CONSTRUCTION OF DEEP FOUNDATION DITCH UNDER A RECONSTRUCTED MULTI-STOREY BUILDING ON WEAK SOILS IN CENTRAL PART OF MEGA CITY

UN AGENCEMENT UNE ÉTENDUE SOUTERRAINE SOUSUNE RECONSTRUCTION UN BÂTIMENT SUR UN SOLSFAIBLES DANS UNE FRACTION UNE MÉGALOPOLECENTRALE

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ABSTRACT: The paper deals with the complex reconstruction of the buildings foundations of the 19-th century as a complete overhaul of the Hotel in Historic Center of St. Petersburg in conditions of weak soil base. The renovated building is located between the existing houses which made necessary to secure and strengthen the foundations of the reconstructed Hotel and adjacent houses. Details are given the of design of reinforced foundations, pits fencing and their technology, which provided the reliability of the reconstructed and minimal settlements of the adjacent buildings. Monitoring results of developments of the settlements of buildings are analyzed and conclusions about an opportunity of the construction of underground space in the reconstructed building near to the neighboring buildings are made.

RÉSUMÉ: Le document traite avec le complexe de la reconstruction des bâtiments fondements de la 19-ème siècle, comme une refonte complète de l'Hôtel dans le Centre Historique de Saint-Pétersbourg, dans des conditions de faible sol de la base. Le bâtiment rénové est situé entre les maisons existantes qui fait le nécessaire pour sécuriser et renforcer les fondements de la reconstruction de l'Hôtel et les maisons adjacentes. Détails de la conception du renforcement des fondations, fosses d'escrime et de leur technologie, qui a fourni à la fiabilité de la reconstruction de la et un minimum d'implantations de bâtiments adjacents. Les résultats de la surveillance de l'évolution des implantations de bâtiments sont analysées et les conclusions sur l'opportunité de la construction de souterrain de l'espace dans le bâtiment reconstruit à proximité de les bâtiments voisins sont faites.

KEY WORDS: reconstruction of the building, underground for parking, reinforcement of the foundations, injecting cement, bore piles, foundation settlements, monitoring.

1 INTRODUCTION

Being reconstructed as a hotel in the central part of Saint Petersburg (a corner of the Fontanka Embankment and Nevsky Prospekt), the former administrative building is a 6-storey building with the cast-in-situ reinforced concrete frame 24,0 m high with the maximum height of 27,7 m. The building was damaged by the direct hit of an aerial bomb (Figure 1, a).
Underneath the entire hotel building, an underground floor with an area of 66,9 x 20,1 m in plan view is provided to accommodate a car parking lot and technical rooms. The foundations of the building are borrowed piles 410 and 550 mm in diameter constructed by the DDS soil compaction technology using the Bauer drilling equipment (RG 25S).
Directly adjacent to the building under construction on the Fontanka Embankment, there is the 4-5-storey residential brick building (No.40) that has cracks in the structural walls (build. 40). On the other side, Building No. 70 in Nevsky Prospekt is adjacent to the reconstruction site - House of Journalists - Petersburg Merchant Society - House of I.O. Sukhozanet - a historical and architectural heritage building, which is 3- 4 -5-storey administrative building with the load-bearing longitudinal and cross walls (Figure 1 b).

Figure 1. View of Building 68, Nevsky Prospekt.a) before reconstruction in 1944; b) after reconstruction in 2012

The building was constructed in 1826-1830, major repairs were done in 1946-50. The building foundations are strip rubble-stone or brick foundations on a natural bed 1,1 and 1,5 m deep from the bed surface. A hold-down slab and a protecting wall are made in the basement. The building walls are made of red solid brick on lime mortar. The external walls are 810 mm thick; the internal ones are 580 to 640 mm thick.

In the course of an engineering survey of the House of Journalists, multiple defects and damages were found out in the bearing structures. The external walls are characterized by a lot of inclined and vertical cracks in the interfenestral bands, window piers and lintels. The crack development has the overall nature, with the crack opening width reaching 15 mm. There are throughwall cracks with the opening as wide as 6 mm.

