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ABSTRACT

Two case histories of heavy damaging the neighbouring buildings in Sankt-Petersburg during construction the bored piles are presented. The analysis of causes of the damages has shown that ground inflow into the housing tubes due to low strength properties of water saturated liquid-plastic loams is the main cause of additional settlements of existing houses during construction the bored piles of large diameter close to them.

KEYWORDS

Bored piles, housing tubes, soil plug, settlement, soil inflow.

INTRODUCTION

Upper soil strata about 30 meters thick in Sankt-Petersburg is presented by quarternary loose water-saturated silty sands and silty clays of marine and limnoglacial origin. At the depth 10-15 m usually there is present the few meters thick layer of stiff glacial moraine which is often used like the reliable foundation for piles. The groundwater level is 1-2 meters below surface. The loose soils have high compressibility and easily transform into liquid state. Geotechnical engineering in such soils is often followed by settlements and deformations of the existing constructions in vicinity.
Here are presented two case histories of heavy damaging the neighbouring buildings around piling works.

THE FIRST CASE

The first case happened at 1991 year during construction of underground garage of the hotel «Nevsky palace» at the center of city. Geological conditions of the site are presented with the following stratification of soils. From the surface the territory is formed by technogeneous soil to the depth 1,5-2,5 m. Under this layer there are the layer of loose sand and silty loam of 2-3 meter thickness. From the depth 4-5 meters there are situated soft band loam of 5-15 meters thickness. The root of moraine loam lays at the depth 15-20 m.
Near the construction site there are situated 3-5-storey brick houses built at the end of XIX century on strip quarry-stone foundations. To prevent additional settlements of existing houses there were designed the wall as row of intersecting bored piles of 900 mm diameter at the distance 1,5-2,5 m from existing houses. The piles had 20 m length and they were based on moraine loam. The holes for piles were excavated by «Bauer» technology. Initially there were excavated holes «over one» with step 580 mm without any reinforcing the body of pile. The secondary piles were made 7 days after concreting the primary piles. Strength of concrete at the moment of boring the holes for secondary piles was designed to be 5 MPa, but it was actually 2-2,5 times larger than designed value.
Boring the holes were executed with pilot jacking the confining tubes to the depth 8-12 m, and the rest 8-12 m were bored without confining tube under the water. Boring was executed by static pressing and rotation motion of tube and periodical extraction soil by auger, rarely by bucket. While works progressed the neighbouring houses in radius about 30 m from pile wall obtained intensive settlements and cracking the bearing elements of houses.
Few ideas were proposed about the cause of deformations the houses and the opinions of specialists separated:
- some of them considered that during boring holes for secondary piles intersecting the primary piles, which had already rather large strength, the dynamic oscillations occurred and that caused activization the pore water motion and consolidation of soils under existing load;
- the second hypothesis following the other specialists opinion supposes the soil inflow into the holes and the observed dynamic actions promoted the soil liquefaction. Ab-

sence of housing tubes below the depth 8-12 m makes this hypothesis looks to be more realistic.
This was the first case of significant settlements of existing houses during the boring process. That's why the subsequent instrumentation was not executed and detailed information about this case is absent.

THE SECOND CASE

The second similar case happened in 1994 year during construction the row of tightly situated but not intersecting bored piles.
The upper technogenous layer of soil was 3 m thick. Just below it there was middle grain middle density sand to the depth 7-8 m and then to the average depth of 20 m there was a layer of liquid-plastic loam with some peat having compression module 3.5-5.5 MPa. Below there was a dense layer of moraine loam.
The new house to be built had a plate foundation 1 m thick, 60×60 m in plane at the depth 4,5 m. To protect the existing house from expected 15-20 cm settlements of new house the wall of reinforced concrete bored piles of 23 m length and 1200 mm diameter with 15 cm spacings was designed (fig. 1). The pile wall destination was also to support the wall of the pit during construction the foundation of new house.

