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Building drainage in dense urban areas

This article analyzes the specific challenges of constructing underground structures under complex hydrogeological conditions in densely built-up urban environments. The construction of pile foundations, tunnels, utility networks, and underground parking areas often obstructs natural groundwater flow, leading to localized flooding. The underground space of a modern city is saturated with water-bearing utility lines prone to unpredictable leaks. In such cases, it is essential to preserve the existing hydrogeological regime and prevent additional structural deformations of adjacent buildings. Therefore, the regulatory framework for the protection of underground structures must be improved in accordance with contemporary engineering standards.

Keywords: hydrogeological conditions, groundwater level, construction dewatering, filtration coefficient, needle filters.

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Introduction

The construction of underground structures (parking lots, bomb shelters, foundations, retaining structures) and utility networks (water, storm water, sewerage, power supply networks, etc.) requires additional measures to protect them from groundwater impact during their construction and operation.

In such cases, hydrogeological conditions and soil filtration properties play a significant role (often a decisive one). New construction sites are often located in dense urban areas. All these factors should be taken into account when designing and performing construction work, as well as during operation.

Review of the latest research sources and publications

Numerous regulatory documents and scientific studies [1÷6] address the issue of groundwater impact on underground structures. It is usually emphasized that during the construction period, various construction dewatering techniques must be applied, and during the operation period, drainage and waterproofing should be installed.

Definition of unsolved aspects of the problem

A wide range of factors and initial data should be taken into account for the qualitative selection of a dewatering method for the construction period. First and foremost, these are the engineering, geological and hydrogeological conditions of the site, the design of underground structures, the possibility of discharging water pumped out during dewatering beyond the site, and the possibility of locating dewatering equipment within the site.

Problem statement

The aim of this study is to investigate methods for protecting the underground portion of a new building from groundwater effects during the construction phase.

To achieve this goal, the following objectives have been defined: conducting engineering-geological and hydrogeological surveys of the site; identifying the filtration characteristics of the foundation soils; and performing calculations to determine the parameters of the dewatering system.

Basic material and results

The construction of underground parts of buildings and structures in difficult hydrogeological conditions requires additional and, therefore, complex and expensive work [5-6].

If the groundwater table is high, special measures should be taken to ensure safe conditions for the construction of underground structures and to prevent or reduce the impact on the surrounding area during such work.

This paper is based on the results of the design of a construction water drainage excavation pit for an administrative and production complex being built in the Podil district of Kyiv.

The site of the new building is located on the right bank of the Dnipro River, within the Eastern European Plain and is confined to the foot of the Kyiv Plateau slope in the historical Podil district of Kyiv. Kyiv. The site is located within the right-bank floodplain terrace of the Dnipro River. The territory of the project object is located in the central planning zone within the historical center of Kyiv. There are no objects of cultural heritage registered with the state among the surrounding buildings.

The site is located in a densely built-up area, which provides for the reconstruction and operation of the administrative and amenity complex in accordance with the requirements of DBN V.1.2-12-2008 [7].

The absolute elevation of 98.00 m, which corresponds to the level of the clean floor of the 1st floor, is taken as the conditional elevation of ±0.000 of the complex.

The foundations of the new building are made of ø620 mm diameter bored-injection piles. The length of the piles is 23 meters. The piles are united at the heads by a 900 mm thick reinforced concrete slab. The bottom of the excavation pit is located at -4.950 (absolute elevation 93.050 m) below the high-rise part. The retaining wall consists of bored-injection piles that are 7.65 to 10.35 m long and 420 mm in diameter, spaced 800 mm apart. Along the street, the excavation pit is excavated with a natural slope. Jet grouting piles are used for waterproofing the excavation perimeter.

According to DBN B.1.2-14-2018, the class of consequences for liability is CC3.

In geomorphological terms, the survey area is located within the right-bank floodplain of the Dnipro River, which was raised during economic development due to soil filling to absolute elevations of 96.56-98.32 m.

The geological section is composed of Holocene alluvial deposits, which are overlain by a thick man-made stratum from the surface (Fig. 1).

The following engineering geological elements (EGE) have been identified in the study area:

IHE-1 - Bulk soil - sandy loam with layers and lenses of dusty sand, with layers of loam, heterogeneous, sometimes with organic matter impurities in the base, from hard to plastic.

IGE-2 - Light, heavy, dusty loam, sometimes with an admixture of organic matter, soft-plastic.

