RECONSTRUCTION IN THE CONDITIONS OF THE RESTRAINT URBAN DEVELOPMENT AND SLOPE DEFORMATIONS

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Introduction

The Postal Square is in the downtown Kyiv and bounded by the Embankment Highway along the Dniepro River and Volodymyrskyi Descent at the foot of Volodymyrska Hill, under which the subway tunnels pass. The complicating geotechnical conditions at the site include the weak water-saturated soils of the Dnipro River floodplains sediments, high groundwaters level regulated by subway tunnels and landslide hazard slope of Volodymyrska Hill. The existing buildings and the subway line impose the strict requirements to the design solutions and work execution as to their preservation ensuring.

Fig. 1. – Architectural model of the post-reconstructed Postal Square

The reconstruction project envisaged the construction of a bidirectional two-lane road tunnel and an above-ground transport overpass (the first stage of construction), as well as a two-storey underground shopping complex of about 8,000 m^2 totalarea (the second stage of construction) and complex landscaping with a park and fountain.

The territory engineering-geological and hydrogeological conditions

According to engineering and geological surveys, the Postal Square reconstruction site geomorphologically belongs to the area of the Dnipro right-bank high floodplain abutment to the steep root slope of the Kyiv plateau.

In the site geological structure, the deposits of diffused Kharkiv, Kyiv and Buchak formations everywhere covered with Upper Quaternary deluvial sediments and fill soils are present up to the 40 m explored depth.

Based on the results of drilling operations and soils laboratory studies within the explored depth, seven engineering-geological elements were identified (from top to bottom).The construction site engineering and geological conditions belong to the III category (complex) because of the possibility of landslides.

The studied site hydrogeological conditions are characterized by the presence of a widespread aquifer complex, which consists of an aquifer confined to Quaternary alluvial deposits, soils of the Buchak formation and a temporary aquifer of "perched water" type.

The amplitude of the groundwater level seasonal fluctuations is 1.0 m. The pressure water piezometric level is recorded at absolute elevations of 90.6 ... 90.7 m, the pressure value is 7.3 ... 7.5 m.

Objects of the probable construction pit impact on the surrounding buildings

The underground facility is designed taking into account the mutual influence of the project and the Postal Square surrounding structures (buildings), which include the transport interchange facilities and subway tunnels, as well as the Post Office, the Church of the Nativity, and the Kyivpastrans building (Fig. 2).

The Post Office is the closest to the construction project with the distances 3.2 m from its end to the enclosure boundary of the pit under the designed project and 5.6 and 9.0 m from the other two sides of the building to the pit enclosure boundary.

The surrounding development of the designed project on the Postal Square also includes the building of the Church of the Nativity, located at a 9.0 m distance from the end and 11.0 m from the main facade to the pit.

Also, there are two subway tunnels near the construction site at distances of about 16.5 and 28.0 m from the pit enclosure.

