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***Strizhelchik G.G.**, PhD, Associate Professor*
ORCID 0000-0002-2213-7062 deptgps@gmail.com
***Iegupov V.Yu.**, PhD, Associate Professor*
ORCID 0000-0002-5836-2659 slavaegu@gmail.com
Kharkiv National University of Civil Engineering and Architecture

PROBLEMS OF SUBWAY CONSTRUCTION IN COMPLEX ENGINEERING AND GEOLOGICAL CONDITIONS BY THE EXAMPLE OF KHARKIV CITY

Scientific, technical and practical problems connected with the construction of subways, such as complex engineering and geological conditions, tunneling need in existing urban development conditions, unfavorable processes emergence during construction and operation are considered. A number of resonant factors that require special decisions when constructing the third subway line ine Kharkiv city have been identified. These factors are large dewatering influence radius threaten surface subsidence and damage of building structures in the area of open tunneling; barrage impact on the groundwater flow in the area of closed tunneling; threat to several buildings located above the tunnels; threat of weak soils dumping in the tunnel face; vibration impact on soils, buildings and structures. Seismic effect assessment on Kharkiv subway objects is discussed.

***Key words*:** *subway, complex conditions, soft soils, accidents*

***Стріжельчик Г.Г.**, к. г.-м. н., доцент*
***Єгупов В.Ю.**, к. т. н., доцент*
Харківський національний університет будівництва та архітектури

ПРОБЛЕМИ БУДІВНИЦТВА МЕТРОПОЛІТЕНІВ У СКЛАДНИХ ІНЖЕНЕРНО-ГЕОЛОГІЧНИХ УМОВАХ НА ПРИКЛАДІ М. ХАРКОВА

Розглянуто науково-технічні та практичні проблеми, пов'язані з будівництвом метрополітенів, серед них: складність інженерно-геологічних умов, необхідність проходки тунелів в умовах існуючої міської забудови, виникнення несприятливих процесів при будівництві й експлуатації. Виявлено ряд резонансних факторів, що вимагають прийняття спеціальних рішень під час будівництва ІІІ лінії метро в місті Харкові: великий радіус впливу водозниження, що загрожує осіданням поверхні та пошкодженням будівельних конструкцій на ділянці відкритої проходки; баражний вплив на потік підземних вод на ділянці закритої проходки; загроза кільком будівлям, розташованим над тунелями; загроза вивалів слабких ґрунтів у забою тунелю; вібраційний вплив на ґрунти, будівлі й споруди. Обговорено оцінку сейсмічного впливу на об'єкти Харківського метрополітену.

***Ключові слова:** метрополітен, складні умови, слабкі горнути, аварії.*

Introduction. As a rule, a number of scientific, technical and practical problems are connected with subway construction. Among the main challenges there are complex engineering and geological conditions, need for tunneling in the conditions of existing urban development, emergence of unfavorable processes during subways construction and operation.

For such cases the existing standards provide survey scientific and technical suppor, design and construction works [1]. Thus, at the «survey» stage, it is often necessary to study the filtration properties of various soils, soil ability to soften under vibration dynamic influences, to assess surface dehydration-gravitational subsidence emergence possibility during dewatering and frost heaving. It is necessary to evaluate the vibration impact on existing buildings and structures, stability of buildings and structures when undermining or close tunneling, excavation pits, tunnel crown and face walls stability etc.

In order to carry out the relevant studies, special support is required by development of technical task development and its implementation. The received survey information with scientific and technical support makes the basis for multi-variant design solutions. And in each case the problems of reliability, safety and economic efficiency must be solved. And if it is considered every point of the geological space to be unique, design solutions development is a rather complex and science-intensive task. For example, by construction of the subway station «Yuzhnyi Vokzal» in Kharkiv it was necessary to apply freezing of watered soils with weak structural bonds, instead of traditional construction dewatering, which would cause significant deformations of existing buildings and structures.

Analysis of recent research sources and publications. Examples of dangerous consequences arising from incorrect design solutions adoption in complex engineering and geological conditions by subway tunnels constrctions are given in a number of works [2 – 10].

