Modern methods of geotechnical defense of buildings in the difficult geological conditions of Ukraine

Méthodes modernes pour la défense géotechnique de bâtiments dans les conditions géologiques difficiles de l'Ukraine

Slyusarenko Y., Chervinskyy Y.
Research institute of building constructions, Kiev, Ukraine

Karpenko Y., Dvornik S.
Ukraine-France enterprise «Osnova-Solsif», Kiev, Ukraine

Malikov S., Rozenvasser G., Lavshuk I.
DE Donetsk Promstroyniiproekt, «Pushkin» Complex Ltd, Donetsk, Ukraine

ABSTRACT: Ukraine is characterized by the considerable variety of geological conditions which complicate the construction and maintenance of buildings and structures. Among them – structurally unsteady collapsible soils (more than 60% territory of country), underworked areas and karsts, landslide slopes, seismic districts. The most widespread types of difficult geological conditions are collapsible soils and underworked areas because of mining. For construction the new methods, directed on defense and normal maintenance of buildings, are constantly developed. In this paper the examples of geotechnical defense methods for new and historical buildings in difficult geotechnical conditions are presented.

RÉSUMÉ : L'Ukraine est caractérisée par la variété considérable de conditions géologiques qui compliquent la construction et l'entretien de bâtiments et de structures. Parmi eux – les sols pliants structurellement instables (le territoire de plus de 60 % de pays), regions travaillées peu et karsts, des pentes d'éboulement, des régions sismiques. Les types les plus répandus de conditions géologiques difficiles sont de sols pliants et des régions travaillées peu à cause de l'exploitation minière. Les nouvelles méthodes pour la construction, orientees sur la défense et l'entretien normal de bâtiments, sont constamment développées. Dans ce journal les exemples de méthodes de défense géotechnique pour les bâtiments nouveaux et historiques dans les conditions géotechnique difficiles sont présentés.

KEYWORDS: underworked areas, landslide slopes, collapsible soils, measures of defense

1. CONSTRUCTION OF NEW BUILDING ON THE UNDERWORKED TERRITORY.

1.1. Description of object.
The hotel complex «Pushkin» in Donetsk is built on territory, underworked by mining. The innovative decisions of geotechnical and structural defense of complex (the 5-storey underground parking under 24-storey building) are realized at planning, building and scientific accompaniment (Fig. 1, 2, 3).

Fig. 1. General view of the «Pushkin» complex building.

The draft design of complex is developed by *Schwitzke* (Germany), the general designer is *Donetsk Promstroyniiproekt*, main contractor – *the Ukraine-France enterprise Osnova-Solsif*.

Fig. 2. Type of parking at 1 level.

Fig. 3. The 5-storey underground parking.

The design decisions of building are accepted on a rigid structural concept both in parking and in above-ground part.

The kerns of rigidity are set equally on all height of building. They are located in middle part of lay-out and on butt ends as two parallel walls.

Underground parking has horizontal sizes 76x15 m under height part and 54x20 m under 5-storey part.

Framework of parking is executed with the diaphragms of rigidity, columns and disks of ceiling of 300 mm thickness; on a ground level the thickness of ceiling is 1500 mm.

Foundation under building is designed as cast-in-place concrete slab of 2000 mm thickness. The columns of parking have the sections 600x600 and 600x1200 mm. Thickness of bearings walls is 600 mm.

Because in underground construction the technology determines the structural decisions and methods of calculation of structures, the design decisions of underground parking are orientated on technology «wall in soil» (wall thickness 800 mm) and method of erection «UP-DOWN» to a depth of 21-24 m (Fig. 4).

Fig. 4. Construction of parking by the method «UP-DOWN»

At the same time the wall in soil have the functions of exception of the influence between existing and new buildings.

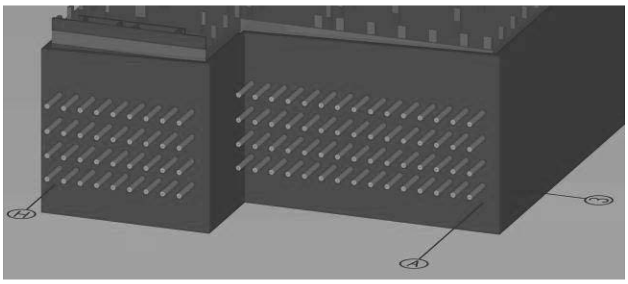

Fig. 5. The multi-tier off-loading system

1.2. The principle design decisions on defense of underground parking.

Design deformations of underworked base are: inclinations i_p = ±3,1 mm/m; relative horizontal deformations ε_p = ±1,9 mm/m; radius of curvature R_p= ± 19,8 km.

