

Landslide25_10**The slope local stability assessment at the gazebos locations on the Volodymyrska Hirka**

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SUMMARY

The report presents the inspection of the slope section with gazebos and the assessment of its local stability, as well as the inspection of the path in Volodymyrska Hirka Park and the evaluation of its technical condition. During the visual survey and assessment of the path and the surrounding slope, numerous defects and damages were identified. According to current regulatory standards, the technical condition was classified as hazardous. On the slope, “drunken forest”-type leaning trees and extensive areas of soil erosion caused by atmospheric water were observed. A lighting pole was tilted due to uneven deformation of its foundation. The local stability of the slopes in the gazebo areas was analyzed using four engineering–geological cross-sections developed based on the survey results. The soil mass was modeled according to the Mohr–Coulomb failure criterion. The calculations indicated that in certain sections, slope failure could occur under water-saturated soil conditions, while in other sections the slopes were found to be in a state of limiting equilibrium.

Introduction

The study object is the Volodymyrska Hirka, a park in Kyiv, founded in the middle of the 19th century. Currently, the park is undergoing the reconstruction and improvement work. There was a need to survey and assess the technical state of a path and to survey the slope portion around it, as well as to survey the slope portion, where the gazebos were arranged, and determine the slope stability. The surveyed area picture is shown in Fig. 1.



Figure 1 Cracks in the paving around the gazebo caused by the base uneven deformation; the crack opening width exceeds 50 mm.

During the visual inspection of the path and slope around it and their technical state determination, the following defects and damages were found: steps that protruded from the plane and were curved; steps having through-going cracks with an opening width of up to 15 mm; steps that were not fixed and had various inclination angles; an area where some steps were completely absent; areas with destroyed steps; the through-going cracks with an opening width of up to 50 mm along the entire height of the walls along the stairs; the drainage trays that were destroyed, leaky, littered with garbage and wall decoration slabs; areas with destroyed paving, tilted curb stones and destroyed causeway were everywhere on the stairs. The totality of the above-mentioned damages was caused by the unfavorable operating conditions, significant period of the stairs use without repair and soil base uneven deformation due to soaking. According to the current regulatory documents, the technical state was considered an emergency. During the slopes inspection along the stairs, the following was recorded: on the slopes there were "drunken forest" inclined trees; the lighting pole was inclined due to the base uneven deformation; on the slopes there were the widespread areas with the soil eroded by atmospheric waters as the water erosion manifestations; the water intake was littered with garbage. The issues of preventing landslide accidents have been considered in many works by domestic and foreign researchers. Among them, we will mention only a few: (Hadiatska, 2019, 2020, 2021), (Ivanik, 2023, 2025), (Kaliukh, 2023, 2024, 2025), etc.

Numerical modelling of the slope areas stress-strain state

Modelling and calculations for assessing the slopes local stability at the studied sites, where the gazebos were installed, were performed on four engineering and geological sections arranged according to the

surveying results. The factor of safety was calculated with a software package using the Bishop (Cray), Yanbu, Morgenstern-Price and Spencer methods for assessing the stress-strain state of soil massifs under the static and dynamic loads action, as well as the stability coefficients of slopes and declivities. The slip surfaces had circular cylindrical shapes or were designated in the form of broken lines. The calculation was performed for 1 RM under the plane strain conditions. When modelling the soil massif, a soil model meeting the Mohr-Coulomb strength conditions was taken. The slope stability was calculated by the method of circular cylindrical surfaces with the Bishop (Cray), Yanbu, Spencer and Morgenstern-Price methods application. In Fig. 2 one of the design schemes for section 8-8 is shown.

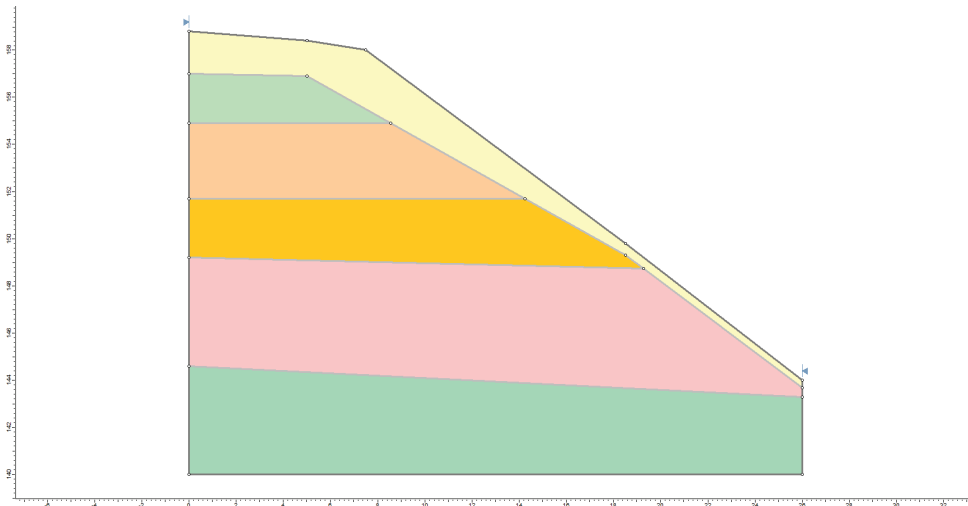


Figure 2 Design scheme (the engineering and geological section 8-8).

