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THE EVENT PROVIDES SEISMIC RESISTANCE OF BUILDINGS AND STRUCTURES BUILT ON MOIST LOESS SOILS

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Abstrakt. This scientific article provides information on measures to ensure the seismic resistance of buildings and structures, i.e. provides information on measures aimed at reducing the calculated seismicity of the site and related to the design of earthquake-resistant foundations. Some options for determining the calculated value of the seismicity coefficient are considered, as ensuring the seismic stability of designed buildings and structures on moist loess soils in seismic areas. Some basic design measures often used in construction to ensure the seismic resistance of buildings and structures built on moist loess soils in seismic areas are described. The article also provides some other features of the construction of buildings and structures in seismic areas on loess soils.

Keywords: loess soil; moistened; subsidence; seismic areas; seismic resistance; coefficient of seismicity; coefficient of seismic stability; estimated seismicity of the site; coefficient of ground conditions; critical and seismic acceleration.

Introduction. The construction of buildings and structures on moistened, loess subsidence soils in seismic areas with ensuring their strength and stability (seismic resistance), as well as reliable operation, is one of the difficult problems of modern construction.

As it is known, all measures to ensure the seismic resistance of buildings and structures built on moistened subsidence loess soils can be divided into two groups:

1) aimed at reducing the calculated seismicity of the site;

2) related to the design of earthquake-resistant buildings and structures [1].

In order to ensure the seismic stability of the designed buildings and structures on moistened subsident loess soils in seismic areas, it is necessary first of all to determine the estimated seismicity of the construction site. Below we will consider some options for determining the calculated value of the seismicity coefficient.

Analysis and results (Results and Discussion). D.D.Barkan, Yu.G.Trofimenkov and M.N.Golubtsova established an increment in seismic intensity for cohesive soils depending on the strength properties of soils. They propose to introduce a correction factor Кгр. to take into account the influence of ground conditions on the value of the seismicity coefficient Кс. The calculated value of the seismicity coefficient $К_С^Р$ is determined from the expression:

$$К_С^Р = Кгр.\ Кс. \qquad (1)$$

To determine the coefficient of soil conditions Кгр. the authors proceed from the value of the calculated pressure on the soil Pp, calculated on the basis of the strength characteristics of the soils of a particular construction site [2-5].

As the average seismic characteristic of the soil, according to which the seismic score of the area is determined, a design pressure of the order of 2.5 kgf/cm2 (0.25 MPa) is recommended, which leads to some conditionality. For such soils Кгр. = 1, for all others, the increment of the score is set in the form of:

Кгр. = $\frac{2,5}{Pp}$ (2)

It should be noted that the results of these studies make it possible to reasonably assess the estimated score of buildings and structures.

где, Кгр.- coefficient of soil conditions;

$К_С^Р$ - the calculated value of the seismicity coefficient;

Pp - calculated ground pressure;

Кс - the coefficient of seismicity corresponding to the area's score and determined for average ground conditions according to the tables of building codes (for example, according to the international scale MSK-64 for 7 points – 0.025, for 8 points - 0.05 and for 9 points – 0.1). According to the developed method of Prof. H.Z.Rasulova (Uzbekistan) “earthquake-resistant foundation” the increment of the score of a specific construction site is calculated based on the values of the seismic stability coefficient $К_{уст}$

$К_{уст} = \frac{\alpha_{кр}}{\alpha_с}$ (3)

where, $\alpha_с$ – the maximum seismic acceleration corresponding to the score on the map of seismic zoning of the territory of the CIS (USSR);

$\alpha_{кр}$ – critical acceleration.

The condition of compliance of the score of this site with the score set for this area on the map of the CIS (USSR), is Куст = 1.0. The magnitude of the maximum seismic acceleration $\alpha_с$ can be determined according to the data of S.V.Medvedev, established for earthquakes with periods of 0.1 – 0.5 s.[6-10].

To perform only preliminary calculations, it is allowed to use the seismic acceleration value given in Table 1.

The values of seismic accelerations on the MSK-1964 scale

Table 1.

