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Review Article

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Geotechnical Engineering Practice in Confined Spaces Urban Development

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ABSTRACT
The problems of underground space development in the cramped conditions of existing industries are a complex geotechnical task and require a specific approach. At the same time, the presence of weak engineering and geological elements significantly complicates the implementation of geotechnical works. Increasing the bearing capacity of the foundation base is always under the close attention of geotechnicians, designers and builders. The use of bored piles arranged using non-standard physical processes in most cases successfully solves many complex and atypical geotechnical problems. The article is a review.

Keywords: Geotechnical Construction, Electrohydraulics, Monolithic Reinforced Concrete Grillage, Bored Injection Piles ERT, Constrained Geotechnical Conditions

The construction of any task (or structure) involves stage-by-stage quality control of construction (i.e., the presence of a technical customer service), which allows for its safe operation in the future. Often, builders often omit this position with the implementation of control by the customer from their attention.

It should be noted that the main recessed building structures for strengthening weak foundations are bored (bored injection) piles [1-13]. The quality of the installation of bored injection and cast-in-place piles during the construction of the zero part of buildings and structures is of great concern, especially if the technological chain is interrupted and proper quality control is not ensured during the performance of different stages of work by different contracting construction organizations.

Below is one of the frequent examples from geotechnical practice of non-compliance with the algorithm for the installation of bored injection piles ERT, which led to a loss in the quality of the manufactured buried reinforced concrete structures (insufficient strength of the concrete of bored injection piles). The working design for a ten-story hotel building provided for the installation of bored injection piles ERT. The geotechnical technology for the installation of bored injection piles under consideration includes the positions given below in positions 1-5.

1. Drilling a well; 2. Concreting the wellbore with fine-grained concrete; 3. Electrohydraulic treatment of the soil of the walls and bottom of the well; 4. Reinforcing the well filled with fine-grained concrete with spatial reinforcement cages; 5. Filling (topping up) the well with fine-grained concrete after electrohydraulic treatment.

Due to the fact that the above-mentioned stages of geotechnical works in positions 1-5 were carried out by four different contractors and there was no proper stage-by-stage control of concrete strength gain on the part of the customer, the technological cycle was disrupted and in more than 50% of cases the bored piles did not achieve the design bearing capacity. Therefore, there was an urgent need to redesign the entire pile field.

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It should be noted that the construction of the facility was carried out in complex engineering-geological and hydrogeological conditions of the construction site in the old beds of the Volga River and the Kovalikha River in the city of Nizhny Novgorod. The engineering-geological section of this site is represented by the following EGE (from top to bottom): **EGE-1.** Fill soil (uncompacted loam with sandy loam and construction waste); **EGE-2.** Non-subsidence tight and soft -plastic loess loam; **EGE-3.** Non-subsidence fluid-plastic loess loam; **IGE-4.** Tight- and soft -plastic loam; **IGE-5.** Hard and semi-hard clay; **IGE-6.** Clayey polymictic sand.

Notes:

1. *The construction of the facility began more than five years before the start of the main construction with the construction of the pit enclosure (to a depth of 9.0 m to the design pit bottom mark) made of two rows of bored piles with a diameter of 450.0 mm with a pitch of one m. The retaining wall of the pit was built along Kovalikhinskaya, Belinsky, and Maksima Gorky Streets. Directly from the side of A. M. Gorky Street, a ten-story large-panel residential building, erected on driven piles, adjoins the construction pit (Figure 1).*
2. *The lack of a monolithic reinforced concrete tie belt on top of the bored-injection piles turned out to be a drawback of the constructed enclosure. This was revealed only when the pit was torn off. A number of bored-injection piles of the enclosure of the construction pit from the side of the adjacent ten-story large-panel residential building leaned towards the construction pit (the maximum displacement reached 85.0 mm). As a result of the critical situation that arose, deformation cracks appeared on the external walls, stairwells and basement of the large-panel residential building. At the same time, the installed gypsum beacons broke and continued to break.*
3. *The emergency commission created in connection with this tasked the design organization to urgently develop emergency response measures to stabilize the deformations of both the retaining wall and the adjacent building. As such measures, a scheme was developed to strengthen the existing retaining wall in the form of spacer structures made of pipes with a diameter of 1 000.0 mm, located on two levels in mutually perpendicular directions (see Figure 1-2). These emergency measures allowed to stabilize the situation. The gypsum beacons on the residential building stopped tearing, horizontal movements of the deformed retaining wall were suspended. At the same time, geotechnical monitoring continued until the end of the construction of the object below the zero mark.*

With the design excavation pit depth of 9.0 *m*, the spacer fastenings were placed at a depth of 4.5÷6.5 *m*. Therefore, in order to avoid negative consequences for the adjacent residential building during further excavation of the pit, a project was developed for the installation of monolithic reinforced concrete buttresses on bored-injection piles ERT with a diameter of d = 0.35 *m* arranged under the sole of the grillage with a length of l = 12.0 to l = 19.0 *m*, depending on the engineering and geological conditions in a particular part of the construction site (Figure 1-2). Geotechnical work on the installation of ERT piles had to be carried out in very difficult, particularly cramped conditions between the pipes, and soil was removed from the pit only manually.

