Ground waters in Quaternary and Neogene deposits as a risk factor in the construction of high - rise buildings in the area of "Belgrade cape"

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Abstract: Central part of Belgrade urban area is located on "Belgrade cape", final stretch of "Sumadija ridge" at the absolute altitude of 100 - 140 m in very complex geological and hydrogeological conditions.
This paper is revealing basic hydrogeological features of "Belgrade cape" and problems encountered in the construction and maintenance of high-rise buildings.

Key words: Belgrade cape, hydrogeological problems, high-rise buildings, construction conditions.

Introduction

Central part of Belgrade urban area is located on "Belgrade cape", being the final stretch of "Sumadija ridge" at the absolute altitude of 100 - 140 m. Basically, this terrain is made of Tortonian, Sarmatian, and Pannonian sediments, and over these deposits there is a discordant bedding of alluvial, piedmont, diluvial sediments of Quaternary. Final lithologic units in the terrain composition are made of marshy and on - shore loess.
Construction of high-rise buildings in the area under study, particularly those with a series of dug-in floors represents a complex problem, primarily hydrological one, and consequently geotechnical as well. The excavations of foundation pits and already built and future high - rise facilities are the new bases of ground waters movements whereby the routes of water motions and water regime will be changed. Along the structural elements there appears a hydraulic linkage of storages of ground waters, which under natural conditions were hydraulically split up. The problems are thus created in the construction and maintenance of high-rise buildings, in other words it brings about the application of a series of technical measures of reclamation. The old part of Belgrade urban area, within the framework of "Belgrade cape", represents a specific urban area by its hydrogeological features and conditions pertaining to the construction and utilization of high-rise facilities.

1. Geological structure of "Belgrade cape" terrain

Geological structure of the area under study is composed of Cretaceous products established through investigation boreholes carried out in the underlying stratum of Neogene deposits from Mostar interchange, over Tasmajdan park and central street Terazije to Skadarlija zone. The largest spread refers to zoogenous reef limestones of Urgon facies.
Over these Cretaceous products, being the part of Neogene solid ground, Neogene Tortonian and Sarmatian deposits: zoogenous reef limestones, marls, sandstones, clays and sands recline discordantly in alternating lateral and vertical replacements.

Scientific paper

Figure 1. Layout map of "Belgrade cape"

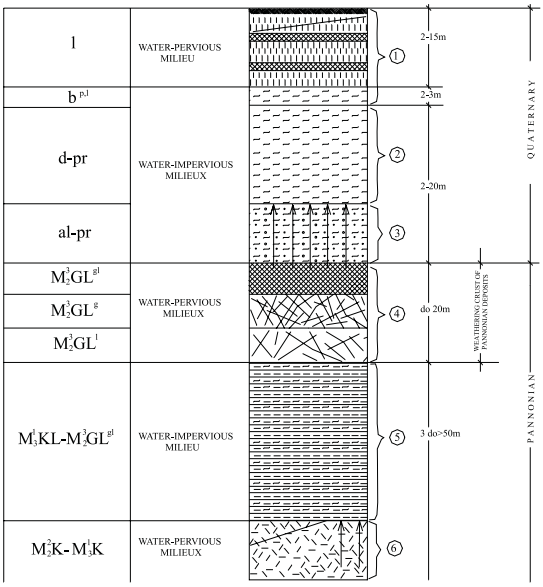
Almost on the entire spread of "Belgrade cape", over the Sarmatian deposits recline concordantly the Pannonian sediments in the facies of marly clays, marls, clayey marls. Neogene deposits were subdivided by faults into smaller or larger blocks on the stretch Chubura - Kalemegdan. In the course of Pliocene a part of Pannonian deposits eroded, whereas in the remaining part the weathering crust appeared with the thickness of more than 20 m here and there. Prequaternary relief of "Belgrade cape" created in the Pannonian series has a great number of depressions and elevations ensued from erosion processes of paleoflows. On such a slope alluvial - proluvial, diluvial and aeolian sediments deposited themselves in a discordant pattern. Preloess deposits, which are found prevailingly on the valley slopes of present streams are represented in the lower part by silts and silty clays with carbonate concretion, and locally by clayey sands and gravels - "Belgrade layers". Over them recline loess silts, sandy and gravel silts and clays - "Terazije layers". Aeolian deposits are represented by marshy and on - thick, and with scattered "scraped soil" 2 - 3 m thick. Loess is practically located on all Belgrade plateaux and overall depth of Quaternary deposits is in the range from 2.5 to 20 m.

