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FOUNDATIONS OF THE HIGH RISE BUILDING IN THE AREA OF UNDERGROUND MINING

Problematic issues of construction of pile-foundation slab of high-rise residential building in the area of underground mining (underground mining with general under working area 25%; the fissured limestone may collapse under the weight of the building) are systematized. The experience of modeling by method of ultimate elements of pile-foundation slab of three-section residential building in the area of underground mining and results of the geodesic monitoring of complex building are presented.

Keywords: *underground mining, pile-foundation slab, fissured limestone, method of ultimate elements, stressed-deformed state, geomonitoring.*

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ФУНДАМЕНТИ ВИСОТНИХ БУДІВЕЛЬ У ЗОНІ ПІДЗЕМНИХ ВИРОБОК

Систематизовано проблемні питання влаштування пальово-плитних фундаментів висотного житлового комплексу в зоні підземних виробок: підземні виробки із загальною площею підробітки 25%; вістря паль спираються у тріщинуваті вапняки, які під вагою будівлі можуть продавитися. Наведено досвід моделювання методом скінченних елементів роботи пальово-плитного фундаменту трихсекційного житлового будинку в зоні підземних виробок і результати геодезичного моніторингу будівництва комплексу.

Ключові слова: *підземні виробки, пальово-плитний фундамент, тріщинуваті вапняки, метод скінченних елементів, напружено-деформований стан.*

Introduction. Terms of construction of modern residential complexes are constantly complicated. On the one hand, the surface area and, accordingly, the load on the base increase, and on the other – as areas for development, the territories are used in densely urban conditions with complex geotechnical properties [1, 2].

One of the options for these problems is the presence of foundations of underground voids. Approaches to determining the bearing capacity of rocks on a cut during drilling also remain relevant [2 – 6].

Analysis of recent sources of research and publications. The experience of erecting the foundations of high-rise buildings, including at the area of underground voids, is given in papers [2 – 6].

From their analysis, it is possible to generalize the high efficiency and reliability of pile-slab foundations for buildings and structures at the underground void area [2 – 8].

The current level of software, in particular the use of spatial solutions of the finite element method (FEM), makes it possible to direct methods for assessing the stress-strain state (SSS) of the foundations and foundations precisely to solve similar, purely practical tasks of geotechnical planners [8 – 11].

However, the problem of the possibility of crushing the thicker rocks from the weight of the building and the methods of their solution in the practice of geotechnical design is still not sufficiently investigated.

Identification of general problem parts unsolved before. Solutions on the erection of foundations in soils, composed of layers of inhomogeneous limestone, with underground voids, and the providing their reliable work require both experimental justification and numerical simulation, which are a debatable issue of geotechnics for the moment.

Basic material and results. The object of research – a residential complex of three separate sections on 24 floors and one – 20 floors (Fig. 1), located in the city of Odessa for the street Genoese, 24, d (Fig. 2). The building has a two-level underground parking. The first three sections are adjacent, the fourth is away from them. The sections have the following dimension: №1 – 32×25 m; №2 – 25×24 m; №3 – 29×24 m; №4 – 26,54×23,3 m. Constructive scheme of the building – monolithic-frame.