Underground structures construction experience in complex engineering and geological conditions in Kharkiv, Kiev, Copenhagen, St. Petersburg and a number of other cities shows that the following negative and dangerous phenomena must considered in construction projects:

– possible inrush of thixotropic liquefied soils into tunnels and excavations, which leads to long breaks in construction and requires significant costs for accident elimination;

– dehydration-gravitational settling of the soil body and surface during long-term dewatering. In this case, the uneven settlement of closely located buildings with shallow foundations can make more than 15 cm (i.e. many times exceeding the regular value);

– suffosion sinkholes after a soil collapse at the tunnel crown.

Identification of general problem parts unsolved before. It should paid special attention to constructing subways problems in complex engineering and geological conditions. At the same time, it must be considered that no model (project) can fully correspond to real conditions. The reasons lie in both complex natural conditions and certain simplification of engineering solutions and sometimes their incomplete correspondence. For example, cutting the crown when tunneling in clay soils in the territory of Shevchenko garden in Kharkiv led to significant settlement of overlying soil body and even to sinkhole formation with the threat of movie and concert hall «Ukraina» destruction». It was needed to eliminate this suffosion sinkhole without stopping subway operation and short-term hall closedown. Other cases of emergency situations during construction are connected with water and soil inrush, as well as excessive buildings settlement which occurred near stations «Prospekt Haharina» and «Ploshchad Konstitutsii».

Problem definition. Nowadays during extension of the third subway line (from «Metrobudivnykiv» to «Odesskaia» station) it becomes necessary to solve a number of problems related to dewatering in the area of tunneling using cut-and-cover method, tunneling under existing buildings, tunneling using caisson method in soft thixotropic soils etc.

Obviously, complex of difficult tasks cannot be solved by single design organization, and scientific and technical support should be provided by skilled professionals from several specialized organizations. Many years of experience shows that scientific and technical support is necessary not only at the stage of survey and design, but also by performance of construction works. Experience shows negative tendencies in design, survey and construction works. First and foremost, this is performers professional level decrease and quality management system lack. Expertise is not able completely eliminate these shortcomings.

Basic material and results. Scientific and technical support of design and survey works on construction of the third subway line in Kharkiv was performed by the staff of the Geotechnics and Underground Structures Department of Kharkiv National University of Civil Engineering and Architecture.

As a result of available design and survey materials study, as well as results of -territory site survey, there was identified a number of resonant factors, which required special solutions:

– wide spreading of soft and specific soils that complicate construction conditions;

– high groundwater level in some areas; barrage effect of tunnels by the drainage absence;

– vibration impact on soils, buildings and structures;

– pressure on the constructions enclosing excavation pits.

In the engineering-geological section of the territory, 34 engineering-geological elements were identified. Soils are heterogeneous in terms of their lithological composition, genesis, textural and structural features and nomenclature. Soils significantly differ in their properties and mode of occurrence. Soil depth changes rapidly, soil lensing can be often observed (Fig. 1).

