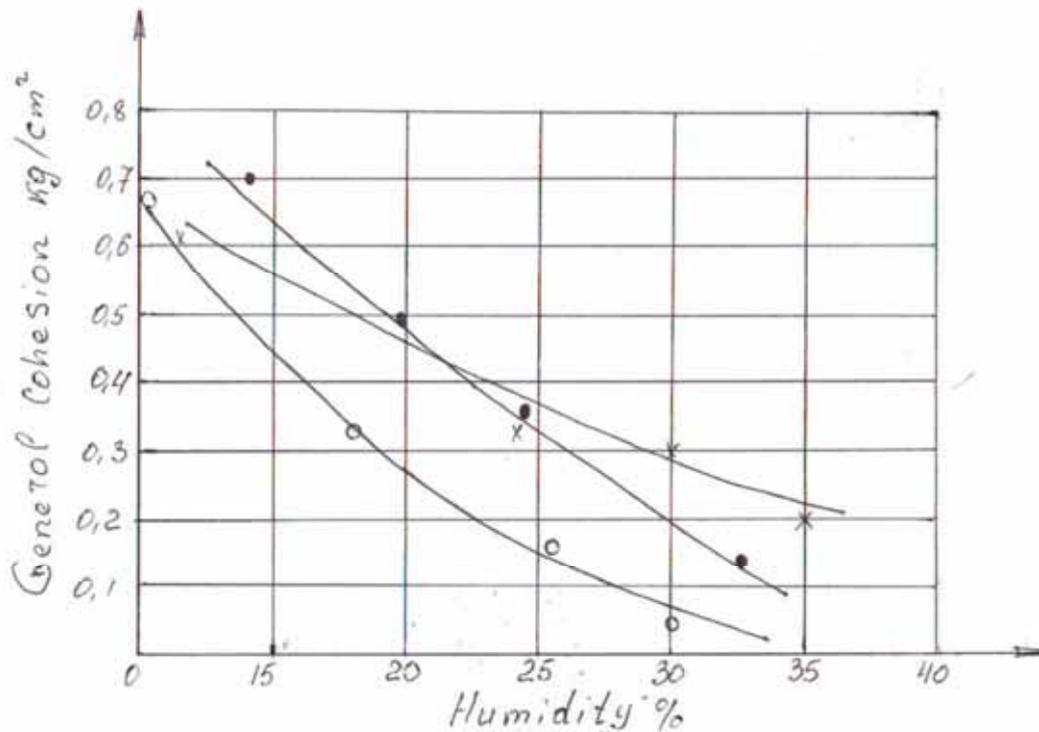


Fig.2.5. Decrease in the connectivity of loess soils with increasing their humidity: 1 - soil number 4, 2 - soil number 8, 3 - soil number 3.

Depending on the strength, all cohesive soils can be divided into three main types: 1) hard clay soils, 2) hidden plastic clay soils and 3) plastic clay soils.

According to the concept of N.N. Maslova, the resistance of cohesive soils to shear (strength) in general form is expressed by the dependence:

$$S_{pw} = P_n * tg\varphi_w + \Sigma_w + C_c, (2.1)$$

Where  $P_n$ - is the normal stress acting in the soil;

$\varphi_w$ - Angle of internal friction at humidity  $\omega$ ;

$\Sigma_w$ - Connectivity of water-colloid nature;

$C_c$ - Rigid structural cohesion.

The structural linkage  $C_c$  gives the rock certain stiffness, hardness and is irreversible. In the case of loess people, such connections are found only in their absolutely dry state, which, due to their weakness, are rapidly violated with intense shocks. Unlike structural cohesion, the connectivity  $\Sigma_w$  has a reversible, restoring character and is inherent in mostly waterlogged loess soils in a plastic consistency. The nature of the cohesion of clay soils, as noted, is due to their coherence. In the light of such an interpretation of the problem in the strength of dry forest, the dominant role belongs to the structural cohesion  $C_c$  (in loesses this type of cohesion is expressed in a very weak form) and internal friction. Resistance to shear of these soils can be expressed as follows:

$$S_p = P_n * tg\varphi + C_c(2.2)$$

In accordance with the expression (2.2), the strength of dry forest under dynamic load can be considered not depending on time. This circumstance makes it possible to state that the question of the drop in strength as a result of transition to a dynamically excited state with regard to the types of loess soils under consideration has no practical interest. In these types of soils, as well as in disconnected soils, the breakdown occurs immediately after the seismic acceleration of the critical acceleration value.

This is confirmed by studies conducted over dry forest. In Fig. 2.6 shows a graph of the dependence of the change in the sedimentation of the soil in time, that is, as a function of  $\eta=f(t)$ . The results of experiments carried out on loess monoliths taken from depths from depths of 6.0 m were reflected in the graph. The beginning of the deformation of such lesos corresponds to the origin of the coordinate system, which confirms our conclusion about the independence of structural bonding and the friction node from the time of shaking.

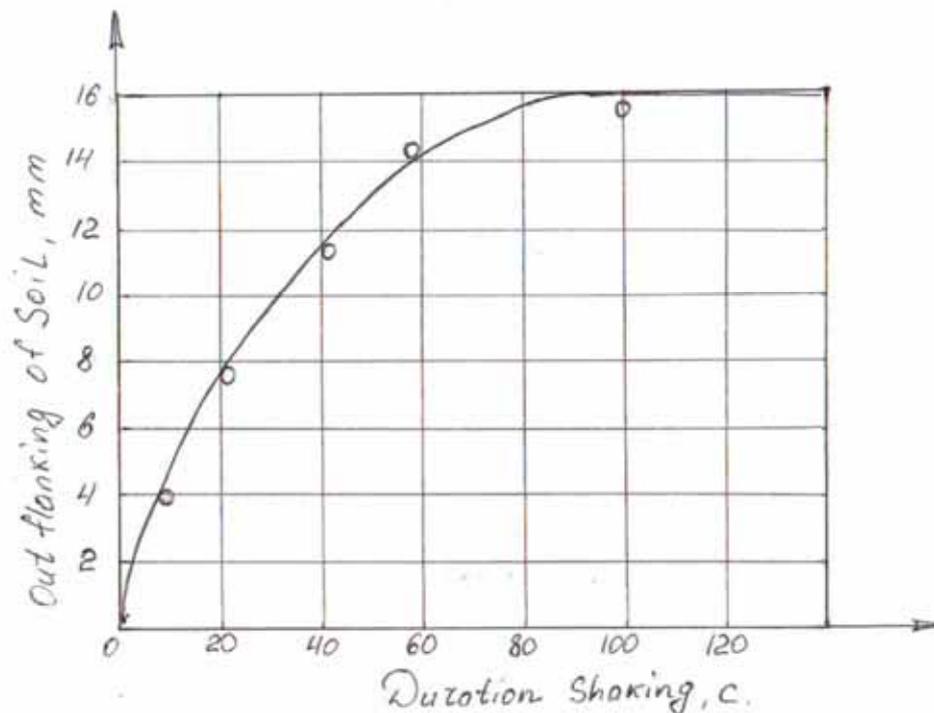


Fig.2.6. The graph of the change in the precipitation of dry loess in time  
 $(\alpha = 2800\text{MM}/\text{c}^2)$

The strength of highly humid loess soils in the plastic state is determined only by the forces of the connection  $\Sigma_w$ , which have a water-colloidal character. In plastic loesses, both the forces of internal friction  $\varphi_w$  and the rigid structural bonds  $C_c$  practically reduce to zero. Hence, from the general expression for the description of the resistance of ductile forest we have:  $S_{w,t} = \Sigma_{w,t}$  (2.3)

As follows from this expression, the strength of plastic loess soils depends on the state of moisture, and therefore they are of particular interest from the point of view of weakening of connectivity in the case of concussion, which is the most exposed. As studies show, these varieties of soils are capable of transitioning to a dynamically excited state with the smallest values of seismic acceleration (with their respective duration), since they differ in small values of the critical acceleration  $\alpha_{kr}$ .

