To the Issue of Consideration the Sediment of Foundation Soil as a Multifactorial Anthropogenic Geological Process

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Abstract. The article substantiates the need to consider the soil sediment of the foundation of structure not as a vertical displacement of the structure due to compression, compaction or other changes in the rocks lying at its base, but as a multifactorial integral engineering-geological process associated with vertical subsidence of the soil of the base of buildings and structures, due to a decrease in soil volume due to its deformation under load or deterioration of its strength and deformation properties in the process of natural and technogenic effects. The estimated predicted precipitation of base soils provided by the project for weakly compressible soils, as a rule, is 40–60% higher than actual ones, and for strongly compressible soils, actual precipitation can be several times higher than calculated. The authors see such a discrepancy in the mechanical approach to modeling the process of sedimentation of base soils, while sediment of base soils is a multifactorial engineering and geological process that changes in space and time. A number of examples in various regions of the country show a wide range of different natural geological and technogenic processes that affect the unevenness, size and duration of sedimentation of base soils under various buildings and structures.

Keywords: Organic farming · Soil management · Crop diversity · Environmental impact and emissions

1 Introduction

All natural processes are distinguished on the basis of the essential components of the environment that determine them. So, according to the latest scientific developments, the geological process is determined by the change in the determining complex of the components of the geological environment in time and space under the influence of natural and man-made factors. In practice, the geological environment acts not as the upper part of the lithosphere in general, but as a specific part of it - a geological body, which should be considered as a lithosphere called "soil mass".

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All natural and man-made geological processes occur exclusively within the soil massifs. At the same time, most of the natural and anthropogenically determined (technogenic or engineering-geological) geological processes, ultimately, manifests itself on the earth's surface as a phenomenon, but not a small part of such processes occurring inside the soil massif in any way (or practically imperceptible to the eyes of the observer) do not appear in the relief [1]. From our point of view, one of these exclusively engineering-geological processes should include the subsidence of the foundation soils.

The last mention in the domestic literature about sediment as a geological process (more precisely, a phenomenon) can be found in the work of P.M. Panyukov (1978) in the classification of engineering-geological phenomena developed by him. In recent decades in our country, under the influence of leading scientific schools in engineering geology, headed by such authoritative scientists as G.K. Bondarik, V.T. Trofimov et al., For reasons we do not understand, the term sediment, as an engineering-geological process, dropped out of the development of genetic-morphological engineering-geological classifications.

In engineering geology, the settlement process as an engineering-geological process was first considered by I.V. Popov in the classic textbook on engineering geology and in the work of V.A. Priklonsky back in 1951. Then, in 1960, the draft was described by N.Ya. Denisov in a textbook on engineering geology for builders, in 1975 L.D. Bely in a textbook for universities on engineering geology, perhaps the first, gave a modern interpretation of the definition of soil settlement as an engineering-geological process [2]. However, already in 1977, in a multivolume textbook by V.D. Lomtadze Engineering geology in the text and in the classification of geological processes, the term "sediment" is already absent [3]. In the later works of such well-known geological engineers as G.K. Bondarik, G.S. Zolotarev, Yu.B. Třitsinskaya, V.T. Trofimov et al., Sediment as an engineering-geological process is replaced by the term "compaction". Thus, in the basic scheme of classification of modern exogenous processes on the territory of the West Siberian plate, V.T. Trofimov (1986) distinguishes at the last step of the ranking (subtype) for the type of processes caused by compaction and convective movement of soil masses - compaction, as an "elementary" natural geological process leading to the formation of phenomena expressed in the relief, or in the soil mass, or in relief and soil mass at the same time [2].

If we apply the same approach to ranking engineering-geological processes, then the class of processes caused by the action of the stress-strain state of the soil massif (i.e., the action of gravitational forces on the uplands according to V.T.Trofimov, 1986) can be subdivided into the type of processes caused by compaction and convective displacement of soil masses, and the latter per subtype - "sediment of base soils".

Thus, it becomes obvious that "compaction" will be an "elementary" natural geological or engineering-geological process caused by spatio-temporal changes in the stress-strain state of soil massifs due to gravity or exclusively mechanical action. In the case of additional participation in such changes in the stress-deformable state of soils of anthropogenic influences, the "elementary" process will be "sedimentation of the foundation soils", but already as an exclusively engineering-geological process.

It is appropriate to note here that in engineering geology, the term "rock compaction" means an increase in the density of rocks under the influence of external loads due to a decrease in their porosity (that is, an exclusively mechanical process), and the definition of the term “sediment of foundation soils»Is absent in the modern geological literature.