Protection from the influence of compression deformations is carried out by the erection of the many-tier off-loading system (Fig. 5). This system consists of horizontal hard members as soil-cement piles, arranged within parking after excavation on the areas of subsequent erection of disks of ceiling or diaphragms of rigidity. Thus soil-cement piles unite with the walls by the members of resolving durability. The length of the off-loading system members is 5.0 m, diameter is 400 mm, the step of setting is 2.0-3.0 m.

Apparently on Fig. 6, the off-loading system reduces frontal pressure on protections to active one.

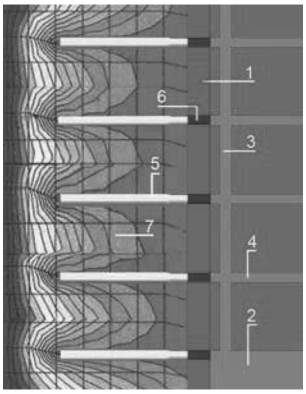

Fig. 6. Mode of distributing of frontal pressure of soil on the wall of parking: 1 - wall is in soil; 2 - foundation; 3 - column; 4 - ceiling; 5 - members of the off-loading system; 6 - support of resolving durability; 7 – picture of pressures (moving) of soil.

Protection from influence of horizontal tension deformations is foreseen by the reinforced concrete preparation and sliding joint (Fig. 7, 8). Preparation of 150 mm thickness has a single-row reinforcement. The chopping-off of «wall in soil» by contraction joints on compartments of 15-18 m length is foreseen.

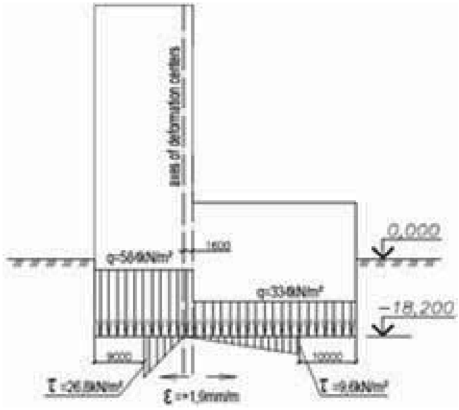

Fig. 7. To the calculation of the reinforced concrete preparation

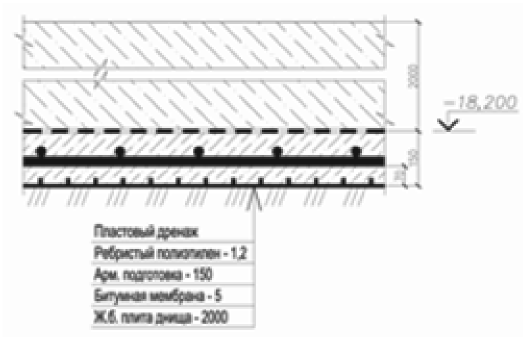

Fig. 8. Design of the reinforced concrete preparation

Other deformation influences as curvature and inclinations are perceived due to strengthening of bearings structures.

The design decisions of underground parking provided the structural and geotechnical safety of building in the terms of straitened construction and influences of uneven deformations of underworked ground massif.

2. DEFENSE OF HISTORICAL BUILDING LOCATED ON TERRITORY WITH DIFFICULT GROUND CONDITIONS.

2.1. Description of building.

The St. Andrew's church is unique sight of history and architecture of 18th century, built in Kyiv on the design of the famous Italian architect F. Rastrelli. The church is built in baroque style, which formality, dynamic of architectural forms, riches of decor, game of light and shade, is characteristic for. A church is erected on tailings of earthen fortress of 17th century. Building is crowned with the central dome and four angular decorative towers. Sizes of church are: length 32 m, width 20 m, height from a terrace to the top of cross of central dome 50 m.

Fig. 9. The St. Andrew's church.

The territory of the St. Andrew's church is located in overhead part of central historical part of Kyiv. The marks of hill surface change from 181.7 m (the planned ground round a church) to 118.5 m (the hill bottom). Slopes are dismembered by spring-beam network, an active slide and erosive processes developed and develop on them.

Within the building area, the unfavorable physical and geological processes take place:

- landslide and landslide-prone slopes;
- considerable layer of collapsible soils;
- substantial heterogeneity of soils on the building area;
- mechanical suffusion of silt particles of sandy loam and sand to the existent neglected gallery;
- surface erosion of the hill massif.