Figure 1: Geotechnical works at node "1" to strengthen the deformed existing retaining wall of the construction pit enclosure: 1-steel pipes with a diameter of 1000.0 mm as bunkers; 2-monolithic reinforced concrete buttresses; 3-construction pit enclosure (bored injection piles, filler made of 50.0 *mm thick boards*).

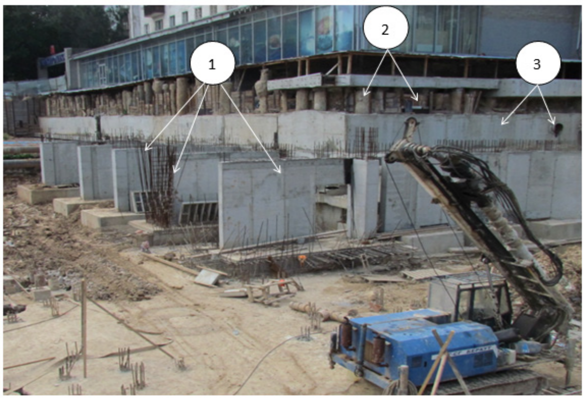

Figure 2: Geotechnical works at node "1" to strengthen the deformed existing retaining wall of the construction pit enclosure: 1-monolithic reinforced concrete buttresses; 2-existing pit enclosure made of bored piles; 3-finished pit enclosure made of monolithic reinforced concrete.

To ensure safe operation of the retaining wall during the construction of the zero cycle, as well as to create conditions for dismantling the steel pipes of the spacer building structures, an algorithm for the installation of monolithic reinforced concrete buttresses was developed (see Table 1). The implementation of construction and installation works for the implementation of the above algorithm made it possible to dismantle the spacer pipes in stages [14]. The results of the geotechnical monitoring confirmed that after the installation of the buried retaining reinforced concrete building structures, no further deformations of the retaining wall of the pit enclosure and the large-panel residential building were detected, which confirms the correctness of the adopted technical solution.

Table 1: Algorithm for the Construction of Monolithic Reinforced Concrete Buttresses

№№ pos	Stage name
I	Breakdown of axes with displacement of spacer structures
II	Monolithing of an existing retaining wall

III	Development of soil up to design marks for the construction of a monolithic reinforced concrete grillage
IV	Device: 1- sand preparation; 2- concrete preparation; 3- pile foundation of monolithic reinforced concrete grillage
V	Construction of a monolithic reinforced concrete grillage with installation of reinforcement outlets under the reinforced concrete columns of the frame of the building under construction and retaining (monolithic reinforced concrete buttresses) walls
VI	Construction of a retaining wall (monolithic reinforced concrete buttresses), reinforced concrete beams. After completion of construction and installation works on one of the monolithic reinforced concrete grillages, it is necessary to start developing the next one according to the serial number of each monolithic reinforced concrete grillage, according to the given numbering indicated on the design documentation.
VII	Completion of construction and installation works on the installation of the next serial number monolithic reinforced concrete grillage, retaining (monolithic reinforced concrete buttresses) walls, reinforced concrete beams, in accordance with the developed numbering indicated on the design documentation
VIII	Dismantling of the remaining steel spacer structures between the two retaining (monolithic reinforced concrete buttresses) walls. Dismantling should be carried out only after the concrete of the monolithic reinforced concrete grillage structures, retaining (monolithic reinforced concrete buttresses) walls and beams has reached the design strength. Backfilling of the sinuses of the monolithic reinforced concrete grillage pit should be carried out up to the absolute mark of +121.000m

Below in Figure 3 is shown a finished joint of buried reinforced concrete building structures of a monolithic reinforced concrete buttress with an existing pile foundation of a residential building, constructed according to the developed algorithm (see above pos. **I – VIII** algorithm of the construction of reinforced concrete buttresses), and in Figure 4 - a real technological unit for strengthening a deformed retaining wall.

It is necessary to pay attention to the fact that is of no small importance in geotechnical construction, that the installation of bored-injection piles ERT under the foundations of monolithic reinforced concrete buttresses was carried out by one contractor, and the construction of buttresses was carried out by another contractor. At the same time, monitoring of horizontal movements of the retaining wall and deformations of the residential building's settlement marks during these works was carried out daily. Due to this, there were no violations in the technological chain "drilling - concreting - electrohydraulic treatment of the borehole walls and heel - installation of spatial reinforcement cages " in this section.

