Assessment of the impact of new construction on additional fallout of the foundations of operating buildings in constrained city conditions

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Abstract. The long-running building on clay soils with a life span of more than 25 years foundations sediments are considered. In the immediate vicinity of the building under consideration, the new neighboring building construction was completed at a distance of 6 m in light. The foundations of the long-used building are tape from monolithic reinforced concrete, and the new neighboring building in the monolithic reinforced concrete slab form. Both buildings foundations are arranged at the same mark. The foundation soils are represented by two engineering-geological elements: from the surface - soft plastic loam (EGE-1) 10 m thick, then - semi-solid clay (EGE-2) more than 12 m thick. The foundations bearing layer is soft plastic loam (EGE-1). The calculation revealed the long-term operated building strip foundation additional precipitations from pressure on the foundation transmitted by the new neighboring building. To reduce the additional sediment foundations considered options for the dividing wall structural solutions (different bending stiffness EI) between buildings. The buildings foundations sediment numerical calculations and their increments are made in the Midas GTS NX software package; given the results assessment.

Introduction

Sotnikova S.N. et al. (1983-1995), Simagina V.G. (1996-2012), Mangusheva R. A. et al. (2013-2016), Petrukhin V.P. and Shulyatev O.A. (2008-2010), Ulitsky V.M., Shashkina A.G. and others (1999-2010), Malganova A.I. et al. (1990-1994), Konovalova P.A. et al. (1980-2012), Nikiforova N.S. et al. (2008-2016), Fellenius V.N. (2006) and others works (1996-2012) are devoted to the state design, operation and assessment of the separation walls between the closely located buildings foundations [1-3]. In the conducted research it is noted that the long-term buildings foundations additional sediments are influenced by the base soils’ properties, the pressure on the soils from the neighboring construction, the distance between the buildings under consideration, etc. However, the question of the stiffness parameter effect EI of the dividing wall between closely located buildings operated for a long time has not been studied enough so far [4-7]. The purpose of this work is to assess the bending stiffness parameter EI effect of the recessed dividing wall between closely spaced buildings on the long-running building foundations settlement in clay soils.

Research methods
To determine the building in operation foundations additional sediment from the new neighboring construction influence, numerical studies in the MIDAS GTS NX software package were performed. The MIDAS GTS NX software package is designed for calculating the structures foundation soils stress-strain state and the geotechnical objects stability for various purposes using the finite-element method on powdered clay and other dispersed soils.

**Figure 1.** The design scheme for assessing the influence of the dividing wall on the building in use foundations draft: 1 - strip foundation of the building in use; 2 - slab foundation of a new (neighboring) building; 3 - separation wall; 4, 5 - engineering-geological elements of EGE-1 and EGE-2; b1, b2 - width of the base of the foundations of the buildings under consideration, d - depth of the foundations of the buildings under consideration; p1, p2 - pressure at the base of the foundations, N - load on the foundations

**Constructive foundations solutions**

The article discusses the two neighboring buildings foundations work, located at a distance of 6.0 m from each other (Figure. 1). One building (long-term exploited) is made on strip foundations with a sole width under the external walls b1 = 1.5 m, has been in operation for more than 25 years. Another building (new) is pointed on a slab foundation with a sole width of b2 = 20 m, one month in operation. The pressure on the sole p1 of the long-term operated building and the pressure on the sole p2 of the new neighboring building are p1 = p2 = 150 kPa. The foundation depth d in both buildings is d = 1.2 m. Between the buildings, a separation wall is arranged to a depth of 11.2 m from the layout surface. A rational design solution of the dividing wall was chosen according to the conditions of its effective work in the soil [8-10]. To simulate the long-running and new neighboring buildings foundations operation in clay soil, the Modified Mohr-Coulomb soil model (MMC Modified Mohr-Coulomb model) was used. The soils characteristics used for numerical studies are shown in Table 1.

**Table 1.** Characteristics of the clay soils of the MMC model for numerical studies of the operation of building foundations

| Characteristics of the soil at the base of the foundations | Characterization | EGE-1 | EGE-2 | units of measurement |
|------------------------------------------------------------|-----------------|-------|-------|---------------------|
| The proportion of soil of natural composition              | $\gamma_{unsat}$ | 17.1  | 19.4  | [kN/m$^3$]          |
| The proportion of water-saturated soil                      | $\gamma_{sat}$  | 18.2  | 20.2  | [kN/m$^3$]          |
Characteristics of the soil at the base of the foundations

| Characterization                  | EGE-1 | EGE-2 | units of measurement |
|----------------------------------|-------|-------|----------------------|
| Porosity coefficient             | 0.64  | 0.44  | -                    |
| The coefficient of dependence of the rigidity of the base from the existing stresses in the soil | 0.8    | 0.6    | -                    |
| Secant deformation modulus (at half the ultimate stress) | $E_{s50}$ | 10000 | 21000 | [kPa]                |
| The modulus of elasticity (discharge) of the soil | $E_{ur}$ | 30000 | 63000 | [kPa]                |
| Poisson's ratio                  | 0.35  | 0.4   | -                    |
| Soil adhesion                    | 12.0  | 42    | [kPa]                |
| The soil internal friction angle  | 18    | 24    | [degree]             |