IGE-2a - Light loam, dusty, slightly peaty, tightly laminated.

IGE-3 - Dusty and sandy loam, plastic.

IGE-3a - Sandy and sandy loam, medium peaty, sometimes strongly peaty, plastic.

IGE-4 - Fine, dense sand with medium density layers, saturated with water.

IGE-4a - Fine sand, medium density, with dense layers, saturated with water.

IGE-5 - Sand of medium size, dense, with separate layers of medium density, saturated with water.

IGE-6 - Light, heavy, dusty, tightly laminated loam.

IGE-7 - Fine, dense sand with some thin layers of medium density, saturated with water.

The hydrogeological conditions of the site are characterized by the presence of a Quaternary unconfined aquifer. Alluvial soils serve as water-bearing rocks. The groundwater mirror is recorded in the alluvial soils at the depths of 2.7...5.3 m at the absolute levels of 92.87...93.69 m. The aquifer is recharged by infiltration of precipitation, surface and groundwater runoff, leakage from water supply networks and hydraulic connection with the Dnipro River. The aquifer is discharged into the Dnipro River and the city's sewer system.

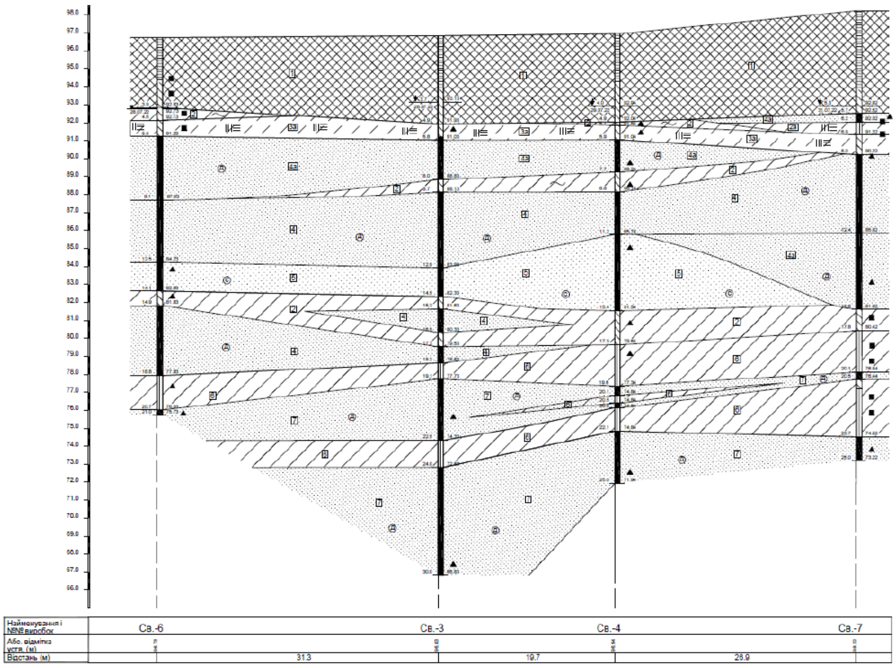

Figure. 1 - Characteristic geological section in the study area

During periods of seasonal heavy rains and snowmelt, the water table may rise, which is facilitated by the heterogeneity of the cut.

The projected rise in groundwater levels is related to the level regime of the Dnipro River. During spring floods, the estimated absolute water level in the Dnipro River is 96.7 m at the 1% flood (once every 100 years); 96.3 m at the 2% flood (once every 50 years); and 93.2 m at the 10% flood (once every 10 years). The maximum levels in the river persist on average for up to 2 weeks (sometimes more), during which the groundwater can become confined.

According to DBN V.1.1-25-2009 [1], the site is classified as naturally flooded.

The groundwater level within the survey area is not stable, which may indicate that the bulk soil has a heterogeneous composition and that there are periodic leaks from the water supply networks.

During excavation, the excavation pit will be flooded. To ensure normal conditions for zero-cycle operations during the construction period, it was decided to perform construction dewatering using needle filters.

Given the size of the excavation pit, it is possible to dewater it simultaneously or by dividing it into two excavations. In the project, water dewatering is performed from the entire area of the excavation pit.

Excavation works are carried out to develop the excavation pit to the -3.950 elevation (absolute elevation 94.050 m). After that, piles are drilled and water lowering equipment is installed.