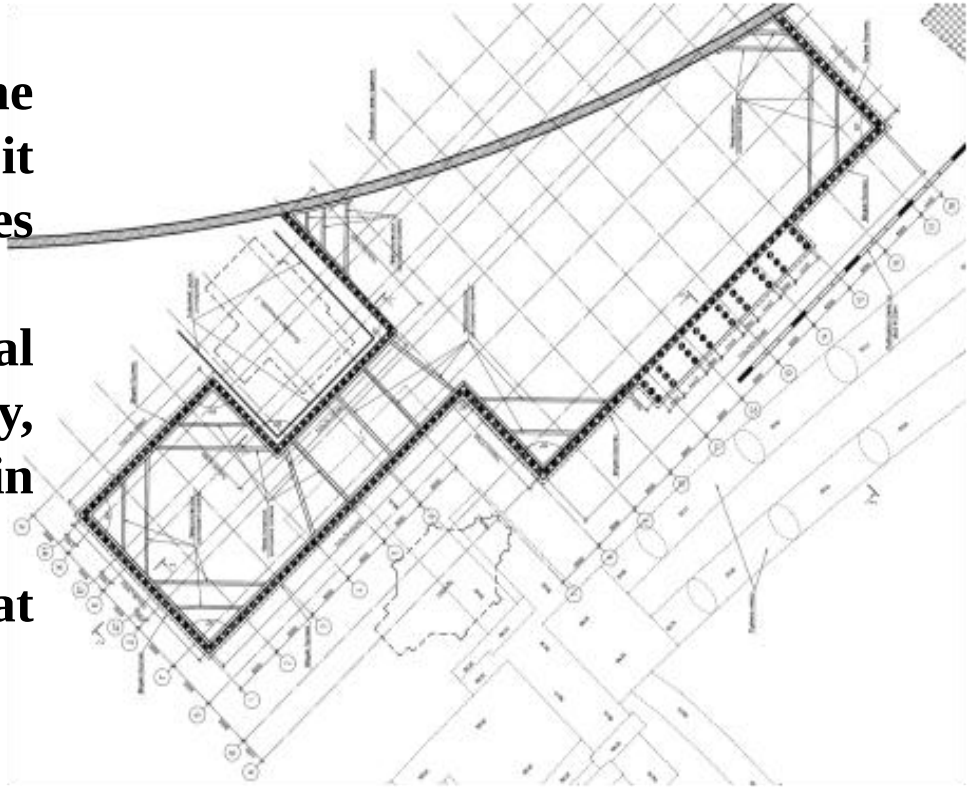


Fig. 2

Pit enclosure structures

The enclosure of the construction pit of a multifunctional object is made of 1020 mm diameter secant piles. The reinforced piles spacing is 1480 mm. The pile tops are connected by a ground beam. The absolute elevation is 104.400 for the piles tops and 78.500 m for the piles tips.

To eliminate the soil particles mechanical internal erosion due to the boreholes execution for piles, around the Post Office building a protective screen of micropiles is arranged with the depth of these piles immersion reaching a layer of sand at the mark of 86.000 m.

The pit enclosure system contains structural elements in the form of spacer structures that participate in the soil pressure perception and transfer to other structures of the pit enclosure. The spacer structures perform the temporary functions.

They are deconstructed during the soil excavation from the pit and the frame structures and underground facility floors construction. The loads from the soil pressure will be transferred to the underground facility frame structures, which must be taken into account in their design. The scheme of pit enclosure is shown in Fig. 2.

Mathematical modeling of the pit stress-strain state

The good perspectives for modern software packages use for the landslide-prone slopes and excavations stress-strain state modeling come-out of the works analysis. Based on these results, the paper authors carried out the facility calculation with the software package "LIRA-WINDOWS" application at the stage of the pit enclosure construction as a spatial system. The spatial calculation model for the facility calculation is given in Fig. 3.