For the buildings of this category, the maximum limit of additional settlement is 20 mm, additional skewing is 0,001 and additional inclination is 0,002, while the permissible foundation vibration acceleration shall not be higher than 0, 15 m/s^2 during the reconstruction TSN 50-302-2004 [1].

The causes of the crack growth on the building facades and walls (cracks existed before the construction has been started) may be general deterioration, reduced rigidity of the entire building, low deformation properties of the foundation soils. The soils of this type are susceptible to the thixotropic changes when exposed to minor dynamic impact (in particular, transport traffic, seasonal frosting, etc.).

2 SOIL CONDITIONS ON CONSTRUCTION SITE.

In accordance with the completed engineering and geological survey, the following soil stratification was identified on the Construction Site [2] (Figure 2).

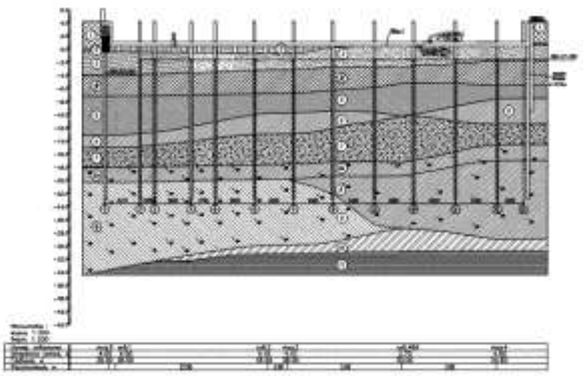


Figure 2 Engineering and geological bed profile across Construction Site

In the top part of the bed, technogenic deposits (tg IV) occur that are represented by man-made filled-up formations. A thickness of the technogenic deposits is up to 3,2 m.

Beneath it, there are lacustrine-and-marine deposits (ml IV) that are represented by sand and silty clay formations: water-saturated grey silty sands, yellow and grey low-plastic silty sandy loam with bands of sand and silty high-plastic loam. The total thickness of these deposits is 4.1 to 9.0 m.

They are underlain by glacial deposits (lg III) in the form of banded and stratified, flow and very soft loams and low-plastic silty sandy loam with bands of sand. A thickness of these deposits is 3,4 to 10.2 m.

It should be noted that the recent lacustrine-and-marine deposits (ml IV) and glacial deposits (lg III) are thixotropic soils with a tendency for the transformation into the flow state when exposed to dynamic action and for the deterioration of the strength and deformation properties.

Under these soils, there are glacial deposits (g III), lacustrine-and-glacial deposits (lg II), glacial deposits (g II) that are represented by low-plastic arenaceous sandy loams with bands of sand and gravel, as well as by semi-hard loams with inclusions of gravel and individual boulders. The total thickness of these deposits is 7,8 to 20 m.

Primary deposits in the form of Proterozoic hard clays (V kt_2) are recorded at a depth of 34 to 37 m.

The underground phreatic water level is located at a depth of 1,2 to 1,6 m from the ground surface.

Thus, the soil conditions on the Construction Site match the principal specific features of the soil stratification for the central part of Saint Petersburg [3].

3 SPECIFIC FEATURES OF PREPARATION OPERATIONS

The main bearing structures of the building to be reconstructed were demolished by mechanical means for 25 days in accordance with the Method Statement.

The dynamic monitoring results of the vibration for the adjacent buildings * showed that, for Building No. 70, Nevsky Prospekt, the vector value of the vibration acceleration was 0,022 to 0,158 m/s^2 at manual demolition, while it was 0,011 to 0,355 m/s^2 at mechanical demolition, with the permissible value being 0.15 m/s^2 for the buildings of this category, i.e., in some cases, it was almost twice higher than the permissible value.

Due to heavy wear of the principal bearing structure of the neighboring buildings that fall within the 30-meter hazard area (Building No. 70, Nevsky Prospekt and Building No. 40, Fontanka Embankment), the foundations of the adjacent walls were underpinned after the remaining structures of the reconstructed building have been demolished according to the Design†.

