PROBLEMS OF GEOENVIRONMENT STABILITY UPON THE SUBSURFACE DEVELOPMENT IN MOSCOW

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V.M. KUTEPOV, N.G. ANISIMOVA
I.V. KOZLYAKOVA, P.S. MIKLYAEV

Institute of Environmental Geoscience, Russian Academy of Sciences
Moscow, RUSSIA
direct@geoenv.ru; kutepov@geoenv.ru

ABSTRACT

Subsurface development in Moscow includes cutting metro and highway tunnels, construction of high-rise buildings with deep foundations, and the reconstruction of old buildings using upper horizons of the subsurface.

Geological properties of the subsurface are not adequately taken into consideration on planning underground engineering structures in densely built urban area. The functional purpose of the object and its anchoring to urban infrastructure appear to be the main criteria for choosing sites of subsurface construction. Mesozoic and Cenozoic clay and water-saturated sand occurring in the upper part of geological section as well as the underlying karstified and fractured Carboniferous limestone with confined aquifer is the enclosing environment for the subsurface engineering structures.

The cases are known of loosing geoenvironment stability upon underground construction, e.g., the quicksand breakout into shafts and tunnels, suffosion outwash of watersaturated sand in deep pit walls, karst and suffosion intensification upon decreasing the groundwater pressure due to pumping out water at construction sites, rock shifting in the mining roofs, etc. The disturbance of existing technonatural conditions upon the subsurface development may cause deformations of buildings and engineering structures.

To preserve the geological environment stability in the megacity, the territory zoning is performed by the subsurface development conditions in respect to various natural and technogenic factors. The geological environment of Moscow is typified on the basis of the analysis of modern and ancient topography, geological structure, geodynamic conditions, and hazardous exogenous processes. Requirements to assessing difficulty of subsurface development are worked out.

Key words: subsurface development, building deformation, geoenvironment stability.

INTRODUCTION

Subsurface is developed in Moscow upon the construction of underground lines, highway tunnels, high-rise buildings with deep foundations, as well as upon the reconstruction of old buildings.

Geological structure in the city is rather complex. Terrigenous-carbonate karstified and fractured deposits of Carboniferous age occur at a depth of 10-100 m. They are overlain by

heterogenous sandy-clayey Meso-Cenozoic massif [1]. Several generations of river valleys of different age are distinguished, the erosional activity of which controlled the ancient and modern relief, mode of occurrence, conditions and properties of Paleozoic, Mesozoic, and Quaternary deposits, hydrogeological conditions, as well as the character and intensity of exogenous geological processes.
The possibility of subsurface use in Moscow is limited by complex engineering geological and hydrogeological conditions, as well as by a dense network of already operating underground engineering structures. Building foundations, metro tunnels and other urban subsurface structures complicates construction significantly and makes it more expensive.
The specifics of geological environment are poorly taken into consideration under the conditions of densely built urban area. The functional purpose of the object and its linkage to urban infrastructure appear to be the main criteria in selecting sites for subsurface construction. Mesozoic and Cenozoic clay and water-saturated sand in the upper part of the geological cross-section, as well as the underlying karstified and fractured Carboniferous limestone containing confined aquifers are used as the enclosing medium for subsurface engineering structures.
The cases are known of loosing geoenvironment stability upon subsurface construction, e.g., quicksand inrush into shafts and tunnels, suffosional withdrawal of water-saturated sand into deep construction pits, intensification of karst and suffosion upon a decrease of groundwater head as a result of water intake, and rock shift in the mine work vaults. The disturbance of natural and technogenic equilibrium upon the subsurface development causes deformations of existing buildings and engineering structures.
In order to preserve the geological environment stability in the Moscow megacity, the territory zoning is performed according to the subsurface development conditions. For instance, we fulfilled this zoning to a scale of 1 : 5 000 for the Moscow Business Center area (the so-called "Moscow City") located in the central part of Moscow on the left bank of the Moscow river.

