Assessment of the impact of pile manufacturing technology on surrounding buildings in soft soils

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Abstract: Nowadays, the decrease in number of urban areas for buildings is observed. Therefore, a novel construction of buildings has to be carried out in dense buildings areas. Construction buildings in historical districts become the most complicated goal. In order to preserve the cultural heritage, to ensure the safety of existing buildings and structures, and also safe building under, it is necessary to competently select the technology of digging pile foundations. Technological precipitation usually occurs at dynamic and vibration effects during the operation of equipment on the site and at pile construction. These effects cannot be analysed and depend on the quality of the work performed, the equipment chosen correctly and the technology applied. It is intended to eliminate the possible technological precipitation of buildings in the surrounding area by applying gentle technology-intensive operations. The article provides and systematizes defects that occur during CFA (Continuous Flight Auger), DDS (Drilling Displacement System), etc. The analysis of factors that influence on the appearance of defects has been made, and also the estimation of technologies from the preparation of wells when installing drilling and embroidery piles on the surrounding development in weak soils has been made.

1 Introduction

Today, different types of construction pile technologies are used in the construction market of St. Petersburg. They are associated with making boreholes in the manufacture of piles in the ground and using various methods of drilling [1]. The practice of performing such works in the historical districts of St. Petersburg shows that there are numerous problems and unresolved issues to ensure the safety of drilling in relation to the historical buildings of the existing development in the zone of influence of construction works [2, 3]. To do this, it is necessary to provide the ongoing drilling processes with technological and technical developments associated with drilling modes and assessing the degree of their influence on the soil mass surrounding the well [4, 5]. These questions form the tasks of studying the drilling process in soft soils, depending on the technology of piling with an assessment of the

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stress-strain state of the soil mass around the well. The study of such processes makes it possible to carry out drilling operations with minimization of the technological impact on buildings of the surrounding development and to exclude, during work in weak water-saturated soils, accidents that lead to the occurrence of low-quality bored piles ("necks", "pinches", lack of continuity along the length of piles) [6-8]. This article analyzes a practical case with the choice of a well production technology for piling in the ground at a construction site in a cramped urban environment on Vasilievsky Island.

2 Materials and Methods

Analysis of the engineering-geological conditions of the site showed that the upper stratum of the IG-section is represented by man-made deposits with a thickness of 1.2 to 4.5 m, as well as lacustrine-marine and lacustrine-glacial deposits, represented by silty and weak sands, clayey soils - loams of fluid and fluid-plastic consistencies with thixotropic properties (the ability to turn into a quicksand state under external dynamic influences that violate the natural structure of soils). Such soils cannot be used as a natural base for the foundation of the high-rise part of the projected building, in connection with which, practically at all historical stages of the project implementation, the pile foundation was considered for the projected building.

Geotechnical substantiation was carried out by specialists of "Geostroy" LLC (headed by D.O. Karlov, 2020).

The calculated draft of the projected building is the following: block 1 in axes 16-19 on a pile base -16.7 mm; block 2 in axes 12-16 on a natural base - 31.4 mm; block 3 in axes 1-12 - 20.7 mm; block 4 in axes A1-A3 on a pile foundation - 6.9 mm.

The calculated values of the additional settlement of buildings in the surrounding buildings ranged from 4.0 mm to 18.3 mm, which is within the standard values (Fig. 2).

The recommendations of the geotechnical substantiation indicate that "the technology for the manufacture of piles should be adopted taking into account the provision of minimal technological impacts during their manufacture".