Settlement of foundation soils - engineering-geological process.

In the modern engineering-geological literature, there is no definition of the term “sediment of the foundation soil” as an engineering-geological process. In explanatory and terminological geological dictionaries, there are definitions of the terms “sediment” (additional, full, final, uneven, suffusion, failure, etc.), “structure draft” mainly as technical terms [3]. At the same time, the definition of the terms “thawing sediment”, “thermal sediment”, “thawing sediment” (from our point of view, the latter terms are synonyms) in the same sources and in the geocryological literature are given as for full-fledged permafrost (cryogenic and postcryogenic) processes [2], and according to the statements of V.T. Trofimov (2017), all permafrost processes should be considered in engineering geology from the standpoint of engineering-geological assessment of their role as geological processes caused by natural and man-made factors [4]. Thus, following a similar logic, “foundation soil settlement” should also be an engineering-geological process.

Considering the subsidence of the foundation soils, the geological engineer must see in it the unity of the process and the phenomenon. As a process of subsidence of foundation soils, it is a complex geodynamic process that affects all elements of the soil massif of the active zone of the structure foundation. It can be considered as an engineering-geological process leading to a change in the state, strength and deformation properties of base soils.

As shown in our recent publications, the process of subsidence of foundation soils is the response of the soil mass to the effect of normal loading from a building or structure. However, subsidence of the foundation soils also occurs under dynamic influences (vibration) on the soil mass. In this regard, from our point of view, the “subsidence of foundation soils” should be understood as a spatio-temporal unidirectional (mainly vertical, different in duration) change in the coordinates of various parts of the soil massif of the active zone of the foundation of structures associated with the transformation of the stress-strain state of the soil massif when exposed to static and dynamic loads, as well as a number of geological and engineering-geological processes.

Due to the absence of a visual manifestation of this process in the relief, it can only be judged by violations in structures (deformation cracks, rolls of structures, the values of settlements of plinths and foundations), which are revealed, as a rule, during geotechnical (geodetic) monitoring, as well as by insignificant the magnitude of the subsidence of the surface of the soil massif directly in the contact parts along the perimeter of the buildings The latter should be clearly distinguished by researchers from the deformations of the earth’s surface (soil massif) associated with the compaction of bulk soils in the sinuses of the excavation.

Given the dynamic growth in the number of mankind on Earth, it can be argued that the sediment of the foundations of buildings and structures is and will be the most common engineering-geological process. Uneven settlement, usually caused by the heterogeneity of the foundation, or the heterogeneity of the impact on it from the side of the structure, or local external impact, often leads to deformation of buildings and structures up to their emergency state. Therefore, the most important task of modern foundation engineering is the development of a reliable method for calculating the settlement of buildings and structures predicted at the project stage.

The modern computational method of layer-by-layer summation of the settlement of the foundation of buildings and structures, used in predicting the settlement in design solutions, in practice, in most cases, very rarely coincides in magnitude with the actual settlement. Even at unique modern facilities, precipitation occurs that far exceed the calculated values and necessitate the use of expensive measures to eliminate the dangerous development of the process. As a confirmation, as an example, one can cite a residential building-tower on Leningradsky Prospekt in the city of Moscow. The amount of settlement in the central high-rise part of the building was much higher than that of the outer low-rise parts. The thickness of the foundation soils had to be frozen to stop the building from settling.

The statistics on forecasts of subsidence of foundation grounds were presented in his doctoral dissertation by the St. Petersburg scientist S.N. Sotnikov. The graph below was first published in our last work in early 2020 [5].

S.N. Sotnikov analyzed the correspondence between the calculated and actual settlement of buildings and structures for 146 objects, using his own observations, domestic and foreign publications (Fig. 1).