Low-moisture loess soils are characterized by the manifestation of the strength of internal friction  $\varphi_w$  and the connection  $\Sigma_w$ , and sometimes in a very weak form and the structural linkage  $C_c$ . Then for wetted forests the resistance to shear is given by the following expression:

$$S_{pw,t} = P_t t_g \varphi_w + \Sigma_{w,t} + C_c (2.4)$$

The transition of such soils to a dynamically excited state requires somewhat more acceleration and durability due to their increased strength. However, in this case, the decisive factors are the moisture state (on which depend on  $\varphi_w$  and  $C_c$ ) and the connectivity of these soils. As studies have shown, increasing the humidity of moisturized forests leads to a decrease in their connectivity, and, consequently, to a decrease in the critical acceleration  $\alpha_{kr}$  value characteristic of these soils.

It can be suggested that the conditions of concussion of cohesive soils remain relatively unchanged in time factors of internal friction  $\varphi_w$  and structural cohesion  $C_c$ . It is believed that the connectivity  $C_w$  preserves the initial state within the effective seismic acceleration to a critical value, and, subject to the condition  $\alpha_{seism} > \alpha_{kr}$ , decreases in time under certain conditions to zero.

Thus, the time factor influences the weakening of the dynamic strength of only loess soils that are in a moist and saturated state. This position was confirmed in our experiments.

In the light of the problems under consideration, the issues of seismic stability of moisturized and waterlogged forests with their shaking, depending on a number of factors, including the time factor, have the greatest practical significance in this respect.

However, the role of the time factor is not limited to the loosening of loess connectivity, but becomes even more important in the development of the dynamic head  $h_z$ , which occurs when the bound particles are densified. As noted, the dynamic head  $h_z$ , along with other factors, is associated with the duration of the shock, as evidenced by the graphs, states from the results of experiments on wetted loess.

All of the above noted once again indicates the essential role of the duration of concussion in the violation of the dynamic strength of moisturized forests.

It should also be noted that in the plan under consideration the whole issue is reduced to establishing a natural cohesion of the soil, the strength of which determines the necessary duration of the concussion.

For this reason, many clay soils can be seismic resistant if they have the strongest connectivity forces. The duration of one or more phases of the earthquake in these cases will not be sufficient to break these bonds. At the same time, with regard to moistened and, in particular, water-saturated loess soils, this question acquires great practical importance.

### **Chapter 3. Criterion for the possibility of disturbance of the structure of wetlands under seismic conditions.**

#### **3.1 General information.**

As noted above, the issue of disturbance of stability of soils under the influence of dynamic loading on them was mainly studied in relation to non-cohesive, in particular, to sandy soils. Various methods are proposed that allow one to evaluate the criterion for the transition to the dynamically excited state of water-saturated sandy soils during their shaking. The existing criteria for breaking the stability of water-saturated sands can be divided into methods based on the state of the initial (natural) porosity of the soil, and methods based on fixation soil compaction in case of concussion. The first group of stability criteria for sandy soils includes the method of critical porosity (I.V.Yarapolsky, 1933, A. Kazagrande, 1935), the maximum structural density of sand (O.A.Savinov, 1964). To the second group, the method of standard explosions (V.A.Florin, P.L.Ivanov, 1951), the console taking into account the creep of the soil skeleton (P.L.Ivanov, 1971), critical acceleration (O.A.Savinov, 1949, N.N.Maslov, 1953), and the like.

It should be noted that all the methods mentioned are based on the ability of the soil to rapidly compact after the structure has been destroyed or other mechanical effects. It is known that the degree of compaction of sands depends on the magnitude of the mutual displacement of the particles when the structure is destroyed and their natural (initial) porosity. In turn, the displacement of sand particles is determined by the nature and intensity of the applied dynamic influences. These provisions were the basis for developing some or other methods for assessing the stability of water-saturated sandy soils during their shaking.

However, in order to assess the stability of the bases, which are composed of different soil conditions and properties, these methods proved to be unacceptable. This is due to the fact that the soils in the base of the structures in rare cases are composed of a homogeneous material (sand). Most often they are represented by various cohesive soils, sharply differing in their physico-mechanical properties from the sand. In addition, the lack of a method for assessing the method for

assessing the stability of such soils puts planners and builders in a difficult position.

In this sense, even a superficial analysis of existing methods for assessing the stability of sandy, bondless soils, already to some extent deprives them of the possibility of using them in connection with cohesive (loess) soils. This is explained by the fact that the process of disturbing the structure of moist loess soils in accordance with our study is caused not by a mechanical breakdown of the structure, but by physical and mechanical phenomena occurring in these soils during their shaking. In the light of this disturbance of the stability of cohesive (loess) in many cases does not begin with the compaction of grains, but with the weakening of bonds during shaking, which contributes to their compaction. This circumstance clearly dictates the need to develop a new method for estimating the dynamic stability of soils, with the help of which it would be possible to establish a criterion for transition to a dynamically excited state, regardless of the type of soil. This approach to the solution of the problem requires the development of an already calculated (theoretical) method for assessing the stability of soils.

In solving this problem, we proceeded from an analysis of our numerous studies and developments, as well as observations of the consequences of earthquakes. It seemed expedient to take as the basis of our developments the method of critical acceleration  $\alpha_{kr}$  as the most suitable criterion for evaluating the seismic stability of weak loess soils. The choice of the method of critical acceleration is justified by the fact that the intensity of the earthquake in quantitative terms is also measured by the magnitude of the acceleration. Comparisons of the two values of the accelerations under these conditions to determine the criteria for the stability of the soil proved to be the most reasonable.

Recall that a critical acceleration  $\alpha_{kr}$  is understood as such an acceleration of the vibrational motion, below the value, which the soil will remain in a stable state, and above its value, the resting ground becomes a dynamically excited state. The method of critical acceleration  $\alpha_{kr}$  was first proposed by O.A. Savinov (1949) for the study of foundations, subjected to vibration as a result of the operation of machines with a dynamic mode. As a criterion for disturbing the structure of dry sands, D.D. Barkan it was called the threshold of vibration compaction. The method of critical acceleration was studied most extensively by N.N. oil (1953) to assess the possibility of disturbing the structure of water-saturated sandy soils during shaking. Due to its simplicity and clarity of definition, the method of critical acceleration has received wide application of scientific practice in the dynamic testing of water-saturated sands.

To determine the critical acceleration of vibrations, the sample under study with the required density is poured into laboratory trays. A non-inertial static load is

applied to its surface, corresponding to vertical compressive stresses acting in the soil mass. By gradually changing one of the parameters (amplitude or frequency) of the oscillatory motion, the value of the critical acceleration  $\alpha_{kr}$  of oscillations is set, at which the process of breaking the sand structure begins. N.N. Maslov recommended two methods for determining the critical acceleration  $\alpha_{kr}$ . According to the first method, observations are made of the sedimentation of the surface of the sand, and the acceleration of the oscillation, in which the first noticeable subsidence of the sample surface is noted for the masses, are applied to the density critical for a given state under the action of a given static load. According to the second definition of  $\alpha_{kr}$ , the moment of destruction of the sand structure is marked by the beginning of the water level rise in the piezometric tube installed on any horizon of the test sample. As studies show, these methods of determining  $\alpha_{kr}$  were interchangeable. The results of the study are formulated in the form of graphs of the changes in the critical acceleration of the oscillations, depending on the porosity of the sand.

The above-described technique for determining the critical acceleration  $\alpha_{kr}$  was proposed, as noted above, taking into account the nature of the disturbance of sandy, rapidly compacted soil structures during fractures. Its use to assess the stability of cohesive soils is not possible without taking into account their specific features in seismic conditions.

Before proceeding to the exposition of the method developed by us, it should be noted that Y. Velli was engaged in determining the critical acceleration for cohesive soils. He established the very possible role of the duration of the forced oscillation, necessary for weakening and destroying the bonds of soils under shock conditions. On the recommendation of Yu.V.Velli, the duration required to destroy the soil bonds was measured in 5 minutes. As a critical acceleration for coherent soils, such an acceleration of the vibrational motion is accepted, under the action of which the coherent soil remains at rest for 5 minutes. Proceeding from this condition it is obvious that with a viscous increase in the acceleration value it is obvious that with a viscous acceleration greater than ( $\alpha > \alpha_{kr}$ ) or with a dynamic impact on the ground of oscillations from accelerations  $\alpha$ , in the course of  $c$  above 5 min, the ground will be able to go over to the dynamically excited state, which is indicated by the indication of the sedimentation of the soil surface or the increase in pressure in the pore water.