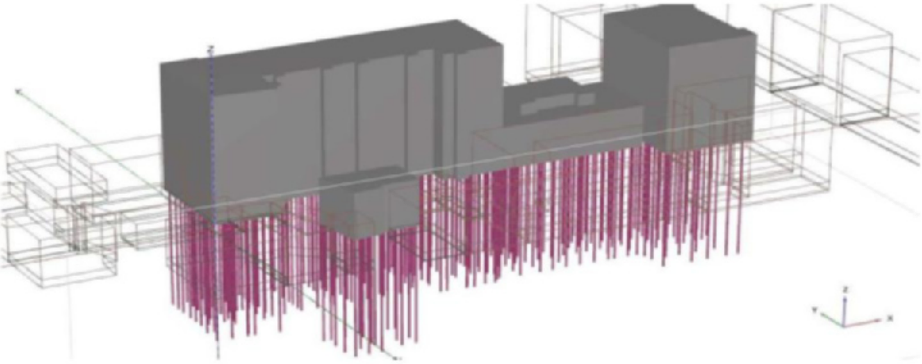

Fig. 1. Three-dimensional FE-model in Plaxis 3D (projected building - blocks 1,3,4 - on a pile foundation, block 2 - on a natural base).

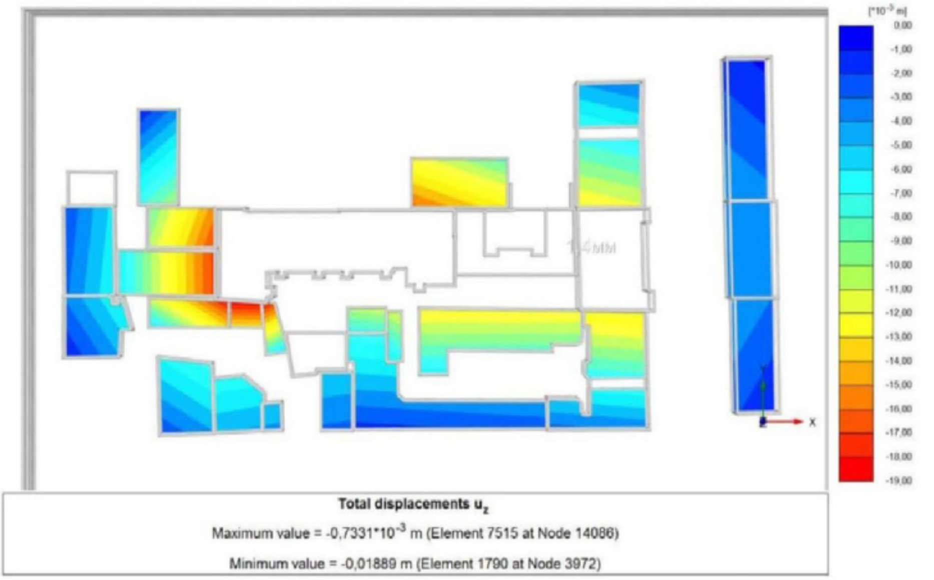

Fig. 2. Additional settlement of the foundations of existing buildings from the weight of the building under construction.

When choosing the type of piles to be installed in the ground, the following well drilling technologies were considered [9-12]:

- drilling a well under the sewn-up inventory casing;
- drilling a well under the protection of mud;
- bored piles, made by a continuous auger;
- drilling a well by the displacement method using Fundex technology with a lost tip;
- drilling a well with a reamer using the DDS technology.

EGE-14 (silty bluish-gray solid clays; $\varphi_{II} = 17^0$, $c_{II} = 1.24$ kg/cm^2, $E = 350$ kg/cm^2, $I_L = -0.61$) was used as a support layer for deepening the lower ends of the piles.

Thus, the length of the piles, determined from the condition of ensuring the embedding into EGE-14 layer, will be about 28 m from the surface (Fig. 1).

3 Results and Discussion

The determining factor when choosing technologies for the production of drilling operations for the object under consideration is the need to ensure the safety of the surrounding buildings and the exclusion of excess deformations of the bases of the foundations of neighboring buildings.

Technological settlements, as a rule, occur under dynamic and vibration influences during the operation of equipment on the site, the device of piles. These impacts cannot be analyzed and depend on the quality of the work performed, the correctly selected characteristics of the equipment, and compliance with the work technology. Possible technological settlements of buildings of the surrounding development are supposed to be excluded through the use of gentle work technologies.