Earthquake strength, point	**Calculated acceleration, мм/с^2**
5	120< $\alpha \leq$250
6	250< $\alpha \leq$500
7	500< $\alpha \leq$1000
8	1000< $\alpha \leq$2000
9	2000< $\alpha \leq$4000
10	4000< $\alpha \leq$8000

The intensity of the seismic impact is estimated using the harmonic oscillation formula:

$$\alpha_с = 4\pi^2 f^2 A \quad (4)$$

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where, α_c- acceleration of oscillation;

f- oscillation frequency;

A- the amplitude of the oscillation.

Critical acceleration of $\alpha_{кр}$ in the concept of Prof. H.Z.Rasulova (Uzbekistan) is generally associated with the strength characteristics of the soil in the following form:

$$\alpha_{кр} = \frac{2\pi g(\sigma_{дин} tg\varphi_w + C_w)}{\gamma_w T_п \upsilon_{сд} sin 2\pi \frac{z}{\lambda_b}} \qquad (5)$$

where, g - acceleration of gravity;

φ_{w-} the angle of internal friction of the soil at humidity w ;

c_w- the adhesion (connectivity) of the soil corresponding to humidity w ;

γ_w - density of wet soil;

T - the oscillation period;

$\upsilon_{сд}$- the velocity of transverse seismic waves;

Z - the depth of the horizon under consideration;

λ_b- wavelength.

The value of the seismic stability coefficient of the Bush is used in calculations as a correction factor that takes into account soil conditions:

$$К_с^р = \frac{1}{Куст} Кс \qquad (6)$$

It can be seen from the above formulas that the coefficient of seismic stability of the Bush depends on the magnitude of the maximum seismic acceleration α_c, which is included in the denominator (determined by natural conditions, all elements of the seismic regime, amplitude, frequency, period, etc. are constant values) and on the magnitude of the critical acceleration $\alpha_{кр}$, which is included in the numerator (under various measures, the formulas may change).

1. Measures aimed at reducing the calculated seismicity of the site.

The seismic stability of soils at the base of buildings and structures can be increased by increasing the strength characteristics of soils (angle of internal friction and adhesion force). With an increase in the strength characteristics of the soil, the values of critical acceleration and, accordingly, the coefficient of seismic stability increase, and the calculated score of the construction site decreases.

It is known that the density of the soil is of exceptional importance in ensuring the seismic stability of the base. Recall that an increase in soil density leads to an increase in the value of the critical acceleration $\alpha_{кр}$ (it is known that each type of soil, depending on its composition, condition and properties, has its own critical acceleration of vibrations of soil particles. Most authors call the critical acceleration $\alpha_{кр}$such an acceleration of the vibration of soil particles, at which the soil is in a state of extreme equilibrium and a slight excess of acceleration against the critical one is sufficient for the water-saturated soil to pass into a state of loss of its dynamic stability, i.e. into a state of liquefaction. As a result of liquefaction, the structural strength of the soil decreases and significant plastic deformations develop both in the soils lying in the zones bordering the foundation and in the basement zone of the foundation, leading to unacceptable deformations of the structure itself.) and thus, to limit the power of the z core down to zero (no dynamic effect) [11-15]. Thus, with an increase in the density of the soil, its strength characteristics (angle of friction and adhesion) increase sharply. Hence, the full significance becomes clear, as a protective measure aimed at increasing the density of clay and loess soils at the base of the structure and, first of all, in the lateral zones bordering the structure, which are in the considered sense the most dangerous. Let us note here that individual cases from the practice of construction strongly confirm this conclusion [16-21].

Construction activities that contribute to improving the strength characteristics of the soil are very diverse. The most common and often used measures in the practice of construction include: - mechanical compaction of soils (ramming) over the entire thickness of weak soil; -chemical fixation of soils (silicatization, bitumization, cementation, etc.) aimed at increasing the amount of adhesion; - heat treatment (roasting) of soil, increasing the strength of connectivity; - drainage of groundwater using various vertical and horizontal drainage devices; - artificial thickening by using various dynamic influences (explosion, vibration, etc.), replacing weak or bulk soils with more durable soils with layered seals.

These measures increase the critical acceleration and thereby reduce the estimated score of the site.