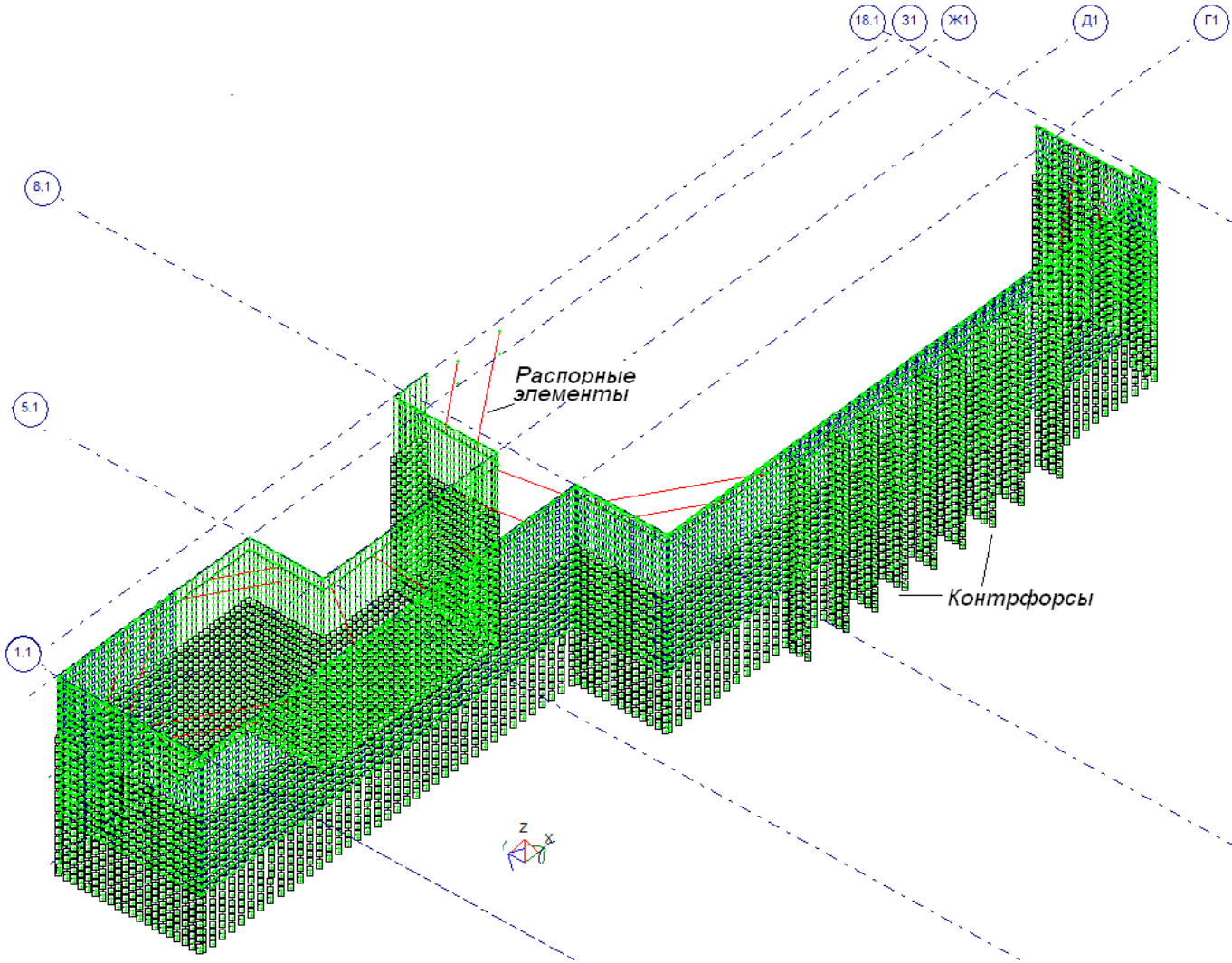


Fig. 3

Mathematical modeling of the pit stress-strain state

In Fig.4 the nature of the elements deformations in the pit enclosure calculation model is shown.