To select the most suitable in terms of safety criterion and the minimum impact on the surrounding buildings, let us consider the effect on the soil near-pile array of the following types of well drilling in the manufacture of piles:

1. Drilling a well with an inventory casing (Fig. 3), which is retrieved as the well is filled with concrete. Such drill piles are made with excavation by means of rotary immersion of inventory, specially made reusable collapsible pipes, the lower section of which is equipped with a cutting drilling tool [13].

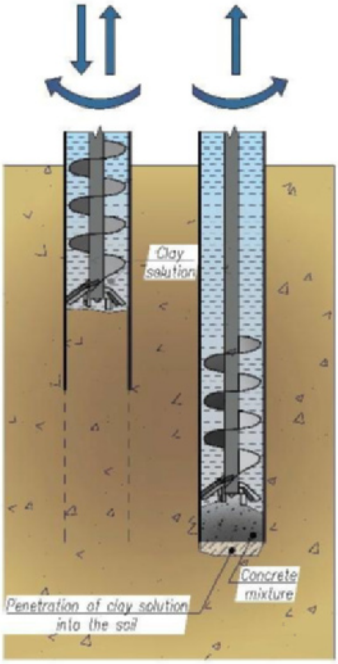

Fig. 3. Well drilling scheme when installing a bored pile under the protection of an inventory casing.

Casing pipes are designed to keep the walls of the wells from collapse of the soil into the cavity of the well during drilling and subsequent concreting. After submersion of the section of the casing, soil is extracted from it. When the casing is immersed in the ground, the drill bit interacts with the soil mass, which leads to a violation of the natural composition of the soil at a distance of 150 mm from the casing. In the lower part of the well, a soil plug is left, the height of which is determined by the design.

This technology has a significant range of possibilities in terms of diameters and depth of drilling, it is considered safe when working near existing buildings, since it does not have significant dynamic and vibration loads on the base soil. The productivity of this drilling method is determined by the technical capabilities of the drilling machine and is about 40 r.m. wells in a work shift.

2. Drilling wells protected by clay (bentonite) mud (Fig. 4) is used for bored piles made with excavation. Drilling is carried out using a tricone bit with a constant supply of drilling mud into the well. The drilling mud performs the transport function and the function of keeping the borehole walls from collapse due to hydrostatic pressure. This method has a successful practical application in weak water-saturated soils with minimal impact on the soil mass during the formation of a well (up to 70 mm).

However, in the work (Ulitskiy et al. 2010) it is noted that this positive property is completely leveled by the lack of guaranteed quality of pile manufacturing. This is indicated by low strain integrity testings [14, 15]. As the results of reflectorgams show, most of the tested piles have defects in the form of a decrease in the pile cross-section. Also, to precisely localize the defect, it is necessary to use additional methods of processing the obtained data when using low strain integrity testing [16].

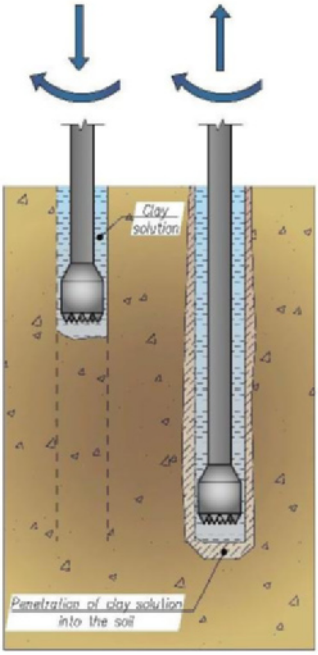

Fig.4. Drilling wells protected by clay (bentonite) mud.

3. Drilling wells using the continuous hollow auger CFA method (CFA, SOB) (Fig. 5). is not recommended for soils with a modulus of deformation less than 5 MPa and an angle of internal friction less than 10^0. Drilling is carried out using an auger - a thick-walled pipe with a spiral winding (flange). The lower part of the auger section is equipped with a pilot burr, which allows to loosen the ground when immersed into it.

