Engineering-geological conditions and interactions of technogenic processes with the environment

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Abstract. The article discusses very pressing problems associated with the engineering and geo-ecological conditions of the city of Zarafshan and adjacent territories, in connection with the expansion of industrial and civil construction. The purpose of the research is to study the engineering and geo-ecological conditions of the distribution of bentonite clays, which are the basis of structures and the intensive development of natural and manmade processes. Modeling shear deformations of foundations on swelling clays is one of the most complex material systems. Swelling clays of the Eocene have pronounced features of deformation behavior, which must be taken into account when assessing deformations and justifying construction projects. Based on this, a danger affecting the stability of the structure is clay shrinkage. Based on the engineering and geo-ecological studies carried out on the territory of the city of Zarafshan, the values of the total deformation of swelling Eocene clays under different loads from the structure for a single-layer model were established. With a constant load from the structure and a variable load of swelling-shrinkage, a system of annually repeated impacts is formed, mainly precipitation and economic activity, which creates a danger for the stability of buildings and structures and the surrounding geo-ecological environment.

1 Introduction

Construction of the city began at the beginning of the last century in the 1960s and 1965 is considered the official year of foundation. At the time of the collapse of the USSR, the city had 12 micro districts with typical Soviet (3-, 4-, 5-, 7- and 9-story) buildings. Currently, a number of high-rise buildings have been built and are being built in New Zarafshan, both as housing and as administrative buildings for various mining enterprises. There were 8 secondary schools and 21 kindergartens in the city.

Initially, the city was created as a residence for workers servicing industrial gold mining facilities located at the Muruntau mine and its industrial zones “Besapan” and “Solnechny”, which are part of the Navoi Mining and Metallurgical Combine.

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Zarafshan became the third industrial city in the Navoi region, after the cities of Uchkuduk and Navoi, built through the development and expansion of city-forming enterprises in the region in the late 50s and early 60s.

The largest division of the Navoi Mining and Metallurgical Plant is located in the city of Zarafshan, this is the Central Mining Department, which currently includes 29 main and auxiliary divisions. The main task of the Central Mining Department is the development of deposits of precious metals (gold, silver) and their extraction.

The study area of Zarafshan is distinguished by the presence of a large urban population, industrial enterprises, various engineering structures (mudflow reservoir, mudflow diversions, aqueduct, etc.) and an artificial lake (Lake Suiming Point in the southwest, Zhemchug in the northeast and Smol in the north -west of the city) in a relatively small area. In this regard, the purpose of the research is to study the engineering and geo-ecological conditions of the distribution of bentonite clays, which are the basis of structures, and the intensive development of natural and manmade processes. Based on the goal, the following task was set to model displacements and deformations of the foundation mass of structures as an assessment of the interaction between technogenic processes and the environment.

In recent years, problems associated with engineering and geo-ecological conditions of the city and surrounding areas have become very acute. These problems attract attention due to the unfavorable expansion of industrial and civil construction in urban areas [1, 2].

An analysis of literature publications showed that as a result of seasonal changes in the moisture content of clay soils, various types of deformation occur at the base of foundations. Experimental studies carried out in the field [3, 4, 5] indicate two main options for deformation of the foundation soil mass - swelling in the center and swelling along the edges of the foundation. As well as studies by Ulitsky V.M., Shashkin A.G., Shashkin K.G. [6] showed that in construction on swelling soils, the technology of constructing foundations using methods of destruction of the soil structure is critical, and in areas of dense urban development, significant geotechnical risks of loss of stability of buildings and structures in expanding areas are generated.

Based on the above analysis, complex geo-ecological studies consist of various methods and tools to study the interaction between geotechnical processes and the environment. In this regard, geo-ecological research methods distinguish several logically sequential stages.

The inventory stage - in most cases, it occupies the preparatory and field period of survey work associated with the identification, description, systematization, mapping of elements of natural and natural-anthropogenic geosystems, and their properties, processes and phenomena. The assessment stage includes techniques for analyzing and synthesizing the interaction of natural conditions and resources with various forms of social activity, identifying, mapping and assessing existing engineering and geo-ecological conditions.