The slope stability safety factors K_{st} obtained in the calculations were compared with the normative safety factor K_{st} , which, according to the requirements of DBN V.1.1-46:2017 and DSTU-N B V.1.1-27:2010, was $K_{st} = 1.16$ for the main combination of loads as for the importance class SS-2 structure. The stability assessment calculations for each section were performed for the characteristics of soils in their natural state and at their water saturation, which were taken according to the surveying results. For each section with the obtained values of stability coefficients less than the normative ones, the results of the obtained stability coefficients values were given as follows: in the range less than 1 (stability was not ensured); in the range from 1 to the normative value of the safety factor K_{st} equalling 1.16 (the slope was in a limit equilibrium state); in the range exceeding 1.16.

Results

In Table 1 the slope stability coefficient minimum values obtained for the considered sections with the soils in the natural and water saturated states are shown. The calculation results indicate that for all sections the slope normative stability is ensured with the design characteristics of the soils in the natural state. The slope along section 6-6 is in the stable state with the characteristics of the soils taking into account their water saturation. The soils stability coefficients for the slopes along sections 7-7 and 9-9 are in the limit equilibrium state. Along section 8-8, the slopes stability loss is possible in some areas with the characteristics of the soils in the water-saturated state.

When carrying out the "Volodymyrska Hirka" park reconstruction, the results of the slopes stability assessment work performed earlier should be taken into account. According to the results obtained earlier, the most unstable portions of the slope are in its lower part, where the predicted slip surfaces intersect the sandy loam and loam soils with a consistency value exceeding 0.4. The calculations consider the overall stability of the slopes. In a natural state, the slopes normative stability is not ensured and a stability loss is

possible for them. When the soils are water-saturated, the slopes stability is not ensured, which leads to the landslide processes and phenomena intensification.

Table 1 Results of slope stability calculations (minimum stability coefficients *Kst*)

Section	Factor of safety obtained by various calculation methods			
	Bishop	Yanbu	Spencer	Morgenstern-Price
In the natural state				
6-6	3,683	3,478	3,688	3,686
7-7	1,998	1,687	2,075	2,083
8-8	1,519	1,476	1,501	1,508
9-9	1,912	1,751	1,914	1,909
In the state of soils water-saturation				
6-6	2,078	2,043	2,081	2,085
7-7	1,130	1,081	1,128	1,130
8-8	0,937	0,917	0,936	0,933
9-9	1,114	1,020	1,109	1,109

Conclusion

1. During the visual inspection of the area, where the gazebo is arranged, and slopes around it, the following defects and damages are found: there are cracks having the opening width of up to 50 mm and formed due to the paving base uneven deformation around the gazebo and cracks with the opening width of up to 10 mm in the gazebo supports foundations; there are no trays for collecting and draining surface water around the gazebo; in front of the plateau, on which the gazebo is located, an intercepting tray is arranged, which does not drain water because is clogged with soil and debris; the water drainage from the intercepting tray is not organized, which is why the slope is washed away by the water flow; the inclined trees called “drunken forest” are spread everywhere on the slope around the gazebo and the angle of some trees inclination reaches 45 degrees; on the slope the soil surface areas eroded by atmospheric waters are widespread, which is a water erosion manifestation; near the area, where the gazebo is located, there are the stairs and a drainage tray along them with the destroyed bottom, through which trees and vegetation grow. The combination of the above-listed damages is caused by the unfavorable operating conditions, soil base uneven deformations and complex engineering and geological conditions (one of the gazebos is located on the slope edge).

2. The calculations results show that for all sections the slope normative stability is ensured with the design characteristics of the soils in a natural state. The slope along section 6-6 is in a stable state with the characteristics of the soils taking into account their water saturation. The stability coefficients of the slope soils along sections 7-7 and 9-9 are in a limit equilibrium state. Along section 8-8, the slope stability loss is possible in some areas with the characteristics of the soils in a water-saturated state.

3. When performing work on the "Volodymyrska Hirka" park reconstruction the results of assessing the slopes stability performed earlier should be taken into account. According to the results obtained earlier, the most unstable portions of the slope are in its lower part, where the predicted slip surfaces intersect sandy loams and loams with the consistency value exceeding 0.4. The present calculations consider the overall stability of the slopes. In a natural state, the slopes normative stability is not ensured and there is a possibility of stability loss on them, with the exception of one section. When the slopes soils are water-saturated, their stability is not ensured, which leads to the landslide processes and phenomena intensification.

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