In our studies it was noted that the duration of the vibrational motion certainly affects the magnitude of the critical acceleration of cohesive soils. So, for example, the disturbance of soil stability does not occur immediately after the application of a dynamic load on the ground, but requires for its manifestation a more or less definite period of time. During the experiments, the main, sometimes decisive, role

of the strength of internal bonds in the duration necessary for the manifestation of the destruction of the soil structure was established. Depending on the strength, the duration of the breaking of bonds at a certain intensity of concussion is also determined. Figure 3.1 shows the graphs in the form  $\alpha_{kr}=f(t_1C_w)$  for several varieties of loess soils. The magnitude of the critical acceleration is determined by the strength of the bonds and the duration of the tremors. For this reason, strict regulation of the time factor  $t$  in the value of the critical acceleration  $\alpha_{kr}$  would lead to some error. Apparently, in the experiments of Y. Velli, clay soils with a sufficiently high value of connectivity were used, the destruction of which required time within 5 minutes.

In accordance with our research, the magnitude of the critical acceleration  $\alpha_{kr}$  is closely related to the strength characteristics of soils, and for cohesive soils - to the strength of internal bonds. This fact is confirmed by many studies.

According to the theory of disturbance of the structure of humid loess soils, the dynamic load applied to the soil is first of all perceived by internal bonds, the disturbances of which determine the further behavior of the soil. This circumstance makes it possible to put the critical acceleration  $\alpha_{kr}$  in dependence on the overall strength of the soil, and for water-saturated cohesive soils - on the strength of these bonds. In our studies carried out to study the weakening of soil cohesion during shaking, the ball method was used, the beginning of the immersion testifying to a reduction in the coherence of the soil.

Under these conditions, with respect to laboratory experiments, for the qualitative prediction of phenomena, it was possible to fix the value of the critical acceleration  $\alpha_{kr}$  at the beginning of the immersion of the ball into the ground. A series of experiments was carried out using this technique, the results of which are shown in Fig. 3.2, 3.3. In all these experiments, the soil is placed in the vibrating pan (in the case of a broken structure, respectively, into the ring) and subjected to shaking with varying intensity.

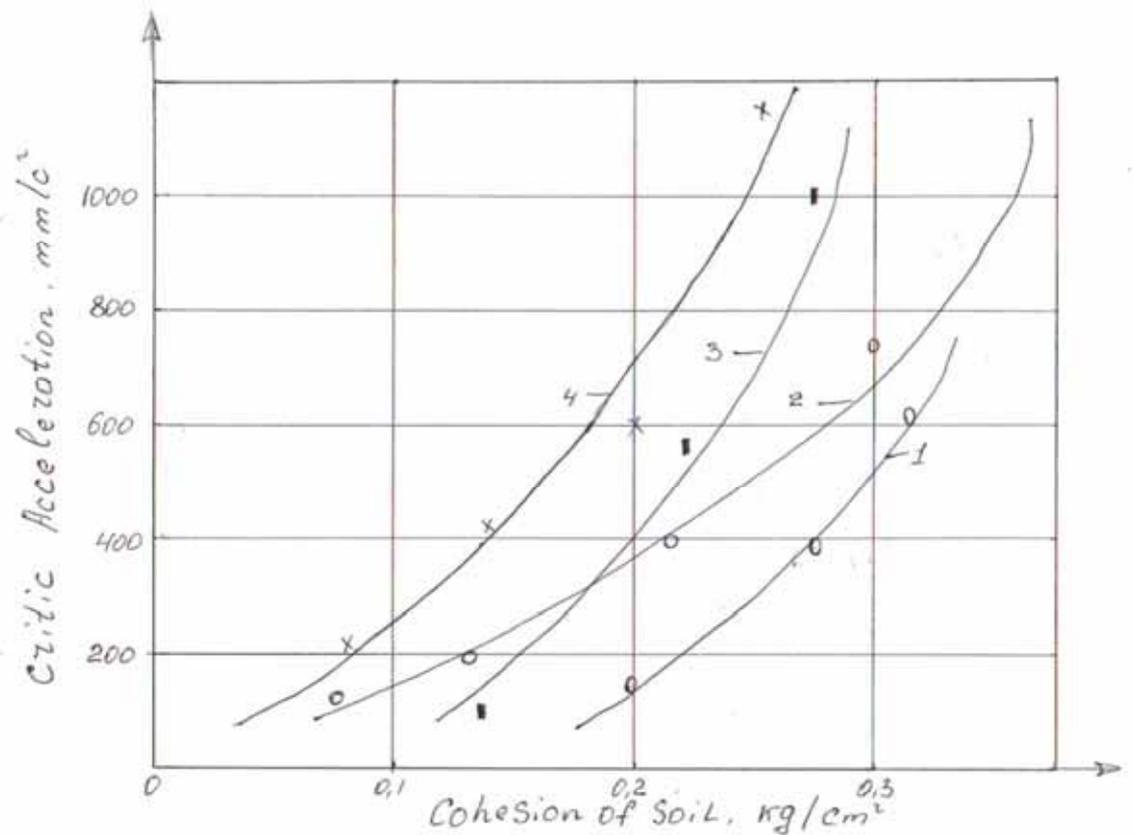


Fig.3.1. Dependence of the critical acceleration  $\alpha_{kr}$  on the cohesion of the soil: 1 - soil number 3, 2 - soil number 2, 3 - soil number 5, 4 - soil number 7.

However, the observation of the immersion of the ball mounted in the sample was temporarily performed. Experiments carried out under laboratory conditions confirmed the dependence of the critical acceleration on the strength characteristics of the investigated soil, the increase of which in all cases led to an increase in the value of  $\alpha_{kr}$ .

It should be noted that laboratory tests for the determination of  $\alpha_{kr}$  are associated with certain difficulties arising from the experimental condition and the instrumentation used in this process.

This definition turns out to be very difficult in connection with cohesive soils, as the disturbance of the stability of such soils causes a complex of phenomena, such as a reduction in connectivity in the weakened location of the strata, the compaction process resulting in a dynamic head, and also in certain conditions the duration of the shock. All these conditions leave an imprint in the reliability of the laboratory determination of the magnitude of the critical acceleration for cohesive soils. In addition, not all designers and not always have the opportunity to conduct a special laboratory test using the most accurate measuring instruments and equipment. For this purpose it is useful to use theoretical (formula) dependencies. However, the absence at the present time of such dependencies forced the designers and builders to calculate by using various coefficients, etc.

The following theoretical method for determining the critical acceleration is based on the conclusions that follow from the theoretical questions discussed in this paper and the results of several other authors of the research.

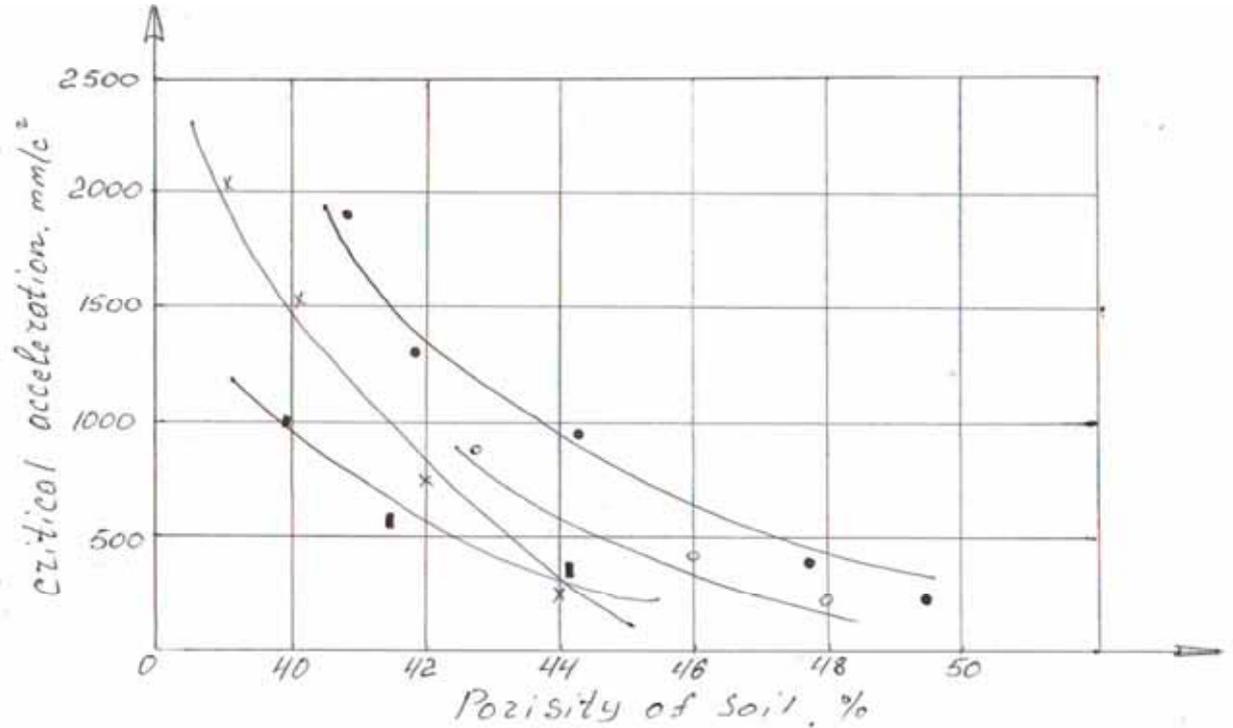


Fig.3.2. The nature of the change in the critical acceleration  $\alpha_{kr}$ , depending on the density of loess soils: 1 - soil number 4, 2 - soil number 1, 3 - soil number 3, 4 - soil number 6.

