Buildings serviceability restoration and reconstruction in the Kyiv urban conditions

Le rétablissement de aptitude de l'exploitation et la reconstruction des bâtiments

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ABSTRACT

The issues are considered concerning the building serviceability restoration and reconstruction in the complicated engineering and geological conditions and under urban built-up areas constraints.

RÉSUMÉ

On examine les questions du rétablissement de aptitude de l'exploitation et de la reconstruction des bâtiments dans conditions géotechniques complexes et dans conditions de la construction urbaine limitée.

Keywords : serviceability, building detilting, calculation model, slope stability, retaining wall

1 INTRODUCTION

When carrying out the Kyiv territory development the special methods of building construction and protection shall be used as the difficult engineering and geological conditions complicating the construction processes characterize the sizeable part of the region. Those difficulties depend on the areas with collapsible soils, landslide-prone slopes etc. The current construction in Kyiv is characterized by the erection of buildings with underground parking facilities, cutting-through of the Metro tunnels under built-up areas, existence of different constraints due to urban narrow circumstances. The effective solving of these problems is possible based on the scientific researches, which have being performed in the State Research Institute of Building Constructions.

2 RESTORATON AND RECONSTRUCTION OF THE MFA OF UKRAINE DIPLOMATIC ACADEMY BUILDING

The building was built based on the design of Vikentij Beretti, a member of the Academy of architecture. It is recognized as a historic and architectural monument. The building is brick-made and consists of the three parts. The central part built at the end of 1858-1859 is three-storyed. The annex of the same height was attached at angle to its longitudinal axis during 1893…95. The two-storyed house church was attached by the building center in the yard in 1900-1901. There is a passage at the first floor level between the building central part and the second outhouse. The basement was arranged under the building left part and under the annex outhouse part.

Setting loess bedding of 7 m thickness lies at the building base. The building was erected without any precautions against the non-uniform base settlements. Due to the man-caused impacts the building base soil was subject to wettings and settings during the building use. That is why the building right wing greatly suffered from deformations. The outer wall of the building yard elevation and inner wall adjacent to it have settled. The outer facing having with a fracture along the full elevation height and adjacent inner wall were substantially deformed. This caused the considerable cracks formation in the longitudinal bearing walls. The similar cracks existed in cross walls too. The fractures have appeared in the two ground floor piers situated alongside, which testified their bearing capability exhaustion. The building central part was also deformed in its left side, though to the less extent, and had a cross fracture in the longitudinal walls.

The annex as the first outhouse experienced much more deformations. Its facing wall had several fractures dividing it into separate blocks. The two of blocks were inclined from the wall surface up to 25 cm along the parapet. The outer wall of the corner insertion between the building and annex had sizable cracks and an inclination of the same degree towards the square. The building was in an emergency condition. The deformation examples are given in Fig. 1.

a)

b)

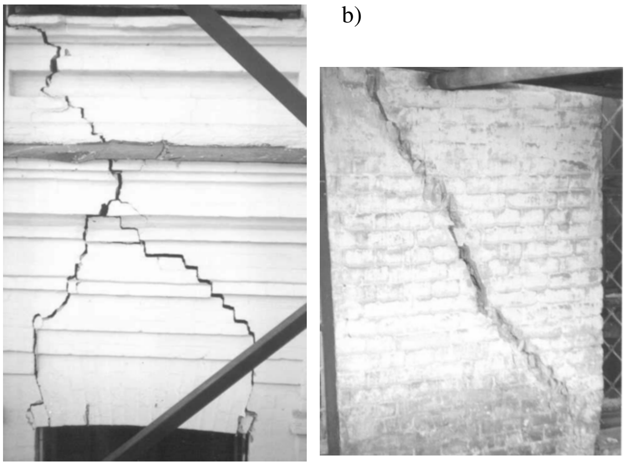

Figure 1. The failures of the MFA of Ukraine Diplomatic Academy building walls:
a - an arch fracture of the brick beam; b – a wall fracture in the ground floor piers level

For the purpose of the building serviceability restoration the works were performed as follows:

- Establishment of the strain joint between the annex and building central part;
- Strengthening of the existing strip foundations by piles pressed in from under the existing foundations base;

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– Improvement of the spatial position of bearing wall blocks by means of the AVK 200-33 automated detilting plant;
– Replacement of the timber overlapping by the concrete one and arrangement of the basement under the whole annex;
– Strengthening with bands and cement mortar injecting into the wall fractures and cracks;
– Replacement of the timber roof by the metallic trusses and carrying out of repair works.

