Investigation of the properties of structurally unstable soils

Adil Zhakulin[1], A. Zhakulina [2], V. Nephedov [3], A. Tungatarov [4] and N. Popov [5], A. Zhakulin[6]

[1, 2 ,3 ,4, 5.6] Department of Civil Engineering, Karaganda State Technical University, 56, Boulevar Mira, 100017, Kazakhstan.

ABSTRACT

The results of the analysis of physical and mechanical properties of structurally unstable soils of the territory of Kazakhstan in the article presented to assess their bearing capacity and deformability. In connection with the 2020 transition to the principles of the design of ground foundations of Eurocode foundations, with the abolition of existing regulatory documents, it is necessary to adapt not only the main provisions and bring the classification of soils in line with international standards. In the studies carried out by the authors, the differences between the normative documents of the Republic of Kazakhstan and the Eurocode listed in the classification of soils. In this case, the design of the bases on structurally unstable soils remains for scientists and designers of Kazakhstan and separately developed in the national application of the adapted Eurocode. Structurally unstable soils include subsidence, swelling, saline and alluvial deposits of the Quaternary of the modern age, represented by loams, sandy loams, sands, clays. In this case, structurally unstable soils, when the humidity is increased, completely change the original properties. Quaternary soils distinguished by the diversity and variability in time of physical and mechanical properties, due to the increase in humidity. For example, when twenty simultaneously coalmines in Karaganda were closed; they filled the formed galleries with water. Thus, the processes of predicting the flooding of territories by groundwater are currently estimated, sometimes just a formal one.

Keywords: soil; water; technological factors; technical factors; collapsible soils; swelling soils; saline soils

1 INTRODUCTION

The article presents the results and graphs of the annual fluctuation of the groundwater level along a well established within the city limits. Apparently, changes in the direction of rising groundwater levels are associated with technogenic factors. The results of the measurement of the groundwater table for two wells in the city within the last 16 years are given. The rise in groundwater was 5.0 m to 9.0 m, which confirms the intensive water supply to the ground base. Thus, studies of the stress-strain state of the ground base before and after the water saturation are actual, in order to avoid unacceptable deformations of the foundations and to ensure sufficient bearing capacity of the base. The reliability of the results of calculations for the corresponding design model determined largely by the extent to which the basic principles of this model correctly observed in an experiment with reliably determined design characteristics of soils in the laboratory or in the field. The results obtained from the data of stamping investigations in full-scale conditions quantitatively confirmed the development of sediments of the bases flowing in time in connection with the increase in humidity. By results of researches, the Quaternary water-saturated ground of bases in natural occurrence is not in condensed condition.

2 THE MAIN FACTORS LEADING TO CHANGES IN PROPERTIES OF FOUNDATION SOILS

2.1 The main factors leading to water saturation of soil stratum are primarily industrial

1. Technical factors associated with intensive construction in the Western Kazakhstan and Astana, have led to changes in the hydrogeological conditions of vast territories, which had been violated existing natural regime and balance of groundwater. Thus arose the processes associated with flooding and rising groundwater levels. The construction and operation of buildings, especially high-rise buildings (over 16 stories) violate existing water balance of the area, the groundwater regime, lead to the deterioration of hydrogeological conditions.

2. Technological factors are determined by the functioning of cities. The city is a complex multi-functional system, where geological and hydrogeological conditions within its territory characterized by high variability in time and space. The main task in urban planning is the creation of a geological model that takes into account the change of the geological environment (stress-strain state of