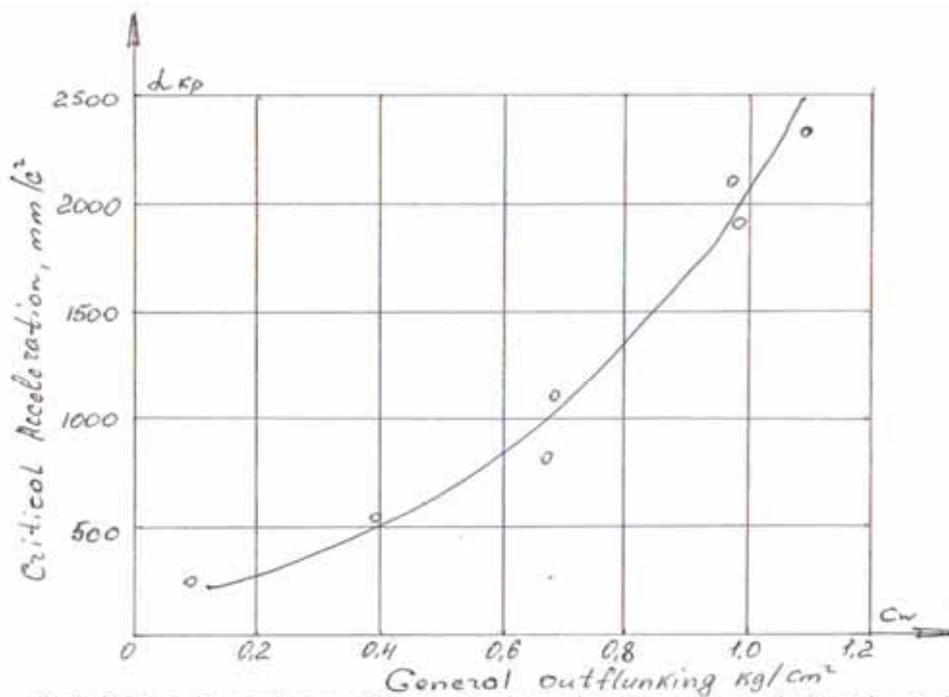


Fig.3.3. The dependence of the critical acceleration  $\alpha_{kr}$  on the total coupling. (soil - loess-like loam, broken structure)  $\alpha=2500 - 2800 \text{ mm/c}^2$

### 3.2 Calculation method for determining the critical acceleration $\alpha_{kr}$

The essence of the theoretical method of critical acceleration  $\alpha_{kr}$  is formulated in the following form (3.2).

Suppose that the determination of the earth thickness  $z$  is subjected to shaking (seismic action) with the same intensity throughout its depth. In such cases, the stability of any particle of ground in a bound state with other particles is determined by the ratio of two forces: the force that ensures the stability of the particle ( $S_{pw}$ ) and the force that causes the particle shift ( $S_{seism}$ ). In this case, the force ensuring the stability of particles in the conditions of concussions in accordance with the soil mechanics is determined in general by the magnitude of the normal stresses ( $P_n$ ) acting on the particle from the weight of the overlying particles and structures, the angle of internal friction ( $\varphi_w$ ) and the general cohesion ( $C_w$ ) contacts of ground grains. Each particle in the thickness of the ground with the power  $z$  will resist the external force with the following strength parameters:

$$S_{pw} = P_n * t_d \varphi_w + C_w (3.1)$$

On the other hand, the external load acting on the thickness causes an effort in the particle, tending to disturb its stable state (shear). This force is characterized in the form of additional stress, perceived by the soil, proportional to the thickness of the seismic inertial force, determined by the mass ( $m$ ) of the thickness, on which the force acts, and the acceleration of the resulting motion,  $\alpha_{seism}$ . This voltage is defined as

$$S_{seism} = \frac{\gamma_w}{g} * T * v_{wave} (3.2)$$

Thus, the condition of limiting equilibrium of any particle of soil in the thickness of the power  $z$  is the equality:

$$P_n * t_d \varphi_w + C_w \frac{\gamma_w}{g} * T * v_{wave} * \alpha_{seism} (3.3)$$

In this case, an insignificant decrease in the parameters on the left side of the equation leads to the destruction of the structure and the transition of the soil to a dynamically excited state. Simultaneously, the increase in the parameters entering the right-hand side of the equation leads to the same consequences.

Taking this circumstance into account, one can find from equation (3.3) the acceleration value considered in this case as a critical acceleration in the form:

$$\alpha_{kr} = \frac{g(p_n * t_d \varphi_w + C_w)}{\gamma_w * T * v_{wave}} (3.4)$$

Formula (3.4) allows us to determine in each particular case the magnitude of the critical acceleration below which the ground particles will be in a stable state. Note that formula (3.4) is derived for the general case, when the ground has, in addition to friction between the particles, and some cohesion forces and from above perceive the load of the weight of the structure. However, in practice, one or

other of these factors may be absent. So, for example, for the case  $C_w = 0$  we have:  $\alpha_{kr} = \frac{g \cdot P_n \cdot tg \varphi_w}{\gamma_w \cdot T \cdot v_{wave}} (3.5)$

or, considering  $P_n = \gamma_w \cdot z + P_0$  (where  $\gamma_w \cdot z$  is the weight of the overlapping horizon,  $P_0$  is the weight of the structure) for the case  $P_0 = 0$  and  $C_w = 0$ , we have:

$$\alpha_{kr} = \frac{g \cdot z \cdot tg \varphi}{T \cdot v_{wave}} (3.6)$$

As follows from these expressions, the magnitude of the critical acceleration is determined mainly by the strength characteristics of the soil, while the critical acceleration will decrease with increasing thickness of the strata subjected to shaking.

The practical use of formula (3.4) is illustrated by an example. It is required to determine the magnitude of the critical acceleration  $\alpha_{kp}$  for a 1-meter surface layer of sandy soil by a coefficient of friction  $tg \varphi = 0,6$ .

Decision. Using the formula (3.6), we find:  $\alpha_{kr} = \frac{9,81 \cdot 1 \cdot 0,6}{10} = 0,588 \text{ M/c}^2$

**Table 3.1. Critical acceleration values for loess (wetted) soils of some construction sites**

type of soil	Average power, M	Volume weight $\gamma_s/m^3$	Angle of internal friction, deg.	The total grip, $\text{kgs/cm}^2$	Critical acceleration, $\text{MM/c}^2$
Loess-like sandy loam with interlayer of loam	4,5	1,55(0,55)	27	0,65	1380
Loess-like loam	7,0	1,68(0,68)	24	1,4	925
Loess-like loam	18	1,77(0,77)	26	1,79	400
Loess-like loam and sandy loam	14	1,62(1,62)	27	2,07	610

Table 3.1 provides data on the determination of  $\alpha_{kr}$ , compiled using formulas (3.4) - (3.6) on the basis of materials taken from various construction sites. It should be noted that in the proposed formulas for critical acceleration  $\alpha_{kr}$  there is not taken into account the time factor, which, as noted above, plays a certain role under certain conditions in firmly bound soils. However, this situation can easily be taken into account by representing formula (3.4) in the form:

$$\alpha_{kr_t} = \frac{g[(P_n - \Delta_B h_{z,t}) tg \varphi_w + C_{w,t}]}{\gamma_w \cdot T \cdot v_{wave}} (3.7)$$

Here, the quantity  $\alpha_{kr_t}$  corresponds to its changed value, taking into account the duration of the shock.