Figure 1 – General view of the residential complex

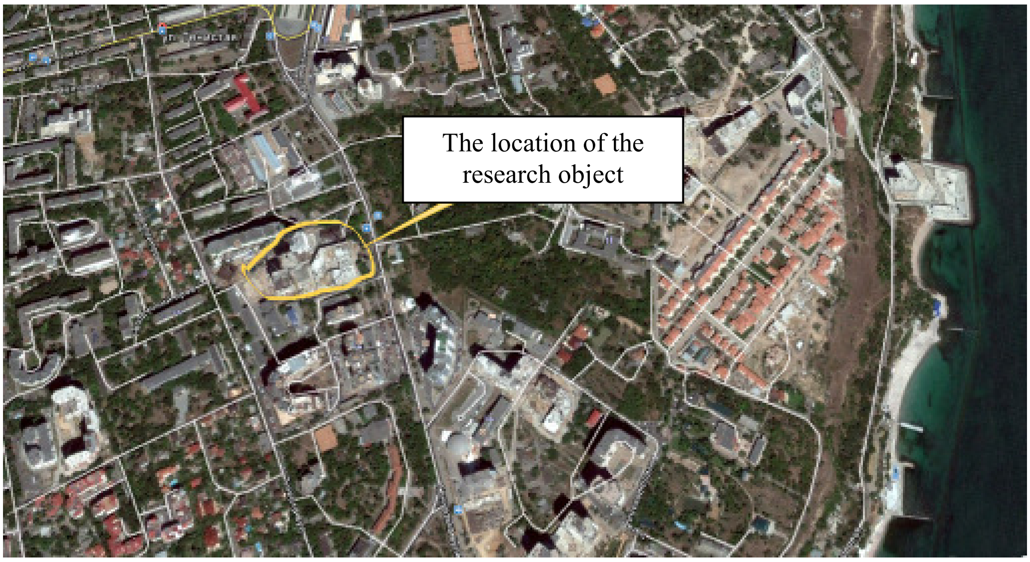

Figure 2 – Situation scheme of the location of research object

The authors have developed a robust, constructive solution to the foundations under these conditions. At the same time, the integrity of underground workings in the height of 2.4 m and 4.0 m in height (Fig. 3), which are in cracked limestones at a depth of 7 ... 8 m under the first three sections (Figure 4) (the value of forgery is 25 %) The design of the foundations provides a bearing ability to cut when crushing the thickness of cracked limestone (h_{min}=9,5 m) weight of the complex.

Figure 3 – General view of underground workings

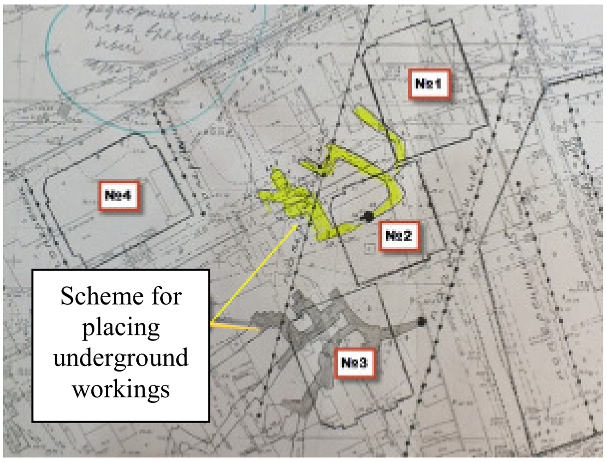

Figure 4 – General plan of the plot with the scheme of accommodation sections of the residential complex and underground workings

To clarify the geotechnical parameters of cracked limestones (underground workings are in them), which are the basis of piles and can be cut off when crushed against the weight of the building, field tests of soils have been conducted. The vertical loading load on a bale with a diameter of 500 mm and a length of 11.45 m with a base in limestone is brought to 2000 kN with its stabilized displacement of 0.95 mm. The vertical dismounting load on a catcher with a diameter of 500 mm and a working length of 1.24 m in lime limestone is brought to 325 kN with its stabilized displacement of 0.67 mm. Terms of limestone work on cuttings are determined by stamp tests.

The calculated resistance of the cut of limestone was R_{cp1} = 280 kPa at fracture on a plane with a slope 33º to the vertical, і R_{cp2} = 220 kPa – with a slope 45º to the vertical. In this case, the permissible stress of the cut is R_{cp} = 157 kPa. Actual compressibility of limestones is determined by stamp tests. The results of field tests of the base used for the geotechnical design of the complex. In zones with underground workings, additional reinforcing elements are the auger injected piles (Fig. 5 and 6).