Existing brick house closes to the construction site by its 5- and 3-storey wings. It has strip quarry-stone foundations 2 m deep. Before the works began the geodesic marks had been installed at the walls of existing house and regularly instrumentations were executed.
The bored piles were constructed with «Kato» technology. Housing tube was pressed into soil under the static load and was simultaneously slowly rotated in counter- and clockwise directions by 30°. Soil was removed from a tube by a grab which was immersed into soil by its own weight. The water level in a tube was supported not lower than soil surface and at the bottom of a tube there was always a soil plug not less than 2 m. After the tube immersion to the required depth it was filled by concrete and extracted.
Settlements of geodesic marks installed at the existing building were continuously observed during construction of bored piles. The settlements achieved 44 mm at the 3-storey wing and 96 mm to the 5-storey one and spreaded to the distance more than 30 m from the pile row (fig. 2a). As a result numerous short cracks appeared at the house walls and the vertical crack of 8-10 cm width was observed at the level of higher storey of 5-storey wing. Firstly the 3-storey wing near which the first piles were placed began to settle (fig. 2b). When the construction of piles was finished the velocity of settlements sharply decreased.
Thus even without any essential dynamic oscillations the settlements of existing house occurred. This case support the second hypothesis that the main cause of additional settlements was soil inflow into the housing tubes.
The observed phenomena may be explained by the following way.

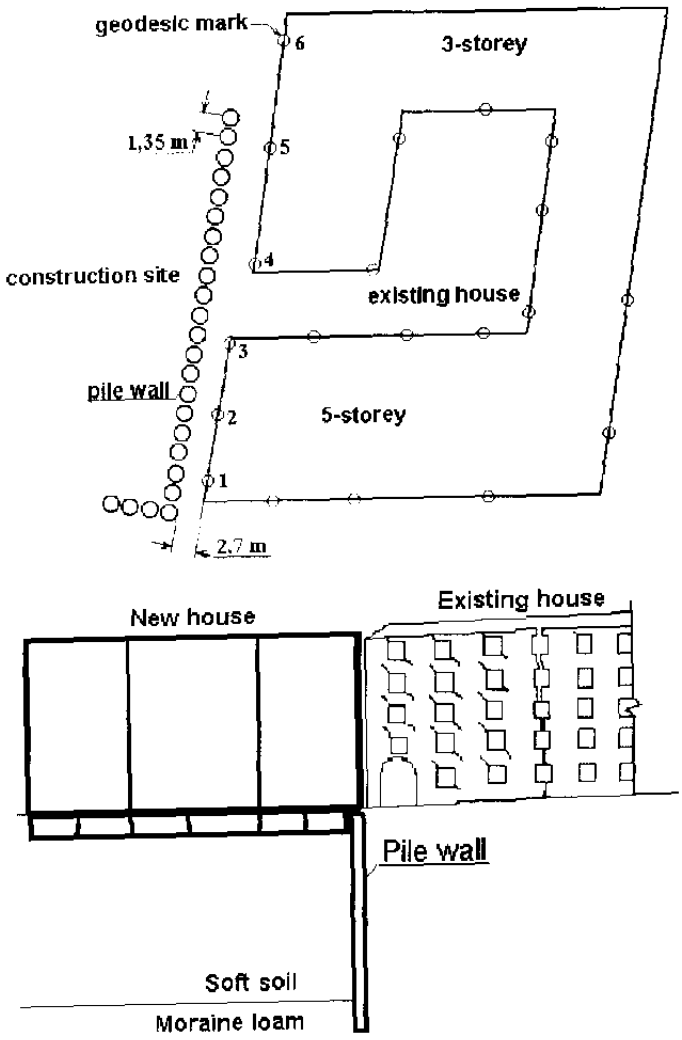
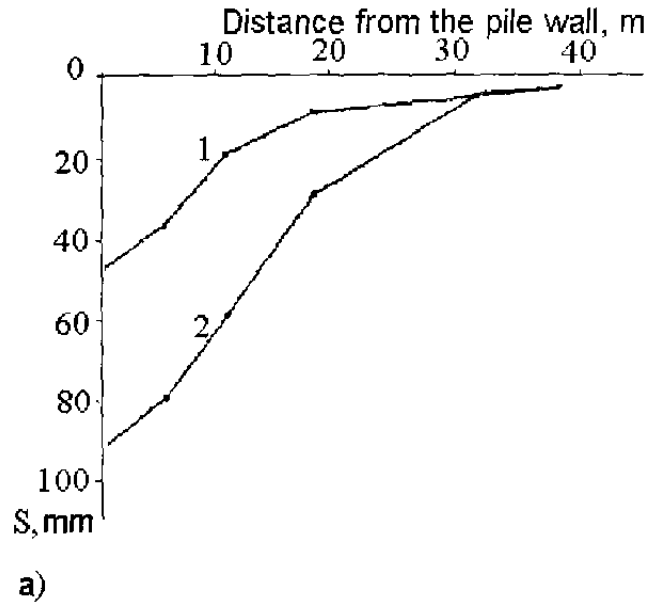