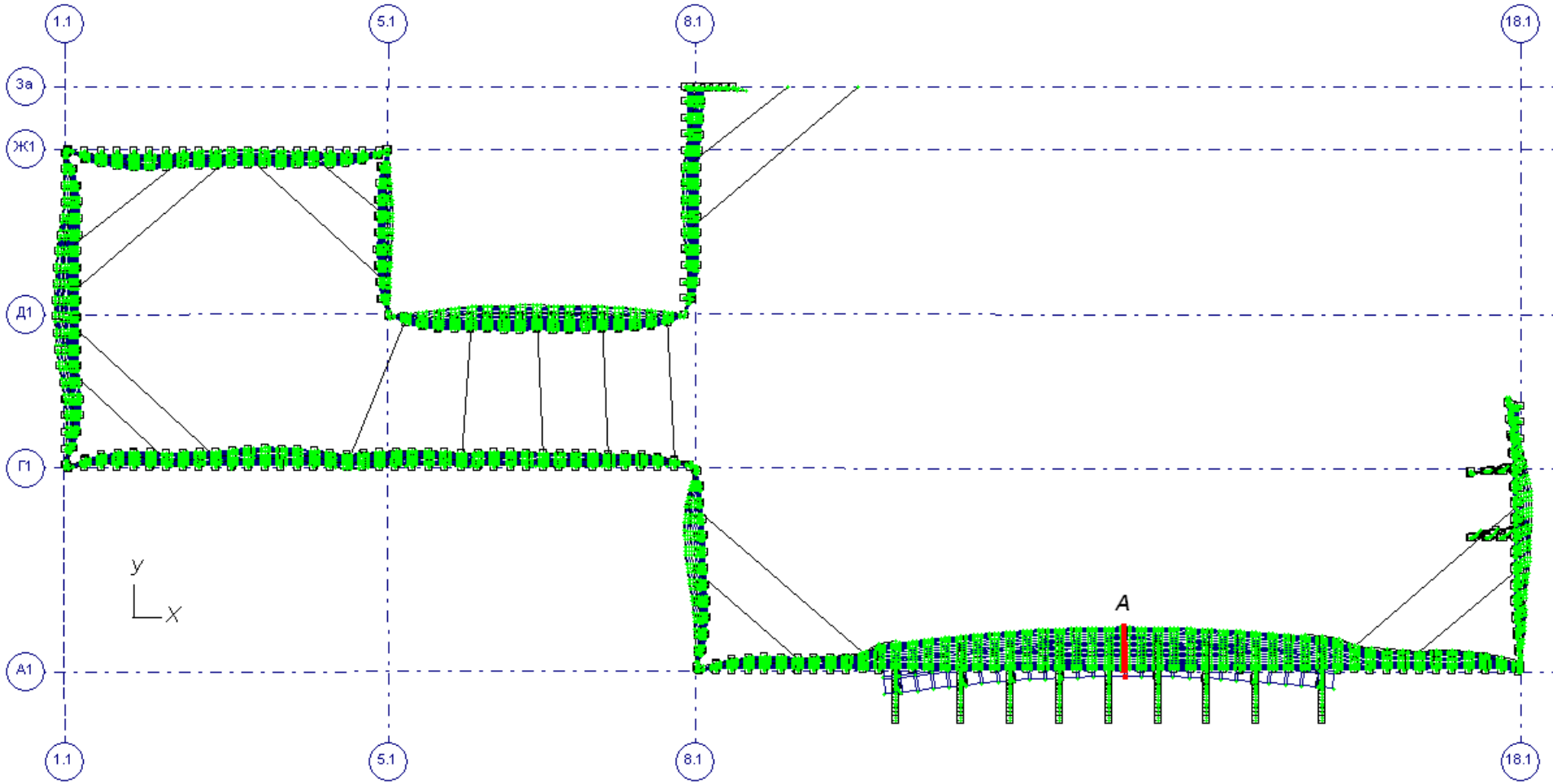


Fig.4

The assessment of the Volodymyrska Hill slope stability and the determination of the pit construction second stage impact on the subway tunnels

The calculations were performed using the modern software packages "Slide" and "Lira-Windows" intended for solving the geotechnical tasks. These software packages are designed to assess the stress-strain state of soil masses under static and dynamic loads, as well as to assess the slopes stability by the methods of Morgenstern and Price, Bishop, Janbu, and Spencer, or finite element method, assuming that the sliding surfaces have a circular cylindrical shape or are assigned like broken lines.

The calculations were performed on 1.0 rm under conditions of plane deformation. For modeling the soil mass, a soil model corresponding to the Coulomb-Mohr strength condition was adopted. At the foot of the slope, the retaining walls, which have been erected during the construction of hotel complexes along Sahaidachnoho Street within the Postal Square boundaries, were modeled.