Visible part of the church building leans against greater in lay-out underground two-story fundamental part. An entrance to the church is arranged by cast-iron stairs which connect a street with parvis. A stylobate – two-story building, coverage of which is a part of parvis, joins to underground fundamental part of church.

Foundation is executed of masonry posts of 3 to 5 m width. The foundation base of the church beds on different marks: in western part – from 166,6 to 165,8 m; in east part which hangs over a hill – from 165,7 to 167,8 m.

Basis of foundations of the south, west and north facades are eolian-deluvium loess sandy loams which are collapsible at saturation. The moraine loams serve as basis of foundations of east part.

The hydrogeology terms are characterized by the presence of underwater of two levels.

It was discovered at the complex inspections of building, that it had substantial damages, main of them were through cracks, local destructions of clout layer and build solution of masonry. The uneven settling of basis, conditioned the presence of collapsible soils and slope slides appeared the principal reason of found out damages.

The technical state of church building was appraised as unapt for normal maintenance that caused the necessity of urgent implementation of reconstruction works.

2.2. General conception of reconstruction works

The reconstruction works of the St. Andrew's church were executed after the followings directions:
- geotechnical measures;
- repair and strengthening of the damaged structural members of building;
- restoration of facades and interiors;
- improvement of the technical state of surrounding territory.

The geotechnical measures were:
- research and analysis of geological conditions of the territory of the St. Andrew's church;
- research, analysis and prognosis of changes in geological conditions and mode of hydrogeology of adjoining territory with development of hydrogeology model;
- research and analysis of slope stability on the area of the St. Andrew's church and adjoining territory;
- research of modern erosive processes of slopes on this area;
- research and analysis of stress-strain state of the ground basis of building.

On the results of geotechnical researches the design decisions were developed.

2.3. Realization of geotechnical researches.

- Improvement of the hydrogeology mode.

For adjusting of underwater level, in addition to existent drainage system, a new drainage pipeline, located in the space after retaining wall on a slope, is erected.

The basic setting of the drainage system is an intercept of ground-water non-admission of saturation of soils in the space after retaining wall, as it increases ground pressure on a wall and diminishes local slop stability near-by a wall. The drainage system helps to avoid additional infiltration of atmospheric water additional getting up of water level in the piles zone.

The drainage system consists of two separate pipelines, located along retaining wall, which throw down water from opposite sides in a sink. From a sink the fault of water is foreseen by an underground pipe – collector in the existent overflow-pipe well of the drainage gallery system.

- Analysis of slope stability.

In obedience to the requirements of national building code, the value of normative factor of slope stability must be not less than 1.25.

For implementation of analysis of slope stability a design complex SLIDE-5 used. The complex has wide possibilities of calculations and interpretation of results – by 9 methods simultaneously (methods of Bishop, Yanbu, Spenser, Fellenius and others).

For the increase of reliability of results the analysis of slope stability were executed also by the program «BOBR», developed on the base of Terzaghi-Chugaev method. Comparison of the got results showed that they coincided in a sufficient degree. Thus, stability factors on lower and overhead areas by the «SLIDE-5» program are 1.015 and 1.229, by the «BOBR» program – 1.083 and 1.219.

On the basis of historical materials study, visual inspections of adjoining to the church building slopes and executed analysis, there was determined that considerable part of slopes of the St. Andrew's church hill are in the state close to the maximum equilibrium.

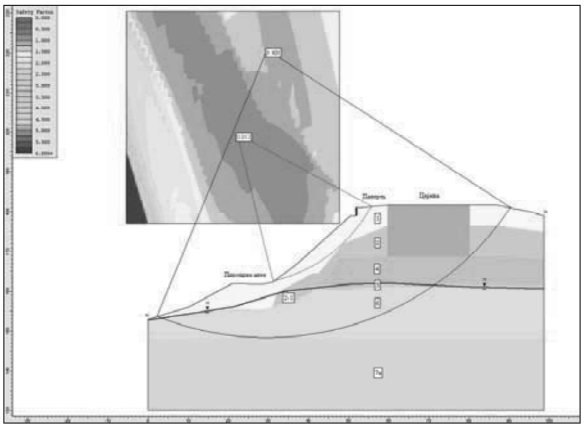

Fig. 10. The results of slope stability analysis of the St. Andrew's church hill.

- Protection from erosive processes.

The water disposal system is designed as concrete chutes which intercept atmospheric water from the church parvis and give this water in the designed sink near the retaining wall.

The basic setting of the water disposal system is non-admission of saturation of soils on slopes of the St. Andrew's church hill, as it diminishes the local slope stability and promotes to water-wind erosions.