In construction practice, there are cases when none of these methods can be applied due to the high and uneven compressibility of weak loess and bulk soils, the impossibility of their compaction due to high humidity, high content of organic inclusions, etc. In such cases, it is necessary to replace weak loess and bulk soil with a more durable soil with its layered compaction or abandon the development of such a site.

For example, during the construction of the multifunctional Humo Arena ice complex (the capacity of the main hall of the complex is 14,500 people) in Tashkent (the seismicity of the site is 9 points on the MSK-1964 scale) in 2018-2019, weak loess and bulk soil with a thickness of 5.5 m was removed from the base of the building and replaced with durable soil with layered seals.

2. Activities related to the design of earthquake-resistant foundations.

Numerous analyses of accidents of structures affected by strong earthquakes have shown that soils lying in areas bordering the foundation often cause a weakening of the bearing capacity of the foundation.

This is due to the fact that the pits opened for the construction of foundations of structures are usually filled with the same soils (loose, bulk) without special observance of measures that increase their dynamic stability. Only in small cases, bulk soils around foundations are compacted using ramming units, which is often ineffective from the point of view of the task we are considering. As a result, the soils lying in the zones bordering the foundation are in many cases the most amenable to dynamic action. This ultimately leads to the unloading of the foundation base and the development of unacceptable plastic deformation of soils in the basement of the foundation [1-5].

Hence, it follows that in order to increase the seismic stability of the loess foundations of buildings and structures, it is effective to load the lateral boundary foundation zones of the structure, increasing the critical acceleration in the base area in order to avoid the dynamic regime of the thickness with the condition that the critical acceleration is greater than the seismic acceleration. Very often these zones are overloaded with elements of the structure itself, otherwise it is effective to load them with the most dynamically stable materials, stone outline, compaction of dynamically stable soils, etc.

It is known that overloading of lateral zones is often used in construction practice and is undoubtedly advisable if it is necessary to increase the seismic stability of the base.

As it is known, the main constructive measure in the construction of buildings and structures is the use of reinforced concrete and metal belts. As you can see, there is some overspending of metal, but significantly reduce operating costs. As is known, the rigidity of buildings increases significantly with the installation of reinforced concrete belts, which are laid continuously at the floor level, and when a significant increase in the rigidity of the building is not required, it is possible to install reinforced concrete belts at the basement floor level and at the floor level of the penultimate soil.

Rigid brick and stone buildings, on weak and highly compressible soils, work much better and deformations in them are much less than structures designed according to a flexible scheme, which are characterized by a long period of free oscillations. Industrial and civil buildings built of brick with reinforced concrete belts allow precipitation 3-5 times greater than panel or block buildings.

It will tolerate the seismic effects of frame-type buildings and structures with antiseismic belts well.

In difficult ground conditions, when designing and constructing multi-storey buildings and structures with a large length, sedimentary seams should be arranged, which should separate the multi-storey parts of the building from each other and divide the buildings into rigid blocks with small dimensions. Sedimentary seams are arranged in buildings of great length, taking into account the engineering and geological structure of the site, as well as in places where the thickness of the layer of weak clay and loess subsidence soils changes, in places where one type of soil is replaced by another with different deformative indicators.

The design of deep foundations or the use of pile stands is most effective with measures that reduce the capacity of weak clay and loess subsidence foundations of buildings and structures.

When building buildings and structures on weak clay and loess subsidence soils, deep foundations are used in construction practice very often, and they are suitable for any buildings and structures.

As it is known, the construction of deep foundations is practically not associated with special difficulties and does not require large material costs, and at the same time it becomes possible to build basements without significantly increasing the cost of construction as a whole. With a significant deepening of the foundation, the overall degree of its stability increases, as more favorable conditions are created for the perception of the load from the building. In this case, it is possible to use a more significant thickness sealing capacity in the lateral zones bordering the structure as a priming.

The presence of basements significantly increases the seismic resistance of the structure in comparison with the structure located on strip and free-standing foundations of shallow laying.

Sometimes such weak clay and subsident loess soils lie at the base of a building that the necessary degree of stability of the building cannot be provided by a number of methods, in particular by deepening the foundation. Then the transfer of the load from the structure to more durable, deeper layers, cutting through weak soils, in many cases is solved in the simplest way-by using pile racks.

