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EXPERIENCE IN STRENGTHENING UNDERGROUND PEDESTRIAN CROSSINGS IN WATER-SATURATED CITY SOILS

Purpose: *to analyze the problem of subsidence of vertical and horizontal elements of underground pedestrian crossings in the conditions of the city of Kyiv (Intersection of Mineralna – Ukrainian streets) taking into account the water-logged structure of the soil. Find a modern solution to this problem using a scientific approach. Using the example of an underground pedestrian crossing, identify the most deformed areas in the elements of the joints of vertical and horizontal structures for further processing and drawing a conclusion for the elimination of similar ones in the future.*

Methodology: *in order to establish the reasons that caused the deformation of structures, to solve the task of engineering survey of the technical condition of their reinforced concrete structures with an instrumental survey of the actual strength, geometry and monitoring of uneven precipitation. Based on the results of field and chamber work, a complex of strengthening and restoration engineering and technical measures was developed and recommended to the customer for implementation, taking into account the requirements.*

Originality: *the article provides an example of the implementation of the construction of the foundations of underground pedestrian crossings erected on water-saturated soils in complex engineering and geological conditions using construction water subsidence, using technological methods, with the aim of excluding uneven deformations of foundation sediments above the zones of depression funnels from water subsidence or artificial foundations from vertical cement-soil reinforcing elements, the frontal part of which must be wrapped in reliable base soils.*

Findings and practical implications. *The sealing of horizontal and vertical technological and sedimentary-temperature seams in the construction of foundations, walls and the covering of underground structures should be carried out using modern types of hydraulic plugs that perceive the hydraulic pressure from underground water and exhibit the property of swelling when in contact with flooding water. Such technological solutions can be used in the construction of underground pedestrian crossings in the conditions of dense urban development, in the presence of significant possible vertical deformations in water-saturated soils.*

Keywords*: subsidence, sediment, crack, depression curve, mountain pressure, waterproofing, pile, cement-soil reinforcing element, monitoring.*

INTRODUCTION

In order to systematize and increase the capacity of the main above-ground and underground transport arteries of the city, as well as to create a safe and comfortable environment for its residents and guests, work on the active development of underground space has been carried out, and continues (metro, multi-level transport interchanges, underground pedestrian crossings, underground single and multi-level parking lots).

Actuality of theme. In our opinion, the overhaul, in terms of protecting the underground parts of buildings and structures from the adverse effects of the environment, would contribute to a significant reduction in the effect of corrosion. This is due, first of all, to the condition of the foundations and basements of buildings and structures. With the use of innovative materials and technologies in the fight against flooding of the underground parts of buildings and structures, the lack of the possibility of filtering ground and surface water, it would significantly increase the service life of buildings built even in the pre-war period, along with the overhaul of utilities and other building systems.

Problems in general and their connection with practical tasks. Known and previously used technologies for waterproofing the underground parts of the building, such as gluing, painting and coating with the use of bituminous mastics, do not meet the requirements of durability. Structures where such technologies are applied do not withstand more than 5–10 years of operation. After this time, due to the diffusion of groundwater, the destruction of foundations and underground parts of buildings and structures begins. New types and modifications of materials are being developed to protect the underground parts of buildings and structures from the action of water. Polymeric materials have high technical and operational characteristics, and are also more convenient in preparation. Properly performed work with the use of polymeric waterproofing materials will significantly increase the service life of structures, as well as reduce the cost of operating the structure.

Analysis of research and publications. The issues of improving technological processes both in construction, reconstruction, and overhaul were dealt with by scientists whose scientific works became the basis for the theoretical and methodological basis of this study: Mustakimenko V.R. M.I. Gorbunov-Posadov, V.A. Illichev, V.I. Krutov, Ninomiya, Y., Hagiwara, R., Azuma, T. Solving and others. were used as the basis for increasing the efficiency of the technology for installing waterproofing systems for the underground parts of buildings in dense urban areas during construction and repair and construction work, depending on various conditions.

The intensive construction of underground facilities contributes to the accumulation of practical experience in the design and construction of underground structures in the special engineering-geological and hydrogeological conditions of the capital of Ukraine, among which weak water-saturated soils should be noted [1].

Problem: Along with the positive experience of designing and building underground urbanization facilities on weak water-saturated soils, there are examples of geotechnical solutions, the practical implementation of which led to the formation of uneven deformations of the sediments of transition structures. There was a need to carry out strengthening and restoration measures. Therefore, in order to exclude technical and technological, and production errors, on the example of two newly constructed underground passages in Kyiv.

MAIN PART

Analysis of literary sources. Experience in the construction of underground pedestrian crossings by the open method in Kyiv.

Over the last period, many underground pedestrian crossings have been built in an open way in Kyiv, using two technological techniques, with the help of modern construction machines and mechanisms. The underground pedestrian crossings at the intersection of Mineral-Ukrainska Street and along Sviatohirska Street are erected once over the entire width of the road, and the construction of a box-walled reinforced concrete skeleton analog of the crossings at the intersection of Mineral-Ukrainska Street is erected with grabs, with the conditional division of the transition tunnel along the axis into two. queues under passageways first in one, and then in the opposite direction of traffic.

Underpasses already at the stage of their construction on weak water-saturated soils, with incorrect surface water reduction, acquired uneven, above-standard precipitation deformations. As a result, cracks of force origin were formed in the covering structures, walls, and bottom of the transition shaft.