ZONING OF THE MOSCOW BUSINESS CENTER AREA "MOSCOW CITY" ACCORDING TO THE CONDITIONS OF SUBSURFACE DEVELOPMENT

The territory zoning by the subsurface development conditions was performed at the depths of 5, 10, 20, and 30 m below the surface. The subsurface development was to be performed by open mining works with isolated protective screens. Several categories of subsurface development conditions were distinguished proceeding from the analysis of geological environment structure specifics. The following are the most important geoenvrionment components that influence the territory development and control the adequate operation of the infrastructure:

- sandy-clayey deposits possessing special properties, i.e., quicksand, swelling soil, heaving and weak soils, organo-mineral and fill soil, etc.;
- often karstified Carboniferous limestone and dolomite;
- ancient buried valleys and gullies filled with water-saturated sand;
- hazardous natural and natural-technogenous geological processes, i.e., karst, suffosion, waterlogging, quicksand phenomena.

Favorable, conventionally favorable and unfavorable categories of subsurface development conditions were distinguished (Table 1).
As a result, the maps of subsurface zoning by its development difficulty were built for each depth of probable subsurface development for the territory adjacent to the Moscow Business Center "Moscow City". Upon assessing the development difficulty, we took into consideration the following:
-engineering geological properties of soils and rocks exposed in the construction pit bottom;
-type of hydrodynamic conditions variation;
-natural and natural-technogenic processes, which may be manifested during construction and operation of building.

Table 1.: Criteria for distinguishing categories of subsurface development conditions.

Category of development conditions	**Criteria**
I. Favorable	1. Presence of clay deposits in the pit bottom, absence of soils with specific properties in the area of engineering structure influence; 2. Absence of conditions favorable for karst and suffosion development.
II. Conventionally favorable	1. Presence of clay deposits no deeper than 5 m from the pit bottom or the presence of weakly permeable limestone and dolomites at the pit bottom; absence of soils possessing special properties within the zone of engineering structure influence; 2. Absence of conditions favorable for karst and suffosion development.
III. Unfavorable	1. Presence of water-saturated sand or highly fractured and water-permeable limestone and dolomite at the pit bottom; absence of clay deposits within the depth of 5 m from the pit bottom; presence of soils with specific properties within the engineering structure influence zone; 2. Possible development of karst and suffosion

Upon assessing the category of subsurface development difficulty, we also took into consideration the adopted technique of driving trenches and pits without affecting neighbor urban infrastructure and without producing depression funnels upon dewatering.
Problems arising in subsurface development in the most densely built-up central part of Moscow may be analyzed by the example of the studies carried out in the framework of the Bolshoi Theater reconstruction project.

SUBSURFACE DEVELOPMENT UPON THE BOLSHOI THEATER RECONSTRUCTION

The building of Bolshoi Theater is an outstanding masterpiece of the Russian architecture of the middle 19th century; it is one of the largest theater buildings in Europe. It was built in 1825 and was restored after the fire in 1853. At present, works on theater building restoration have begun. The reconstruction project is aimed, on one hand, at preserving the building as an architectural monument; and on the other hand, at transforming it to an engineering structure fitting up-to-date technical standards. The subsurface part of the building will locate a concert hall, make-up rooms, decoration storage, checkroom, and other lodgments.

According to the project, for the reconstruction purposes, the building should be surrounded by a protective wall in ground to a depth of 24 m below the earth surface. A total rock volume to be excavated upon digging the construction pit below the building exceeds 200 thousand cubic m. The pit depth will reach 20 m, and its square will far exceed the square of the modern theater building. The reinforced concrete foundation plate will be laid at the pit bottom. No excavation work will be performed beneath the auditorium, lobby, and colonnade of the theater; so, the rock massif of rectangular shape will remain intact protected by sheet piling. All existing buildings will be placed at reinforced concrete piles rested on Upper Carboniferous limestone preliminary reinforced by cementation. The rocks are to be dewatered before digging the construction pit. The designed wall in rock and the foundation plate should provide total hydro isolation of the pit.

The site of Bolshoi Theater is specified by complicated engineering geological conditions [2]. It is located within the Neglinnaya river valley (the Moscow river tributary) and encompasses the floodplain and the second river terrace composed of a thick (up to 15 m) massif of alluvial (mainly sandy) deposits. The Neglinnaya River is enclosed into a stony pipe and is buried under a thick (above 10 m) fill. Technogenous deposits of variable composition and texture are spread everywhere within the studied area (Fig. 1).