Strengthening of the existing strip foundations was carried out by driving the bore pits at 1.5 m below the base level, arranging the distribution beams, pressing in the piles under the building dead weight (the point load up to 120 t was applied from the pressing equipment to the distribution beams), concreting the grillages. The arrangement of recesses for positioning the jacks and horizontal joints for the distribution beams and grillages separation accompanied these operations. At the same time the soil was excavated with a purpose of the subsequent organization of basement rooms. Those works caused additional cracking in the walls and even the exhaustion of bearing capability of some ground floor piers of a small section located in the yard elevation wall. So the necessity of their urgent strengthening with metallic bands arose.

For the analysis of parameters and procedures for structures spatial position improvement the building calculation model was elaborated with the building structures strains, fractures and cracks arisen during the building use period taken into account. The improvement of the bearing walls spatial position using the AVK 200-33 automated detilting plant featured the works executed to elevate the Diplomatic Academy building structures. The maximum lifting of the building central part walls reached 15 cm, of the annex – 26 cm. The fractures and cracks in the walls elevated into the vertical position were closed, and the overall inclinations were put into the permissible limits.

Fig. 2 gives a general view of the building after its spatial position detilting.

Figure 2 The MFA Diplomatic Academy building after detilting its position in a space.

3 OFFICE BUILDING RECONSTRUCTION

The reconstruction of the existing building at Sahajdachny St. envisaged that the new volumes in the form of one four-storyed and two five-storyed sections would be attached to its above-ground part, and an underground parking would be arranged.

The project site is situated in restrained circumstances between a motor road at the Vladimirskyi Spusk on the one side and a natural slope of Vladimirskaia Hill on the other side. The building under reconstruction is situated at the foot of a sliding slope. There are two open line shallow Metro tunnels in the immediate vicinity of the existing building. The design building structures are partially positioned above the open line Metro tunnels.

The site subsurface geology contains such engineering-geological elements: D1 (Д1), D2 (Д2), 2Dp (2Дп)- fill-up soil, EGE-12 (ИГЭ-12) – fine clayey low-green sand, EGE-13 (ИГЭ-13) – semisolid silty sandy clay, EGE-141 (ИГЭ-141) – semisolid shattered marl clay, EGE-1411 (ИГЭ-1411) – firm marl clay, EGE-14111 (ИГЭ-14111)– firm carbonate sandy clay with sand bands, EGE-15 (ИГЭ-15) – liquid-filled fine compact clay sand (Fig. 3).

The site is subject to underflooding. The arrangement of culvert systems has changed the underground waters behavior.

When designing the building reconstruction the tasks were solved for ensuring:

а) the stability of Vladimirskaya Hill slope at the bottom of which the new building volumes are erected with the necessity of the slope undercutting in order to uncover the foundation pit for new buildings taken into account;

б) the existing building protection against the undercut slope influence during the construction and at the time of use;

в) the existing building protection against deformations due to the foundation pit arrangement during the construction;

г) protection of the open line Metro tunnel structures against the new construction influence;

д) new buildings structures protection against the dynamic impact of the Metro trains movement through tunnels and vehicular traffic on the road.

The current slope stability and the stability of the undercut slope is determined by mathematical simulation of land tract with landside control structures. For estimation of slope stability, it was necessary to use a computer program based on the method of circular cylindrical surface. The calculations resulted in stability coefficients for the available slope (before construction of the building) and for the slope undercut by foundation, which values were 0.422…1.183 and 0.221…0.994 correspondingly. The maximum value of sliding pressure was 13.05…256.63 ton-force/running meter.

The existing building is protected against influence of undercut slope by erection of retaining walls RW-1 and RW-2 (see Fig. 3). These structures provide the slope stability when constructing and operating the building.

The retaining wall RW-1 includes three lines of cast-in-situ piles. The piles from two lines out of three are 1.0 m in diameter and 30 m in length and have a spacing of 1.5 m. The distance between lines is 2 m. The pile lines are joined by reinforced concrete grillage. The third line of piles is 0.82 m in diameter and 14m in length. The distance between the second and the third line is 2.4 m. The piles of the third line are joined by reinforced concrete grillage with each other as well as with the piles of the second line. The filling material is placed to the height of trenching under the grillage. The width of the filling material is 0.3 m.