The use of formulas (3.4) and (3.6) makes it possible to solve the most important practical problems associated with the assessment of seismic stability of soils, the determination of the increment in the scale of the construction site, and the calculation of the foundations of structures in seismic regions.

### **3.3 Experimental verification of factors affecting**

the value of critical acceleration

According to the formula (3.4), the magnitude of the critical acceleration of soils is related to the strength characteristics of the soil ( $\varphi_w, C_w$ ), the magnitude of the normal stress (both from the self-weight of the overlapping horizon and the weight of the overload from the structure), and the thickness of the soil strata subjected to shaking. The role of internal friction ( $\varphi_w$ ) and cohesion ( $C_w$ ) of loess soils and their seismic stability was described in more detail in the second chapter. As a result of the studies carried out by the author, a direct relationship between the strength characteristics of the soil ( $S_{pw}$ ) and its seismic stability (critical acceleration  $\alpha_{kr}$ ) was established. Now let us consider the influence of factors of the intrinsic weight of the soil strata, on the magnitude of the critical acceleration.

#### **3.3.1 Proper weight of the strata.**

The influence of the own weight of the strata on the stability of soils was studied by a number of scientists - V.A. Florin, N.N. Maslov, P.L. Ivanov, A.A. Nichiporovich and others. As early as 1953, P.L. Ivanov noted the large role of the initial stressed state, that is, the state due to the intrinsic weight of the strata, in ensuring the stability of water-saturated sand masses, which is under dynamic influence; under this condition, the stress state arising in the thickness from its own weight has a very beneficial effect on the depth The spread of the zone where the soil (sand) loses its stability. Thus, P.L. Ivanov believed that the degree of stability of water-saturated sandy soils at a certain depth is determined for a given intensity of dynamic impact by the value of the intrinsic weight of the sand column.

N.N. Maslov and his collaborators established the limited role of the intrinsic weight of the water-saturated sandy strata in the degree of its dynamic stability. This limitation is related to the frequency of the vibration applied to the ground, at high values of which (15-25 Hz), there was no positive result of its own weight, which, apparently, is due to the onset of the resonance phenomenon. The influence of the soil's own weight on the value of its dynamic stability ( $\alpha_{kr}$ ) was subjected to a more thorough study in the author's studies (1965 - 1968) to study the effect of the soil's own weight on the value of  $\alpha_{kr}$ . Numerous experiments with various sands were performed. The granulometric analysis of the investigated soils is given in Table 3.2.

**Table 3.2 Granulometric composition of the investigated sands.**

Fraction, mm	Sand №1		Sand №2		Sand №3		Sand №4		Sand №5	
	%	amount								
More 2	0	-	0,059	100,0	-	-	0,36	100,0	-	-
2-1	0,115	100,0	0,71	99,4	0,02	100,0	31,15	99,56	-	-
1-0,5	40,01	99,85	19,44	99,23	3,92	99,98	47,47	64,41	0,19	100,0
0,5-0,25	50,94	59,84	58,42	79,79	69,32	96,06	16,64	20,94	42,8	99,0
Less 0,25	8,9	8,9	21,37	21,37	26,74	26,74	4,30	4,30	57,0	57,0

The influence of the soil's own weight on the value of its dynamic stability ( $\alpha_{kr}$ ) was subjected to a more thorough study in the author's studies (1965 - 1968) to study the effect of the soil's own weight on the value of  $\alpha_{kr}$ . Numerous experiments with various sands were performed. The granulometric analysis of the investigated soils is given in Table 3.2.

**Fig.3.4. Vibration unit with vertically directed oscillations.**

Experimental work was carried out on a vibrational installation specially designed by the author for a vertically directed oscillation (Fig. 3.4). The thickness of the water-saturated soil was about 165 cm. The experiments were carried out with a predetermined frequency and amplitude of the oscillatory motion. The installation made it possible to oscillate the amplitude of the oscillations within the limits from 0.01 to 1.0 mm and the oscillation period of 0.2 – 0.033 s. (respectively, the frequency from 5 to 30 Hz). The main experiments were carried out at periods of 0.14; 0.1; 0.07 s and accelerations from 10 to 2800mm/c<sup>2</sup>(from 0.001 to 0.3 g). The magnitude of the critical acceleration was registered by measuring the onset of

the onset of pore pressure (dynamic head) by means of electrical pressure transducers DPD-0.3 simultaneously at 6 points in depth. In addition, the sediment was measured at different depths of the ground with the help of special frames and the vibration mode using a vibration sensor of the  $K - 001$  type. Dynamic head changes and vibration mode were recorded via an 8 – *ANCH* amplifier using an  $H - 700$  oscilloscope.

Analysis of the results of the studies as a whole made it possible to note the following: the intrinsic weight of a series of water-saturated soils with the application of a dynamic load increases the dynamic stability of the soil, which is confirmed by the previously concluded conclusion of P.L.Ivanova. However, during the dynamic impact on the thickness of the water-saturated soil, the role of own weight as a factor increasing the dynamic stability of the soil is diminished.

This circumstance is confirmed by the following phenomenon occurring in a continuous process in the water-saturated soil stratum under conditions of dynamic impact on it:

- a) Gradual disturbance of soil structure during its shaking;
- b) The movement of ground grains downward under the influence of their own weight under conditions of disruption between partial contacts;
- c) Occurrence in thickness and successive increases of excess pressures (dynamic head  $h_z$ ) in time to the maximum possible value for a given horizon;
- d) Successively in time the penetration of the "active" zone associated with a simultaneous decrease in the value of critical acceleration in the lower horizons (layer-by-layer dilution phenomena according to P.L.Ivanov).

Such a phenomenon will occur in all fully water-saturated loose soils under the influence of dynamic load on them. The results of experiments with water-saturated disconnected soils are formulated in the form of a relationship:  $\alpha_{kpz} = \alpha_{kpz1} + a\gamma_w * z$  (3.7)

Where  $\alpha_{kpz}$  - the value of the critical acceleration at a depth  $z$  from the surface of the layer;  $\alpha_{kpz1}$  - is the critical acceleration corresponding to the surface non-overloaded layer at a depth  $z1$  ( $z1$  is a relatively small value);  $a$  - is a coefficient that depends on the strength characteristics of the soil.

In accordance with the dynamic regime of the thickness of the expression (3.7), it become:  $\alpha_{kpz} = \alpha_{kpz1} + a(\gamma_w * z - \Delta_B * h_z)$  (3.8)

As follows from this expression, the quantity  $\alpha_{kr}$  gradually decreases as the dynamic head  $h_z$  increases in the earth's thickness and, under the condition  $h_z=z$ , according to the expression (3.8), we have:

$$\alpha_{kpz}^c = \alpha_{kpz1} \quad (3.9)$$

Equality (3.9) corresponds to the limiting state of ground loss of its stability (liquefaction conditions). The ground in this case does not resist the dynamic load. Insignificant in the whole value of will be able to conduct a dynamically excited state of the soil lying above the horizonz. In this case, the charitable role of one's own weight is reduced to zero. Thus, it can be noted that the intrinsic weight of water-saturated soils has a positive effect on the value of the critical acceleration at the time of application of the dynamic load, which in future depends on the duration of the shock.

### 3.3.2. External load.

Many scientists have studied the effect of the external load on the magnitude of the critical acceleration. It has been established that the influence of the critical acceleration  $\alpha_{kr}$  is associated with the effect on the thickness of normal stresses and usually increases in a linear dependence that is in good agreement with the empirical Maslov's formula:  $\alpha_{kr} = \alpha_{kr}^0 + aP$  (3.10)

Where  $\alpha_{kr}^0$  - the value of the critical acceleration, which corresponds to the condition of absence of external load;

$P_0$ - is the external load.

Experiments carried out by P.L.Ivanov (1956) showed that the drainage overload (rock outline) significantly influences the value of  $\alpha_{kr}$ . Further, developing the provisions on the dependence of the critical acceleration  $\alpha_{kr}$  on the external load and the intrinsic weight of the soil strata, the author establishes a relationship in the form:

$$\alpha_{kpz}^p = \alpha_{kpz}^0 \left[ \frac{P_z}{\gamma_w(z-h_{deep})} + 1 \right] + a(P_z + \gamma_w * z) \quad (3.11),$$

we obtain the following result:

Where  $P_z$  -is the normal voltage from external overload at a depth  $z$  from the ground surface;

$h_{deep}$  The depth of the foundation.