Water lowering can be performed at one time from the entire area of the excavation pit or in two times (in 2 excavation zones). Dewatering is also performed at the site of the tower crane installation.

When performing dewatering, needle filters are installed in the excavation pit at a distance of 1.0 m from the retaining wall along its perimeter. For more efficient operation of the dewatering system, an additional branch of needle filters is installed in the central part of the excavation pit (Fig. 2). After excavating the pit to the -3.950 elevation (abscissa 94.050 m), needle filters are installed and a collector with needle filter connection is mounted.

A dewatering system is installed at the site of the tower crane. The excavation is carried out to the -3.550 elevation (absolute elevation 94.450 m). Needle filters are installed and a collector with needle filter connection is mounted.

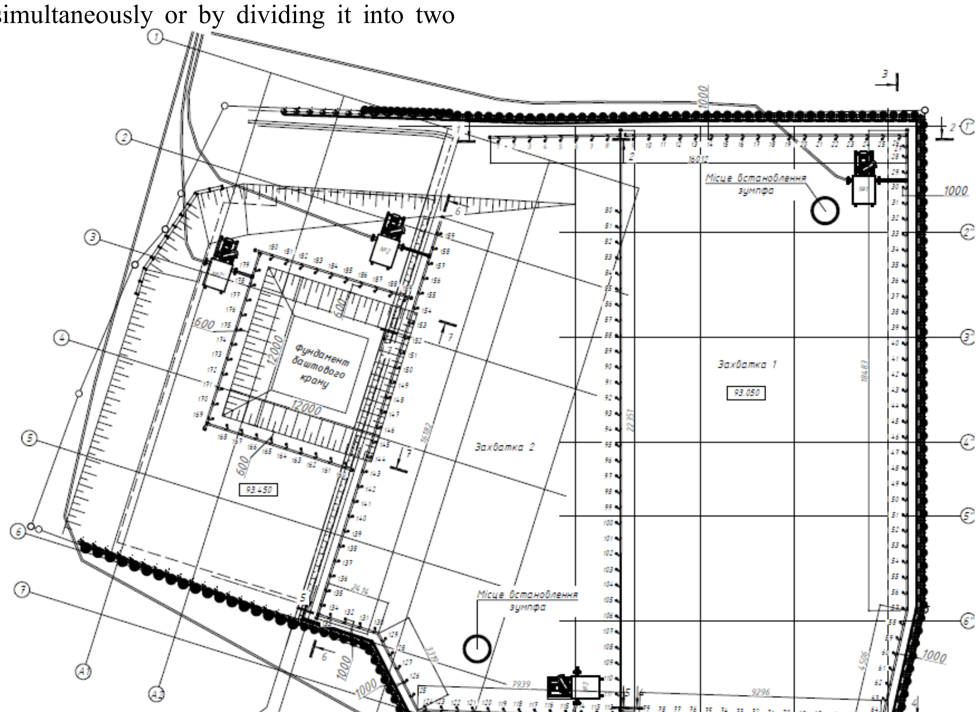

Figure 2 - Layout of needle filters in the excavation pit

After installation of the dewatering system, an as-built diagram of the actual arrangement of the system and its quantitative composition should be made.

The layout of dewatering systems may vary depending on the situation at the construction site.

Before starting construction dewatering, remove the soil to the level of the needle filters. This elevation should be at least 0.5 meters above the groundwater level. The temporary water supply system is laid out, coarse sand is brought in, temporary power supply is installed, and other preparatory work is carried out.

The dewatering procedure can be adjusted during construction and dewatering works.

After the water lowering system is launched, the second stage of excavation is carried out up to the bottom of the excavation pit.

Pumping units of the UVV-3A-6KM type are used for dewatering. Their number is determined by the results of calculations, and their installation locations are determined during their construction.

The collectors are fixed on supports or directly installed on the ground.

Install the needle filters with polymer sleeves Ø160 mm PVC160 SN4 to allow for concreting the foundation slab; after dismantling the needle filters, the holes should be concreted with concrete of the design class.

When arranging a suction collector with a diameter of 133 mm, it should be fixed to the structures of the retaining wall along the perimeter of the excavation pit.

Due to the fact that the groundwater level is on average ≈0.35 m above the bottom of the excavation pit, the water level should be lowered by 1.35...1.50 m. When determining the depth of lowering, it should be understood that the depth of lowering may vary, as the water level may change during the work, but these changes are not predictable, as they depend on many factors (time of work on the excavation sections, actual time of zero cycle work, the possibility of performing water lowering simultaneously or alternately, time of year, rainfall, etc.) The depth of groundwater lowering is determined if it is possible to achieve normal working conditions in the excavation pit, the depth of the minimum water lowering is ≥1.0 m below the bottom of the excavation pit.