The Quaternary deposits overlie the preglacial erosional surface composed of upper Jurassic clay and upper Carboniferous limestone, clay and marl. Thalwegs of preglacial tributaries of the pra-Neglinnaya river are distinguished at the preQuaternary surface. The upper Carboniferous terrigenous carbonate deposits are exposed at the preQuaternary surface in thalwegs and on slopes of ancient gullies and river valleys; and they occur beneath the upper Jurassic clay at the remaining territory. The thickness of the Upper Carboniferous and Upper Jurassic clay underlying limestone does not exceed 10 m.

At the investigated territory, the groundwater consists of above-Jurassic aquifer confined to alluvial sand. Two aquifers, i.e., Izmailovo and Perkhurovo aquifers, are distinguished in the Upper Carboniferous limestone. The Izmailovo aquifer is characterized by an insignificant water head (up to 2.5 m), while the Perkhurovo groundwater is unconfined aquifer, with its table lying below the limestone roof.

Geological structure and hydrodynamic conditions in the area are favorable for the karst and suffosion development in some places. The Upper Carboniferous limestone is fractured an karstified. The weakly permeable clay layer overlying limestone is less than 10 m thick, and somewhere it is entirely eroded. The overlying Quaternary deposits are thick, being specified by predominantly sandy composition. The groundwater table occurs higher than the head of Carboniferous aquifers, which causes descending vertical percolation of water through the weakly permeable clay.

To analyze the changes in geological conditions in the area upon the theater reconstruction, we compiled the geological maps to a scale 1:500 for the level of the wall-in-rock bottom and the construction pit bottom. As proceeds from these maps, the wall-in-rock will cut through the Quaternary deposits, the Upper Jurassic clay layer, the Upper Carboniferous limestone of Izmailovo series, Meshcherino clay and marl horizon, and partially Perkhurovo limestone horizon. Below the projected pit bottom, weakly permeable clay is spread everywhere at the site of the theater; they should tightly surround the "wall in rock" from all sides thus providing hydro isolation of the pit. Meshcherino clay, Izmailovo limestone, and upper Jurassic clay will be exposed in the pit bottom. These rocks will serve as a foundation plate base, which rest on piles deepened into the massif by 6 m. Piles will end in Perkhurovo limestone.

In the southern part of the building, i.e., under the auditorium, lobby, and colonnade, the geological base will remain unchanged. In this part of the building, the geological sequence from the top to the bottom is the following: technogenous mainly sandy deposits of up to 4 m thick, the Upper Quaternary and modern alluvial sand of 2-5 m in thickness, Upper Jurassic clay of 6-8 m thick, Upper Carboniferous limestone of Izmailovo series, and clay of Meshcherino series.

In accordance with the reconstruction project, the geological conditions will become unfavorable for the development of karst and suffosion, since the soil not resistant to suffosion is to be removed at the bulk of the territory. Karst-related deformations of the subsurface part of the building may be induced only by the collapse of karst cavity roofs. Perkhurovo and Izmailovo limestone is highly fractured, somewhere crushed to gruss and boulders. The projected cementation of the carbonate massif in the pile basement as well as the monolith foundation plate of reinforced concrete to be placed in the construction pit bottom will rule out any karst-related disturbance of stability in this building unit. However, the possible development of karst and suffosion will remain in the adjacent territory.

Thus, the project decisions of the Bolshoi Theater reconstruction take into account possible geological hazards that may arise in the territory. Prevention of the substantial changes in geological environment in the surrounding territory was one of the main aims of the project.