saturated soil grounds) and anthropogenic factors. The development of this model will require extensive and reliable information for a long time (years, decades) and a study of hydrogeological conditions in the city. However, in Kazakhstan, at this stage, the solution of this question is problematic and practically impossible. Factors affecting the hydrogeological conditions of the territory of the cities divided into two groups: deterministic (backwater of groundwater from the reservoirs, seepage losses from different channels, etc.) and accidental (leakage from utility networks, impaired drainage of surface runoff, etc.). If the first group can be taken into account in the design and subsequent construction of, the second group takes into account undetermined probability or even not taken into account. For example, at the closure of the coal mines of Karaganda, to fill the voids flooded with water. However, no event warning or predicting the consequence of impounding twenty mines conducted. Thus, the process of prediction of flooding in urban areas of groundwater is currently estimated, sometimes just a formality. As an example, Figure 1 shows the data Zhakulin, A.S. (2015) annual schedule of fluctuation of groundwater level in wells installed in the yard of a large Department store (in Kazakhstan). The greatest increase of groundwater level fall in the summer, when precipitation is not enough. Apparently, changes in the direction of the rise of groundwater level are associated with a lot of leakage from the utility networks in the summer. In addition, according to the observations in figure 1.5 shows the results of measuring the groundwater level in two wells in the city for 16 years. The rise of groundwater amounted to 9 m with the filtration coefficient is 0.55 m/year, and at well 2 – 5 m with a filtration rate of 0.3 m/year. If you conduct constant monitoring of the hydrogeological conditions of the territory of the city and to have experimental results of measurements of groundwater levels to predict time changes in the stress-strain state of saturated grounds in order to avoid unacceptable deformations of foundations of buildings constructions or accidents.

2.2 The main factors leading to water saturation of soil stratum are primarily climate

Climatic factors, primarily determined on the territory of Kazakhstan long winters with a capacity of snowpack thickness greater than one meter and depth of soil freezing up to 3.0 m, and not short and hot rainy summer. These climatic conditions represent the following: Foundation soil within one calendar year working in dynamic mode "freezing – thawing – water saturation". Figure 1, Graph of fluctuations of groundwater during the year in the territory of Pavlodar (Kazakhstan) Zhakulin, A.S. (2015).

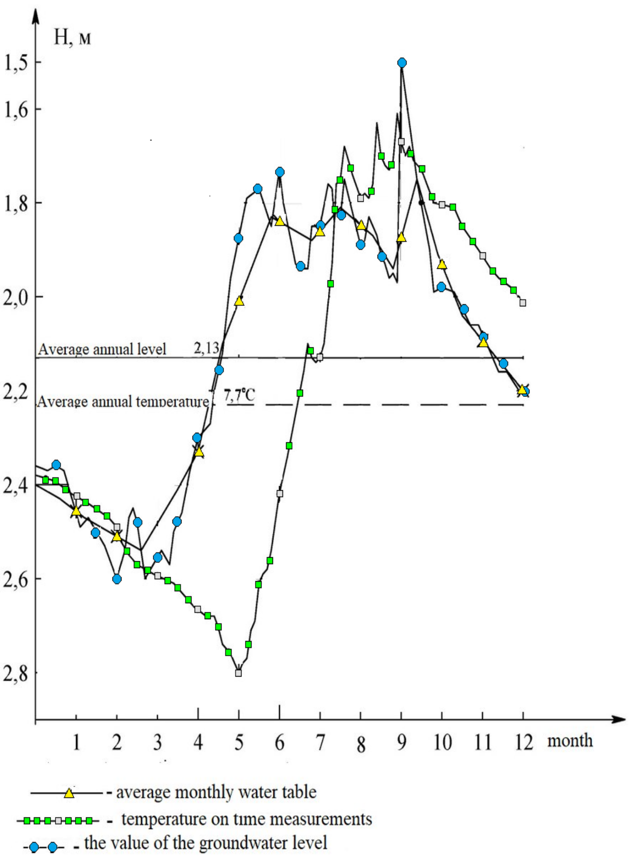

Fig. 1. Graph of the fluctuations of groundwater during the year in Pavlodar (Kazakhstan).

The above factors lead primarily to a change in the amount of moisture soils that cause the decompression and reorientation of solid mineral particles of soil as the result of hydrostatic weighing them, increasing their porosity and filtration coefficient, resistant and soft cohesive clay soils and significantly altered the original structure.