The forecasting final stage is aimed at predicting expected changes in geo-ecological situations over a given period of time. The stages are completed by compiling a model and optimizing the properties of the geosystems of the area where swelling clays occur in the city of Zarafshan.

2 Research methodology

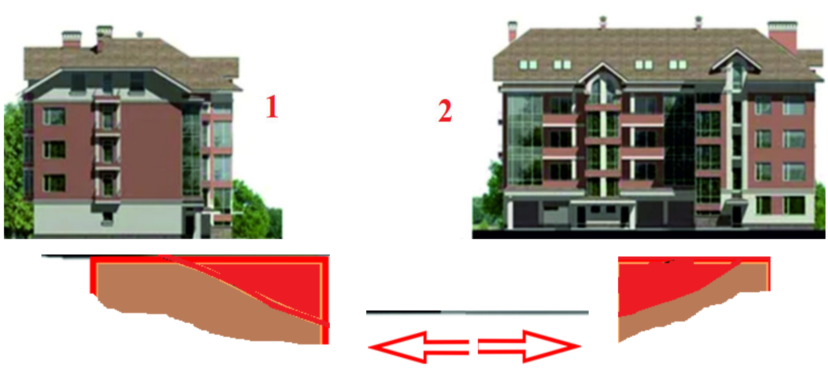
The theoretical and methodological basis of the study is the basic scientific principles and concepts developed within the framework of the problem of interaction between nature and society, reflected in the works of scientists, engineer-geologists, hydrogeologists, ecologists, seismologists and other related sciences. Based on the multidimensionality and diversity of engineering and geo-ecological problems, a comprehensive study and assessment of the state of the urban environment is carried out on an interdisciplinary basis. In this regard, the most important theoretical position and conclusions of this article are based on research in the field of the theory of environmental geology - traditional for the sciences of the geological cycle, studied by man as an ecological-geological system. They are reflected in the works of V.T. Trofimov, D.G. Ziling (1994,1995) - Kh.T. Tursunov (1994,2023), I.P. Gerasimov, Yu.V. Medvedkov, A.A. Mints, V.S. Preobrazhensky, E.L. Reich (1998-2021); architects and urban planners - V.V. Vladimirova, V.L. Glazycheva, A.E. Gutnova, S.B. Chistyakova (1994-2020), etc. In this regard, the scientific research of scientists of Uzbekistan is also of certain importance: O.B.AtaMirzaeva, E.A.Akhmedova (1992-2000), M.M.Zakirova, I.A.Agzamova, D.K.Begimkulova, G.E.Ochilova, Ya.S.Ermatova (2018-2023), etc. [13,14,15].

3 Results and discussion

Modeling of displacements and deformations of the soil mass of the foundations of structures has been known for a long time [5, 7, 8], in particular, the finite element method is widely used in geomechanics. There are fundamental reasons for the complexity of solving problems of geo mechanical modeling of displacements and deformations of a soil mass, due to the extremely high diversity of soils as natural and manmade material systems. Modeling displacements and deformations of foundations on swelling clays is one of the most complex material systems. General systemic ideas about soil modeling have not been developed yet, which hinders the development of geo mechanical modeling methods [9, 10, 11].

The analysis of displacements and deformations under loads from the structure is considered during the development of the territory of swelling clays in the city of Zarafshan, Navoi region. Swelling clays of the Eocene have pronounced features of deformation behavior, which must be taken into account when assessing deformations and justifying construction projects. Relationships have been identified for the preliminary prediction of displacements and deformations in swelling clays, subject to Darcy's law or with deviations from it.

An analysis of the displacements and deformations of the swelling clay mass under the load from the building was carried out to identify factors that negatively affect the stability of buildings and structures. In this case, conditions arise when the base is in the negative deformation zone -a; - part of the base is in the negative deformation zone, -b (Figure 1).



zone of possible deformations

Fig. 1. Various conditions for the location of building foundations in the zone of possible deformations.

