Common mistakes made under facility construction in cramped conditions

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Abstract. Construction of facilities in cramped conditions requires a special approach connected with the development and implementation of measures to ensure safe operation of the surrounding buildings within the geotechnical influence. Builders often neglect the impact of a new facility construction technology on possible negative effects resulted in the existing buildings (cracks on the facades due to uneven settlement, tilts, etc.). So far the concept of a minimum price has been used when erecting a building part below the zero mark. This approach completely ignores the notion of engineering viability. At the same time builders resort to every kind of trick to reduce the cost of construction. Such an irrational method may eventually result in a substantial increase in the cost of the zero building part construction. As a rule, it can increase the construction time (agreement on a new project when replacing it with another geotechnical technology, and undergoing new expert review). This paper examines a negative case from the geotechnical practice of constructing a 16-storey residential house next to the existing five-storey one.

1. Introduction

The construction of facilities in cramped conditions is the most problematic in terms of construction technology of parts below the zero mark. Design and construction should include a set of measures to ensure safe operation of existing buildings. Modern geotechnical technologies make it possible to succeed in solving these problems [1-6]. This paper describes a negative example of a multistorey residential house construction next to an existing building.

2. Methods and Materials

Current geotechnical technologies make it possible to produce drill-injection piles with increased capacity. The electric discharge technology of a pile arrangement (EDT piles) is best suited to achieve these goals [7-17].

The arrangement of EDT piles with multiple extensions is considered as the most interesting. Thanks to extensions along the pile shaft and under its foot, it is possible to arrange a deep reinforced concrete structure with the possibility of controlling both the pile-load-bearing capacity and that of the soil.

A pile with multiple extensions works as a deep reinforced structure with a number of supports corresponding to the quantity of extensions. At the beginning of loading, the upper extension comes
into operation. As the load increases, the underlying extensions are gradually activated, with each extension serving as an additional support.

The practice of making such piles has proved to be very effective. The load-bearing capacity of the piles is 2.0-2.5 times higher with one extension and 3.0-3.5 times higher with two ones than that of the piles which are made without extensions.

The advantages of EDT drill-injection piles with multiple extensions are as follows: 1) the simplicity of implementation (one easy operation is added); 2) the possibility of exact determining the extension place (determined by the loss of a fine-grained concrete mix); 3) the possibility of having a required number of extensions on order to calculate a load bearing capacity along the pile length; 4) minimization of technological settlements; 5) the maximum load-bearing capacity of the pile, as compared with any other boring pile technology, both on the soil and on the material.

3. Results and Discussion

A new construction project consists of one single monolithic block having a rectangular shape. The above-ground part of the building consists of 16 floors and a mechanical storey. The structural design represents a concrete, monolithic, non-rigid framework with self-bearing outer walls made of foam-concrete blocks supported by intermediate monolithic reinforced concrete floors. A monolithic reinforced concrete base plate is proposed as the foundation. The depth of the pit on different sections ranges from 9.3 m to 9.6 m. The absolute depth of the pit is 175.30 m according to the Baltic Elevation System 1977 (BES). The width of the pit is 27.0 m in plan and 40.0 m in length.

In accordance with paragraph 9.36 of CR 22.13330.2011 “Updated Edition of CS and R 2.02.01-83* “Soil Bases of Buildings and Structures” the radius of the new construction influence area is equal to \( r_a = 4 \cdot H_k \) for the pit developed with a steel pipe fence arrangement. Thus, the area of influence makes 38.4m. In the above-mentioned area a five-storey two-section apartment building is located.

The category of technical condition of the residential building under study is assumed to be satisfactory, which resulted from the technical survey reports. It is a frame-free brick building with longitudinal bearing walls. The spatial rigidity of the building is ensured by hard disks of intermediate floors, coatings and staircase blocks. It’s a five-storey building with a basement. The dimensions are 54.0x12.75 m in plan and 17.0 m in height. The foundations of the building are taped prefabricated from standard foundation blocks (SFB) of 400-500 mm thick laid on a monolithic concrete belt mounted on the base plates. The depth of the foundation is 2.79 - 3.05 m. The walls of the building are made of silicate brick with a thickness of 510.0 mm laid on the cement-sand grout. Internal load-bearing walls of 380.0 mm thick are made of silicate brick, and intermediate and attic floors are made of 220.0 mm thick reinforced-concrete hollow-core slabs.

In the original design, it was planned to build a braced sheet wall with two levels of Atlant ground anchors for strengthening the pit walls (see figure 1 (a)). For that case, steel pipes with a cross section of 530x8 according to GOST 10704-91 “Electric Longitudinally Welded Steel Pipes. Grade”, with a pitch of 1.0 m were used. Along G-axis the pipes were arranged with a pitch of 0.8 m. In addition, the pipes were filled with heavy concrete in the immediate vicinity of the building. The pipe top mark of the braced sheet wall was taken as a variable from 184.54 m to 184.84 m of the Baltic Elevation System (BES). The bottom of the fencing pipes along axes 1, A and 12 was at the marks from 171.54 to 171.84 m of the BES, at a length of pipes equal to 13.0 m, whereas along G-axis the bottom of the fencing pipes was at the mark of 166.84 m of the BES at a length of pipes equal to 18.0 m. Boards with a thickness of 40.0 mm were set between the fencing pipes.

At the request of the building contractor (LLC Scientific-Production Company FORST) we were given an assignment to develop an alternative option of a braced sheet wall the with the use of steel pipes of the same cross-section size, but with ground anchors in three tiers, made by Electrical Discharge Technology (EDT Anchor) (see figure 1 (b)). At the same time, the estimated depth of steel pipes embedment was larger than that of the original design. In addition, in the areas adjacent to the existing houses, we designed braced sheet walls made of tangential drill-injection EDT piles with a diameter of 350 mm with a monolithic reinforced-concrete binding belt at the top of the piles. A
designed wall was made as a solid, monolithic, buried reinforced concrete structure that could prevent the soil from falling under the base of an existing dwelling house during a pit excavation.