Along with the above-mentioned factors (overload and the soil's own weight), the depth of the structure penetration into the ground will also have a positive effect on the value of  $\alpha_{kr}$ , which is very important in the design of structures. Any penetration of the structure contributes to an increase in the value of  $\alpha_{kr}$  and thus its stability. However, the appearance of a dynamic head  $h_z$  in the zones bordering the foundation above its base can lead to a decrease in the depth effect, and, consequently, to reduce these conditions, the values of  $\alpha_{kr}$ . The magnitude of the critical acceleration  $\alpha_{kr}$ , which is quite large under the overload, decreases rapidly with depth and with reaching the lower end of the normal stress from the overload, the increase of  $\alpha_{kr}$  is already observed as a function of the self-weight of the soil. It should be noted a very remarkable fact that the further increase of  $\alpha_{kr}$  as a function of the intrinsic weight of the soil has its value somewhat larger than the value of

$\alpha_{kr}$  in these horizons in the absence of an overload. Here, obviously, the effect of overload is affected by the appearance of a dynamic head  $h_z$  in the earth's thickness under these conditions also leads to a decrease in the value of.

### 3.3.3. Thickness of the strata.

As follows from expression (3.4), increasing the thickness of the strata subjected to shaking leads to a decrease in the critical acceleration  $\alpha_{kr}$ . The logical conclusion derived from this follows from the well-known law of dynamics about the proportionality of the inertial force applied to the body and its mass. Probably, for the same, the volume of the soil increases with increasing power, which requires a correspondingly large inertial force. At one time, the well-known seismologist B. Gutenberg, describing the destruction of structures due to earthquakes, noted that along with the intensity of the tremor has a great influence on the process of deformation of the earth during earthquake composition and earthquakes. In his opinion, the presence of a powerful layer of alluvial deposits in the base of the structures sharply increases the danger of their destruction during an earthquake.

The influence of the power of water-saturated weak soils on the magnitude of the critical acceleration was studied by the author. In accordance with the investigation, when the backpressure sand (dynamic head  $h_z$ ) is applied in the thickness of the sand, a decrease in the value of  $\alpha_{kr}$  is observed.

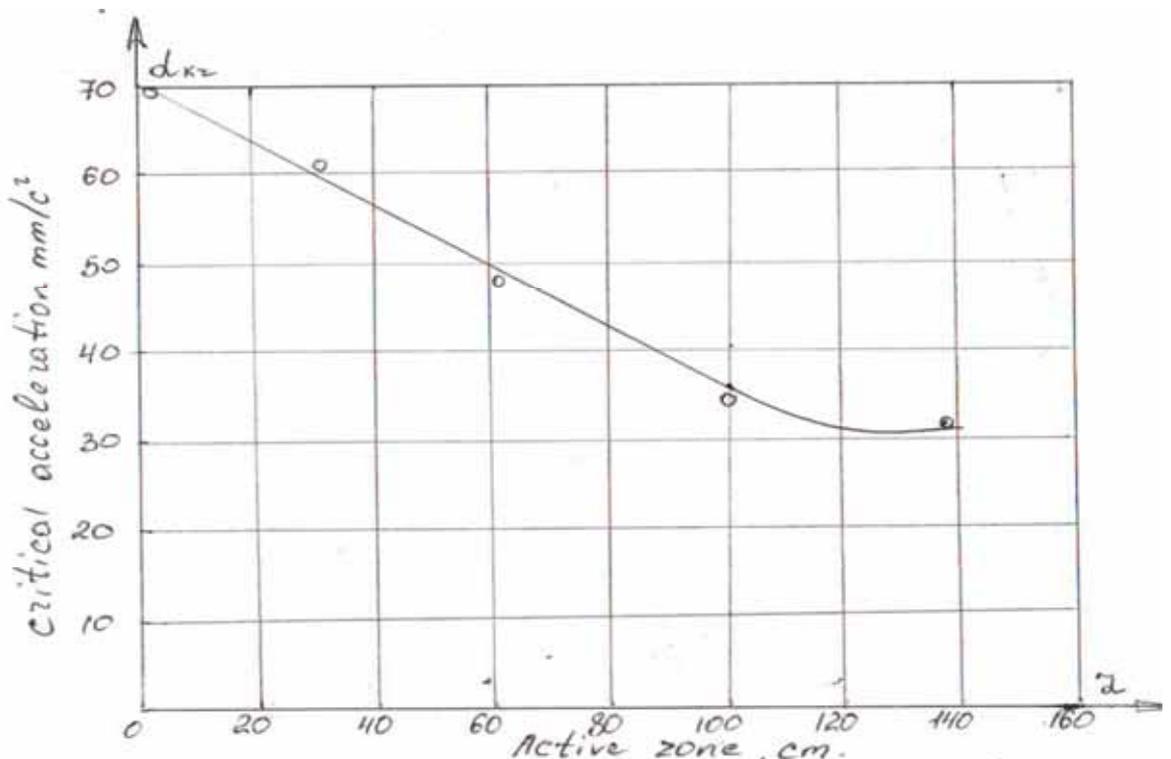


Fig.3.5. The graph of the dependence of the critical acceleration on the core L.

This circumstance makes it possible to put  $\alpha_{kr}$  in inverse dependence on the dynamic head  $h_z$  acting in a disconnected ground. To elucidate this dependence, the author carried out numerous experiments with various incoherent soils. The increase in time of the dynamic head  $h_z$  at the horizon  $z$  is accompanied by an increase in the core  $L$ , which is the result of a decrease in the intrinsic weight of the soil due to the weighing effect of the back pressure  $\Delta$  in  $h_z$ . The dependence  $\alpha_{kr} = f(L)$  (Fig. 3.5) was obtained from the data of an experiment carried out with medium-grained sands in the absence of the weight of an overload on the soil. The increase in the active zone  $L$  in the earth's depth above the horizon  $z$  in question leads to a decrease in the value of the critical acceleration  $\alpha_{kr}$ , which is characteristic of the horizon  $z$ . The thickness of the strata subjected to shaking should lead to an increase in the core  $L$ , with a subsequent decrease in the values of  $\alpha_{kr}$ .

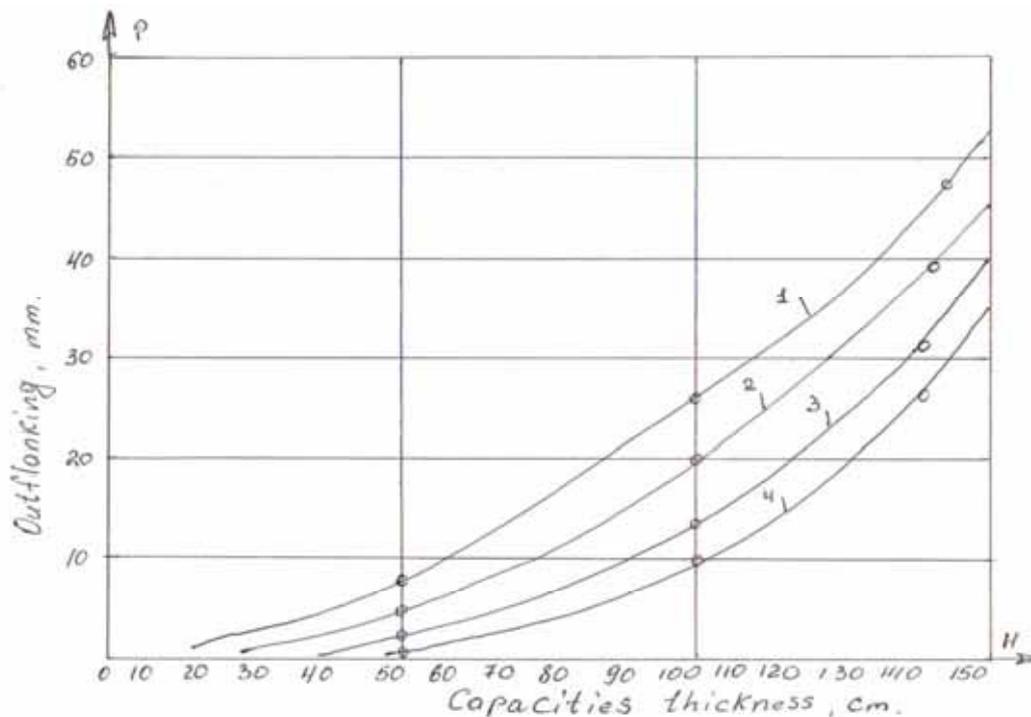


Fig. 3.6. Dependence of the final value of the precipitation at different depths: (1-z = 10sm; 2-z = 20sm; 3-z = 30sm; 4-z = 40sm) from the total thickness of the water-saturated sandy strata.