The assessment of the Volodymyrska Hill slope stability and the determination of the pit construction second stage impact on the subway tunnels

A schematic layout of the design cross-sections (lines) is given in Fig. 5. As a result of the slope stability calculations analysis, the following conclusions are made.

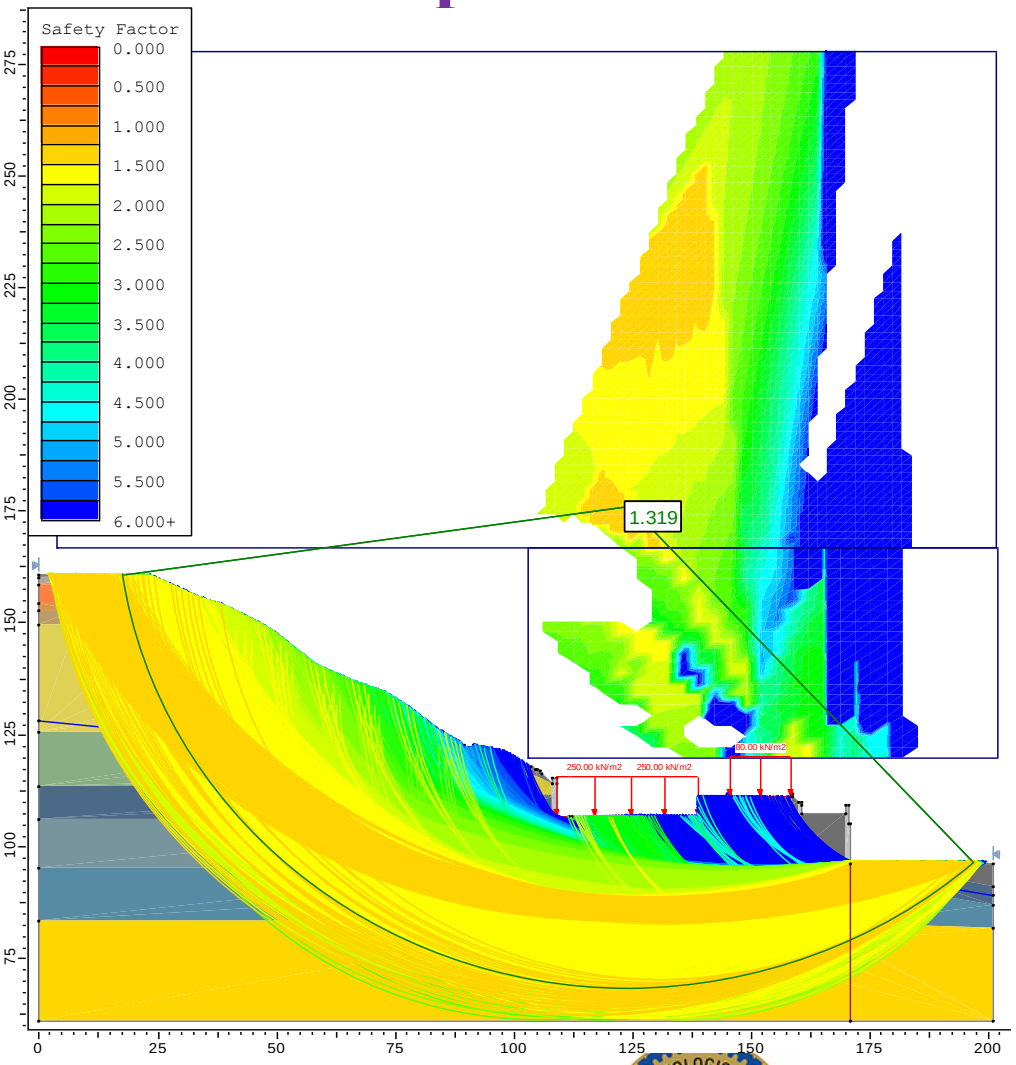
Taking into account the landslide protection structures erected at the Volodymyrska Hill slope foot during the construction of hotel complexes and along the Sahaidachnoho Street within the Postal Square, the slope stability coefficients values are as follows:

1.440 ... 1.447 (taking into account the piles cutting) and 1.288 ... 1.353 (with a circular-cylindrical surface passing below the piles toes) for the design cross-section I-I;

1.355 ... 1.581 (taking into account the piles cutting) and 1.319 (with a circular-cylindrical surface passing below the piles toes) for the design cross-section II-II (Fig. 5).