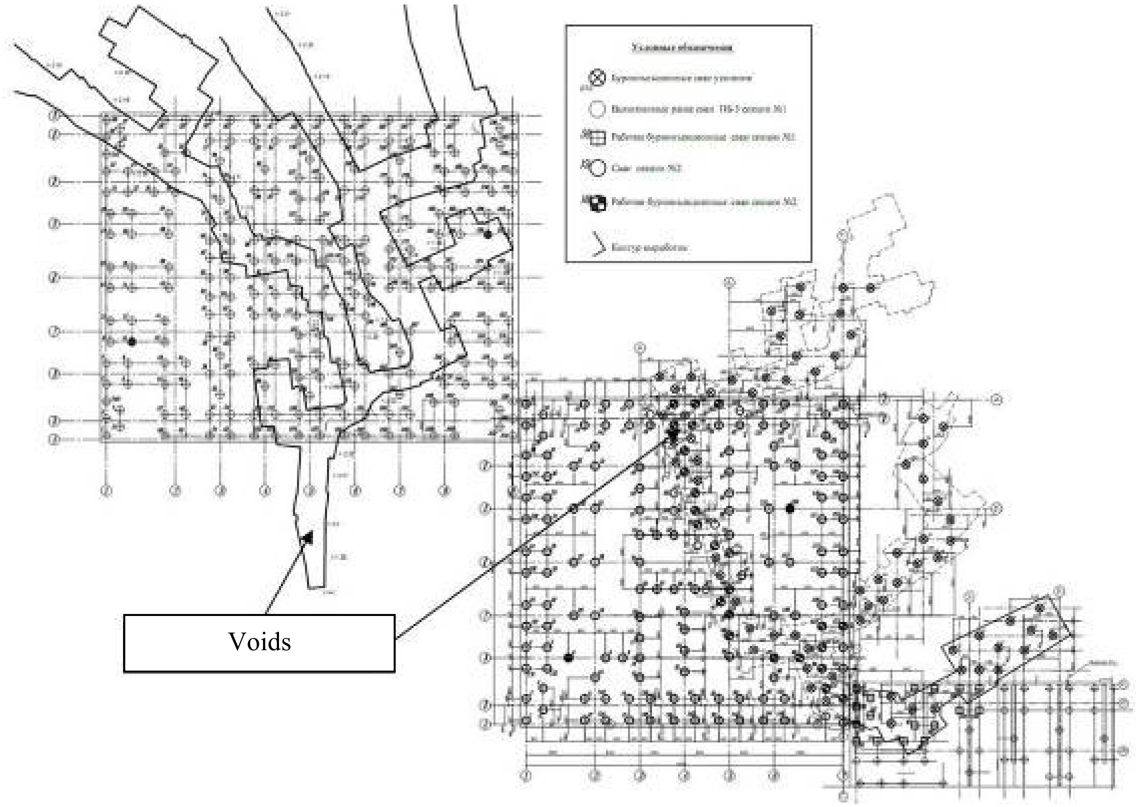

Figure 5 – Scheme of location of excavations and pile field
(fixing of workings in the area of the 3rd section is not shown conditionally)