3 THE PROPERTIES OF SPECIFIC SOIL

3.1 Collapsible soils

Collapsible loess soils occupy approximately 5% off all foothill lands on the South and West of Kazakhstan. Outside the Kazakhstan vast areas of land classified as loess soils in following countries: Ukraine, Russian, Spain, China Iran, Afghanistan, USA; and the countries of North Africa, Central Asia and South America. Ukhov, S.B. et al. (2002). Zhakulin, A.S. and Zhakulina, A.A. (2015). Das, M. Braja. (1994). The peculiarities include that the granulometric composition of subsidence loess soils is characterized by a high content of dust particles 0.05 ... 0.005 mm in size (more than 50%) and a significantly lower content of clay particles less than 0.005 mm in size (no more than 10-15%). Clay particles often represented mainly by such minerals as kaolinite and hydromica, which contribute to the development of subsidence. The density of loess soils depends on the mineral composition, structure and water content in them and ranges from 1.33 to 2.0 g/cm3. They also characterized by low skeletal density (usually less than 1.5 g/cm3). For subsidence soils characterized by high porosity and the presence of macropores, which reach 1-3 mm in diameter and are distinguishable by the naked eye. The porosity coefficient is more than 0.9. The natural moisture content of loess soils is usually small and ranges from 6 ... 11%, which is less than the rolling limit. At the same time, according to the results of laboratory tests, the characteristics for loams are density - 15–16 kN/m3; porosity coefficient – _> 0.9 with small mechanical properties. According to the results of compression tests, loams, occurring to a depth of 15.5–21.0 m, show a drawdown when soaked. At the same time, the strength properties of soils deteriorate up to 50%. Figure 2 shows grafik changes in the relative kollapsible - Q_{sl} in depth-H.

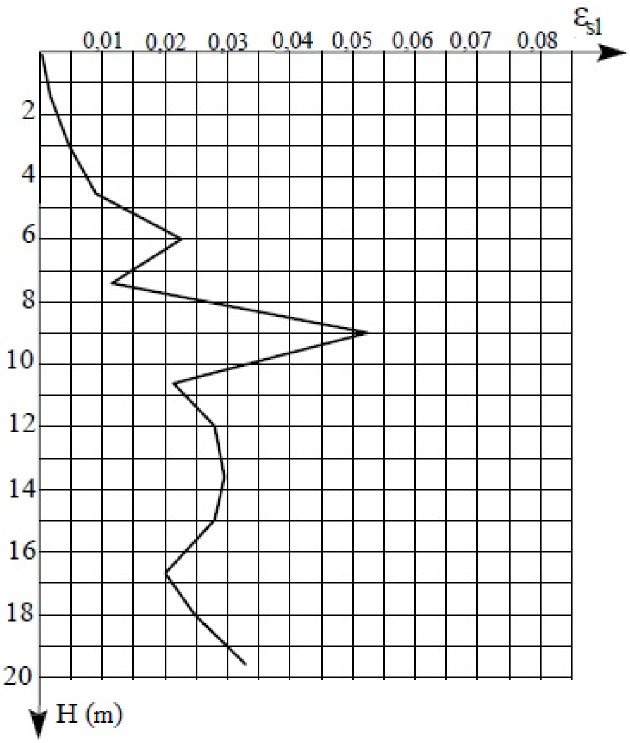

Fig. 2. Graph of changes in the relative kollapsible by depth.

Based on the graph of the relative kollapsible - Q_{sl} soils in depth, determine the total draft of the base by the formula:

S_{sl}= Ñ Q_{sl} ·h_i=0.016x130+0.017x150+0.03x150+0.037x x150+0.05x150+0.028x150+0.028x150+0.024x150+ +0.023x150+0.028x150=38.8 sm.

