

PECULIARITIES OF CHANGE IN SEISMIC PROPERTIES OF FOREST SOILS WHEN FIXING THEM BY SILICATION METHODS.

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ABSTRACT:

The paper presents the results of research on the use of silicatization methods to improve the physical and mechanical properties of loess soils during construction in seismically hazardous areas. It was found that silicatization of loess soils increases their seismic resistance, and under the studied regional conditions, the effect of silicatization is significantly higher. Certain advantages of the investigated methods and the possibility of their widespread use in the preparation of foundations for construction or their strengthening in the built-up area in seismically hazardous areas are revealed.

Introduction. Loess soils as the basis for most buildings and structures are a kind of medium for the transmission of seismic loads to the structures of the structure. However, a feature of these soils is the presence of subsidence properties, which are manifested under additional loads from the weight of the structure and moisture due to technogenic leakage or an increase in the groundwater level. To eliminate the subsidence properties of soils, various methods of technical reclamation and engineering preparation of the base are used.

Engineering preparation of loess foundations of foundations allows you to significantly change their physical and mechanical properties and eliminate subsidence in construction sites. As a result, an artificial foundation is created, which differs from natural soils [1]. At the same time, the categories of soil according to seismic properties also change. By improving the seismic properties, i.e. by increasing the seismic stiffness of the foundations by anti-subsidence measures, it is possible to reduce the magnitude of the expected seismic impact on buildings.

However, the reduction of seismic effects on the designed buildings and structures through increasing the stiffness of the soil depends on many factors, such as the condition and properties of natural soil strata, the method of engineering preparation, dimensions (area and depth), the quality and duration of work to improve the properties of soils.

Among the many methods of engineering preparation of loess foundations, the method of soil consolidation with silicate mortar has a special place. This method is more effective in consolidating moist soils. The article presents the results of studies on the study of the influence of silicatization methods on the change in the seismic properties of loess soils at construction sites. The studies were carried out on the territory of Tashkent.

Theoretical analysis. On the territory of the republic, subsidence loess soils are widespread in the central and eastern parts, where the centers of strong earthquakes are concentrated. In terms of area, they occupy 17-20% of the territory of the republic, however, on the territory of more than 80% of cities they are developed. Areas of widespread loess species with a thickness of 5-10 to 100 m are located in these areas or in their immediate vicinity. Currently, for earthquake-resistant construction throughout the territory of Uzbekistan, the existing maps of seismic microzoning, as well as "Building norms and rules. Construction in seismic regions "(KMK 2.01.03-96) [2], approved by the State Committee of the Republic of Uzbekistan for Architecture and Construction in 1996 (current for 2020). According to this standard, a table is given to determine the categories of soil by seismic properties, where:

- loess soils (loess-like loams, sandy loams and clays) with a porosity coefficient $e < 0,8$ at consistency indicators $I_L \leq 0,5$ or with the speed of propagation of seismic waves $V_p > 500$ m/c и $V_s > 300$ m/c belong to the II category of soils in terms of seismic properties;

- loess-like soils (loess, loess-like loams, sandy loam and clay) with a coefficient of porosity $e \geq 0,8$ or with a coefficient of porosity $e < 0,8$ at the value of the indicator of consistency $I_L > 0,5$ or with the speed of propagation of seismic waves $V_s \leq 300$ m/c belong to the III category of soils in terms of seismic properties.

In a note to the table, it is noted that in the presence of loess-like collapsing soils in the soil mass, it is recommended to take measures to eliminate subsidence and the calculated seismicity to be determined based on the results of artificial improvement of the base. However, this item is still not used in engineering surveys. Nevertheless, the use of this item has significantly increased the seismic characteristics of loess soils and, as a result, reduced the estimated seismicity of the construction site.

In work [2,5] it is noted that the peculiarity of the manifestation of seismic intensity in loess territories is, first of all, a sharp change in the propagation rates of longitudinal (V_p) and transverse (V_s) waves depending on humidity, porosity, chemical and mineralogical composition of soils and external factors. These parameters are used to justify the increment of the seismic score ΔI at construction sites relative to the "average soil", which is selected individually for each settlement in accordance with the table in the building codes.

In [4] it is emphasized that the elimination or elimination of subsidence properties of soils is achieved by using various methods of compaction or strengthening, aimed at changing the natural structure of soils, increasing density, improving their strength and deformation properties, which in turn change the estimated seismicity of the construction site. Among the compaction methods, there are and are applied the method of tamping and pre-soaking; to eliminate subsidence and increase strength, the following are used: single-solution silicatization for physicochemically active loess soils, gas

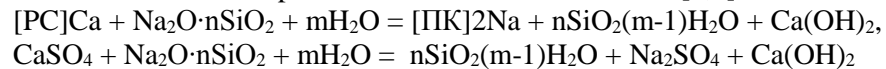
silicatization, two-component silicatization with the use of gel-forming solutions, mainly for inactive loess soils; the ammonization method is used to eliminate subsidence.

Silicatization method. One of the effective methods of engineering preparation of the base is chemical consolidation, in particular, silicatization of loess soils. Studies to assess the impact of different modifications of the silicatization method on the change in the physical-mechanical and seismic properties of loess soils were carried out at two construction sites in Tashkent [5].

- During the construction of buildings of the National Bank of Uzbekistan, single-solution silicatization of soils was carried out. The thickness of the subsiding stratum of the loess soils was 15 m. The injection of the solution (with a density of 1.15 g / cm³) was carried out according to the scheme from top to bottom in approaches (1-2 m) with a solution flow rate of 15-20 l / min. The injection wells were located at a distance of 2.2 m from each other.