In soft soils, thixotropic softening of the soil occurs in the near-pile massif with surface settlement and a decrease in the physical and mechanical properties of the natural constitution at a distance of up to 1.5 meters from the drilling axis [17]. In the literature, there are many examples of the negative impact of this technology on buildings of the surrounding development in the manufacture of walls from such piles or pile fields (Ulitskiy et al. 2010).

In the conditions of the construction site under consideration, this technology definitely cannot be applied, since there are soils at the base with low values of the deformation modulus and subject to thixotropic loosening.

4. Drilling a well using the soil displacement method with a lost drill bit for making Fundex piles (Fig. 6). The principle of the technology is based on soil compaction with the help of a conical tip, which is the main rock-cutting tool of the drill [18]. The lost tip has a tapered shape, on which there are no additional cutting elements. The destruction of the material occurs only due to the small flanges on the tip itself. The tip is connected to the casing of a smaller diameter using a tool joint (connector), which allows drilling a well with rotation in only one direction. After the completion of drilling, the casing pipe detaches from it and is filled with concrete mixture due to reversed rotation, as well as due to the fact that the soil compresses the tip.

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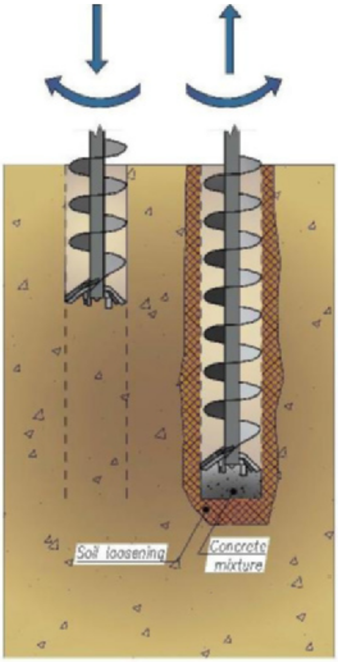

Fig. 5. Diagram of the drilling process using the CFA technology.

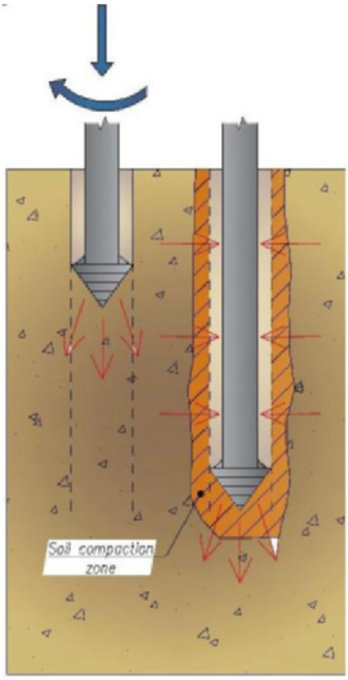

Fig. 6. Well formation scheme using the displacement method in the manufacture of Fundex in situ piles.

5. Bored piles made without excavation using DDS technology.

The technology consists in the development of a well without soil extraction [19]. First, the rock is loosened, then it is compacted with the help of an ellipsoidal auger, which forms a shell of compacted soil around the pile in a rolled well. The zone of compacted soil (Fig. 7) depends on the physical and mechanical properties of the soil massif. At the same time, the load transfer area increases by 30% due to the volume of compacted soil included in the work.

Due to soil compaction, friction on the lateral surface of the pile increases by about 30%, the resistance of the pile tip increases by 50-70% in relation to the load taken by a conventional drill pile. (Mangushev & Sbitnev 2008).

On the basis of the research carried out, we made a qualitative assessment of the technological impact on the soil massif, buildings of the surrounding development, depending on the method of drilling a borehole in the manufacture of piles (Table 1).

