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47 The Importance of the Existing Engineering Geological Conditions During the Building Construction on the Terrain Affected by Sliding

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Abstract

Performing of the deep excavations leads to an imbalance in the terrain and consequences are frequent occurrences of local sliding, collapse, settlement and even destruction of the adjacent facilities. Therefore, knowledge of the existing engineering geological data is very important, because in urban areas problems of interaction of the new facility and geological environment are not the only ones that need to be solved, but also the influences of the other structures located in vicinity. Aggravating circumstances are terrains with complex engineering geological conditions affected by active, dormant but also stabilized landslides. In this paper the importance of knowing engineering geological conditions and history of landslide processes is highlighted with the example of the construction of a shopping mall in a densely populated area of the Serbian capital-Belgrade. The results of engineering geological and geotechnical researches are chronologically presented starting from the first landslide activation in 1970 and its reactivations in 1981 and 1992. By the latest research results, the existence of "fossil" landslide is registered for the first time in this part of the terrain. Based on that, the project for the protection of surrounding terrain was done due to the deep foundation pit excavation.

Keywords

Engineering geological conditions • Fossil landslide • Residual strength

47.1 Introduction

In developed urban areas, the lack of available space on the surface is a problem and it is solved by the use of underground space. This often includes the performance of deep excavations with the protection of existing facilities. However, the choice of inadequate protection measures often leads to negative consequences with significant material costs and in some cases human lives are endangered. Due to the specific conditions of performing a deep excavation such as: variation in different soil types, limited space, difficult and demanding work conditions, excavation speed etc., conditions of the natural geological environment are especially important. Therefore, the base for the deep excavations performances is the engineering geological maps which should be practical, concise, clear and with adequate graphical and numerical representation of the terrain.

47.2 Geological Terrain Composition and Characteristics of the Sliding Process

The terrain where the shopping mall was built is a densely populated, hilly area of the capital of Serbia—Belgrade. The terrain basis, within the exploration area, consists of marine basin sediments which are the oldest sediment layers of Paratetis near Belgrade. They are presented with marls (Lg),

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which are intensively modified in the surface layer, and they formed a surface weathering zone of degraded marl clays (Lg*). Quaternary cover is formed over this complex and it is made of different lithogenetic sediments in which diluvial sediments dominate on the slope ground part and alluvial-proluvial sediments on the flat part of the terrain next to a stream. Loess diluvium (dl-l) and a thin layer of diluvial clays (dl-gl) are separated within the diluvial sediments. Alluvial-proluvial sediments are characterized by polycyclic sedimentation with material gradation in vertical direction, so that within these sediments three areas are distinguished: clays (al-gl), clayed sands (al-gp) and clayed gravels (al-gš). Greater part of the terrain is covered by uncontrolled fill mainly made of construction waste, and it is divided into two parts: the so-called old fill (n_s) which was formed before 1970 and the fill which was formed after that (n). The wider zone of the terrain belongs to the region that includes an area of active, dormant and stabilized landslides (Fig. 47.1). The shopping mall is located on the landslide that was activated for the first time in 1970. Its activation started due to the trench excavation for the installation of sewer pipes along local streets. Then the first engineering geological terrain explorations were performed and based on these results its remediation was carried out by the system of drainage trenches filled with sand and gravel. This drainage system was not sufficient to perform a permanent repair, because the landslide was reactivated in 1981. The researches that were performed in 1981, had an aim to protect the street that propagates through the frontal area of the landslide scar, but the remediation of the entire slope towards the local stream was not considered. For those reasons, in the frontal part of the landslide the retaining structure of reinforced concrete piles was built, with the average length of 12 m. Afterwards, the terrain surface affected by sliding was arranged. The slope got a natural layout that did not indicate the existence of the active sliding process. However, in 1992, the sliding process was reactivated and expanded to the southwest of the site, and the landslide re-affected central parts of the slope below the retaining structure. For these reasons, the retaining structure was extended along the street, and the gravel embankment (n_k) was built out in the central part, at the bottom of the slope which beside the function of ballast provided mitigation of the slope inclination (Fig. 47.2). It can be concluded that the sliding process on this site was periodically active and with uneven temporal frequency. It is exactly due to these frequent sliding processes, that the terrain was avoided for construction even though the site is in the narrow city core.