OOO Geoizol carried out the underpinning of the foundation in the structures adjacent to the Construction Site. The underpinning of the foundations included the injection underpinning of the foundation body by injecting cement grout and the construction of 75 inclined anchor Titan 73/75 piles 25 m long and 200 mm in diameter from the bed surface using the HUTTE HBR 202D Rig. The boreholes for the anchor piles were drilled without casing piles by the percussive-rotary drilling method, with the pressure feed of flushing cement grout via the internal channel of the rod (Figure 3). Under the foundations of Building No.70, there wwere installed 35 piles.

* The works were carried out by ZAO Geotechnical Monitoring Center.

† The Design was made by OOO SK Gidrokor.

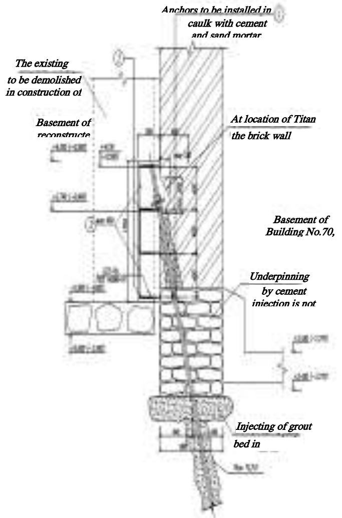


Figure 3. Schematic view of Titan pile construction

Figure 4 shows a plan of the constructed piles.

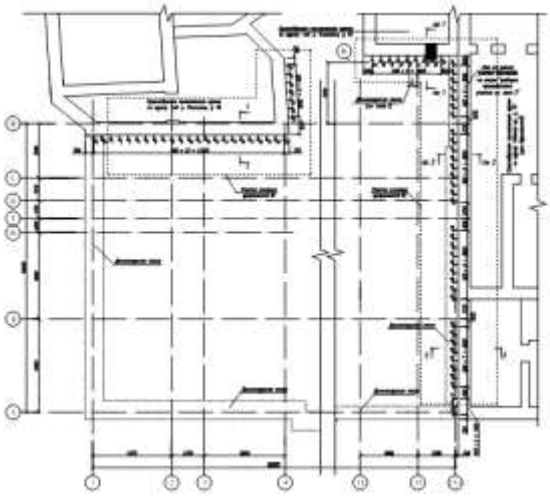


Figure 4. Layout of underpinning Titan piles for foundations of buildings adjacent to Construction Site

The dynamic monitoring in the process of the foundation underpinning showed [4] that, for Building No. 70, Nevsky Prospekt, the vector value of the vibration acceleration was 0,110 to 0, 146 m/s^2 when injecting cement grout under the foundation bed and 0,015 to 0,234 m/s^2 when constructing the underpinning Titan piles, which also was higher than the permissible value of 0.15 m/s^2 for Category III of the building technical conditions according to TSN 50-302-2004 [1].

On the Construction Site, arrangements were made to take inclination measurements of the party walls of Building No. 70, Nevsky Prospekt (4 sections). In three sections, the inclinations towards the Construction Site were recorded that were higher than the permissible ones: TSN 50-302-2004, values i = 0, 002. They were as follows: Section 1: i = 0,00056, Section 2 : i = 0,0053; Section 3: i = 0, 0037 and Section 4: i = 0, 0049.

A cause for that may be the original inclination of the walls and the works to demolish and to underpin the foundations of individual walls. For the works of these types, the impact of the vibration acceleration might bring the changes to the thixotropic properties of the soils of the lacustrine-and-marine and lacustrine-and-glacial deposits and cause additional non-uniform settlements of the walls adjacent to the excavation pit.

An additional justification for that might be the monitoring results of the vertical movements of the settlement benchmarks located on the party wall of Building No.70, Nevsky Prospekt.

Thus, it was observed a rise of all settlement benchmarks and their further non-uniform lowering. During the same period, the monitoring using aperture meters and telltales showed additional opening of the existing cracks in the walls of Building No.70, Nevsky Prospekt.