- When strengthening the foundation of the emergency building of the State Design Institute No. 4, the consolidation of the subsidence stratum (in the depth interval of 3.5-9.5 m) was carried out by the method of gas silicatization with preliminary activation of the soil with carbon dioxide. The total thickness of the subsiding strata was 9.5 m. The application of this method is due to the increased moisture content of subsiding loess soils in this region.

When sodium silicate interacts with loess soil, as a result of exchange processes on the surface of particles and aggregates, thin films of silicic acid gel are formed. Physicochemical processes occurring during the strengthening of loess soils can be represented in the form of reactions [1,3]:

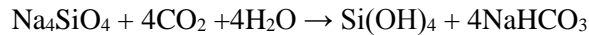


Пленки геля кремниевой кислоты, образующиеся в результате физико-химических процессов, обеспечивают неразмокаемость и сохранение структуры грунта в ненарушенном состоянии, ликвидацию просадочности. Непрореагировавшая часть раствора силиката натрия в порах лессового грунта поли конденсируется и образует гель кремниевой кислоты, который тампонирует капилляры, вследствие чего его пористость и проницаемость значительно снижается. Не полностью вступивший в реакции с компонентами грунта силикат натрия обеспечивает присутствие в поровом Na₂O solution, which later turns into Na₂CO₃, due to which a highly alkaline environment is created (pH = 10-11).

Results and discussion. The studies were carried out on loess-like loams, in which the content of the clay fraction (<0.002 mm) varied over a wide range - from 9 to 28% (average 18%). The clay fraction is represented mainly by hydromica minerals; kaolinite, chlorite and a small amount of montmorillonite are present as impurities. The carbonate content in soils ranges from 18 to 33%.

Formation of a micro layer of cementing new formations provides an increase in soil strength up to 1.3-1.5 MPa. Along with this, the indicators of the velocities of longitudinal and transverse waves are almost 2 times higher compared to the original soil [6].

When using the gas silicatization method, the effectiveness of strengthening loess soils is increased. The volume of cementing neoplasms increases due to Ca(HCO₃)₂, образующегося в результате растворения карбонатов кальция воздействием CO₂. The preliminary injection of CO₂ into the soil and the subsequent injection of the sodium silicate solution ensures its more complete curing. The reaction of their interaction can be represented as:



The resulting cementing gel of silicic acid $\text{Si}(\text{OH})_4$ gives the silicated soil additional strength and water resistance. The intensification of the silicatization process, which occurs under the influence of CO_2 , provides an increase in the volume of the fixed massif and an increase in the strength of the soil by 1.5-2 times compared with traditional silicatization. This is due to the more complete curing of sodium silicate with carbon dioxide. Table 1 shows the results of field experimental studies.

Table 1. Changes in the properties of loess soils during consolidation by different methods of silicatization

Property indicators	Methods for fixing loess soils			
	One solution silicatization		gas silicatization	
	Before	After	Before	After
Soil density (ρ), g / cm ³	<u>1,62÷1,94*</u> 1,70	<u>1,84÷2,14</u> 1,98	<u>1,68÷1,85</u> 1,74	<u>1,87÷2,13</u> 2,03
Density of the soil skeleton (ρ_d), g / cm ³	<u>1,29÷1,66</u> 1,46	<u>1,63÷1,79</u> 1,75	<u>1,48÷1,70</u> 1,50	<u>1,68÷1,75</u> 1,72
Humidity (W), %	<u>10,8÷16,9</u> 14,8	<u>12,6÷19,6</u> 13,9	<u>14,8÷17,9</u> 16,4	<u>17,8÷20,5</u> 18,7
Porosity (n), %	<u>38,6÷52,0</u> 45,7	<u>33,0÷39,2</u> 35,3	<u>39,2÷47,4</u> 45,1	<u>34,5÷42,2</u> 37,0
Longitudinal wave speed (V_p), m / s	<u>500÷650</u> 560	<u>1100÷1200</u> 1140	<u>700÷1000</u> 870	<u>2200÷2500</u> 2360
Shear wave speed (V_s), m / s	<u>300÷350</u> 320	<u>550÷600</u> 570	<u>350÷400</u> 360	<u>1000÷1100</u> 1030
Wave velocity ratio V_p/V_s	1,8÷2,0	1,6÷2,3	2,0÷2,5	2,2÷2,6
Seismic rigidity ($V_{si} \cdot \rho_i$)	545	1130	625	2090
Seismic point increment ΔI	+0,18	-0,35	+0,08	-0,78

* limit values / arithmetic mean.

The table shows that the speed characteristics have increased 2-2.5 times. The uniaxial compressive strength of the soil, strengthened by gas silicatization, was 1.8-2.4 MPa. The absence of free alkali in the pore solution leads to a decrease in the pH of the solution to 8.4-8.6. This creates optimal conditions for the formation of water-resistant forms of silicic acid with a degree of polymerization of 94-96%. The increment in seismic intensity during ordinary silicatization decreased from +0.18 to -0.35, and during gas silicatization from +0.08 to -0.86 points.

Conclusion. Based on the experimental studies carried out, the advantage of using the gas silicatization method with preliminary soil treatment with carbon dioxide has been reliably established. The effectiveness of this method is traced for all indicators of the studied properties of loess soils in comparison with conventional silicatization. When gas silicatization is used, the strength is 1.5-2.0 times higher compared with one solution silicatization at equal concentrations of sodium silicate, and the volume of the fixed soil increases almost twice. According to the results obtained, the effectiveness of the gas silicatization method for strengthening loess soils is traced by a significant change in their physical, mechanical and seismic properties at a fairly early date.

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