To reveal this dependence, we conducted several series of experiments with different (50, 100, 150 cm) thick layers of water-bearing sand under the same experimental conditions (concussion, density, etc.). Experimental work, different in its formulation, showed that there is a complex dependence associated with the conditions of occurrence in the thickness of the dynamic head  $h_z$  and its weighing action ( $\Delta_B h_z$ ), the nature of the seismic actions ( $A, T$ ), the condition and soil conditions ( $n, K\phi$ ). Reversible to Table. 3.3.

**Table 3.3 The dependence of the core measurement rate on the thickness of the water-saturated sand layer (z) (sand No. 1)**

Number of experience	Cycle number	Porosity, %	Acceleration mm/s <sup>2</sup>	Dynamic head, cm	Time is off. core, with	Draft atop. Soilmm	Speed crooked. Active zones sm/s
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Sample Height z=52sm

25	1	44,6	100	8,5	8	7	6,5
26	»	»	450	22,8	7	9	7,4
28	»	»	1460	32,2	4,5	18	11,5
30	»	»	1900		2,5	25	20,5

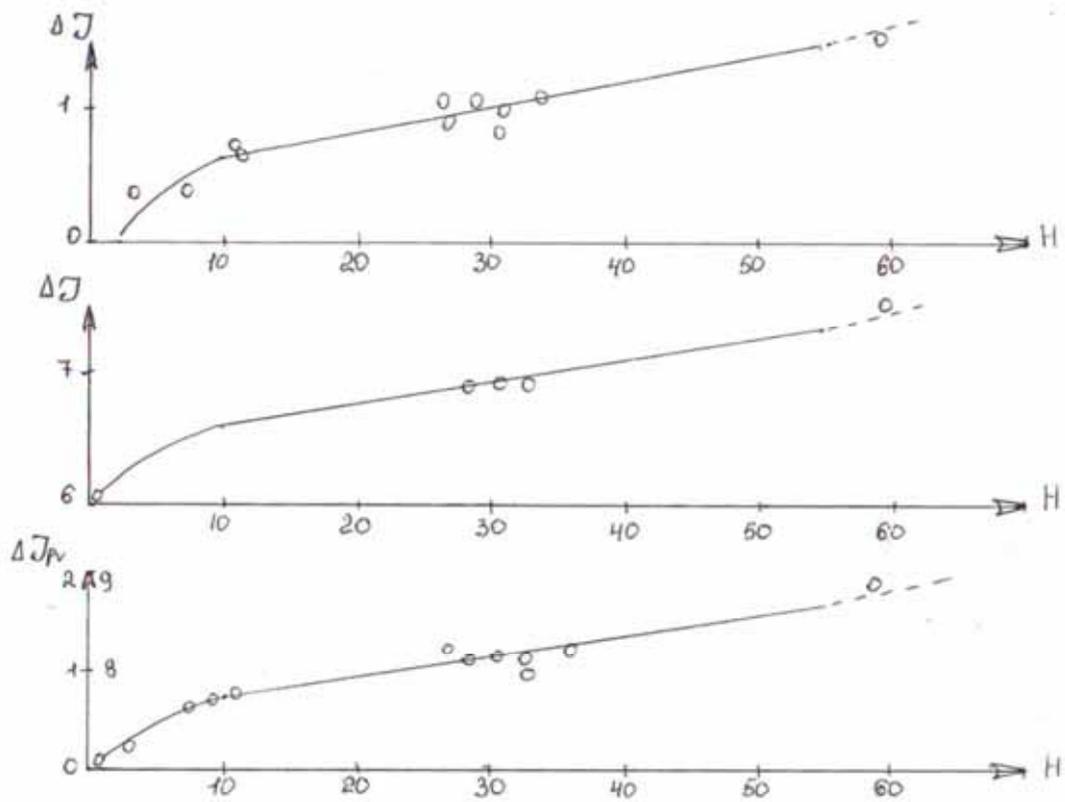
Sample Height z=104sm

18	»	»	140	36,5	10	8	10,0
21	»	»	348	76	6,5	25	15,2
24	»	»	1885	82	4,5	31	24,0
22	»	»	2040	90	3,0	65	34,5

Sample Height z=154sm

5	»	»	100	41,2	8,5	22	18,0
10	»	»	290	73	6,0	45	24,0
9	»	»	1000	103	4,5	60	35,0
35	»	»	2520	238	2,5	100	58,0

From the data of the table obtained from the results of experiments carried out under identical experimental conditions, with the exception of one factor - the power of the test layers, a very characteristic conclusion follows that the value of the active zone  $\Delta$  depends on the total thickness of the thickness  $z$  subjected to shaking. Figure 3.6 shows the dependence of the final sediment thickness on the indications of surface frames, starting from different thicknesses of the sand column. With the change in the thickness of the thickness, within which the disturbance of the soil structure takes place, the value of the sediment also changes. Similar phenomena occur when seismic influences on the thickness of the ground, when its own strata is subjected to shaking for all its power with a constant intensity. It is obvious that the main reason for the observed phenomenon can be considered an increase in the volume of water liberated from the sand during the compaction process and the ever increasing weighing effect of the counter pressure of the heads, which is related to the increase in the core power transferred to the dynamically excited state under seismic conditions. As early as the 1930s, the



**Fig.3.7. Dependence of increment of seismic intensity on the thickness of loess soil in Tashkent: a- on instrumental data; b) macro seismic data; c) acoustic data. (According to V.M.Mirzayev).**

seismologist was aware of an increase in the region's scale with the increase in thickness of loose sediments. According to field seismic observations, V.M.Mirzaev, and others, the increment of seismic intensity is determined depending on the thickness of the loess layer of the territory of Tashkent. The resulting linear dependence was used in the compilation of the seismic microzonation map of Tashkent. In Fig. 3.7 graphically depicts the dependence of the increment of severity on the thickness of the loess soil of the city's territory, which shows a decrease in the dynamic stability of the lesos with an increase in their capacity.

## **Conclusion**

In conclusion, the following should be noted. A number of issues considered by us are related to the estimation of the dynamic (seismic) stability of the weakest (water-saturated) loess bases of buildings and structures that are most common in seismic regions. In connection with the lack of research at this stage in the work, much attention has been devoted to studying the physics of phenomena occurring in such soils during their shaking.

As theoretical dependencies on the determination of the strength of loess soils over time and the magnitude of the deformation of the structure, the methods for calculating the bases, taking into account the drop in the strength of the soils and determining the calculated seismic load, were based on the author's basic formula for establishing the criterion of soil stability (critical acceleration) during shaking. At the same time, along with certain advantages, the proposed methods are certainly not devoid of shortcomings related to the simplification of the individual phenomena examined, especially in the initial stage of the study of questions.

Apparently, only a comparison of the results of our conclusions with the data of field observations of the behavior and deformation of structures during strong earthquakes will make it possible to clarify and more objectively evaluate their dignity and shortcomings. In addition, these studies do not exhaust all issues in general in this area.

This circumstance makes it possible to consider that the author makes his first steps in a very important and extremely difficult area of dynamic stability of cohesive soils, which has so far been little studied.

The author hopes that the presentation in this work will contribute to the proper design and construction of more seismic buildings and structures in areas prone to an earthquake.