The retaining wall is a shoring of excavation from one side of the foundation pit. The metal embedded bracing is designed for protection of the other three walls. The bracing includes 2 double-T wall plates (double-T of No.45) with spacing of 0.9 m joined by longitudinal metal girders consisting of two channel bars of No.16. Blocking lumber is used as a filling material.

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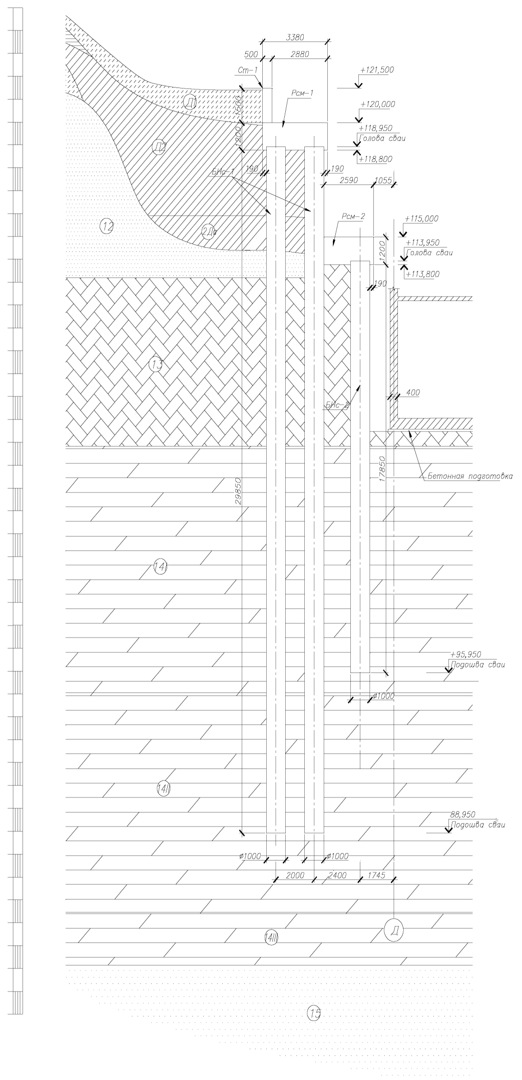

Figure 3. Section of retaining wall RW-1 fitted for the geologic profile

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After the erection of the retaining wall, the slope stability calculations were made for two calculation cases using the first group of limiting states.

In the first calculation case, it was necessary to determine the most dangerous sliding surface of circular cylindrical shape having the minimum stability coefficient after the erection of the retaining wall.

In the second calculation case, it was necessary to define the most dangerous sliding surface of circular cylindrical shape with the minimum stability coefficient after the erection of the retaining wall provided the maximum possible ridge load.

As a result, it was found for two calculation cases that the values of minimum stability coefficients of the most dangerous sliding surfaces were 1.252…1.312 (Fig. 4). Basing on the calculations, a conclusion can be drawn that the given slope with landside control structures in the form of three pile lines joined by grillage and maximum ridge load of 150 kN/m^2 is stabilized with the minimum stability coefficient of 1.252. This fully meets the requirements of standards valid in Ukraine.

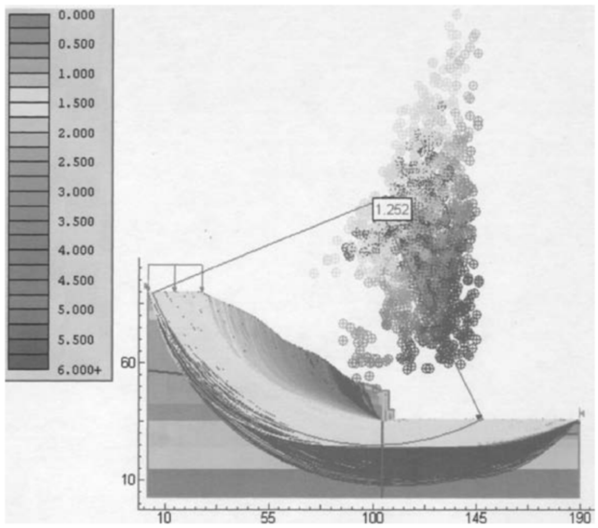

Figure 4. Slope stability according the second calculation case - Calculation results – Circular cylindrical sliding surfaces calculated

To check the taken design decision, a calculation model of landside control structures was developed (Fig. 5). The model was defined as a space system consisting of cane and plate-like segments as well as special end elements. Cane and plate-like segments simulate the pile and grillage behavior and special end elements are used in simulation of pile-land tract interaction. Effective loads (structure dead weight, sliding pressure, soil dead weight active pressure) influencing the system are calculated using computer programs "Lira-Windows" and "Prolog" what makes possible to take into account joint behavior of the structure and land tract.