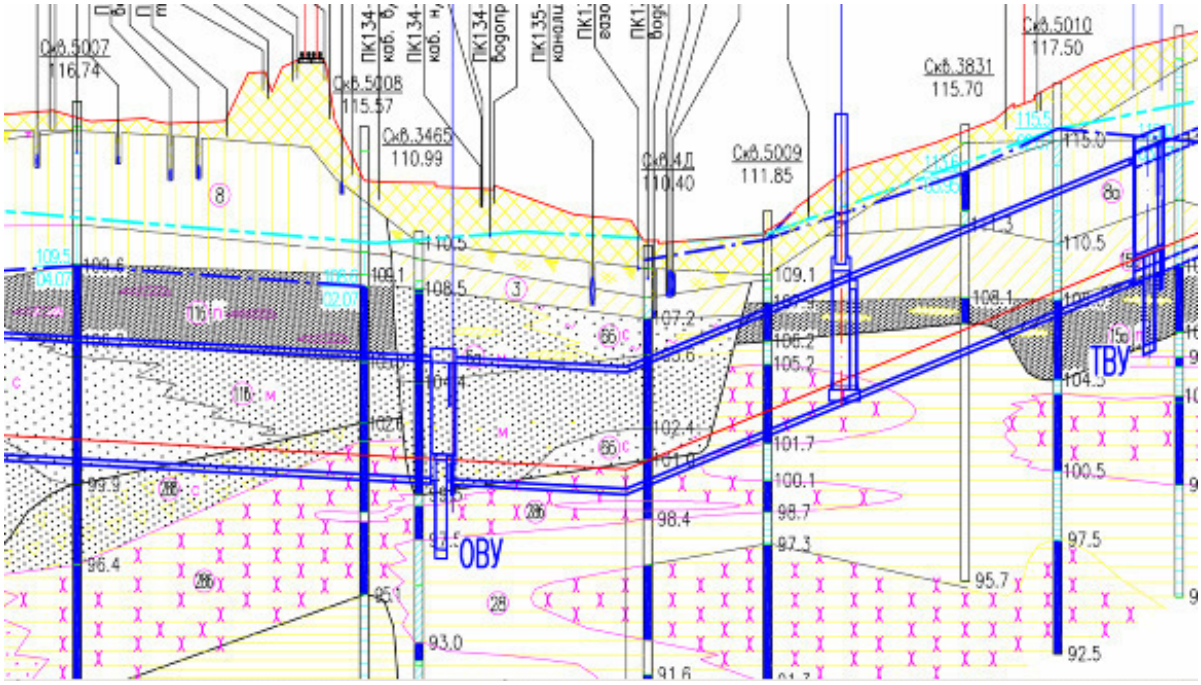

Figure 1 – The most complex section where the tunnels are crossing Hlybokii Yar ravine

Within the studied depth, there are two aquifers in impaired mode with low water pressure and possibility of negative geological and hydrogeological processes development, both in construction period and during operation. In accordance with DBN A.2.1-1-2014, ground conditions relate to the highest category of difficulty III a.

One of the major resonance factors in the area where tunnels are crossing Hlybokii Yar ravine is a high groundwater level (0.5 m beneath the ground surface), which means that tunneling under this level requires taking a number of special measures. Such measures include: construction dewatering, which provides possibility of constructing auxiliary tunnel facilities using cut-and-cover method; installation of a culvert or drainage system to prevent barrage effect and flooding of the upstream buildings.

Complex geotechnical conditions are connected with the fact that the subway route passes through several geomorphological elements having complex geological structure (three Lopan River terraces), crosses Hlybokii Yar ravine and filled up Sychevskii gully.

Complex construction conditions are connected with wide spreading of watered, semi-stable and unstable soils, as well as subsiding soil in some areas, presence of operated railway tracks and numerous utility lines. As tunnels are near to waterproof ground determined use of a powered tunneling aggregate for tunneling.

The radius dewatering system influence and possibility of dehydration and gravitation processes development under the footing of existing buildings and structures were not considered in the project of construction dewatering. In addition, the presence of dusty sands watered lenses makes tunnel flooding risk during construction works and by installation of excavation pits slops. Thus, in the presence of such lenses it is necessary to thicken a network of water-dropping wells or wellpoints. To exclude the negative impact on the environment due to the barrage effect of subway tunnels and stations, drainage is used in the flow of groundwater in the areas of embedding into the aquifer.

Vibration impact on soils during construction may cause thixotropic liquefaction of silty-clayed soils and fine sands and, correspondingly, flooding of excavation pits and tunnels with liquefied soils and sands. Due to possibility of the negative impact of vibration from underground trains passing closely to buildings and structures (Fig. 2), it is necessary to strictly comply with the normative remoteness of these objects or development and application of special protective measures.

In potentially flooded areas network of observation wells to control groundwater level should be equipped regardless of the construction work process. Organization of monitoring observations and analysis of their results allows to quickly assess impact of construction on the hydrogeological conditions.

In the area of tunneling using cut-and-cover method, reliability and safety of work is ensured by secure fixation of the pit walls. Installation of metal piles and filling in the space between the piles with wooden shields are most effective in this area under the condition of construction dewatering.

The issue of estimating seismic conditions is considered separately, because according to DBN B.1.1-12-2014 seismic intensity in the territory is estimated in 7 points. This evaluation requires special consideration, as the territory of Kharkiv is far from seismogenic areas. Formal application of regulatory requirements will lead to unwanted rise in construction costs.