## REFERENCES

- Байнатов Ж.Б. Графаналитический метод определения устойчивости откосов. // Труды 1-го Центрально-Азиатского геотехнического симпозиума. Т.1. – Астана, 25-28 май 2000. – С.149-153.
- Бауск Е.А., Головки С.И., Швеи В.Б. Влияние динамических воздействий на устойчивость склона. // Тезисы VII Конференции «Динамика оснований и фундаментов и подземных сооружений». – Днепропетровск, 1989. С. 148-149.
- Готман А.Л., Суворов М.А. Противооползневые свайные конструкции. // Материалы Международной научно-технической конференции. – Тюмень, 2007. С. 25-30.
- Жакулин А.С. Оценка напряженно-деформированного состояния водонасыщенных грунтов. // Труды 1-го Центрально-Азиатского геотехнического симпозиума. – Астана, 2000. –С.171-176.
- Жусупбеков А. Ж. Влияние порового давления на устойчивость откоса намывных плотин. // Труды 1-го Центрально-Азиатского геотехнического симпозиума. – Астана, 2000. Т.1. – 176-187.
- Иванов П.Л. Грунты и основания гидротехнических сооружений. –М. : «Высшая школа», 1985. – 352 с.
- Исфара - Баткенское и Таваксайское землетрясения 1977 г года. – Ташкент: Изд-во «Фан», 1981. – 152 с.
- Казиев А.С. Влияние внешней нагрузки на устойчивость откосов водонапорных сооружений. // Труды ВНИИГ им Веденеева «Вопросы гидротехники», 1984. – С.182-187.
- Лим В.В., Винниченко С.М. Современные оползневые катастрофы в Таджикистане. //Материалф конференции « Геориск: оценка и уменьшение». – Ташкент: Гидроингео,2003. – С.154-156.
- Маслов Н.Н. Механика грунтов в практике строительства (Оползны и борьба с ними). – М.: Стройиздат, 1983. – 320 с.
- Материалы Международной Конференции «Проблемы оценки сейсмической опасности и снижения последствий землетрясений». – Ташкент, 2008. – С. 184-259.
- Расулов Х.З. Сейсмостойкость грунтовых оснований. –Ташкент: Изд-во «Узбекистан», 1984. -192 с.
- Расулов Х.З. Прогноз деформации сооружений в результате пластического течения грунтов при землетрясениях. // Труды 1-го Центрально-Азиатского геотехнического симпозиума. – Астана, 2000. Т.1. – 266-270.
- Расулов Х.З., Ташходжаев А.У. Условия образования оползневых процессов при землетрясениях. // Материалы Международной Конференции

«Проблемы оценки сейсмической опасности и снижения последствий землетрясений». – Ташкент, 2008, №5. – С.240-242.

Расулов Х.З., Садиков А. Прогноз оползневых явлений в природных склонах и откосах. // Ж. «Архитектура, строительство и дизайн». –Ташкент: Изд-во ТАСИ, 2009. –С. 45-49.

Расулов Х.З., Садиков А.Х. Критерия оползневой устойчивости лессовых склонов при сейсмических воздействиях. // Ж. «Меъмрчилик ва курилиш муаммолари» . – Самарканд: Изд-во СамГАСИ, 2009, №4. – С.50-53.

Ставницер Л.Р. Об опасности разжижения водонасыщенных грунтов при динамических воздействиях. // Материалы Международной научно-технической конференции. – Тюмень, 2007. – С.77-78.

Шерматов М.Ш., Бимирзаев Г.А., Камалетдинов Р.Г., Ташпулатов М.М. Унаследованность вторичных оползневых процессов в древних оползневых очагах. //Материалы Международной Конференции «Проблемы оценки сейсмической опасности и снижения последствий землетрясений». – Ташкент, 2008. – С.245 - 249.

ҚМҚ 2.01.03-96. Строительство в сейсмических районах. Издание официальное. –Ташкент, 1996. – 48 с.

Gulatilake P. Development of a new peak shear strength criterion for anisotropic soils joints. // Proc. of the First Central Asian Geotechnical Symposium. – Astana, 25-28 May 2000, Vol 1. – P. 319-

Intraratna B. Redana I. W., Salim W. Modeling of behavior of vertical drains in soft clay. // Proc. of the First Central Asian Geotechnical Symposium. – Astana, 25-28 May 2000, Vol 1. – P. 79-98.

Hay T., Kanamori H., Ammon C. Y. et al. The great Sumatra-Andaman Earthquake of December 26, 2004. // Science 2005. Vol. 308. P. 1127-1133.

Proceeding of International Geotechnical Symposium “Geotechnical Aspects of Natural and man-made disasters”. - Astana, 2005. - P. 307.

Rasulov Suxrobbek Avazbek o'g'lining “ **Lyoss  
gruntlarning dinamik mustahkamlik shartlarini  
ishlab chiqish** ” mavzucidagi dissertatsiyasiga

**T A Q R I Z**

Magistrant Rasulov S.A. bajargan magistrlik dissertatsiyasining mavzusu hozirgi kunning dolzarb muammosining yechimiga bag'ishlangan. Unda mavzuni yoritish uchun zarur bo'lgan nazariy va amaliy masalalar dissertatsiya talabiga ko'ra yetarlicha hal qilingan. Ayniqsa kafedramizning ilmiy tajribaxonasidagi tebranma uskunada o'tkazgan lyoss gruntlar tarkibidagi bog'lanish kuchlarining o'zgarishi, lyossarga nisbatan kritik kuchni aniqlashga oid izlanishlari e'tiborga loyiqdir.

Lyoss gruntlarning dinamik turg'unligini baholashga oid muvozanat tezlanishini nazariy usulini turli nishabli qiyaliklarga tadbiiq etilishi dissertantning muvaffaqiyatlaridan biridir.

Dissertatsiyaning yangiligi sifatida Rasulov S.A. tomonidan ishlab chiqilgan “Lyosslardan tashkil topgan to'g'onlarni hisoblashga oid ko'rsatmalar” ni qayd etish mumkin. Undan foydalanish orqali seysmik koeffitsiyentning hisobiy miqdorini aniqlash va to'g'on zilzilabardoshligini oshirishga oid tadbirlar belgilash mumkin. Bu esa seysmik rayonlarda barpo etiluvchi inshootlar turg'unligini oshirishga va mustahkamligini ta'minlashga xizmat qiladi.

Hulosa qilib mazkur dissertatsiyani magistrlik talablariga to'liq javob berishi va Rasulov S.A. texnika fanlari magistr darajasiga loyiq ekanligini ta'kidlayman.

t.f.d, prof.



H.Rasulov

Rasulov Suxrobbek Avazbek o'g'lining "Lyoss  
gruntlarning dinamik mustahkamlik shartlarini  
ishlab chiqish" mavzucidagi dissertatsiyasiga

## TAQRIZ

Magistrlik dissertatsiya hozirgi kun uchun dolzarb masalani yechimiga bag'ishlangan, zero harqanday quriladigan inshoot o'zining qanday maqsadga bag'ishlanganidan qat'iy nazar mustahkam, turg'un va harqanday tashqi kuchlarga chidamli bo'lmoqligi lozim. Lyoss gruntli qiyaliklarning dinamik ta'sirda zo'riqish-deformatsiya holatini o'zgarishi gruntli to'g'onlarning seysmik ta'sirga hisoblashning asosiy qismidir. Dissertant ushbu masalani yechishning uddasidan chiqqan.

Rasulov S.A. lyoss gruntlarga dinamik ta'sirni o'rganish jarayonida ta'sirning asosiy ko'rsatkichlari, dinamik ta'sirning grunt holatiga ta'siri, zilzila kuchlari, va uning gruntli to'g'onga nisbatan ta'siri, shuningdek to'g'on turg'unligini hisoblashda zilzila ta'sirini nazarda tutish kabi ilmiy ahamiyatga ega masalalarni hal etgan.

Dissertatsiyaning uchinchi bobida o'z aksini topgan zilzila jarayonida lyosslarning turg'unlik darajasini oshirishga yo'naltirilgan tadbirlar mening fikrimcha gruntli to'g'onlar loyihalash va hisoblash ishlarini bajarishda amaliy ahamiyat kasb etadi.

Dissertatsiya mavzusiga aloqador 4 ta ilmiy maqola chop etilgan.

Dissertatsiyada bajarilgan izlanishlar menimcha kelajakda davom ettirilsa va ba'zi masalalar, ayniqsa 3-bobdagi izlanishlar ustidagi tajribalarni kengaytirilsa fan nomzodlik dissertatsiyasi darajasiga olib chiqilishi mumkin.

Taqriz olib borilgan ushbu dissertatsiya magistrlik talablariga to'la javob beradi va uning muallifi Rasulov Suxrobbek Avazbek o'g'li texnika fanlari magistri darajasiga loyiq deb hisoblayman.



t.f.n. Usmonxo'jayev I.I.