Fig. 5

The assessment of the Volodymyrska Hill slope stability and the determination of the pit construction second stage impact on the subway tunnels



Based on the performed calculations, it is possible to conclude that the stability of the slope along the Sahaidachnoho St. with retaining landslide protection structures erected during the hotel complexes construction and their loads, as well as with the subway tunnels being taken into account, is ensured with a minimum safety factor of 1.319 (Fig. 6), which meets the requirements of the Ukrainian regulations.

Fig. 6. – Calculated circular cylindrical sliding surfaces located below the toes of piles with a minimum safety factor of 1.319.

The assessment of the Volodymyrska Hill slope stability and the determination of the pit construction second stage impact on the subway tunnels

The site of the designed underground structure construction is adjacent to the subway tunnels location area. The distance from the pit enclosure wall axis is about 16-18 m to the nearest tunnel boundary and 28 m to a more remote tunnel.

To determine the degree of influence of the pit enclosure arrangement for the new multifunctional facility on the subway tunnels structures, including the impact of soil excavation from the pit, two tasks are solved.

The first task is to determine the pit enclosure structures deformations during excavation. The problem is solved based on the proposed spatial model of the pit enclosure system.

The second problem envisages the determination of the nature of the deformations distribution in the soil mass outside the pit enclosure with an allowance for the subway tunnels inclusion in this mass. The problem is solved using a plane calculation model.

Assessment of the groundwater level changes resulting from the pit enclosure arrangement at the construction second stage

To assess the groundwater level changes after the pile foundations arrangement for the designed building, the geotechnical model of a soil mass area was built based on the result of the engineering geological and hydrogeological surveys before and after installing one row of piles along the A1 axis.

The initial data for the calculations include the filtration coefficients of engineering and geological elements that constitute the soil mass to the explored depth. The calculation model, split into IGE and divided into finite elements, is shown in Fig. 8.