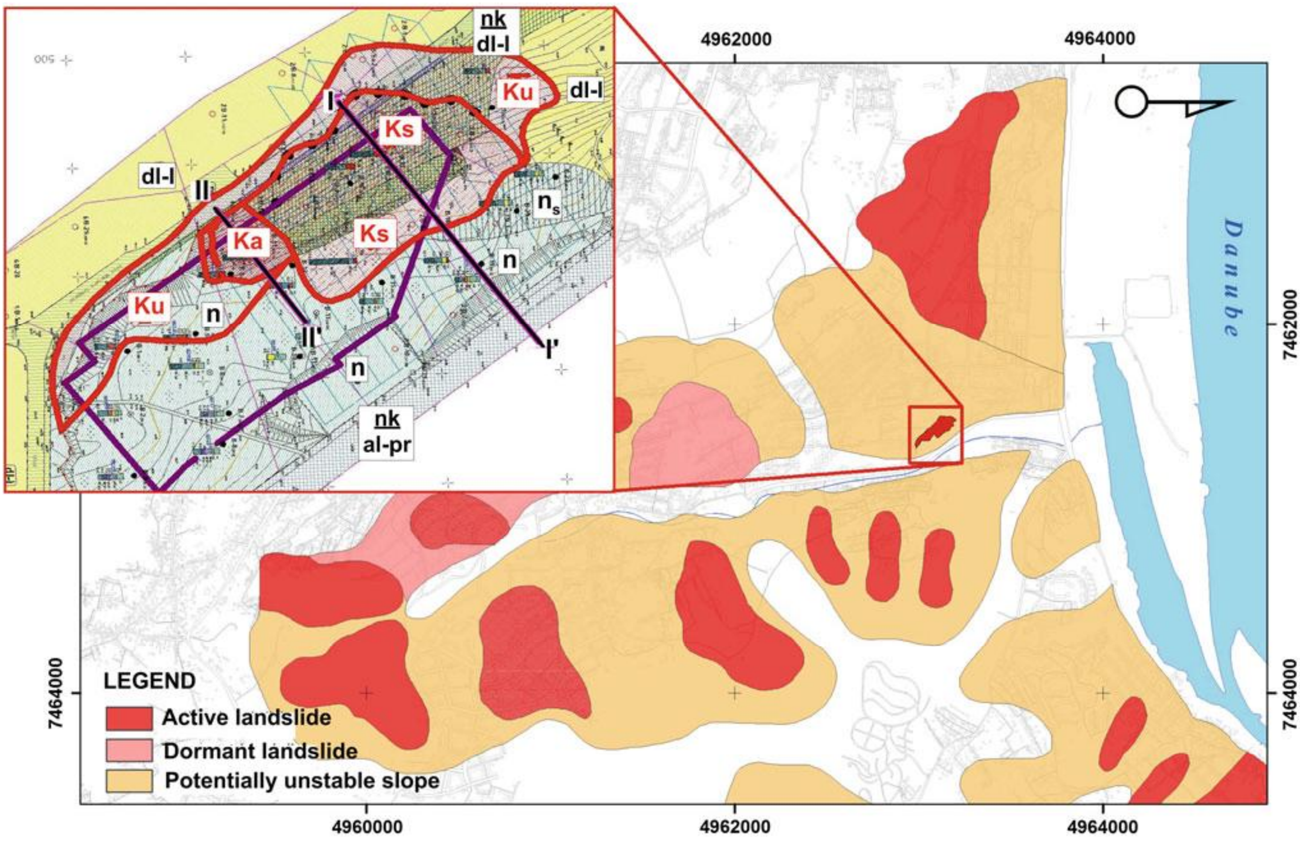

Fig. 47.1 Map of registered landslides along the local stream with engineering geological map of microlocation