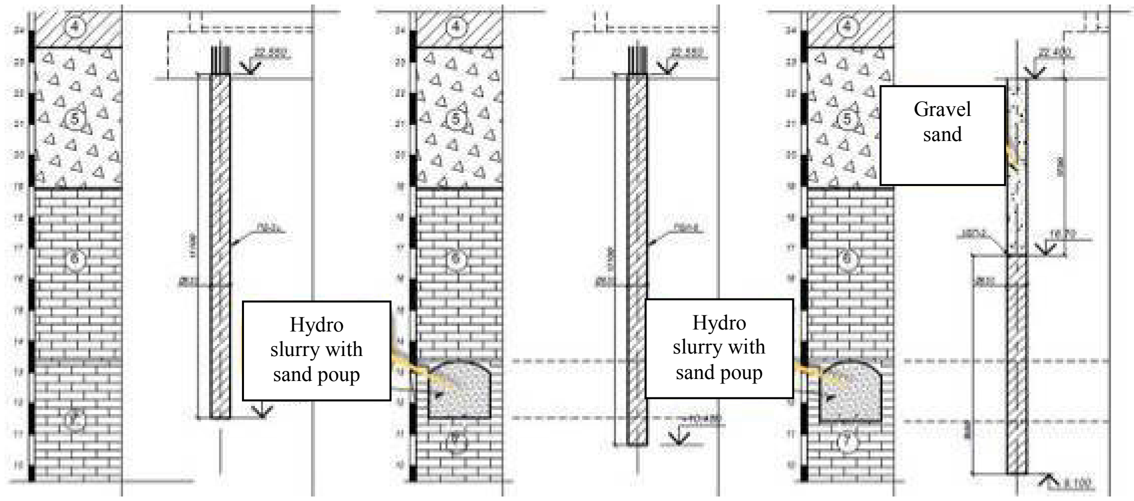

Figure 6 – Scheme of piling:
a – working pile outside the working area;
b – a working pile that falls into the area of development; c – a gain booster;
EGE-4 – hard clay; EGE-5 – limestone hewn to the bottom, gravel, hardwood, with clay filler;
EGE-6 – limestone, slab, cracked, low strength; EGE-7 – limestone cracked, low strength

Their function is the perception of tensile forces arising from tangential stresses outside the cut, and the transfer of compression effort to an array of soil higher and lower than workings due to their work on the lateral surface. Underground hydrocarbons with sand puddings and subsequent «tightening» of their roofs with cement-sand mortar.

It is accepted in designing a solution tested by simulation of ITU in spatial formulation. In this model of soils and their parameters were selected on the basis of their field tests. In order to obtain the maximum possible deposition, including uneven, in the simulation of the stress-strain state of the pallets, the characteristics of non-limestone, and clay filler were set. The simulation results of the maximum total summation and the roll of sections of the building did not exceed the allowable values of values.

An imprint of soil behavior is the elastic-plastic model with the Mohr-Coulon strength criterion. For concrete, a linear elastic model is used. Interface (interface strength) was used to distinguish between the elastic behavior of the pile body, where small displacements, and the surrounding soil massif, where possible plastic behavior with the Coulomb-Mora strength criterion, was used. This is done to avoid the appearance of peak stresses and deformations that do not have a real physical meaning. Spatial rigidity of all structural elements was calculated in accordance with the adopted design decisions of the building (Fig. 7).

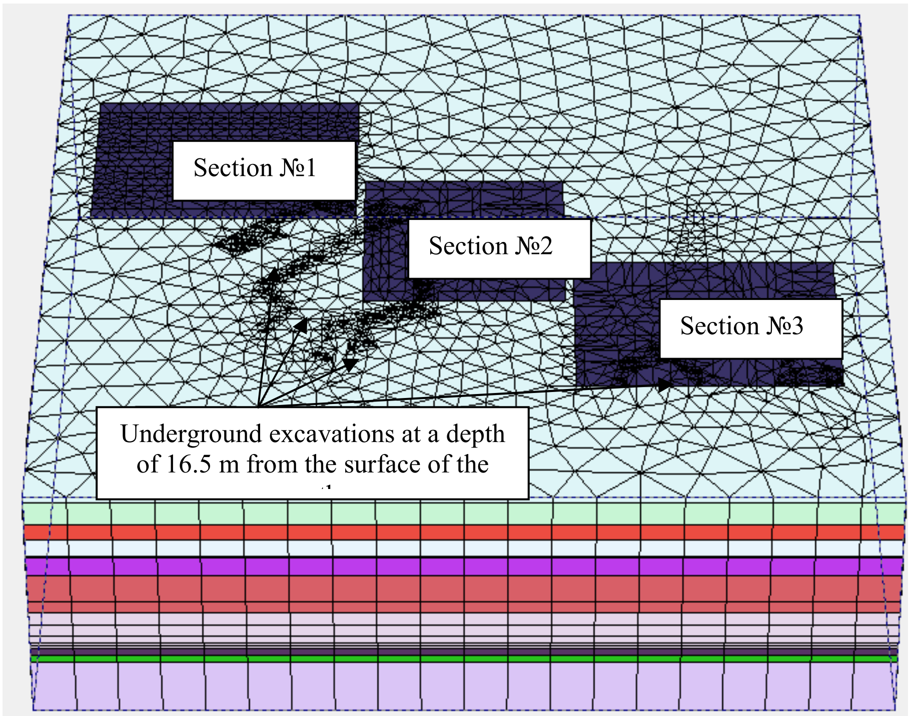

Figure 7 – Spatial design scheme for mutual influence modeling of foundations and foundations with underground workings of sections №1, №2 and №3