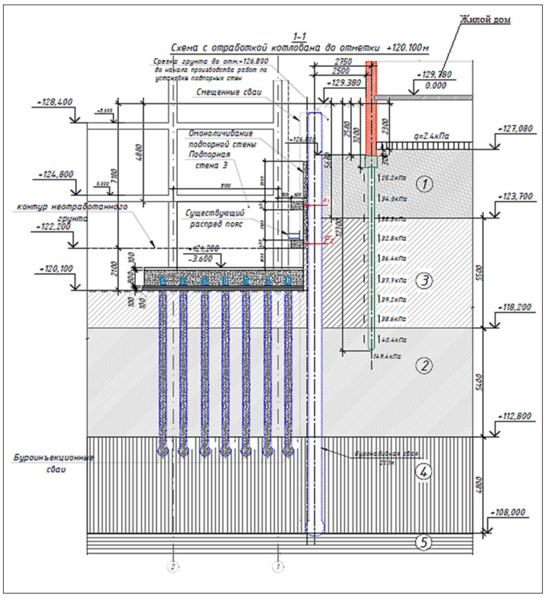

Figure 3: Junction of the monolithic reinforced concrete buttress structures with the existing pile foundation of a residential building

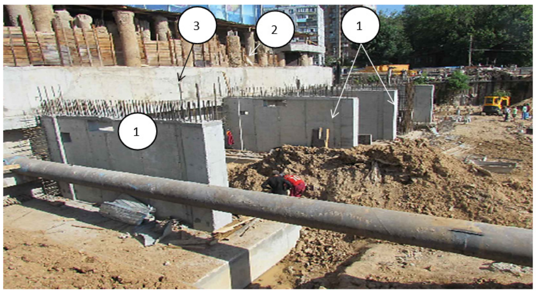

Figure 4: Fragments of completed monolithic reinforced concrete buttresses: 1 - monolithic reinforced concrete buttresses; 2 - existing pit fencing made of bored piles; 3 - finished pit fencing made of monolithic reinforced concrete; 4 - steel pipe (bulk)

In this case, the mandatory stages that confirmed the compliance of the designed bored-injection piles ERT for the buttress foundations with the project were:

1. Laboratory strength tests of pre-fabricated concrete cubes of fine-grained concrete intended for the production of bored-injection piles;
2. Tests of static vertical pressing load of experimental bored-injection piles ERT. At the test site (within the area of production of monolithic reinforced concrete buttresses) two pile clusters were made using the electric discharge geotechnical technology with widenings.

Notes:

1. *As the area of the pit was freed from the spacer structures, a significant area in the construction pit was freed for the installation of the pile field. Due to the investor's reduction in the construction time of the building, the customer decided to increase the speed of construction of the zero part by dividing the installation of bored injection piles ERT into stages. In this case, one construction organization was contracted to perform drilling operations, another - concreting with fine-grained concrete, a third - electrohydraulic processing of the walls and heel of the well, a fourth - the manufacture and immersion of*

spatial reinforcement cages in finished wells filled with fine-grained concrete and processed using electric discharge technology.

2. *Accordingly, the quality of work performed at different stages was controlled by different organizations and the probability of its reduction increased sharply. And the results of pile tests for vertical pressing static load confirmed these concerns (Table 2).*
3. *For more than 30.0% of the tested piles, the design bearing capacity was not achieved for both soil and material. The main reason for their low bearing capacity was the low strength of fine-grained concrete due to the lack of proper supervision of its installation. The low bearing capacity for soil was due to the destruction of the pile shaft.*
4. *It should be noted that one of the contractors responsible for concreting the piles used a RM-750 concrete mixing plant, which at high speeds saturates fine-grained concrete with air, which led to a shortage of strength in the fine-grained concrete.*

Table 2: Results of Static Tests of Bored Piles ERT for Vertical Static Pressing Load

№№ piles	Load-bearing capacity, F_d, kN	Estimated load, N , kN	Concrete strength of pile body, kPa	Reason for the negative result
789	62.8	52.3	60.0	Low concrete strength of the experimental pile
710	75.9	63.3	65.0	Low concrete strength of the experimental pile
579	95.0	79.1	78.0	Low concrete strength of the experimental pile
822	251.2	209.1	1200,0	Breakdown of anchor piles
728	565.2	471,0	2500,0	Breakdown of anchor piles
767	376.8	314.0	2600,0	Breakdown of anchor piles
803	251.2	209.3	1300,0	Breakdown of anchor piles

Conclusions

1. To ensure the design load-bearing capacity of monolithic reinforced concrete grillages with defective piles, it was decided to supplement them with ERT bored-injection piles with multiple widenings. The entire pile field and all grillages were redesigned taking into account the results of tests of experimental piles for load-bearing capacity. Thanks to this, it was possible to ensure the design load-bearing capacity of the entire foundation of the building as a whole.
2. Due to the execution of geotechnical works on the installation of bored-injection piles ERT by four contractors, the necessary stage-by-stage quality control was not ensured and large additional funds were spent to correct the negative consequences of this. Customers must exclude the possibility of such situations.

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