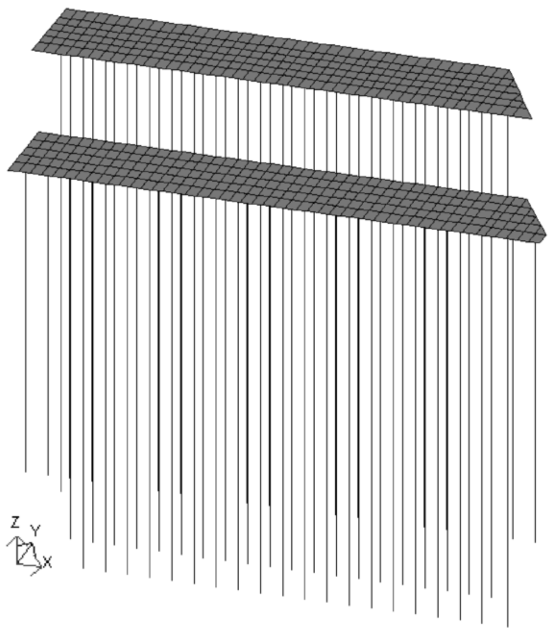

Figure 5. Calculation model for retaining wall RW –1

For the strain behavior of one of retaining wall cross-sections as well as for bending moment diagrams of piles, see Fig. 6.

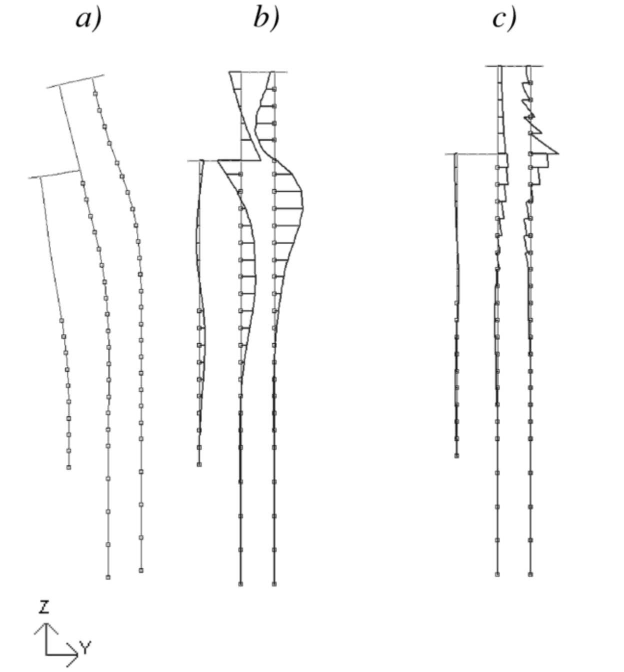

Figure 6. Cross-section of retaining wall RW-1. Calculation results
a – node displacement of the calculation model; *b* - diagrams of bending moments *Mz*; *c* – diagrams of shear forces *Qy*

To protect Metro open line tunnels against the influence of new construction, some measures related to foundation design were taken. Cast-in-situ piles with Ø 0.62 m and 16 to 19 m in length joined by plate grillage are accepted as foundations for new parts of building. Piles are placed under the building except for tunnel stretch areas with taking into account stop areas. Stop areas are 1.5.m wide and are located on the each side of tunnel. The grillage plate hangs over tunnel stretch areas as well as stop areas so that structural load doesn't transfer to tunnel load. The pile base is placed 2 m lower than the tunnel structure so the structural pressure of building doesn't influence the stressed state of soil base of tunnel.

The negative dynamic impact of Metro rolling-stock and moving motor transport on building structures was taken into account when designing the pile foundation. To reduce the dynamic loads to those given in Ukrainian valid Sanitary standards, a special structure where pile crown and grillage were mated through damper was developed.

When designing the underground part of building and its superstructure, the calculation model of the whole building and related calculations were carried out using the computer programs «Lira-Windows» and "Prolog".