The problem was solved step by step:

1) gravitational loading of the calculated area with underground workings by the own weight of the soil and modeling of the initial VAT of the array;

2) excavation of the pit, water-curing of the cavity of the production spot, the device of piles and foundation plate, as well as the simulation of loading from the erection of section number 1, Fig. 8;

3) excavation of the pit, watering the cavity of the manufacturing spot, the device for piles and plates, modeling the load from the erection section number 2, Fig. 9;

4) excavation of the pit, watering the cavity of the production spot, the device of the pile and foundation plate, as well as modeling the load from the erection of section number 3, Fig. 10

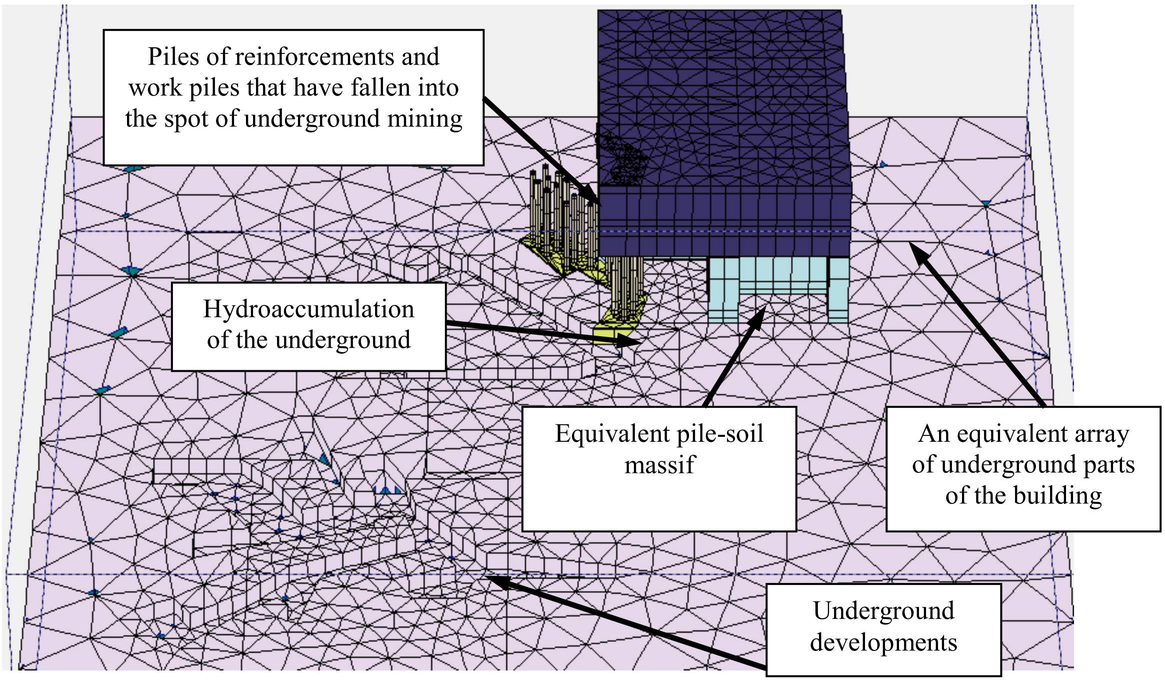

Figure 8 – Estimated spatial CE scheme of the second stage of modeling with the switched off clusters of EGE-1 ... EGE-5

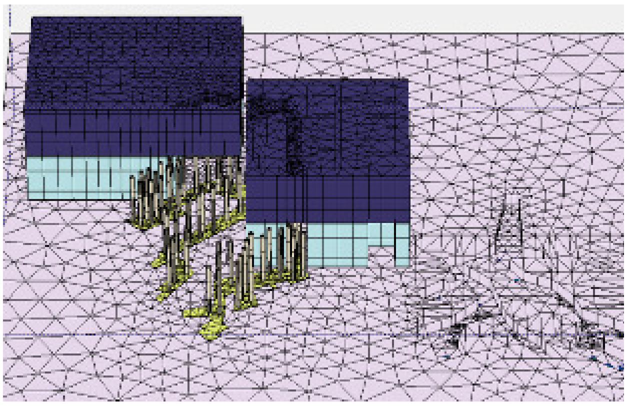

Figure 9 – Calculation scheme
(The second stage of modeling)