The initial drawdown pressure varies from 0.028 to 0.361 MPa (0.112). The ratio of relative subsidence at a specific pressure of 0.05 MPa ranges from 0.001 to 0.056; with a specific pressure of 0.1 MPa - 0.001 - 0.064; with a specific pressure of 0.2 MPa - 0.001 - 0.105; with a specific pressure of 0.3 MPa - 0.019-0.113. The calculations state that total amount of settlement is around 38.8 – 73.51 sm. According to Republic of Kazakhstan, settlement conditions classified kROODSVLEOH soils as second type. Zhakulin, A.S., et al. (2016), Krutov, V.I. et al. (2016) , Klepikov, S. N., et al. (1987), Ilichov, V. :. , et al. (2016).

3.2 Swelling soils

Swelling clay soils are widespread in the territory of Central Kazakhstan, when soaked with water or another liquid, increases in volume and have a relative deformation of the swelling without a load, Q_{sw}> 0.04. According to the classification of soils, clay soils are divided by the magnitude of the relative deformation of free swelling into four varieties - from non-swelling (e_{sw} <0.04) to strongly swellable (Q_{sw}> 0.12). Ukhov, et al. (2002). Swelling is the most common in conventional silty-clay soils (not swelling when saturated with water) or they are soaked with chemical drains or technological solutions of various industries (especially solutions of salts, acids, alkalis). After soaking, all swelling soils show a decrease in density, a transition from solid and semi-solid to plastic consistency, and a 3–4 times reduction in strength characteristics. If the natural composition of the swelling soil is disturbed (for example, when it is used as a backfill soil), the free swelling value can increase up to 1.5-2 times. Highly dispersed clays with reversible coagulation and stabilization structural bonds are more susceptible to shrinkage and swelling. As a rule, the content of particles smaller than 0.005 mm exceeds 40 ... 60%, the density is more than 1.5 ... 1.7 g / cm^3, the humidity is less than 0.20 ... 0.30, the plasticity number is 0.28, the limits of rolling and yield, respectively, exceed 0.27 and 0.55. The composition of these clays contains minerals of groups of montmorillonite. Ukhov, et al. (2002). The swelling of the soil in depth from the results of laboratory studies was determined by the formulas (Figure 3.):

$$Q_{sw} = (h_{sat} - h_n)/h_n, \qquad (1)$$

where: h_n - is the height of the sample of natural moisture and density; h_{sat} is the height of the same sample after soaking to full water saturation.

Fig. 3. Graph change of a swelling soil depth.

3.3 Saline soils

Saline soils are widespread in the Caspian lowlands of Western Kazakhstan. Saline soils are sandy-clay deposits, in which the accumulation of salts occurred in the process of their formation. When evaluating soils, it is important to know the content of water-soluble salts in them.

Fig. 4. Deformational modulus relationship to water saturation – W, and alkalinity – d_0 of saline soils

Humid and dry saline soils when wetted dramatically change their deformation, strength and filtration properties due to the removal of salts. As an example, Figure 5 shows the effect of changes in the moisture content of saline soils and salt leaching on the strain modulus.

As can be seen from Figure 4, the considered soils with a natural moisture content W = 0.08 and the natural salt content (d_0 = 5.7%) have a high deformation modulus. With an increase in humidity or leaching of salts, the decrease in the strain modulus is 4 –10 times or more Ukhov, S.B., et al. (2002). Leaching of salts leads to a decrease in the density and carrying capacity of soils, as well as to an increase in their permeability. Filtering through the soil water becomes aggressive with respect to concrete, mortar and metal.

CONCLUSION

At the same time, they create a problem of anthropogenic character, connected with the water saturation of the base soils. These geotechnical investigations and laboratory testing results show that the soils have relatively high density and low void ratios. The laboratory studies confirm an increase in water content of soils and the transition from a semi-solid to a low-plasticity consistency. According to the results of compression tests, loams, occurring to a depth of 15.5–21.0 m, show a drawdown when soaked. At the same time, the strength properties of soils deteriorate up to 50%.

In Kazakhstan, specific (saline, swelling, collapsible) soils that are less investigated common. At the same time, the provisions of the Eurocode design on specific soils impose on domestic scientists. Thus, the introduction of the Eurocode requires that the design of the base on specific soils is a detailed study of their properties and methods of calculation.

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