Fig. 1. Row of bored piles dividing the construction site from the existing house

When the soft soil is bored in housing tube then the soil at the borehole face is subjected to unloading due to natural stress decreasing (fig. 3). The stress decreasing leads to lift of bottom and at a some level of residual stress may inflow into the tube. It is evident that the soil volume which inflow will be excavated from the tube by grab and consequently the volume of the excavated soil will be more than the volume of the borehole itself. The soil inflow will be accompanied with large strains in the area near borehole face and zones of limit state will occur arround it and the soil surface will settle forming the settlement crater.
According to the caisson theory if the applied pressure at the bottom edge of the tube is more than the pressure of ground water, it guarantees the absence of water and soil inflow from the bottom.
However in the given case, the volume of the settlement crater clearly testifies that the volume of extracted soil was much more than the volume of tubes. The analysis of the situation allows to suppose that during the grab lifting it acts as a piston of a vacuum pump and the soil at the end of the tube is partially unloaded with backpresure σ_z^{bck} de-



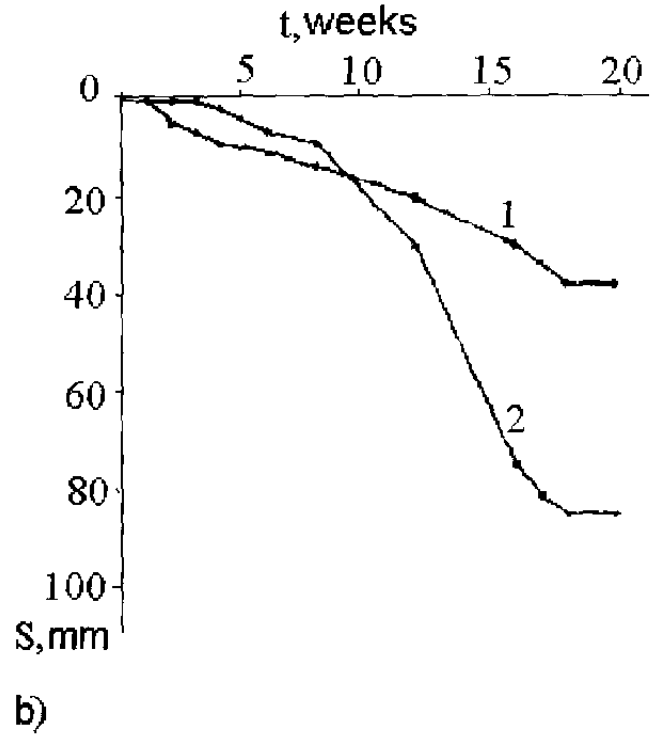


Fig. 2. Settlements of existing house during pile works: a - settlements of walls versus distance from the pile wall; b - the settlements development in time: 1 - 3-storey wing, 2 - 5-storey wing

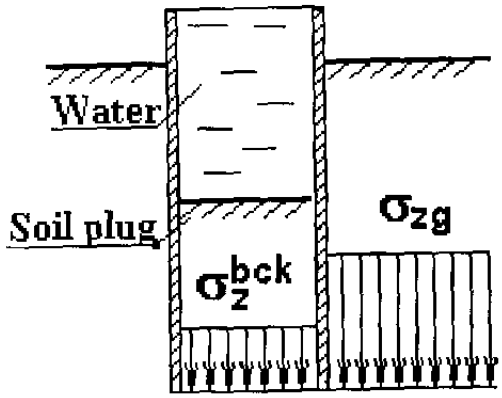


Fig. 3. Scheme of loads during soil excavation from the borehole

creasing which leads initially to little elastic lifting of the soil plug and finally it may cause soil inflow into the tube.

In the first observed case the dynamic oscillations promote liquefaction the soil and subsequent its cohesion decreased which leaded to the soil inflow. The fact of soil inflow was observed also during sinking by vibration tubular concrete prefabricated piles with opened end [1] in similar soils, which caused to decreasing the bearing capacity of piles.

CONCLUSIONS

1. Construction of large diameter bored piles in Sankt-Petersburg soft clays may be accompanied by settlements of neighbouring houses. The main cause of these settlements is soil inflow into the housing tube. Radius of settlement crater have a such order as the thickness of soft soils.
2. Soil inflow decreases the bearing capacity of the constructed piles.

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