Structural solutions dividing wall

To evaluate the separation wall operation in clay soil, six variants of its design solutions were considered:

1. The operating buildings option without a separating wall (option 1);
2. The injection piles dividing wall constructive solution with a step of 0.9 m (option 2);
3. The separating monolithic concrete wall constructive solution with thickness of 0.3 m, arranged by the “wall in the soil” method (option 3);
4. The metal tongue type dividing wall Larsen-5 constructive solution (option 4);
5. The brown injection piles two rows dividing wall Constructive solution (row spacing - 0.9 m, pile spacing - 0.9 m) (option 5);
6. The brown injection piles two rows separation wall constructive solution (row spacing - 1.5 m, pile spacing - 0.9 m) (option 6).

In the building construction considered variants, the decision was made on the injection piles length and their diameter for the separation wall: length $L = 10$ m from the foot of the grillage, pile diameter $dcb = 0.3$ m.

The numerical studies result

In the software package MIDAS GTS NX, the separation wall considered structural solutions finite element models were made (Figure. 2). The building foundations settlement in use was calculated in stages [11–13]. According to the numerical studies results, data were obtained on the distribution of stresses and displacements (sediment) at the base of the foundations of buildings, with and without taking into account the construction of the separation wall of various design solutions (Figure 2, 3). Data on sediment increments were summarized for each option considered. At the same time, the long-term operated building foundations additional sediment average calculated values were recorded at various flexural rigidity of the dividing wall, as well as in its absence (Table 2).

Analysis of the results obtained (Table 2, Figure 4) indicate a decrease in the increments of the sediment $\Delta S$ with an increase in the flexural rigidity $E_I$. For example, the dividing wall of the Larsen-5 type sheet pile has such flexural rigidity (155 MN * m), at which additional $\Delta S$ sediments are reduced by 30-40% compared with option 1 when the separation wall is absent. For reinforced concrete dividing walls, the most rational is option 6 with a double row arrangement of injection piles at which the greatest flexural rigidity is reached $E_I = 790$ MN * m, and the increments $\Delta S$ are reduced by 50-55% compared to option 1 when the separation wall is absent.

Thus, it was revealed that the parameter of bending stiffness $E_I$ influences the building in operation foundations $\Delta S$ additional sediment development in clay soils. The most rational way to reduce additional sediment foundations $\Delta S$ of the building in use in this case is to use a reinforced concrete partition wall of two rows of brown injection piles.
Figure 2. A finite-element model for calculating the additional draft of the existing foundations of a building from a new construction in the Midas GTS NX PC: 1 - strip foundation of the operated building; 2 - slab foundation of a new (neighboring) building; 3 - separation wall of two rows of injection piles (option 6)

Figure 3. Picture of the soil additional vertical movements at the foundation plate base (at $p = 150$ kPa) when constructing a dividing wall of injection piles (option 6), where 1 is the strip foundation of the building in use; 2 - slab foundation of a new (neighboring) building; 3 - separation wall

Table 2. Data on the building in operation foundations additional sediments from the neighboring construction influence

| Considered options | Average additional precipitation of the strip foundation (mm) of the operated (existing) building with the pressure at the sole $p$ (kPa) from the adjacent foundation | Flexural wall stiffness per running meter of wall length $EI$, MN*m |
|--------------------|-------------------------------------------------------------------------------------------------|-----------------------------|
|                    | $50$ kPa                                         | $100$ kPa                   | $150$ kPa       |

Summary
According to the research, the following main conclusions were made:

1. Based on numerical studies in the Midas GTS NX software package, a graphical dependence of the separation wall flexural stiffness parameter \( EI \) influence between closely located buildings on the long-running building additional foundation sediments \( \Delta S \) development was obtained. It has been established that the additional draft of the basement of a long-term operated building from the influence of a new (neighboring) construction in clay soils in the absence of a dividing wall may be 9.2 mm or more; the separation wall device at the same time will allow to reduce it almost twice.

2. It was revealed that the most rational constructive solution of the dividing wall between the foundations of closely located buildings with a pressure \( p \) along their base equal to \( p = 150 \) kPa is the

| Option | Flexural rigidity \( EI \), MN\( \cdot \)m | Additional sediment \( \Delta S \), mm |
|--------|-----------------|-----------------|
| 1      | 3.9             | 7.3             | 9.2             | 0 |
| 2      | 4.7             | 5.6             | 7.5             | 40 |
| 3      | 3.95            | 5.23            | 7.15            | 68 |
| 4      | 2.75            | 3.86            | 5.75            | 155 |
| 5      | 2.14            | 2.65            | 4.95            | 560 |
| 6      | 1.73            | 2.32            | 4.5             | 790 |

Figure 4. Graph of the closely located buildings foundations \( \Delta S \) additional sediment dependence on the dividing wall between buildings bending stiffness \( EI \) parameter
construction of two rows of injection piles with a length of about 10 m, a diameter of 0.3 m, a pile spacing of 0.9 m, a spacing between rows Piles 0.9 - 1.5 m.

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