Geotechnical conditions contributing to negative geological process development in urban areas (the case of Kemerovo-city)

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Abstract. The paper addresses the issue of intensive urban development in the area of Kemerovo-city. Underestimation of geotechnical conditions of the area at the project and construction stages results in negative geological processes such as erosion, waterlogging, soil subsidence, and underflooding. These processes can lead to deformation and failure of buildings and constructions.

1. Introduction

Modern urban areas are creating conditions conductive to the development of hazardous geological processes such as landslides, gulleys, frost penetration etc. Underflooding, which has been recently growing in scale, belongs to this array of negative processes. Underflooding results in flooded basement and negative changes in soil physical properties. Flooded landfills and catch pits are a source of chemical contamination of groundwater. What is more, underflooding can cause the development of negative geological processes related to groundwater behavior, such as subsidence and swelling. As a rule, urban underflooding is technogenically conditioned. It results from interference with natural dynamic water balance of the area. Human activities, such as urban residential development, lead to such interference which is developed by two stages: while construction activities and building maintenance. Technogenic underflooding has been only recently faced with and studied, so the preventive measures have not been fully developed and put into practice yet [1, 7, 8, 9, 10, 11, 12].

2. Materials and methods

Kemerovo city is the administrative center of the Kuzbass region. There are a lot of high-rise apartment blocks and underground constructions are being built in the city nowadays. The increase in building density and anthropogenic load makes it necessary to ensure safety, social and environmental comfort for the residents, as well as to improve economic efficiency of urban development. The constant growth of geotechnical investigations resulted in a large amount of geotechnical data which require to be analyzed and integrated for further use while carrying out current geotechnical and engineering activities, forecast mapping, and monitoring geological processes for the city to be developed. We have considered several cases of underflooding in Kemerovo.

The first is the construction site of Kuzbass technopark. The construction site of the designed Technology Transfer Center with an exhibition hall is situated in Rudnichny district, Kemerovo city, bounded by three streets: Institutskaya, Tereshkovoy, and Sosnovaya [2]. In terms of geomorphology

the site is located within the bounds of the right side valley of the river Tom'. General topographic south-east inclination is observed, the altitude is 223-228 m.a.s.l [2]. The results of previous geotechnical investigation made up to the depth of 10 meters show the following profile (from top to bottom): sedentary clays and clay loams with sedimentary debris and gravel, medium fine gravel, and sandstone on argillaceous cement (block zone of weathering crust) (Table1).

Table 1. Values of soil physical parameters.

Soil type	Density, ϱ, g/cm^3	Porosity factor, units	Soil modulus E, mPas	Angle of internal friction, φ, deg.
Sedentary clays and clay loams (e P_2 - Q)	2.0-2.17	0.4-0.73	25	
Medium fine gravel and cobble sedentary soils (eP_2)	2.15		30	
Sandstone on argillaceous cement (P_2)	2.35		50	45

During the investigation made by "Geotekhika" Ltd. (December 2009, July 2010, March 2011) up to the depth of 10 meters the groundwater was not found [2].

The investigations made in November and May 2012 revealed temporary perched groundwater in the northern part of the area. Its depth varies from 2.3 m to 4.2 m. The horizon is a spreading groundwater dome in the area intensively fed with technogenic water. The temporary perched groundwater dome is formed in dense layers of the lower part of eluvium (eQ_{II}), with low filtration properties – coefficient of permeability k = 0,001 m/day. The groundwater conditions are unstable, which is characteristic of technogenic water-fed horizons. The annual cycle fluctuation range of ground water is predicted within 1.0-1.5 m. The highest water table is in May and June. In terms of chemical composition the ground water is sulfate-chloride-hydrocarbonate, calcium-sodium. The chemical composition is characterized by high content of nitrates, chlorides, sulfates, and ammonium, which is typical of technogenic water sources [3].

The investigation made in February 2013 recorded groundwater level at the depth of 5.2-6.2 m in some parts of the site, which corresponds to 219.45–221.00 m.a.s.l. The groundwater occurs as a sporadic spreading dome in the zone fed by technogenic water most intensively and having the loosest soils of the weathering crust. Technogenic origin of the groundwater is indirectly proved by the chemical analysis result (values of hydrocarbons, nitrates, and nitrites). The groundwater regime is unstable and conditioned by the volume of technogenic water losses and infiltration of precipitation. The results of special geotechnical survey carried out within the Tekhnopark area show that the temporary perched ground water is technogenically contaminated as well[4].

The second area is a construction site of a business-incubator building. Administratively, the construction site belongs to Rudnichny district, Kemerovo, and is situated on the crossing of Tereshkovoy and Institutskaya streets. In terms of geomorphology the studied area is confined to the right side valley of the river. The altitudes are 227–229 m.a.s.l. The geo-lithologic profile of the area was studied up to the depth of 10 meters and consists of the following layers (from top to bottom): fill ground (layer 1), loess loam (layer 3), and sedentary clays weathered to argillaceous and debris rocks (layer 4, 5a); sandstones of different degree of weathering were discovered at the depth of 5.8 – 6.5 m (Table 2).