- Analysis of stress-strain state of building and ground basis.

Analysis of stress-strain state of building was carried out taking into account the deformation of the ground basis. As a result the values of stresses and deformations of bearings structures of building and their comparison with values of durability of materials are conducted.

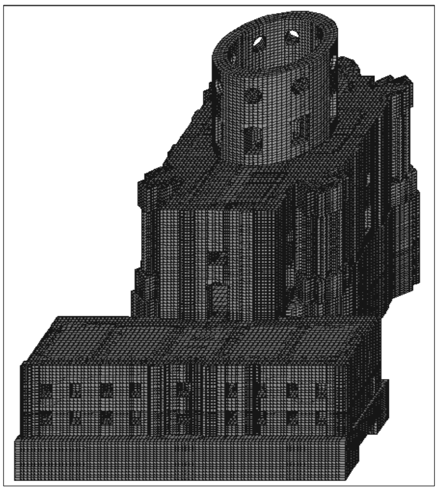

Fig. 11. Design model of the church building.

At the analysis of existence of the St. Andrew's church the followings groups of calculations of the system "building – basis" are executed:

Group 1 – analysis for determination of reasons of crack appearance in the walls of building and it stylobate part:

– at descriptions of soils in the natural state;

– design of saturation of basis under the whole building of church and its stylobate part;

– design of saturation of foundation basis of the north-eastern part of building;

– design of saturation of foundation basis of stylobate and the south-west part of building;

– design of saturation of foundation basis of the central part of building (under a dome).

Group 2 - analysis of actual stress-strain state of building structures taking into account damages fixed at inspection.

Group 3 - are analysis of forecast stress-strain state of building structures at the possible changes of the basis descriptions. Different variants of basis saturation under the whole building of church and its stylobate part are considered.

The modeling of soil saturation in calculations was carried out by setting to the soils, which bed in the foundation basis, the descriptions met the state of saturation. Thus takes into account also the appearance of zones of weakening and cavities in soils as a result of the suffusion to the gallery system which exists close to the foundations.

For the removal of subsequent uneven deformations of foundations and fixing of soils in the basis of bearings walls the stream cementation of soils (jet-columns) was executed. The design decision on strengthening of basis is showed on Fig. 12.

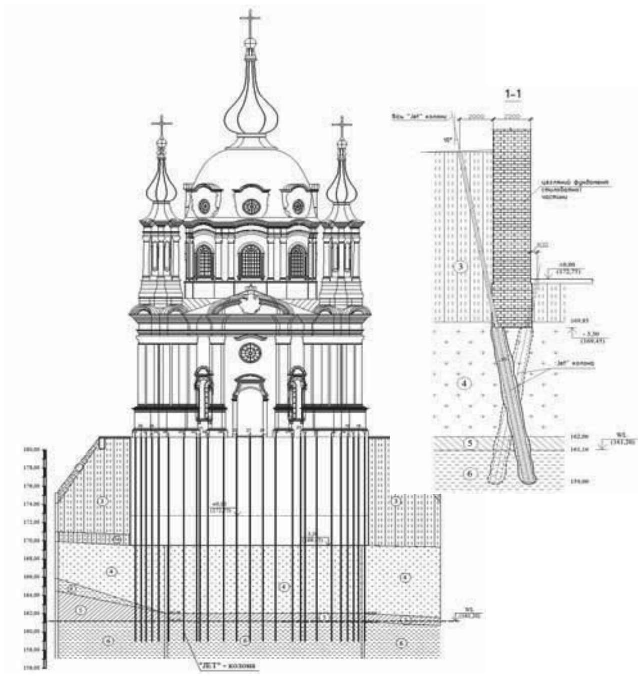

Fig. 12. Strengthening of the church foundations.

Analysis of the building taking into account the members of strengthening was executed on the basis of model in which there were taken into account existent through cracks in walls and overstrained areas of foundations. The results of analysis clearly showed the actual stress-strain state of structures after strengthening. In the design model the arranging of jet-columns under part of foundations was taken into account by substituting of the deformation modulus of soil in the natural state by the average deformation modulus of natural soil and jet-columns.

In addition to geotechnical measures, there were the executed works for restoration the integrity of building structures by strengthening of the damaged areas of masonry walls by the method of injection and reinforcement of cracks.

The monitoring of the state of building after implementation of reconstruction works showed that the deformations of the ground basis had stopped practically and the new damages of building did not arise up.

3. CONCLUSION

The modern methods of geotechnical defense for new and old buildings may provide the reliable protection from unfavorable geological processes and guarantee durable maintenance of these buildings.