From Figure 1, in the case of the first option, displacement and deformation of the base occurs in the negative deformation zone. Possible distortion of the building and structure may not be observed. In the second case, deformation may occur due to uneven settlement of the base of the structure. The behavior of foundations consisting of swelling clays depends both on the mass of the building and the occupied area, and on the composition and condition of the swelling clays, located in the negative zone of deformation under conditions of swelling or shrinkage after loss of moisture. In such conditions, the load from the structure is the main element influencing the change or manifestation of deformation [11, 12].

Analyzing various vertical loads on swelling clays in the foundations of structures under conditions of swelling or shrinkage after loss of moisture, the pressure from the structure during swelling leads to a decrease in vertical displacements, and during shrinkage to an increase in vertical displacements. Based on this, a danger affecting the stability of the structure is clay shrinkage. At the same time, the possibility is not excluded that when maximum loads from the structure on the foundation occur, a danger to stability arises. In this regard, below we will consider several options for the location of the foundations of buildings and structures relative to the zone of possible deformations:

1. A building or structure is at risk when part of the base is in the zone of possible deformation, and swelling clays are in a state of shrinkage after loss of moisture. And also, there is a loss of vertical stability of the structure;
2. A building or structure is at risk when the base is often in the zone of possible deformations, and the clays are in a state of swelling, and the scale of movement is less. The nature of deformations for the building and structure is the same as in the first option, and the probability of damage to buildings is somewhat lower.

In the case where the base is completely in the zone of possible deformations, and the swelling clays are in the shrinkage phase, the danger for buildings and structures is higher than in the second option (Figure 2).

Fig. 2. The manifestation of cracking in buildings in the case when the foundation is completely in the zone of possible deformations.

Factors associated with the climatic transition from seasonal rains to a long dry period, characteristic of the Central Kyzylkum, introduce a number of significant aspects into the deformation behavior of swelling clays: in a narrow near-surface layer up to 1.5 m thick, there is a highly active deformation behavior of clays initiated by heat-humidity exposure to the atmosphere and at depth, deformation effects and characteristic processes of swelling and shrinkage for Eocene clays are observed**.** Relationships between displacements and deformations of swelling Eocene clays in the state of swelling and shrinkage under load from the structure. In many cases, swelling clays, with maximum settlement in the zone of possible deformations in time t, are expressed:

$$S_t = hm_v p\ (1-\frac{8}{\pi^2}e^{-N}), \qquad (1)$$

where

$$N = \frac{\pi^2 C_v}{4h^2},$$

p - ground pressure.

In this case, the consolidation coefficient:

$$C_v = \frac{k_\Phi}{m_v \rho_w} \qquad (2)$$

m_v - relative compressibility coefficient; ρ_w- specific gravity of water; k_(f) - filtration coefficient under the load from the structure in the expression P, the total pressure has the form:

$$P = p_1 \pm p_2 \qquad (3)$$

where p1 is the pressure associated with the swelling and shrinkage of clays without taking into account the pressure from the structure; p2 - pressure from the structure.

During swelling, partial or complete compensation of pressures occurs, and relation (3) has the form:

$$P = p_1 - p_2 \qquad (4)$$

And in the case of shrinkage, the pressure from the structure increases and the equation takes the form:

$$P = p_1 + p_2 \qquad (5).$$

Thus, the maximum settlement in the zone of possible deformations in time t is determined by the equation:

$$S_t = hm_v (p_1 - p_2)(1-\frac{8}{\pi^2}e^{-N}) \qquad (6).$$

And during the shrinkage process:

$$S_t = hm_v (p_1 + p_2)\ (1-\frac{8}{\pi^2}e^{-N}) \qquad (7).$$

Thus, using equation (6), (7) it is possible to calculate the main parameters of displacements and deformations of Eocene clays in the phase of swelling and shrinkage under load from the structure.

From equation (1) and its derivatives we can distinguish:

- t-expressing the complete settlement of clays without taking into account time hmvp;
- t-determining the kinetics of the shrinkage process taking into account time $(1-\frac{8}{\pi^2}e^{-N})$.