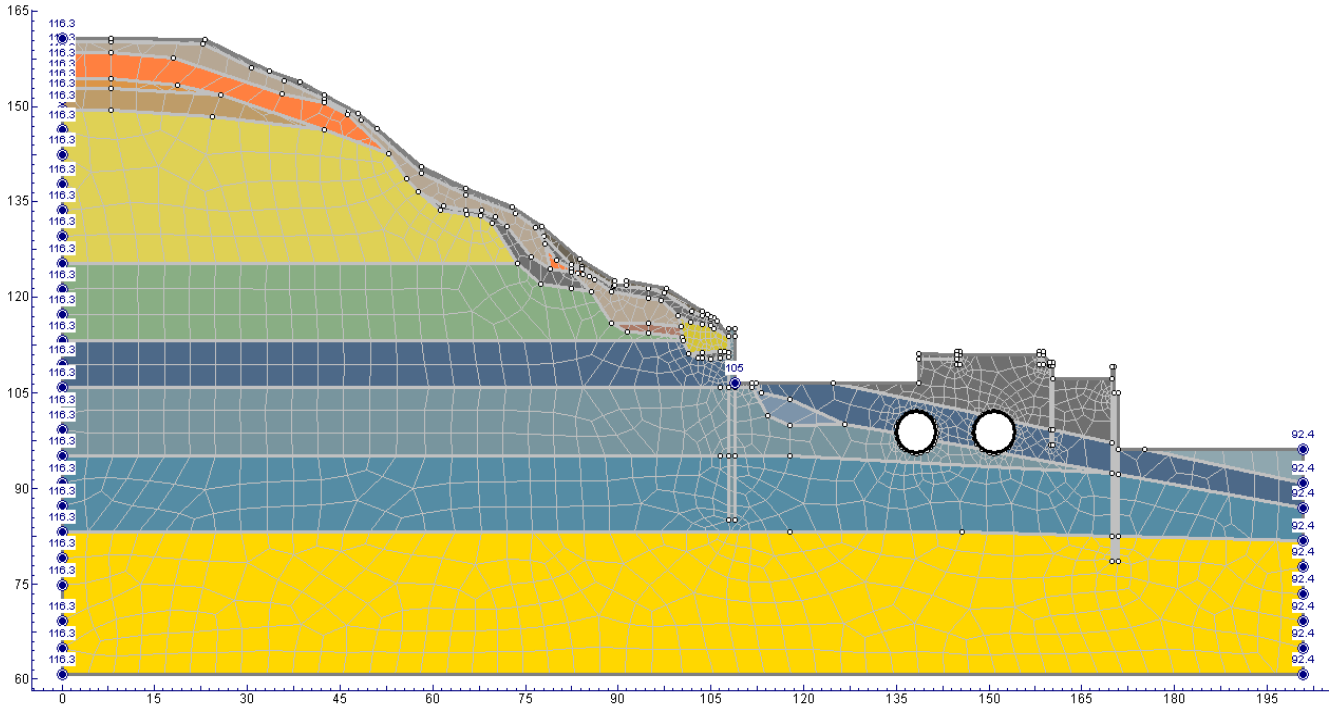


Fig. 8. – Calculation model of a soil mass for calculating the groundwater level change.

Assessment of the groundwater level changes resulting from the pit enclosure arrangement at the construction second stage

In the place of the future pit enclosure structures installation, the groundwater level absolute elevation before arranging one row of bored cast-in-place piles along the A1 axis is 96.700 m.

The total head value and the depression curve of the soil mass area after installing one row of bored cast-in-place piles along the A1 axis are shown in Fig. 9.

The absolute elevation of the groundwater level in front of the pit enclosure structures, after their installation, is 99.800 m.

