Approaches to increase the load bearing capacity of bored injection piles

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Abstract. The issue of strengthening weak or overloaded bases is an important task for the development of underground space. This is especially true in the presence of alternating weak layers at the base. The paper considers a case from the geotechnical practice of strengthening the overloaded base of a reinforced concrete foundation plate of a 25-storey residential building under construction.

Combined ground piles consisting of Get (type 1) ground concrete piles reinforced along the longitudinal axis with made drill-injection piles using electric discharge technology (EDT piles) are used as buried structures. This method of arrangement of a combined buried reinforced concrete structure is due to the need to increase the load-bearing capacity of the pile on the ground by two times or more.

1. Introduction
There are increased requirements for modern geotechnical construction [1-4]. In most cases, this is justified. It is often not possible to achieve the design values of the bearing capacity of the bases using existing geotechnical technologies. Using several existing technologies together, it is possible to create a buried structure of increased load-bearing capacity. Modern geotechnical construction allows solving most of the problems that arise both during construction and during the operation of objects.

The case of strengthening the base of a reinforced concrete slab foundation of a multi-storey residential building is described below.

2. Methods and Materials
Using several existing technologies together, it is possible to create a buried structure of increased load-bearing capacity. Modern geotechnical construction allows solving most of the problems that arise both during construction and during the operation of objects. The case of strengthening the base of a reinforced concrete slab foundation of a multi-storey residential building is described below. The studied object already during its construction (5 floors were built) began to deform at a rate of up to 2.0 mm per week. We proposed a reinforcement based on the technology proposed in [14], which is a synthesis of 3 geotechnical technologies: 1. Get-technology – the arrangement of soil-cement piles according to “SP 291.1325800.2017 Reinforced soil-cement structures. Design rules Moscow. 2017”; 2. SFA technology – the arrangement of drill-injection piles.
with the help of continuous passing screws (CPS) in the body of the soil-cement array along its axis of symmetry, usually with a diameter of no more than 300 mm; 3. Discharge-pulse technology of the arrangement of drilling-injection piles. The electrohydraulic effect that occurs when processing fine-grained concrete contributes to its insertion into the ground-cement array. Thus, there is a more complete coupling of these two structural elements.

This circumstance allows constructing a fundamentally new buried reinforced concrete structure – a ground-concrete pile.

3. Results and Discussion

The studied object already during its construction (5 floors were built) began to deform at a rate of up to 2.0 mm per week. We proposed a reinforcement based on the technology proposed in [1-13], which is a synthesis of 3 geotechnical technologies:

1. Get-technology – the arrangement of soil-cement piles according to “SP 291.1325800.2017 Reinforced soil-cement structures. Design rules Moscow, 2017”;
2. SFA technology – the arrangement of drill-injection piles with the help of continuous passing screws (CPS) in the body of the soil-cement array along its axis of symmetry, usually with a diameter of no more than 300.0 mm;
3. Discharge-pulse technology of the arrangement of drilling-injection piles. The electrohydraulic effect that occurs during the processing of fine-grained concrete contributes to its introduction into the ground-cement array. Thus, there is a more complete coupling of these two structural elements [5-13].

This circumstance allows constructing a fundamentally new buried reinforced concrete structure – a ground-concrete pile.

Figure 1 shows the scheme of the combined soil-concrete pile arrangement. The buried reinforced concrete structure – a ground concrete pile (GCP) shown in figure 1 (b), unlike other types, has a complex cross-section structure. The load-bearing element is an electrohydraulically treated and reinforced SFA pile (CPS) (pos. 3). Its load-bearing capacity on the outer surface depends on the friction characteristics of the soil-cement component (pos. 1) (see figure 2).

In addition, the SFA pile (CPS), together with the cement soil array works like concrete pile friction on the lateral surface of the surrounding soil (see figure 3). Engineering-geological section of the amplified combined soil concrete piles of foundation is presented by bulk soils, sands from small to medium-grained, from wet to saturated and loam smooth consistency, hard and semi-hard clays.

The description of engineering-geological elements (IGE) and physical-mechanical characteristics of IGE are given in the table below.

| № of IGE | Name of soils, E, MPa | $\rho_1$, g/cm$^3$ | $C_1$, Mpa | $\varphi_1$, degree | $\rho_2$, g/cm$^3$ | $C_2$, Mpa | $\varphi_2$, degree |
|---------|----------------------|------------------|-------------|-----------------|------------------|-------------|-----------------|
| 1       | Bulk soil sand with the inclusion of 10% of construction debris | Calculated resistance $R_q = 200$ kPa |
| 2       | Fine sand, medium density 25 | 1.99 | 1.97 | 1 | 0.15 | 0.85 | 0.29 |
| 3       | Fine sand, dense 38 | 1.79 | 1.77 | 1 | 0.15 | 0.85 | 0.29 |
| 4       | Fine sand, loose 18 | 1.93 | 1.91 | 1 | 0.15 | 0.85 | 0.29 |
| 5       | Sand of medium size, medium density 28 | 1.73 | 1.71 | 1 | 0.15 | 0.85 | 0.29 |
| 6       | Medium-sized sand, loose 18 | 1.95 | 1.93 | 1 | 0.15 | 0.85 | 0.29 |
| 7       | Soft-plastic loam 18 | 2.00 | 1.98 | 1 | 0.15 | 0.85 | 0.29 |
| 8       | Semi-hard clay 15 | 1.72 | 1.71 | 1 | 0.15 | 0.85 | 0.29 |

Note: the numerator shows the values of the deformation characteristics at natural humidity, the denominator at water saturation.
Figure 1. The scheme of the device of a ground concrete pile (GCP).

Figure 2. Scheme for determining the load-bearing capacity of the SFA pile (CPS) on the ground-cement base Fd1. 1 is ground-cement array, 2 is SFA pile (CPS).

Figure 3. Scheme for determining the load-bearing capacity of the SFA pile (CPS) together with the ground-cement array on the ground (ground-concrete piles (GCP)). 1 is ground-cement array, 2 is SFA pile (CPS).

As a result of geotechnical engineering calculations grounds taking into account the actual geological conditions of the construction site, the deficiency of bearing capacity of foundation slab base. At the same time, it is up to 50.0% of the design values. It should be noted that the height of the
basement is 3.3 m. Based on this, the choice of existing geotechnical technologies for strengthening the considered base is not very large.

If we consider the Get technology as a base reinforcement design, then the soil-cement pile is capable of bearing up to 50.0 ts (500.0 kN) in cross-sectional strength with a diameter of ∅ 600.0 mm. At the same time, it should receive up to 120.0 ts (1200.0 kN) to overcome the design load deficit. The use of a ground concrete pile (GCP) solves the problem. Arranging a ground concrete pile and reinforcing it with drill-injection piles ∅ 250.0 mm made by electric discharge technology according to the algorithm (given in [14]), the problem of restoring the deficit of the bearing capacity of the ground base is solved. Figure 4 shows the plans and sections of ground concrete piles. CBS piles are designed to be 14.0–19.0 meters long with a bearing capacity on the ground from 110.0 (1100.0 kN) to 150.0 ts (1500.0 kN). At the same time, the coefficient of the load-bearing capacity of the reinforced base is K=1.4.

4. Conclusion
The technology of reinforcement of drill-injection piles, manufactured by electric discharge technology (EDT) enables solving problems of strengthening congested grounds and piles of extra load bearing capacity.

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