Table 1. Qualitative assessment of the technological impact of pile technologies.

№	Type of pile manufacturing technology	Characteristics of the effect on the soil near the pile	Degree of influence on the soil massif in soft soils	Degree of influence on the surrounding buildings	Technological effectiveness	Risk of poor quality of pile manufacturing
1.	Installation of bored piles under the protection of the casing.	Mechanical destruction of soil during drilling with the presence of a soil plug at the bottomhole during drilling	Low or medium, depends on the diameter of the pile, drilling tool (4.0)	Low (4)	Medium (3)	Low (4)
2.	Installation of piles under the protection of clay solution	Mechanical destruction of soil during drilling, soil moistening in the drilling zone	Low (5)	Low (5)	Low (2)	High (2)
3.	Piles made according to the CFA technology (CFA, SOB)	Mechanical resolution of the soil and its continuous transportation along the auger flanges to the surface	High (1)	High (1)	High (5)	Medium (3.0)
4.	FUNDEX in situ piles (displacement)	Crushing, compaction and displacement of soil from the volume of the well down-side-up	Medium and high (3.0)	Medium (3.0)	High (5)	Medium (3.5)
5.	DDS in situ piles (rolling)	Crushing and compaction with the displacement of soil from the volume of the well down-side-up, crushing during pressure testing with a concrete mixture	Medium and high (3.5)	Medium (3.5)	High (5)	Low (4,5)

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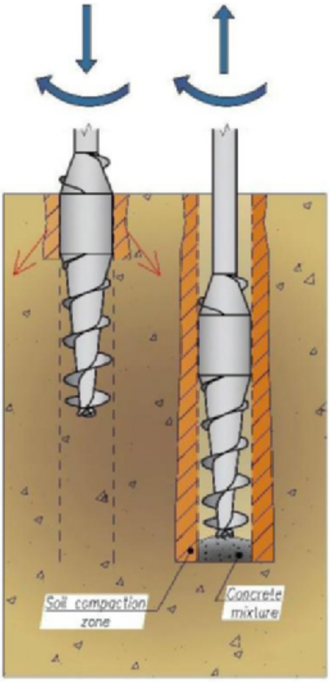

Fig. 7. Well compaction.

4 Conclusion

The result of the presented study makes it possible to form an understanding of technological factors on the additional settlement of the building S_{tech} (1), located in the zone of influence of geotechnical construction (pile foundation device):

$$S_{tech}=f\,(G,M_{dp},T_{cb}), \qquad (1)$$
$$G=f\,(\gamma,\ \varphi,\ c,\ E,\ W,\ I_L,\ W_L), \qquad (2)$$
$$M_{dp}=f\,(M_{rot},\ N_p,\ C_{dst},\ P_{con}) \qquad (3)$$

where, G = *the parameter evaluating the influence of the geotechnical conditions of the construction site (2)*: γ = the specific weight of soil, kN/m^3; φ = the angle of internal friction of the soil, degrees; c = specific adhesion, KPa; E = modulus of total soil deformation, MPa; W = natural soil moisture; I_L = consistency indicator; W_L = groundwater level; M_{dp} = *the parameter that evaluates the impact of drilling technology and the formation of a bored or in situ pile (3)*: M_{rot} is the value of the torque, kN*m, N_p = the feed force of the working body, kN, C_{dst} = the design of the working body, P_{con} = the method of feeding the concrete mixture into well; T_{cb} = technical condition of the surrounding buildings.

On the basis of the presented methodology for a qualitative assessment of the impact of drilling technology on possible additional deformations of buildings located in the affected zone, the technology of piling using the DDS technology of rolling a well was chosen. The observations carried out during the manufacture of piles showed satisfactory convergence with the calculated values of the expected settlement of buildings located in the zone of influence of geotechnical works. The bearing capacity of the piles made using the DDS technology was verified by testing the experimental piles with static loading, which made it possible to optimize the design solution with an improvement in investment and construction indicators.

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