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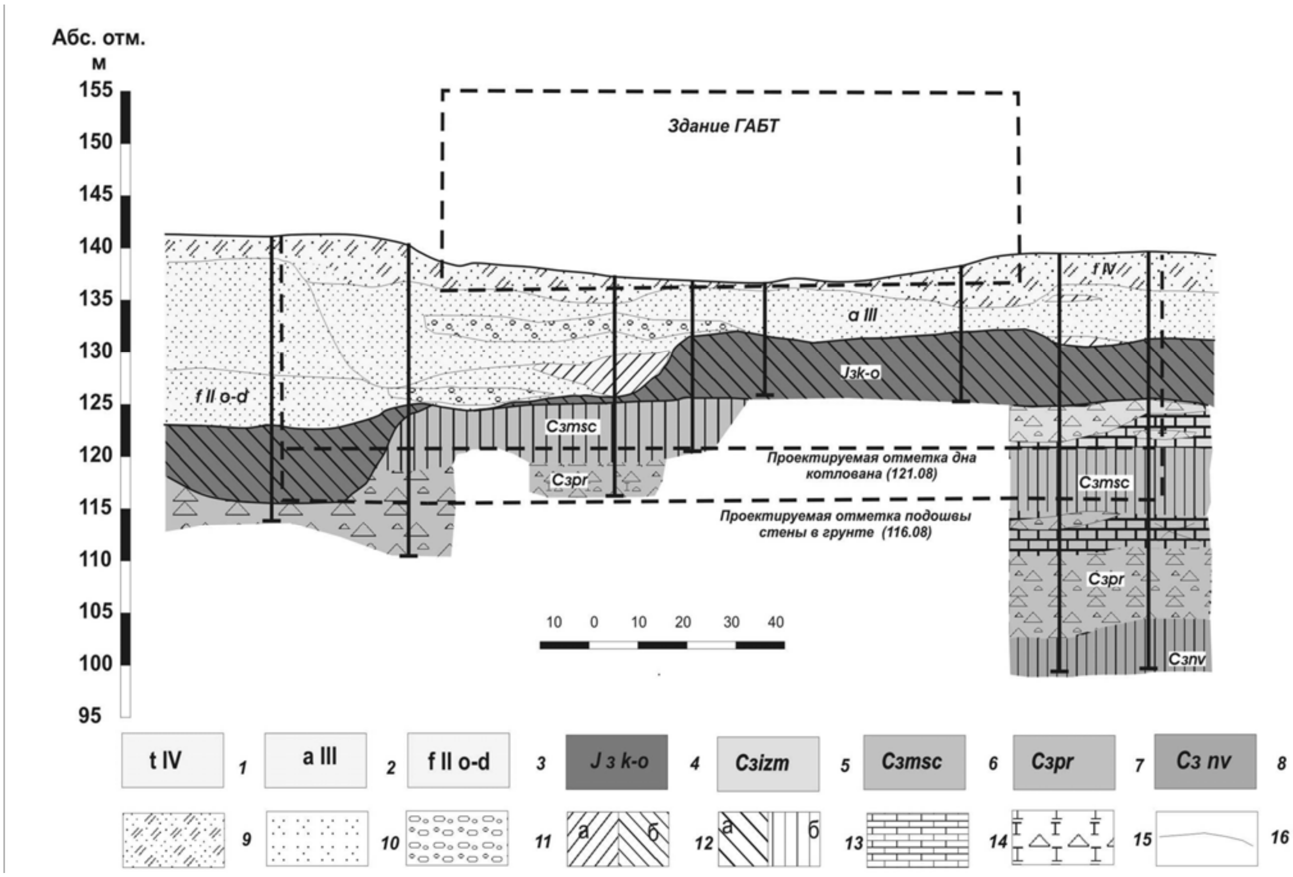

Figure 1.: Geological cross-section at the site of Bolshoi Theater reconstruction. Designations: Stratigraphy: 1 - technogenous deposits; 2 - alluvium of floodplain and the second terrace of the Neglinnaya river; 3 - fluvioglacial deposits of Oka-Dnieper age; 4 - upper Jurassic deposits of Callovian and Oxfordian stages; upper Carboniferous deposits: 5 - Izmailovo series; 6 - Meshcherino series; 7 - Perkhurovo series; 8 - Neverovo series. Lithology: 9 - fill; 10- sand; 11 - gravel and pebble; 12 - Quaternary (a) and upper Jurassic (b) loam and clay; 13 - upper Jurassic (a) and upper Carboniferous (b) clay; 14 - limestone; 15 - crushed limestone; 16 - geological boundaries.