Yu.G.Trofimenkov (Russia), considering the methods of foundation design taking into account the seismic conditions of Japan, notes that large precipitation during earthquakes was observed in the case of hanging piles in the thickness of weak water-saturated soils, and *deformations were insignificant with strut piles. Also, accidents of structures during earthquakes in the United States and other countries have shown that the greatest precipitation occurs in buildings located precisely on hanging piles of weak water-saturated soils. It follows that the use of suspended reinforced concrete piles in subsident loess soils in seismic areas is not recommended. Given this, instead of hanging reinforced concrete piles in weak water-saturated clay soils in seismic areas, it is necessary to arrange sand cushions, vertical sand drains and drainage slots with loading embankments or lime piles with subsequent compaction of soils with heavy rammers.*

Some designers and builders believe that pile foundations, even in weak soils, can protect buildings from destruction during seismic impacts.

To reduce the seismic impact, the Fundamentoproekt Research Institute (Russia) has developed a special design of pile foundations with an intermediate crushed-sand or gravel-sand cushion arranged between the pile heads and a grillage that rests on this cushion, without contact with piles, as on a natural foundation. Prefabricated heads with a plan size of 60x60 cm and a thickness of 20 cm are put on top of the piles. With this design, a vertical load of 85% of the load on the grillage is transmitted from the grillage through the cushion to the heads and piles. The horizontal load from the grillage is transferred to the piles in the amount of about 15%, the rest of the load is assumed by the soil reinforced with piles. The advantage of the design is that the pile almost does not work on a horizontal load and, therefore, it does not need to be additionally reinforced for bending.

Pile foundations with a high grillage can significantly reduce the natural vibration frequencies of the structure, working as a flexible ground floor and noticeably changing the seismic load depending on the spectrum of impact.

The use of deep foundations and pile foundations can reduce the capacity of weak soils and lower the estimated score of the construction area of the projected buildings.

Conclusions and recommendations. Studying the measures that ensure the seismic resistance of buildings and structures built on moistened subsidence loess and other clay soils, we came to the following conclusion*:*

1. The main features of the construction of buildings on weak moistened clay and loess soils in seismic areas are the use of constructive measures that increase the rigidity of buildings and the installation of artificial foundations. When constructing buildings on weak moistened clay and loess soils in seismic areas, the use of constructive measures is mandatory, since this not only increases the seismic resistance of buildings, but also ensures their durability, as well as insensitivity and stability in case of possible uneven deformations of the base.

2. The seismic stability of soils at the base of buildings and structures can be increased by increasing the strength characteristics of soils. With an increase in the strength characteristics of the soil, the values of critical acceleration and, accordingly, the coefficient of seismic stability increase, and the calculated score of the construction site decreases.

3. Currently, the foundations of the main types for the most common ground conditions can be designed taking into account seismic influences, which will ensure the seismic resistance of buildings and structures with high technical and economic indicators.

4. As the research of many experts has shown, the use of deep foundations and pile foundations can reduce the capacity of weak soils and lower the estimated score of the construction area of the projected buildings. The presence of basements significantly

increases the seismic resistance of the structure in comparison with the structure located on strip and free-standing foundations of shallow laying. In this case, it is possible to use a more significant thickness sealing capacity in the lateral zones bordering the structure as a priming. Pile foundations, even in weak soils, make it possible to protect buildings from destruction during seismic impacts. Also, pile foundations with a high grillage can significantly reduce the frequencies of natural vibrations of the structure, working as a flexible ground floor and noticeably changing the seismic load depending on the spectrum of impact.

5. The use of hanging reinforced concrete piles in subsident loess soils in seismic areas is not recommended. Considering this, instead of hanging reinforced concrete piles in subsident moistened clay and loess soils in seismic areas, it is necessary to arrange sand cushions, vertical sand drains and drainage slots with loading embankments or lime piles with subsequent compaction of soils with heavy rammers.

6. Buildings built of brick with reinforced concrete belts allow precipitation 3-5 times greater than panel or block buildings. Frame buildings with antiseismic belts will withstand seismic impacts well.

7. The above measures to reduce the calculated score of the construction site and increase the seismic stability of structures are just some examples, along with numerous existing in construction practice and used for other purposes.

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