Determining the displacements and deformations of Eocene swelling clays serving as the foundation of structures, an analysis takes place that determines the complete completion of deformation from the processes of swelling and shrinkage and the nature of the load.

Thus, to determine η_{max} - the completed deformation of the base, we use the expression:

$$\eta_{max} = S_t = hm_v P \qquad (8)$$

Based on the above, we will consider below two possible conditions for the structure and occurrence of swelling Eocene clays of the Central Kyzylkum. Both single and double layer models.

A two-layer model is a highly deformed horizon up to 1.5 m thick, which has constant interaction with atmospheric factors and an underlying layer with slightly deformed Eocene swelling clays.

The Table below shows for a single-layer model the values of the total deformation of swelling clays under different loads from the structure. As can be seen from the Table, the range of displacements of the screened base in the swelling and settling phases is from 7.5 to 22.5 cm.

The two-layer model reflects the calculation scheme, taking into account the fact that the first layer with a thickness of up to 1.5 m is under the influence of climatic factors, and the underlying layer is slightly deformable. In this case, the total settlement of the entire base can be determined by the well-known method of layer-by-layer summation:

$$S = \sum_1^n h_i m_{vi} P_{zi} \, , \tag{9}$$

where h_i is the thickness of the i-th layer; mvi is the relative compressibility coefficient of the i-th layer; P_zi - natural pressure in the i -th layer.

The parameters for the two-layer model differ in the indicator mv, which has higher values in the upper layer of the load from the structure p2=0.5 MPa mv=0.002 cm2/H and for the lower layer p2=0.5 MPa, mv=0.001 cm2/H (see Table).

Table1. Results of total deformation of swelling clays in the base with different loads from the structure for a single-layer and two-layer model.

	Options	Parameter values max with different loads, cm					
loads from the structure for a single-layer model	Settling stage $P=p_1+p_2$						
	p_1 as much as p_2	0	0.1	0.2	0.3	0.4	0.5
	η_{max}, sm	15	16.5	18	19.5	21	22.5
		Swelling stage $P=p_1-p_2$					
	p_1 as much as p_2	0	1,0	0,2	0,3	0,4	0.5
	η_{max}, см	15	13.5	12	10.5	9	7.5
loads from the structure for a two-layer model	Settling stage $P=p_1+p_2$						
	p_1 as much as p_2	0	0.1	0.2	0.3	0.4	0.5
	η_{max}, sm	22.5	24.5	27	29.5	31.5	33.75
	Swelling stage $P=p_1-p_2$						
	p_1 as much as p_2	0	0.1	0.2	0.3	0.4	0.5
	η_{max}, sm	22.5	20.5	18	15.75	13.5	11.25

Deformation associated with the transition of compression to uplift deformation occurs as a result of the activation of swelling processes of Eocene clays at sufficiently large values of p1/p2 under the conditions of a two-layer model.

Under the conditions of a single-layer model, due to shielding the surface of swelling Eocene clays from the influence of natural and climatic factors, it leads to a decrease in sediment deformation and affects the stabilizing state of the Eocene clays at the base of buildings.

The combination of a constant load from a structure and a variable “swelling-shrinkage” load forms systematically repeated impacts of natural and man-made factors that exceed the maximum deformation and negatively affect the stability of buildings and structures.

4 Conclusion

Based on the engineering and geo-ecological studies carried out on the territory of the city of Zarafshan, the values of the total deformation of swelling Eocene clays under different loads from the structure for a single-layer model were established. The two-layer model also reflects the calculation scheme, taking into account the fact that the near-surface layer up to 1.5 m thick is under the influence of climatic processes and is highly deformed, while the underlying layer is slightly deformable.

With a constant load from the structure and a variable load of swelling-shrinkage, a system of annually repeated impacts is formed, mainly precipitation and economic activity, which creates a danger for the stability of buildings and structures and the surrounding geo-ecological environment.

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