The filtration coefficient of sand below the groundwater table was assumed to be 7.0 m/day in accordance with the data of engineering and geological surveys. The filtration coefficient of loam and sandy loam overlying the sand was assumed to be 0.5 m/day.

Dewatering is performed using a system of needle filters made of thin metal pipes that are immersed around the excavation pit. The lower ends of the pipes are equipped with filters, and the upper ends are connected to a suction manifold. The project envisages vacuum water lowering of the groundwater level using UVV-3A-6KM pumping units.

If the distance between the wells is less than two drawdown radii, then such wells interact when pumping water simultaneously. This leads to the closure of the drawdown curves and the formation of a common zone of groundwater level decline.

The UVV-3A-6-KM units are used for dewatering sandy soils and loams in various geological structures. The set includes needle filters (up to 100 pcs.), a water collector with a diameter of 133 mm and two centrifugal pumps, one of which is a backup, to ensure the uninterrupted operation of the plant.

The needle filter is a 38 mm diameter pipe, up to 8.5 m long (Fig. 3, 4), to the lower end of which is attached a filter link consisting of two pipes: an inner pipe, which is a continuation of the common 38 mm diameter pipe, and an outer pipe with a diameter of 60 mm with evenly distributed holes for water passage. The outer pipe is wrapped with 3 mm diameter wire and covered with filter and protective mesh. The filter link ends with a tip, inside which there are ball and ring valves.

The needle filters are submerged into the soil by hydraulic means.

Needle filters are installed along the perimeter of the dewatering excavation pit according to the set of working drawings.

Upon completion of the dewatering, all equipment is dismantled, and the dewatering wells are abandoned. Depending on the hydrogeological conditions, depth and location in relation to the nearest structures, abandonment grouting is performed in almost all rocks, except for loose and quicksand.

Figure 3. Needle filter designs
1 - tubular frame with slot perforation; 2 - lining longitudinal rods; 3 - water-receiving surface made of wire winding; 4 - lining spiral winding; 5 - water-receiving surface made of stainless mesh; 6 - water-receiving surface made of stamped sheet with holes.

Dewatering calculations are performed to determine the total flow rate (Q is the flow rate diverted from the site), the radii of influence of the adopted systems, and the actual decrease in groundwater levels, as well as to the selection (refinement) of the most effective measures of technological schemes of dewatering [8]. When determining the amount of groundwater inflow to the excavation pit, two groups of pits are distinguished: trenches and rectangular pits (width to length ratio 1 : 10); wide pits of square, rectangular, round and other shapes (width to length ratio more than 1 : 10). In this case, the pits that cannot be extended in length lead to an idealized equivalent circular area with radius r_0.

To calculate the dewatering, the natural conditions and the adopted dewatering system are schematized.

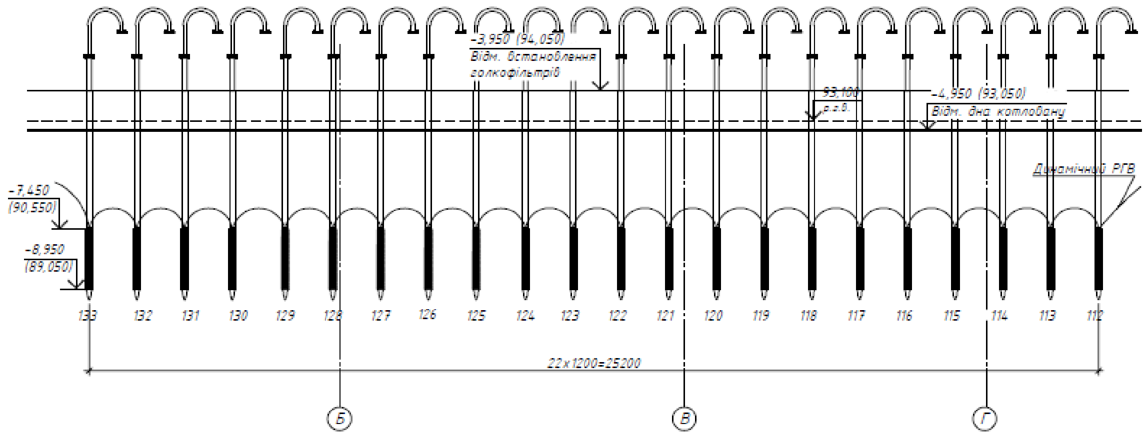

Figure 4. Cross section of the dewatering system

The general procedure for calculating a dewatering system is as follows:

- the necessary reduction in groundwater level is determined;
- the inflow to the dewatering system is determined;
- the parameters of the dewatering system are determined;
- selection of the necessary equipment.