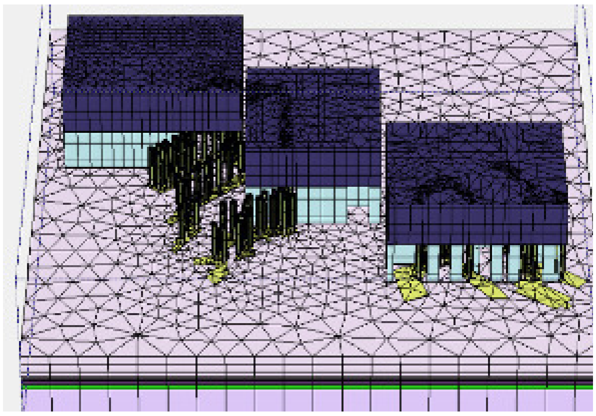

Figure 10 – Calculation scheme
(The third stage of modeling)

The maximum vertical displacement of the foundation of the pile-and-slab foundation was obtained after the construction of Section No. 1 – S = 9.9 cm. The base plate slope towards the underground mine was less than i = 0.0008.

The maximum vertical displacement of the base after the construction of Section No. 2 is S = 8.6 cm (Fig. 11) with the foundation plate sloping – less than i = 0.0006. Additional drafts of Section No 1 from the construction of Section No. 2 will be about SD = 1.5 cm with the plate heel – i = 0.0016. The maximum vertical displacement of the base from the construction of Section No. 3 is S = 9.9 cm (Fig. 11) when the slab is sloping towards the underground mine – to i = 0.0008. The additional drafts of Section No. 2 from the construction of section No. 3 are about SD = 1.8 cm with the plate heel – i = 0.0016. Effects of the construction of section number 3 on section number 1 will not be. The maximum total precipitation and roll does not exceed the maximum permissible values Su = 18 cm, iu = 0.005. As a result of the numerical analysis, the sediment values obtained are overestimated, which indicates the need to verify these data by full-scale geodetic observations.

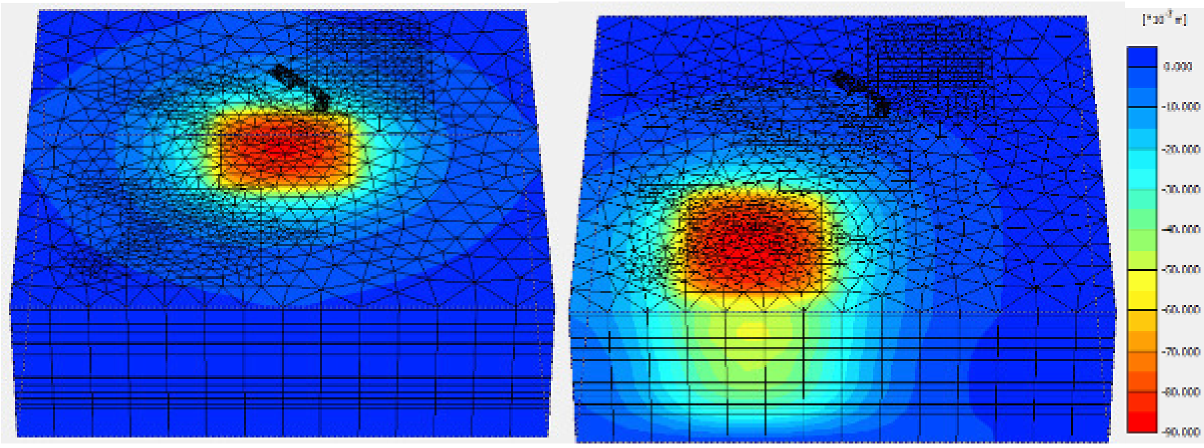

Figure 11 – Vertical displacement isopoles for 3D mesh after the construction of the second (left) and third (right) sections

Geotechnical monitoring in the process of construction of the complex was organized to verify the results of the calculation at the facility (Fig. 12).