Figure 1. Variants of braced pit sheeting with ground anchors: (a) Atlant anchors; (b) EDT anchors.

Having studied both options of pit sheeting, the Customer came to rather a strange conclusion about the reduction of the cost of the pit sheeting project. In that case, engineering viability of the project was totally neglected, although its economic efficiency was gained. Thus, they ordered the third variant of the pit sheeting without anchoring though with the use of steel pipes and steel strut rails, as in the previous projects, but without making solid braced sheet walls in the areas adjacent to the existing house. A distribution belt of 50B2 paired channels was designed to ensure a uniform perception of the stresses from the ground and to pass them on to the strut rails. Attention should be paid to the fact that steel pipes previously applied were used as construction material for strut rails. During the excavation of the pit, the pipes suffered significant deformations (bends, cross-section deformations, soil and asphalt failures). At the same time, the absence of solid braced sheet walls in the areas adjacent to the existing dwelling house during the excavation work led to falling-out the soil from the foundation base. As a result, the existing dwelling house got immediate deformation, which was evidenced by the appearance of deformation cracks on the vertical façade surfaces progressing in time. Urgent geotechnical monitoring of vertical settlement (see figures 2 and 3) confirmed the worst. Part of the dwelling house on the side of new construction had become deformed and continued to deform (see figure 4).

The Customer immediately decided on developing a project of the deformed base part cementation and its immediate implementation (see figure 4). The results of the geotechnical monitoring showed that even after geotechnical work on cementing the bases had been done, deformation went on developing. All the maximum permissible deformations had already been exceeded. For example, the most deformed settlement mark had a vertical displacement of 52.0 mm (see figure 5) with a tolerance of 20.0 mm.

The descriptions of the engineering and geological elements (EGE) according to the technical report on engineering and geological surveys carried out at the future construction site are shown in table 1. The construction territory refers to the north-western end of the Volga Upland and is located on the high Oksk-Volga right bank. Against the city part situated on the other river bank, the mountainous part is raised by 100.0-136.0 m, forming a plateau limited by the Oka and Volga riverside slopes.
Table 1. Geotechnical actions to restore the serviceability of an existing dwelling house.

| Name of geotechnical technology | Measures envisaged for existing building protection | Implemented measures | Additional geotechnical actions | Work results |
|--------------------------------|---------------------------------------------------|----------------------|-------------------------------|--------------|
| A braced retaining wall with steel pipes and Atlant EDT ground anchors in two tiers | — | The project is cancelled | — | — |
| A braced retaining wall with steel pipes and EDT ground anchors in three tiers | A solid wall from tangential drill- injection EDT piles is designed | The project is cancelled | — | — |
| A braced retaining wall with steel pipes and two strut rail belts | Sheet from 40mm-thick wooden boards is designed | The project with strut rails in one belt was carried out | 1. Base cementing was completed; 2. The foundations of the existing house were strengthened. | 1. Deformation of the house continues; 2. Deformation of the house stopped |

The terrain of the construction site was planned. Surface marks of 184.3-184.9 m BES were set along pit mouths. The workings control was carried out by linear measurements starting from solid contours. The engineering and geological structure of the site up to a depth of 30.0 m is represented by: 1. Modern technogeneous sediments (tQIV); 2. Middle-upper quaternary sediments of problematic genesis (prQII-III); 3. Middle-quaternary lacustrine-alluvial deposits (laQII).

Figure 2. Typical floor plan of building № 1.
Figure 3. Facade of building № 2.

Figure 4. Vertical binding of the facility under construction and base cementation of the existing house № 1 to the geotechnical cross-section.

Figure 5. Settlement curves of deformation control marks set around the existing house № 1.
Table 2 provides EGE descriptions with their placement in depth.

Table 2. EGE descriptions with their placement in depth.

| № of layer | Age, genesis, soil description, area distribution | Layer thickness, m |
|------------|--------------------------------------------------|-------------------|
|            | Quaternary Period                                |                   |
|            | Modern sediments(QIV)                            |                   |
|            | Technogeneous sediments                          |                   |
| tQIV Backfill | It is brown, dark brown, with layers of sand, road stone, broken brick, wood chips loam. It is done by dry filling and classified as a pile of mixed soils with non-uniform density and compressibility. Borehole 2 uncovers the brickwork from a depth of 0.5 to 3.2 m. The soil was uncovered from the surface by all wells. | 0.7-3.2 |
| prQII-Ill loess soil | It is brown, yellowish brown, with the inclusion of manganese and iron hydroxide, mica, with parts of clayey sand. It’s uncovered all over under the filled-up ground. | 0.6-2.1 |
| edQII | It is brown loam, sandy in the roof, layered, with layers of clay | 1.4-8.0 |
| P2t | The polymictic sand is brown, strongly clayey, with layers of clay, with the inclusion of limestone rubble, weakly smeared sandstone. It was uncovered in thick Tatarian clay. | Uncovered 0.2-9.2 |
| P2t | The clay is reddish-brown, dark-brown, with layers of polymictic sand, with the inclusion of aleurite, alevrolite, sandstone nests and layers. It was uncovered everywhere in the lower part of the open cut. | Uncovered 0.5-5.8 |

4. Conclusion

1. Modern geotechnical methods make it possible to construct large and responsible structures on weak bases with minimal settlement after setting the facility to work.

2. The main design option for each individual site should be chosen on the basis of a feasibility study and the tasks to be performed by the structure.

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