Conclusions. Scientific and technical support the third subway line construction in Kharkiv contributed to identification and consideration of the following adverse processes and phenomena:

– barrage impact on groundwater flow in the area of tunneling using tunneling machines;

– threat to several buildings and structures in the areas where tunnels run close to the surface level (instability of the crown with regard to vibration impact);

– threat of soft thixotropic soils inrush into the tunnel face;

– soil conditions and intensification change of soil pressure on the enclosure structures of the excavation pits in the area of tunneling using cut-and-cover method.

a)

b)

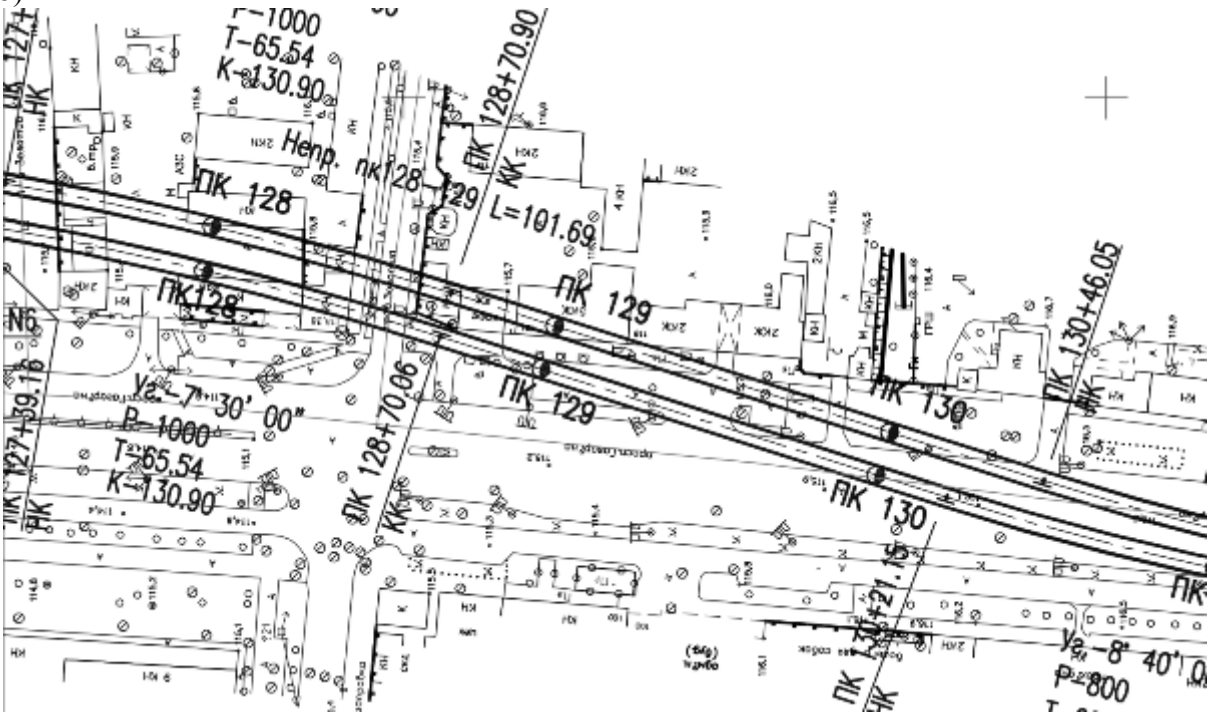

Figure 2 – A solid five-story building located directly above the tunnel been designed:
a – a photo (January 2017); b – a design plan of the tunnels

Considering the problems of subways construction in complex engineering and geological conditions, it should be noted that almost any construction in a large city requires solving many engineering, environmental and economic problems. To find solution of such problems it is necessary to involve leading scientific organizations and specialized departments of higher educational institutions. It is not within the framework of traditional tender procedures and requires special legislative regulation.

Unfortunately, it should be noted that the tendency to minimize costs for the complex of construction works (e.g. call for bids) contributes to quality reduction. As a result, small savings can lead to multimillion losses or emergency situations.

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