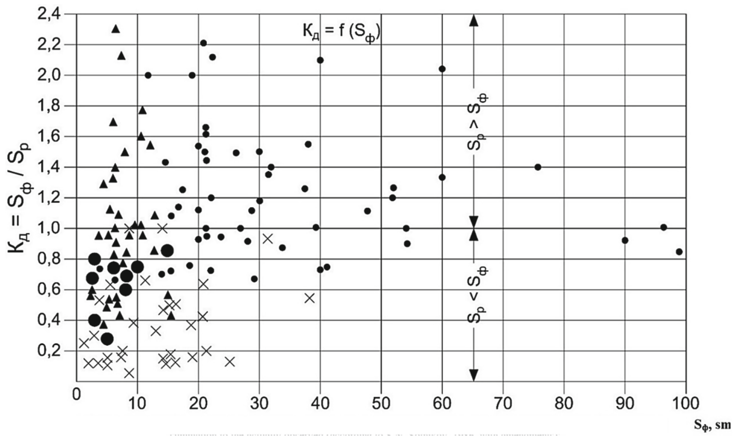

Fig. 1. Diagram of the distribution of errors in calculating the settlement of buildings and structures by the method of layer-by-layer summation to the actually observed (according to S. N. Sotnikov, 1986, with amendments): • - $K_Д$ values for soft soils (band clays, silts, peat sandy loam and loam, etc.); • - for moraine loams of semi-hard and hard consistency;▲- sandy loamy-loamy soils of different consistency; × - for slightly compressible soils, mainly sands.

The abscissa shows the total value of the actual precipitation in centimeters. On the ordinate axis, the ratio of this value to the design settlement obtained by the layer-by-layer summation method, which today, according to the building rules of SP 22.13330.2016, remains the main method for designing the natural-technical system foundation-foundation. From our point of view, the analysis of the chart has not lost its relevance today.

Theoretically, with a reliable forecast of the sediment of the foundation soils, all points should lie on a horizontal straight line with the value $K_d = 1$, or grouped along it due to measurement errors ($K_d = S_{ph}/S_r$ - the ratio of S_{ph} - the actual settlement to S_r the calculated draft). However, there is no grouping. The points are almost evenly scattered over the field of the graph, which indicates a large discrepancy between the forecasts and the real precipitation of buildings and structures.

According to soil conditions, all objects of S.N. Sotnikov were divided into two groups: erected on soft soils (silts, band clays, peat sandy loams, etc.) and on dense soils (bedrocks of different composition: clays and moraines of semi-hard and hard consistency, sands of dense and medium density, etc.)… Results for slightly compressible soils are shown as diagonal crosses.

Based on the results of observations and calculations by SN Sotnikov, the ratios of S_{ph} - the actual settlement to S_p - the calculated draft were calculated. The ratio on the graph is designated $K_d = S_{ph}/S_r$. The graph shows that the draft of most objects on dense soils was no more than 25 cm, on weak soils no more than 60 cm. The draft of 9 objects on soft soils exceeded 1 m. They are not shown on the graph because of the scale. Calculation of S_p in most cases led to large errors. Thus, the deviation of S_p from S_{ph} by no more than $\pm$ 10% was noted only in 16 cases (11%). The coincidence of the calculation results with the actual draft can be considered as a random phenomenon, and not as a rule.

For objects on dense, slightly compressible soils, the calculated settlement turned out to be greatly overestimated in comparison with the actually achieved settlement. The ratio of the calculated settlement to the actual one for these soils reaches 5 and even 10, i.e. the error is hundreds of percent of the actual draft. However, such calculation errors are not dangerous for buildings and structures on a homogeneous base. In most cases, they do not require additional measures during the operation of buildings and structures and only indicate a significant overspending of materials and working time for the construction of the foundation. On the contrary, on objects with weak soils, the calculated draft is usually less than the actual one. The excess of the actual settlement over the calculated one reaches 200% of the calculated value, which undoubtedly requires measures to strengthen the foundations and consolidate the soils after the completion of construction.

The reasons for unacceptable errors in the forecast of precipitation according to S. B. Ukhov are reduced to two points: (1) the imperfection of the computational model in soil mechanics; (2) errors of survey data included in the calculation.

The values of the error in determining the characteristics of the base mass during surveys and its effect on the calculation error of the settlement were partially considered in previous works [6, 7] and came to the conclusion that for certain types of foundations, errors in determining the geological boundaries and errors in determining the characteristics of soils with modern survey methods can give a deviation in the calculation of the subsidence of the foundation soils by up to 50% of the calculated value. Therefore, it turns out to be relevant to clarify the nature of errors of the first kind, i.e. associated with the inaccuracy of the model of the process of soil subsidence of the foundation It is necessary to speak not only about the geomechanical model, but also about the engineering-geological model of the process.

Computational geomechanical models of the settlement process are based on the idea that settlement is soil compression under load according to Hooke's law or other laws that take into account filtration consolidation, the plastic component of deformation and other features of the soil. But the process of subsidence of the foundation soils, which is recorded by geodetic methods according to the marks on the walls of the building and the slopes of its architectural axes, has a more complex nature than only the compression of the foundation soils from mechanical static and/or dynamic loads.