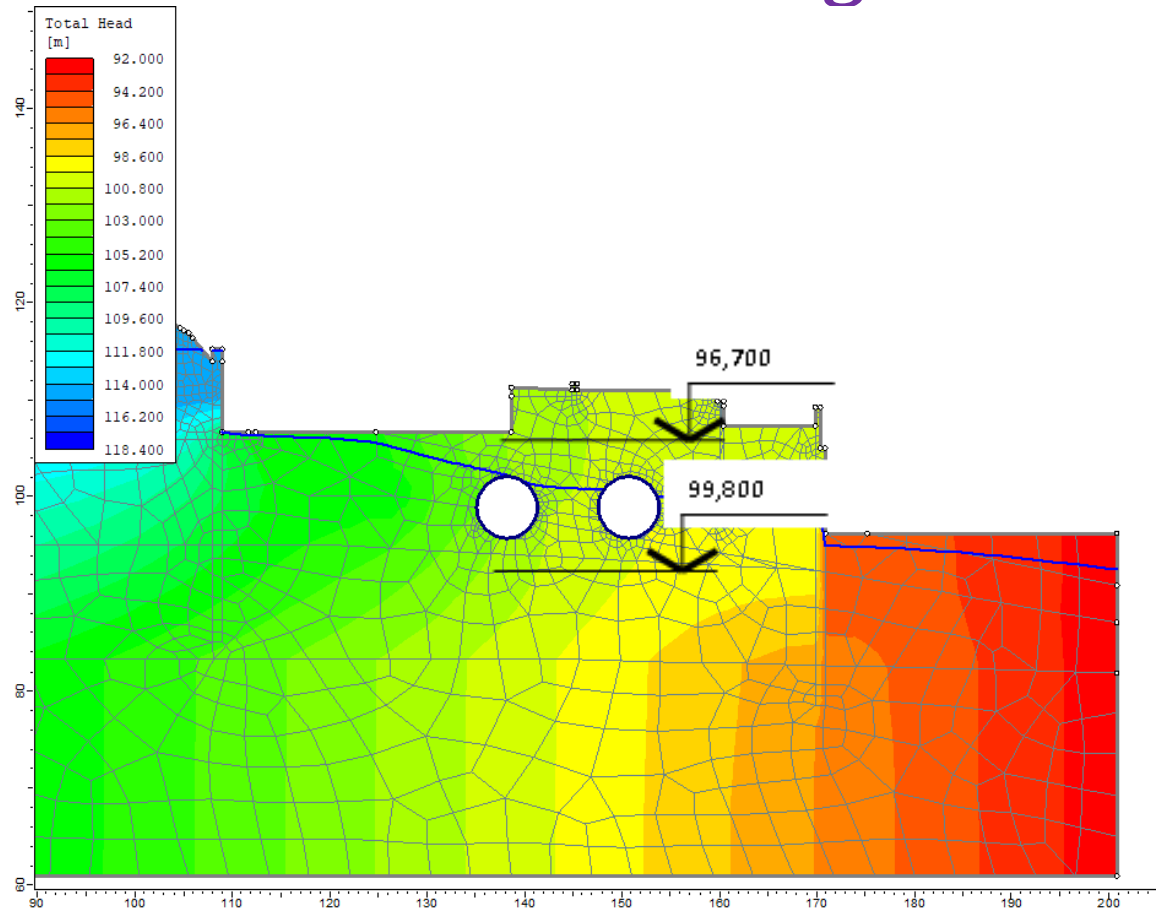


Fig. 9. – The total head value and soil mass depression curve after installing one row of bored cast-in-place piles along the A1 axis.

Assessment of the groundwater level changes resulting from the pit enclosure arrangement at the construction second stage

It follows from Fig. 9 that installing one row of the pit enclosure secant piles for the construction of underground space without drainage system (vertical and horizontal) will raise the groundwater level in front of these structures by 3.1 m.

Such a rise in groundwater level will lead to the complete soaking of the soil mass around the subway tunnels with the subsequent change of physical and mechanical characteristics of soils constituting it. This will lead to the subway tunnels additional deformations.

To avoid the groundwater level raising after the pit enclosure structures construction, the vertical and horizontal drainage installation for the underground space of the second stage of construction was envisaged.

In 2015 archaeologists discovered the well-preserved unique artifacts – a log structure and a stacket, which, according to scientists, belonged to the times of the Kyiv Rus of the 11-13th centuries (Fig.10).

The news caused a public response. Kyivans to stop construction work on the Postal Square and continue excavations.

Kyiv Mayor Vitaliy Klitschko agreed to abandon the mall construction for a while and archaeologists received the green light.

Fig. 10. Plot of the coastal city quarter of the medieval Kyiv (the 11-19th centuries) on Postal Square.

CONCLUSIONS

1. Advanced methods are used for the new buildings construction and existing ones protection; the pit enclosures are made of secant and bored cast-in-place piles with the use of protective screens with small diameter piles and bentonite solutions; the groundwater level stabilization is achieved by a temporary vertical drainage with mechanical and permanent bed draining; to ensure the stability and minimal deformation of the pit enclosure during soil excavation, spacer structures are used.

2. Monitoring of the subway tunnels deformations is carried out by means of inclinometers; monitoring of the groundwater level is performed using piezometer wells; observation over surrounding structures is performed by instrumental geodetic methods. Monitoring of subway tunnels and surrounding buildings deformations and groundwaters level during construction showed the values that are within the limits allowed by building codes of Ukraine.

THANK YOU FOR YOUR ATTENTION!