4 ZERO-CYCLE WORKS (SHEET PILING, CONSTRUCTION OF PILES AND FOUNDATION SLAB

Initially, provision was made to use metal pile sheeting with the penetration depth of 27, 0 m and the construction of a diaphragm wall for the sheet piling. At the Detailed Design Stage, check calculations were made that allowed reducing the penetration depth of the pile sheeting based on the safety condition and abandoning the expensive solution involving the diaphragm wall construction. In the following, the sheet piling, the pit support and excavation, the construction of borrowed piles and foundation slab were carried out based on the ZAO Geostroy design(Figure 5) *.

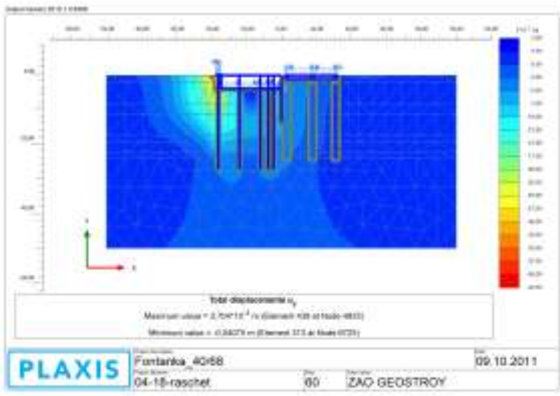


Figure 5. Assessment of design deformation of adjacent buildings in numerical modeling of pit excavation.

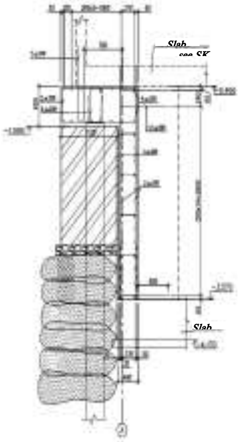
Along Gridline И and Gridline 13, the sheet piling was made using metal Arselor AZ 37-700 pile sheeting 13,5 m long.

On the side of Fontanka Embankment and Nevsky Prospekt, the sheet piling was made using the old foundation, through which drilled borrowed piles 410 mm in diameter and 27 m long were constructed.

Along the existing foundation on the internal side, jet-grouting piles were constructed that were spaced at 450 mm to a depth of at least 2 m from the existing foundation beds (Figure 6).

* Design made by ZAO Geostroy. Reference Number): 11/047. Team of authors: N.K. Voitovitch, N.B. Yudina, T.N. Shakhtarina, K.V. Dzerzhinskaya, D.O. Karlov.

a)



b)

Figure 6. Schematic view of foundation underpinning using jet-grouting pile technology (a) and works to demolish soil-cement areas for construction of protecting wall (b)

Figure 7 shows the layout of the pile sheeting made using jet-grouting technology and drilled cast-in-situ pile sheeting.

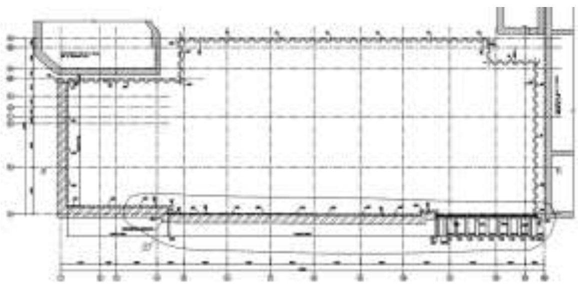
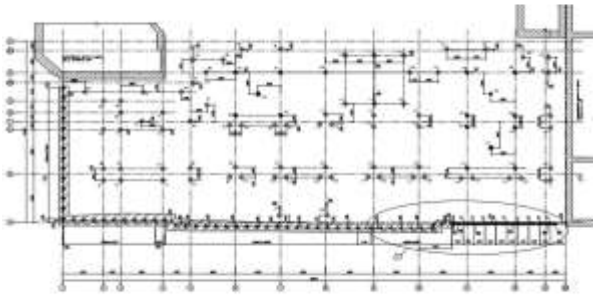


Figure 7. Layout of pile sheeting and completed jet-grouting

Made on the basis of Bauer technology, drilled cast-in-situ piles 550 mm in diameter and 27 m in length from the ground surface were used to construct a pile foundation for the building frame. In total, 162 drilled cast-in-situ piles were made. Figure 8 shows a layout of the piles.