2. TERRAIN HYDROGEOLOGICAL CHARACTERISTICS OF "BELGRADE CAPE"

In all chronostratigraphic units of the area under study there are rock masses with lesser or greater water - perviousness wherein numerous storages of ground waters had been created with differing mechanism. The exception refers to the Pannonian stage under the weathering crust in the facies of water - impervious marly clays, marls and clayey marls. These rock masses act as water - impervious roof to the water - bearing milieus of Sarmatian and Tortonian

in relation to the weathering crust impervious roof of Pannonian deposits.
Water - bearing milieus as per indicated chronostratigraphic units, relevant for the construction and utilization of high - rise facilities (Fig.2) are as follows:

- Tortonian and Sarmatian zoogenous reef limestones;
- weathering crust of Pannonian clayey - marly deposits;
- Quaternary "Belgrade layers";
- Quaternary on - shore loess.



1. Loess with "scratched soils"
2. Marshy loess & "Terazije layers"
3. "Belgrade layers"
4. Weathering crust of Pannonian deposits
5. Pannonian marly clays, marls & clayey marls
6. Cretaceous, Tortonian and Sarmatian zoogenous reef limestones

——— Ground waters free levels
--- Subartesiana aquifer

Figure 2. "Belgrade cape" - hydrogeological column chart

Ground water storages, i.e. aquifers had been created within the framework of these water-bearing milieus and they represent various risk factors in the construction and utilization of high - rise facilities. Risk rate is dictated by the characteristics of certain water - bearing milieus, i.e. ground waters found therein and structural elements of the facilities themselves. In accordance with the hydrogeological conditions pertaining to the construction of high - rise facilities with two or more storeys under the terrain surface in the area of "Belgrade cape", one may, generally, single out three types of terrains, as follows:

- terrains with Tortonian - Sarmatian limestones at the depth up to 3 m;
- terrains with Quaternary deposits and weathering crust set directly over Tortonian - Sarmatian limestones;
- terrains with undegraded Pannonian clayey - marly deposits in the underlying stratum of the weathering crust and Quaternary deposits.

In the *first type of terrain* only the buildings which would be built at considerable depths, under the aquifer surface, i.e. in the water - saturated part of this water - bearing milieu, and therefore these facilities would require certain measures of protection from ground waters. Until nowadays such facilities in this particular area have not been built as yet.
In the *second type of terrain*, which is encompassing the peripheral parts of Tasmajdan and Kalemegdan ridge, the ground waters accumulated in the weathering crust of Pannonian deposits leak directly, whereas from loess they leak indirectly into Tortonian -Sarmatian limestones wherein the piezometric levels are quite below the underlying stratum of the weathering crust.
In the *third type of terrain*, which is encompassing the prevailing part of "Belgrade cape" and the same is typified by extensive thickness of Quaternary deposits and weathering crust over undegraded Pannonian (almost impervious) deposits, whereby the ground waters thus hinder the stability of foundation pits and consequently the structural solution pertaining to the construction of facilities.
Numerous facilities with 2-4 storeys under the terrain surface were built in this type of terrain. Recently, the protection of foundation pits and buildings themselves was carried out by setting the diaphragms and drainage "carpets" with horizontal or vertical drainage tubes. In order to build the department store "Srbijateks" in the main street of Belgrade, the excavation of the foundation pit was provided with a diaphragm, whereas the protection of storeys under the terrain was carried out by a complex drainage system around the facility, with horizontal drains ∅ 120 mm and drainage "carpet" with offtake pipes. Overall initial inflows of ground waters into the drainage system amounted approximately Q = 2.5 l/s. The protection of hotel "Slavija", i.e. its annex with two storeys below the terrain surface, was carried out with diaphragms and tie - rods, anchored in marly clays, whereas the facility was protected from ground waters impact by resorting to horizontal drains on the edges and through the drainage "carpet" under the flooring of the second storey. The same procedure was applied in the protection of foundation pits and buildings from the inflow of ground waters for hotel "Park" in Svetozara Markovica St., National bank on the Slavija square, buildings of "Slavija banka" and "Beogradjanka" in the main street, etc. On the plateau of "Belgrade cape" from Terazije to Slavija, almost in all buildings, i.e. in their storeys under the terrain surface there is a break through of ground waters, which must be evacuated by pumping - "Albanija" palace and hotel "Moskva".

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