Table 2. Values of soil physical parameters.

Soil type	Density, ϱ, g/cm^3	Porosity factor, units	Moisture content, S_r, units	Soil modulus E, mPas	Angle of internal friction, φ, deg.
Sedentary clays with debris inclusions		0.38-0.58	0.73-1.0	28	
Fine sandstone	2.35			50	45

The groundwater was not identified while the survey (from July to December 2009) being conducted up to the depth of 10 meters.

The third area to consider is a site designed for dwelling house construction. Administratively, the projected house № 25 belongs to the 12th micro-district, Rudnichny district, Kemerovo city.

In terms of geomorphology, the site is located on the slope of Tom' watershed. The land surface is undulated and slightly inclined south-eastwards to the Tom' valley. The altitudes are 247.27-248.49 m.a.s.l. A foundation pit had been excavated and some piles been driven by the time the geotechnical investigation took place on the site (the piles were driven approximately in 2008 year) [5]. Later, the building construction was abandoned, the pile field has not been conserved and the foundation pit has been filled with water by now.

According to the survey made in September 2007 up to the depth of 25 meters, the geological profile of the site consists of the following layers (from top to bottom): deluvial-proluvial loams from stiff to very soft ones, deluvial stiff loams, eluvial-deluvial loams and clays from hard to very soft ones (Table 3). The groundwater level was found at the depth of 1.8-2.45 m, which corresponds to the altitude of 245.22-245.29 m.a.s.l.

Table 3. Values of soil physical parameters.

Soil type	Density, ϱ, g/cm^3	Moisture content, S_r units	Soil modulus E, mPas
plastic clay loams (d-pr Q_{III})	1.90-1.95	0.95-1.0	4.9
stiff loam (d Q_{III})	2.0-2.09	0.95-1.0	11.9
plastic and stiff loams (ed Q_{II-III})	1.92-2.11	0.99-1.0	10.5
stiff loam (ed Q_{II-III})	1.93-2.07	0.95-1.0	19.6
firm clay (ed Q_{II-III})	2.03-2.08	0.89-1.0	

The survey made in June 2013 showed the groundwater level at the depth of 2.2-2.6 m, the altitudes are 245.07-245.74 m.a.s.l. The groundwater is recharged from infiltration of precipitation, surface water during river floods, as well as from confined water of underlying Upper Permian formation. The groundwater is drained through the local hydrographic network. The groundwater regime is characterized as unstable [5].

The next sampling site is administratively situated in the 12th micro-district, Rudnichny district, Kemerovo city. It is a construction site of projected apartment block №24.

In terms of geomorphology, the site is located on the slope of Tom' watershed. The land surface is slightly inclined, undulated, and lowering to the south-east towards the Tom' valley. The altitudes are 246.67-248.93 m [5].

Piles had been driven and the zero cycle construction had been completed by the time the geotechnical investigation took place on the site (the piles were driven approximately in 2008 year). Later, the building construction was abandoned, the pile field has not been conserved and the foundation pit has been filled with water by now.

In 2007 "Geotekhika" Ltd. made a survey for the construction project development. According to the survey the geotechnical profile of the site up to the depth of 25 m comprises the following soil layers (from the top to bottom: deluvial-proluvial loams from stiff to very soft ones; deluvial loams from semi-heard to stiff ones; eluvial-deluvial loams and clays from hard to soft ones (Table 4).

Table 4. Values of soil physical parameters.

Soil type	Density, ϱ, g/cm^3	Moisture content, S_r, units	Soil modulus E, mPas
plastic clay loams (d-pr Q_{III})	1.89-1.98	0.98	5.6
stiff loam (d Q_{III})	2.0-2.04	0.95-0.99	13.3
plastic and stiff loams (ed Q_{II-III})	1.94-2.07	0.99-1.0	11.2
stiff loam (ed Q_{II-III})	1.96-2.11	0.91-1.0	

In September 2007, the level of groundwater was found at the depth of 2.0-2.6 m from the land surface, which corresponds to the altitude of 244.85-246.10 m.a.s.l. In May 2013, the groundwater level rose up to the depth of 1.5-2.3 m, which corresponds to the altitude of 245.17-245.66 m.a.s.l. [6].

3. Conclusions

The surveys prove that the hydrogeological conditions of the construction sites have dramatically changed. The survey conducted in 2009 showed no groundwater to the depth of 10 meters, however, the surveys of 2012-2013 identified groundwater, with some evidences of its technogenic origin. Groundwater increases humidity in basements and ground floors of buildings and leads to underflooding of foundations and basements. Moisture increase results in changes in soil physical properties and reduces soil stability, which can have negative impact on building sustainability and reliability. Therefore, it is essentially important to assess the impact of exogenous geological processes (EGP) on urban area, which, in its turn, should be taken into account while choosing a site for construction in terms of its feasibility study. We also consider it reasonable to apply GIS-technologies to assess hazardous geological processes. It necessitates not only developing a clear system of input, filing and keeping the data obtained by geotechnical investigations, but also deep understanding of particular geological processes typical for a studied area.

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