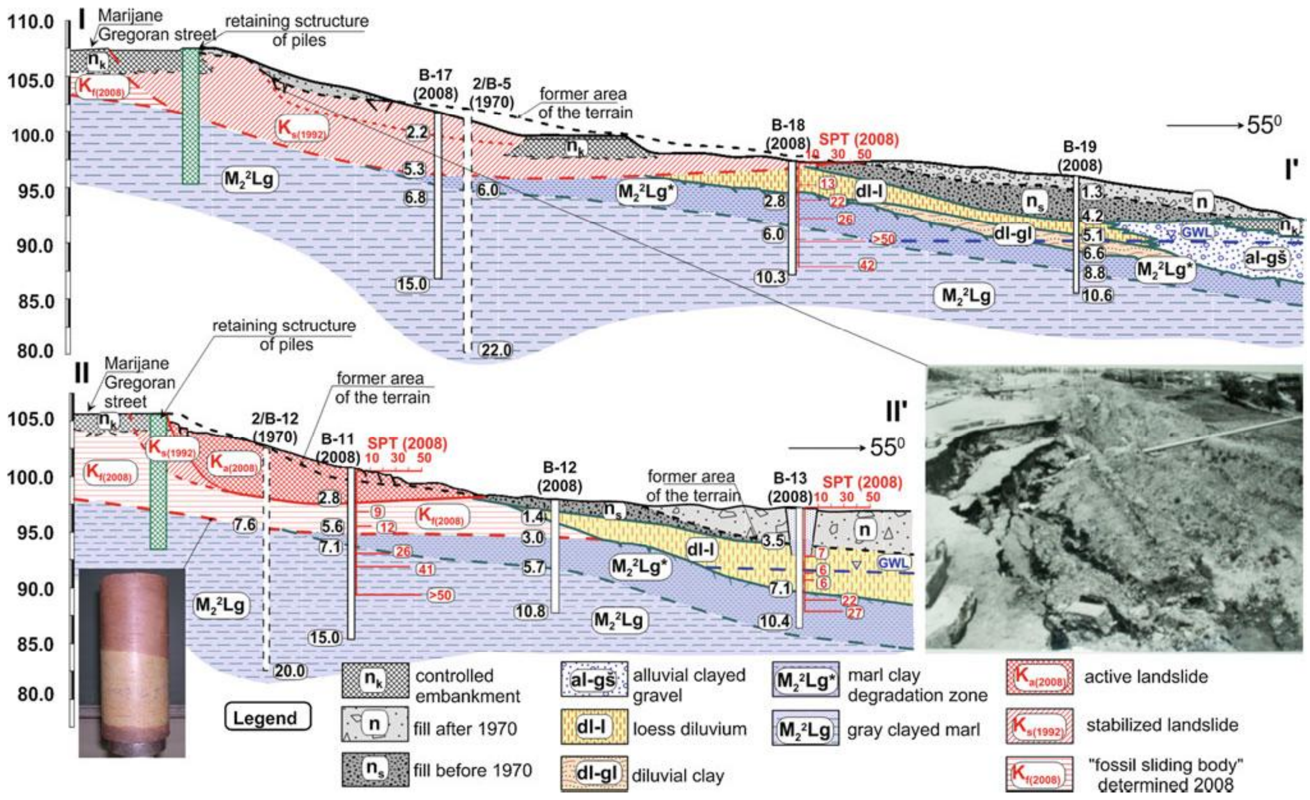

Fig. 47.2 Characteristic engineering geological cross sections of the terrain

47.3 Defining Engineering Geological Models

The latest engineering geological explorations at this site were performed for the construction of the shopping mall "Merkur", which was built in the meantime. For this occasion, the terrain zoning according to degree of stability was performed (Fig. 47.1), where the terrain was separated into: terrain affected by an active sliding (Ka), terrain on which the remediation measures were carried out (Ks) and terrain on which the landslide was dormant (Ku). Based on these researches, the active slip surface at a depth of 5.0 m (Fig. 47.2) was determined. In the repaired part of the sliding body, the groundwater table was determined at a depth of 3.5 m up to 8.0 m, while in the landslide foot part in the active zone of the sliding body, the groundwater table was measured at a depth of 1.6 m. Apart from the fact that the causes of relatively recent slides formation were determined, the latest engineering geological researches, helped discover for the first time the existence of "fossil landslide" in this part of Belgrade's terrain (Fig. 47.2).

This confirms the known fact that in the wider Belgrade area along the right bank of the Danube, the sliding processes occurred in the past and in most cases were stopped by the formation of the loess cover (Rakić et al. 2009). This periodic activity of terrain sliding had caused a chaotic mixture of several lithological members within the colluvial mass where degraded marl clays (gL*) and diluvial clays (dl-gl) dominate. Lithological heterogeneity also affected the parameter values of shear strength that varied in a wide range. Due to the prevailing primary brittle, crystallizing and cementation bonds, cohesion of immovable degraded marl clays was $c' = 42$–60 kPa, while in the predominantly saturated, cracked and softened weathering zone it is minimized to the so-called apparent i.e. temporary cohesion of the weak and unstable hydrocolloid relations and equalled $c' = 5$–22 kPa (Rakić et al. 2000). In 1970 and later in 1981 laboratory tests were performed and gave the results of the residual internal friction angle of saturated colluvial soil samples. Also, the back-analyses were performed giving the mobilized shear strength parameters at failure along the slip surface. The latest laboratory tests have mostly yielded lower residual values for the internal friction angle $\varphi'_r = 11$–$12°$ (Fig. 47.3).