The following results were obtained: the average subsidence of the first section is 9 mm (construction work performed on 98%); average settling of the second section – 10 mm (works executed on 85%); the average subsidence of the third section is 12 mm (works performed on 85%); The average subsidence of the fourth section is 10 mm (work performed on 80%, Fig. 13).

In fig. 14 the schedule of settling the foundations of the foundations of section №4 is given. The settlements by geodetic monitoring are similar to those simulated using high values of the deformation module IGE-6 ... IGE-8 (E6 = 100 MPa, E7 = 50 MPa, E8 = 500 MPa).

Figure 12 – General view of the frame of sections of the residential complex

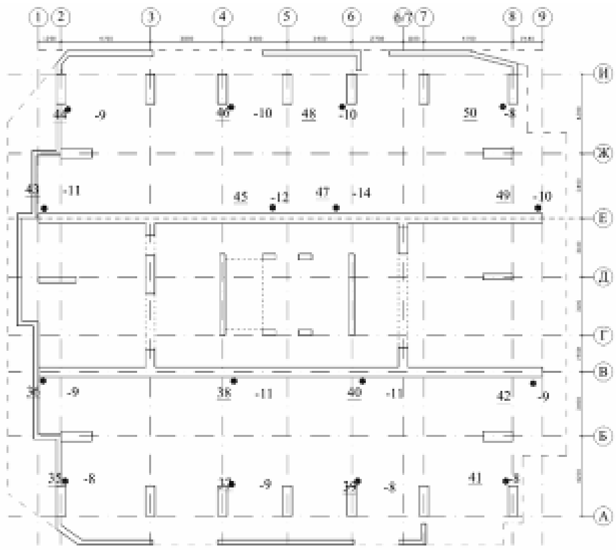

Figure 13 – Results of observations in the 4th section
(44 – the number of the mark, 9 – the value of settling in mm)

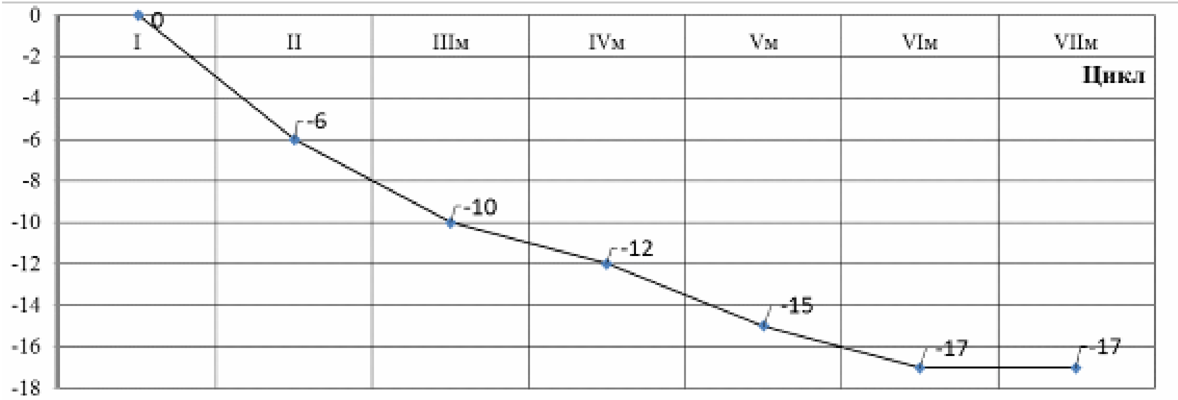

Figure 14 – Schedule of settlements of the foundation of the foundations of section №4

So, **conclusions**, from the analysis of the results of residential complex construction monitoring, it was found that the solutions adopted in geotechnical design have a sufficient level of reliability. Therefore, after additional analysis of the calculation scheme of Section 4, it was allowed to build it on 2 floors above (22 floors instead of the project 20) without changing the constructive decisions of the foundations.

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