Settlement of foundation soils is a multifactorial integral engineering-geological process that takes place in the foundation of a building and a structure with the participation of structures of the structure and the natural-technical environment surrounding the building, which is not included in the calculated volume of the "onion" of the foundation. In addition to static and dynamic loads, the amount of subsidence of foundation soils is influenced by various geological and engineering-geological processes occurring in the core of the foundations of buildings and structures throughout their entire life cycle. Such processes can be swelling, shrinkage, decompaction due to flooding or leaks from water-bearing communications, suffusion, heaving and thawing processes, if freezing spreads under the foundation, and others. Additional settlement can be caused by flooding, which is associated with a change in the deformation characteristics of clay soils. Flooding is often associated with a change in the composition of soils and the composition of groundwater, and a change in the ionic composition of water changes the deformation characteristics of soils and leads to an increase in precipitation. A change in the stress state of the basement mass due to the nearby excavation works on the construction of pits, trenches for communications and vertical planning, and even the replacement of the asphalt pavement can cause additional settlement of the buildings in use, the settlement of which was completed long ago. Suffosia loosens sandy soils, usually in certain parts of the base, and causes uneven settlement of certain parts of the building during different periods of its operation.

Let us consider the most illustrative example of the manifestation of the process of subsidence of foundation soils in the life cycle of a structure, when the designers' blind faith in the number and formula led to repeated sedimentary deformations of the building. In 1990, two of the authors of this article conducted research into the causes of renewed sedimentary deformations in the 4-storey building of the dormitory of the V.I. Tsarevich Alexei (formerly "Komsomolets") in the city of Yegoryevsk. The building was built in the early post-war years on a strip foundation laid in 1941. On the facade of the building, to its entire height, there was a through, winding, but generally vertical tearing crack. Inside the building, it crossed walls and ceilings with a floor offset of several centimeters. In the assignment for the survey of the building, it was indicated that the crack appeared during the construction process and was repaired before handing over the object to the customer. The crack resumed after three years of operation. It was repaired again and resumed for the third time 40 years after the construction of the building. At the time of the survey, there was water in the basement with a layer of 10–15 cm. The building was flooded.

It was found by drilling and pits that the building of the hostel of the Yegoryevsk Technical School stands on fluvioglacial deposits. The immediate soils of the base of one half of the building are represented by loam, the other half - by sand. The values of the deformation moduli of sands and loams under flooding conditions were significantly different, since loams became more susceptible to deformations when soaked. By analogy with neighboring areas, it can be concluded that, before soaking, sands and loams had similar values of the total deformation modulus (E), approximately E = 18 MPa. Obviously, for this reason, they are in the project, in the calculation of the precipitation were combined into one calculated geological element. Therefore, according to the project, the building had to have the same draft in all parts.

At the same time, it was not taken into account that sands, as an elastic medium, are rapidly compressed by the load during the construction process, while loams are deformed slowly and for a longer time, having the property of plasticity.

Already during the construction of the building, the sands actually completely stopped deforming under its load. The part of the building lying on the sands settled by the calculated value, while the loam during the construction process did not gain the calculated deformation value. Therefore, a sedimentary crack appeared over the border of sands and loams by the end of construction, it was repaired and the house was put into operation. Three years later, the sedimentation of half of the building, located on the loam, was completed. Therefore, a crack appeared on the facade of the building again. The third time, the crack appeared after the foundation was flooded, when the deformation capacity of the loams increased due to a change in their state, and half of the building standing on them additionally sagged. Our prediction was that the crack would not re-emerge for the fourth time as the soils were fully compacted under soaking conditions.

2 Conclusion

The above examples show that the calculation of settlement by the layer-by-layer summation method without predicting the effects on the foundation during the construction and operation of buildings leads to gross errors in projects, which result in new costs for the developer for strengthening the foundations, foundations, and sometimes supporting structures, as well as repairing facades….

In geodynamics, the engineering-geological process of sedimentation of the basement soils has long dropped out of the attention of researchers [8]. Calculations by the layer-by-layer summation method do not provide the required accuracy and differ significantly from the actually observed values of the base soil settlement.

The design of modern buildings and structures dictates the need for surveyors and geotechnicians to consider the subsidence of the foundation soils as a multifactorial integral engineering-geological process and, on the basis of this, the development of a reliable method for calculating the sediment of the foundations of buildings and structures of different composition and condition for their entire life cycle.

The argumentation presented in the work, from our point of view, rather convincingly testifies to the need to consider and further study the subsidence of foundation soils as the most common engineering-geological process. For the first time, the definition of subsidence of foundation soils as a multifactorial engineering-geological process is given.

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