In the process of the stability analysis, several engineering geological cross sections of the terrain were considered taking into account the groundwater level. Considering that the newly formed sliding body affected surface parts of "fossil

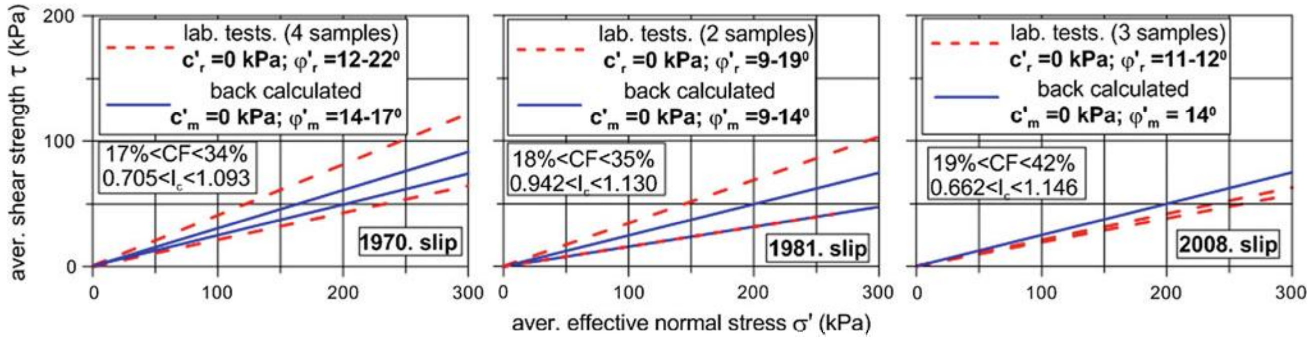

Fig. 47.3 Residual shear strength depending on the time activity of the landslide