According to the results of the calculations, it was found that when performing dewatering simultaneously over the entire area of the excavation pit, needle filters within the excavation pit are installed at elevation 94.050 m. The total length of the needle filters is 5.0 m. The dewatering area (pit) is serviced by three vacuum pumping units UVV-3A-6KM. Two sumps are installed in the excavation pit to collect and discharge surface water entering the pit.

According to the results of the calculations, the total groundwater extraction rate during dewatering over the entire area of the excavation pit will be:

949 m^3/day = 39.5 m^3/hour.

The drawdown curve is formed within 5 days. The radius of the drawdown curve is 120 m.

For the site where the crane is installed, it was obtained that the needle filters are made from the elevation of 94.450 m. The total length of the needle filters is 7.0 m. The dewatering section is serviced by 1 vacuum unit UVV-3A-6KM, which also serves as a backup for dewatering in the excavation pit.

According to the results of the calculations, it was obtained that the total water consumption during dewatering in the area where the crane is located will be 230 m^3/day = 10.5 m^3/hour. The formation of the drawdown curve occurs within 5 days. The radius of the drawdown curve is 120 m.

The total number of needle filters is 189.

The number of needle filters, their installation locations and length, and the location of the UVV-3A-6KM units are specified during the work.

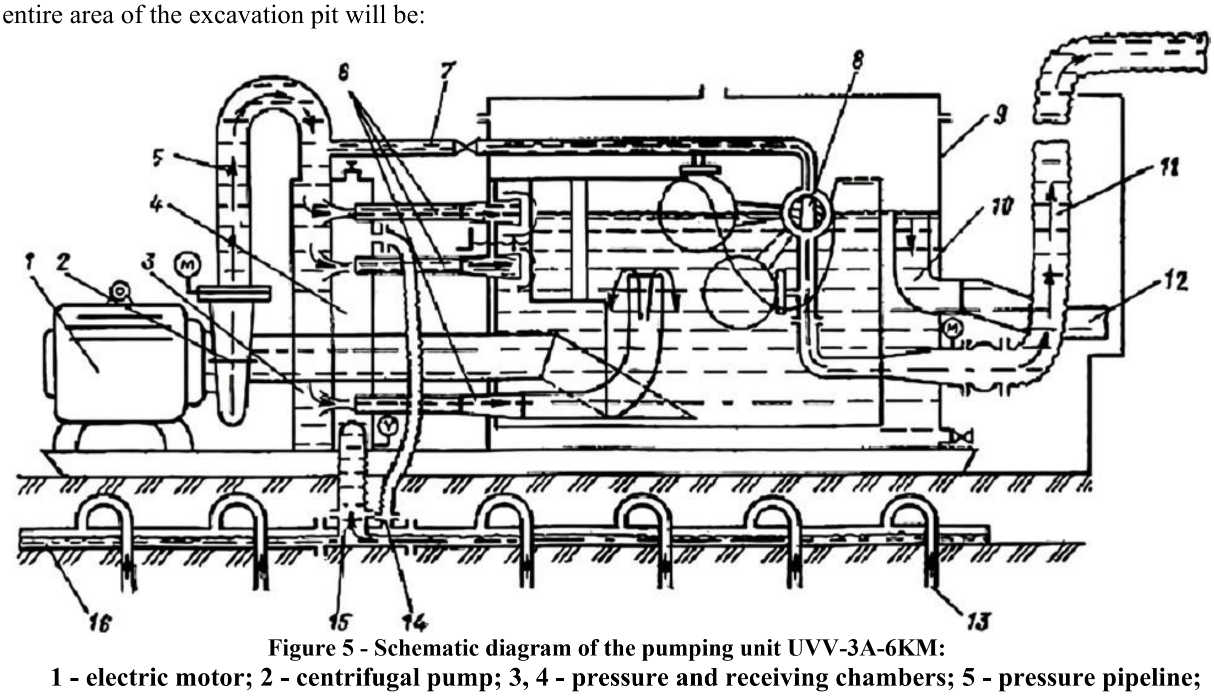

Figure 5 - Schematic diagram of the pumping unit UVV-3A-6KM:

1 - electric motor; 2 - centrifugal pump; 3, 4 - pressure and receiving chambers; 5 - pressure pipeline; 6 - ejectors; 7 - discharge pressure line; 8 - control valve with float; 9 - circulation tank; 10 - drain riser; 11 - discharge pressure pipeline; 12 - free drain line; 13 - needle filter; 14, 15 - air and water transition hoses; 16 - suction manifold.

In pumping units of the UVV-3 type (Fig. 5), two water-air ejectors are used to reproduce a stable vacuum in the cavities of the suction manifold and needle filters, which pump out the air released from the water-air mixture that enters the needle filters. With limited air flow to the water intake part of the needle filters, a vacuum of about 5 m Hg or more develops in their cavities. Water is pumped out by a water-water ejector. All three ejectors, which are part of the same module, are supplied with working water from a centrifugal pump. With a significant content of one of the components (water or air) in the water-air mixture, each of the ejectors is able to partially take over the functions of the other.

The unit ensures the lifting of water that is pumped to a height of up to 20.0 m. When protecting excavation pits, the unit is placed in a ring pattern.

During the excavation of the excavation pit and the installation of underground structures, dewatering was performed using needle filters, which ensured the necessary and safe conditions for construction work, confirming the correctness of the technical solutions adopted in the dewatering project.

Conclusions

The implementation of construction dewatering using needle filters under complex geotechnical and hydrogeological conditions ensures safe working conditions for excavation, provided current regulatory requirements are met.

The rational location of dewatering equipment ensures that optimal conditions are achieved for construction work. The construction conditions for each facility should be taken into account.

Considering the existing hydrological situation and substantiating the methods of protection of excavation pits with appropriate calculations and in compliance with the relevant requirements of regulatory documents at a high level of groundwater, effective methods of protection of construction sites can be developed for the construction of underground structures during the construction period.

At present, the performance of excavation protection works is regulated by regulatory documents developed in the USSR, so it is necessary to update the regulatory documents in this part to meet modern requirements.

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Будівельне водозниження в умовах щільної міської забудови

Проаналізовано особливості будівництва заглиблених конструкцій та споруд в складних гідрогеологічних умовах та в щільній забудові. Урбанізовані території є прикладом потужного і незбалансованого впливу на геологічне середовище техногенних факторів, які порушують гідрогеологічні та геоекологічні умови території. Спорудження фундаментів на палях, тунелів, інженерних мереж, а також підземних паркінгів в більшості випадків призводить до баражування потоку ґрунтових вод, та як наслідок, до підтоплення території. Підземний простір сучасного міста насичений водонесучими комунікаціями, які мають непередбачувані витоки. Витоки вод з комунікацій викликають значний підйом рівнів ґрунтових вод верхнього водоносного горизонту, які мають випадковий характер і важко піддаються прогнозуванню. В таких випадках основною вимогою є збереження, по можливості, існуючого гідрогеологічного режиму та недопущення виникнення додаткових деформацій споруд, що розташовані поруч. У разі необхідності виконання будівельного водозниження з ризиком значного зниження рівня ґрунтових вод період їх виконання повинен бути обґрунтованим та обмеженим в часі, при цьому повинні бути виконані умови для безпечного виконання робіт нульового циклу. Існують різні варіанти виконання захисту заглиблених споруд від негативного впливу ґрунтових вод. В статті розглянутий варіант виконання робіт з захисту заглиблених конструкцій за допомогою голкофільтрів. Такій варіант є найбільш доцільним при необхідності зниження рівня ґрунтових вод на 3...4 м. Як що слід понизити рівень ґрунтових вод нижче, можна виконати водозниження в декілька ярусів. На даний час виконання таких робіт не регламентується в повної мірі сучасними чинними в Україні нормативними документами. Використовуються норми, що були розроблені при СРСР, але на даний час вони є діючими в нашій країні. Тому необхідно вдосконалювати нормативну базу щодо захисту заглиблених споруд з урахуванням сучасних вимог.

Ключові слова: гідрогеологічні умови, рівень ґрунтових вод, будівельне водозниження, коефіцієнт фільтрації, голкофільтр.

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