a)

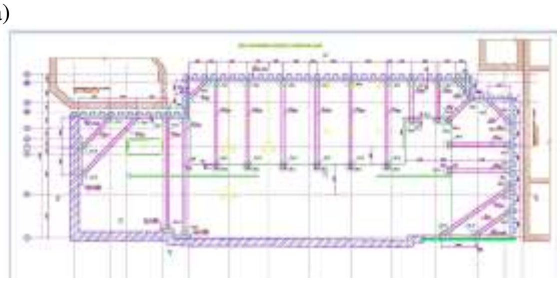


b)

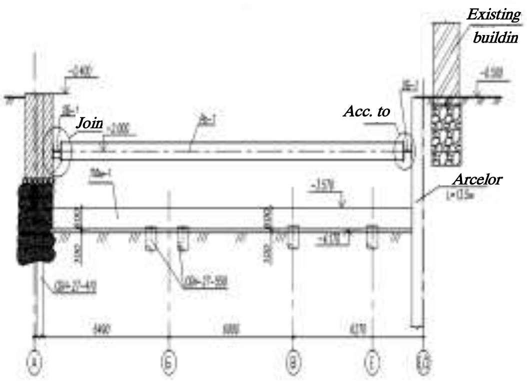
Figure 8. Plan of pile field of drilled cast-in-situ piles (a) and view of drilling rig in process of pile construction (b).

In order to provide the stability of the pile sheeting in excavating the pit, horizontal braces were installed that were made of metal pipes (Figure 9).

a)



b)



c)

Figure 9. Plan (a) and schematic view (b) of horizontal brace installation in opening the pit; c) view of pit in process of making reinforcement using bracing structures*.

5. GEOTECHNICAL MONITORING

When constructing the piles and sheet piling, the geotechnical monitoring was conducted to measure of the vibration acceleration [4]. Thus, in constructing the first 10 piles, the vector value of the vibration acceleration was 0,011-0,038 m/s^2 with the permissible value being 0,15 m/s^2.

The regular geodetic monitoring of the vertical deformation development in the building foundations within the 30-m hazard area showed a certain rise of the settlement benchmarks, which is, apparently, associated with the insignificant heave of the foundation soil at the time when the drilled cast-in-situ piles were constructed. In building No. 70, Nevsky Prospekt, this rise in the settlement benchmarks was, in average, not higher than 3 to 5 mm and can be considered as safe for the building structures.

Later on, in excavating the pit, constructing the slab and carrying out the superstructure construction, minor settlements were observed for the geodetic benchmarks on the walls of Building No. 70. At that, the maximum recorded additional vertical deformation was not higher than 8 mm for the settlement benchmarks located on the party wall of Building No. 70. The maximum settlement was 15 mm [4].

It should be noted that, in the process of all zero-cycle works and the beginning of the superstructure construction, a value of the additional settlements of the benchmarks located on the House of Journalists (Building 70, Nevsky Prospect) was not higher than the maximum permissible value of 20 mm for this building. When the construction of the reconstructed building superstructure was continuing, some geodetic benchmarks were covered or lost for the purposes of further monitoring.

As can be seen from the above, the development nature of the additional settlements and the dynamics of the crack growth in the walls of the neighboring building (No.70, Nevsky Prospekt) caused no concerns in the further reconstruction of the hotel building.

6. CONCLUSION

1) The regular monitoring and the scientific-and-technical support showed that the selected solutions were correct for the reconstructed building and for the buildings adjacent to it. These solutions were the lowest-impact technological solutions for the adjacent buildings.

2) During the zero-cycle operations – the construction of the drilled cast-in-situ piles, the excavation of the pit, the concreting of the slab, and in the beginning of the superstructure construction, the additional settlements were not higher than 20 mm at the foundations of the adjacent buildings, in particular, in the House of Journalists (Building 70, Nevsky Prospect). Such additional settlements were not hazardous for the neighboring building.

3) Completed works are proved the possibility of the construction large underground structure under renovated buildings near the existing buildings in soft soils conditions.

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* ZAO Stroyfort was engaged in reinforcing and concreting the slab.