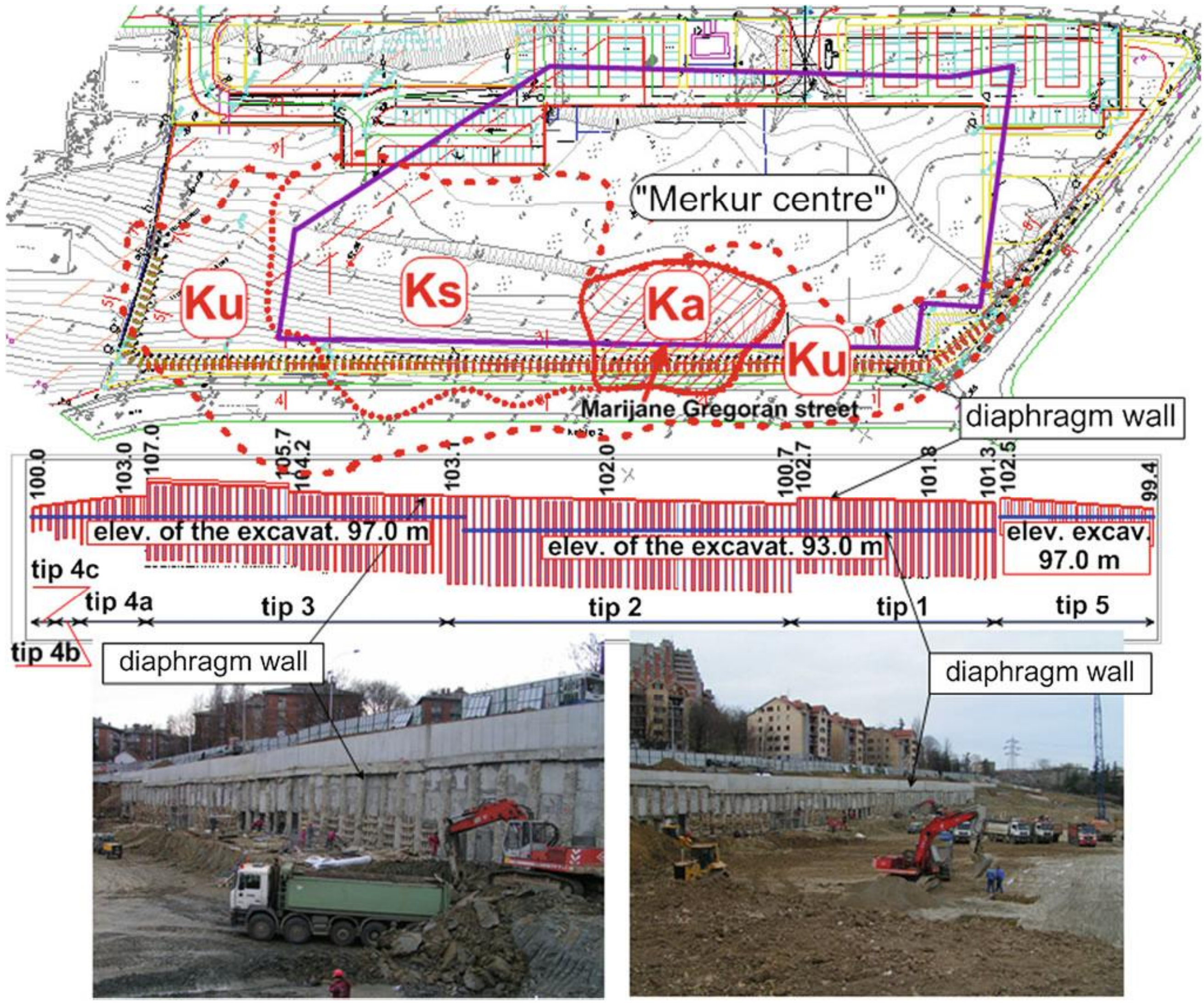

Fig. 47.4 Protection of foundation excavation

landslide" in one part of the terrain, as a corresponding slip surface for the securing of the foundation pit, a contact of the zone of degraded marl clays and grey marls was proposed. Conditional internal friction angle was determined from the limit equilibrium condition by back-analysis i.e. for the adopted safety factor $F_s = 1.0$, and assuming that along the slip surface $c'_r = 0$ kPa (Popescu 2002). The value of the conditional internal friction angle $\varphi'_m = 14°$ (Fig. 47.3) was obtained by the back-analysis method, which was later used to determine the force of a potential sliding body on the retaining structure.

47.4 Remediation Measures

Depending on the morphology of the terrain, the depth of the foundation pit excavation ranged from 8.3 to 14.0 m. This implied removing the entire colluvial part in the facility domain, whether it is the active, stabilized, dormant or "fossil" part. It also required taking into account the possibility of cutting the existing drainage trenches which were built after sliding in 1970.

Thus formed excavation had a lower elevation related to the pile base elevation of the existing retaining structure along the street, questioning its stability and the stability of the major road i.e. the slope above it on which there are residential buildings (Fig. 47.4). As the basic remediation measure and the foundation pit protection measure, the reinforced concrete diaphragms were designed. Along the street of Marijana Gregoran they were placed in the so-called "comb arrangement" perpendicularly to the reinforced concrete structure of piles, and connected with the overhead slab at a certain depth (Anagnosti and Stambolić 2008). Groundwaters from the slope are collected by the drainage curtain, which was placed between the diaphragms, and transferred in a controlled process through drainage pipes and shafts system to the city sewage. The reinforced concrete diaphragms were designed according to deepest determined slip surfaces ("fossil" or dormant), which were defined in the contact of degraded marl clay zone and grey marl zone.

47.5 Conclusion

Due to the inaccessibility of locations, as well as the economic factors and scarce resources for research purposes, we are not always able to perform the necessary amount of exploration works which are objectively necessary to obtain reliable data. This especially refers to urban areas, where not only the problems of interaction between the new structure and geological environment need to be solved but also the influence of other structures located in the vicinity. In this regard, systematization and reinterpretation of the existing engineering geological and geotechnical data are very useful, because in these areas the unfavourable engineering geological conditions are not the only problem, but also insufficient knowledge of them. Therefore, we should not forget that the absence of sliding traces on a surface does not always prove its past stability.

References

Anagnosti P, Stambolić S (2008) The main project for securing the foundation pit of the "Merkur" shopping mall. Karaburma, Belgrade

Popescu ME (2002) Landslide causal factors and landslide remedial options. In: Proceedings of 3rd international conference on landslides, slope stability and safety of infra-structures. Keynote Lecture, Singapore, pp 61–81

Rakić D, Čaki L, Dragaš J (2000) Progressive softening of the belgrade clayey deposits owing to underground construction. In: An international conference on geotechnical and geological engineering. GeoEng2000, Melbourne, Australia

Rakić D, Nikolić A, Kostić S, Berisavljević Z (2009) Geotechnical investigations terrain for building the trade center "Merkur". In: Karaburma, 3th conference geotechnics in civil engineering, Association of Civil Engineers of Serbia (ACES), Zlatibor, pp 123–128