Table 1- Properties of layers

№№ IGE	Naming of engineering and geological elements	Power of IGE, m	γ, kN/m3	φ, grad	c, kPa	E, MPa
IGE -1HC	Bulk sand with crushed stone to 40%	0,5-0,7	-	-	-	-
IGE -1A	Loose clay in a liquid state	1,2-1,5	-	-	-	-
IGE -2	Soft-flowing plastic loam	1,5-2,0	19,2	23	20,0	3,0
IGE -2A	Clay is flowable	3,5-4,0	18,2	16	22,0	3,0
IGE -3	Peat	2,5-3,0	12,4	18	14,0	0,4
IGE -6	Medium-grained, dense, water-saturated sand with loam lenses	2,5-3,0	19,4	36	0,0	33,0
IGE -6A	Sand Wed. size, average density, water-saturated loam with lenses	-	20,1	34	0,0	35,0

The goal. In order to establish the reasons that caused the deformation of the structures, the authors solved the task of engineering survey of the technical condition of their reinforced concrete structures with an instrumental survey of the actual strength, geometry and monitoring of uneven precipitation. Based on the results of field and chamber work, taking into account the requirements of DSTU-N B V.1.2-18:2016 [2], a complex of strengthening and restoration engineering and technical measures was developed and recommended to the customer for implementation [3, 4].

The proposed solutions have been implemented and the technical condition of underground structures is being monitored.Underground pedestrian crossing at the intersection of Mineralna-Ukrainska streets in Kyiv. The structure was erected in 2011 and is an underground pedestrian crossing, the spatial rigidity of which is ensured by a framework made of monolithic reinforced concrete.

The reinforced concrete box framework consists of a bottom, vertical walls and a cover plate (Fig. 1). The underground passage complex includes: a tunnel shaft, stairs with ramps, and technical maintenance rooms.

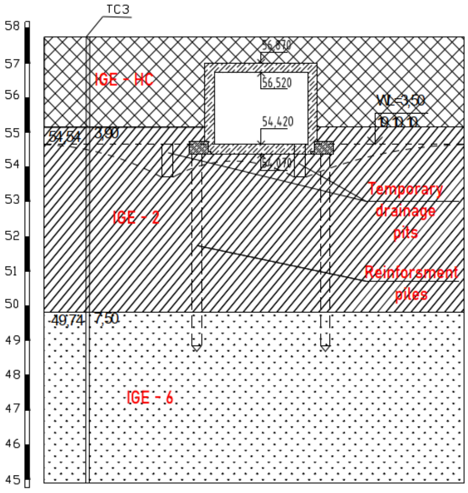
The long sections of the underground pedestrian crossing are divided into separate blocks of a simple geometric shape using the arrangement of deformation (sedimentary) seams. The thickness of the reinforced concrete bottom of the tunnel is 400 mm, the walls of the tunnel are 300 mm, the thickness of the coating is 350 mm. The height and width of the tunnel part of the transition are 2800 mm and 4500 mm, respectively. The stairs are made with a width of 3000 mm and steps with a height of 150 mm and a width of 300 mm.

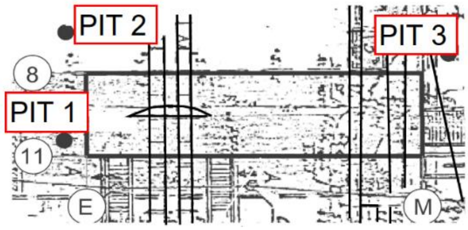
The building area is a wetland. Seven engineering and geological elements participate in the geological structure, from top to bottom, to a depth of 15.0-20.0 m (Table 1, Pic. 1, a).

The hydrogeological conditions of the construction site are characterized by the presence of two aquifers. The first aquifer is Verkhovodka and is exposed at depths of 0.9-1.4 m (56.14 - 56.60 m, BS). The second - which has a local onslaught, is exposed in the sands at depths of 7.4-10.8 m (46.75-50.14 m BS). The established level of groundwater is recorded at depths of 3.6-4.2 m (53.35-53.90 m BS).

In connection with the high level of underground water and the aggressiveness of the environment, construction water lowering of the pressure underground water level was carried out during the construction by the method of open drainage. For this, three sumps with a depth of 1.2 m below the sole of the tunnel bottom were provided on the construction site, along the trunk of the tunnel part, from which water pumps were used to regularly pump out pressurized water with discharge into the drainage system (Pic. 2).

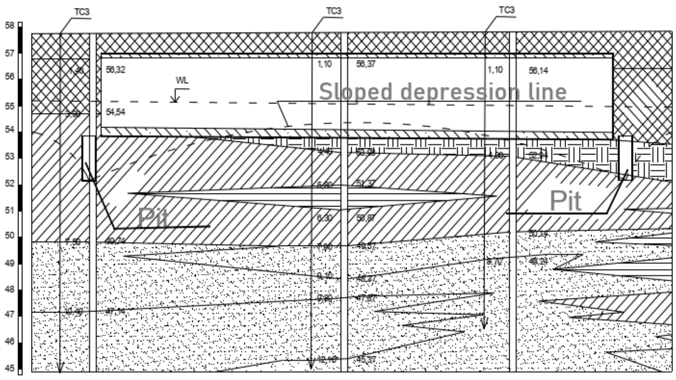
During the construction of an underground structure in an open way in water-saturated soils, along the entire perimeter of the pit, a sheet pile fence is made of steel pipes with a pointed lower end, hammered with the help of a pneumatic plunger (Pic. 3, 4, 5).





Picture 1(a) - Engineering and geological section ***Picture 2 - Plan with the location of sumps***

An instrumental engineering survey with an overview of the characteristics of reinforced concrete structures of the tunnel, using non-destructive testing methods, established that the concrete class is B22.5 (M300), frost resistance is F200, water resistance is W4, reinforcement is made with rods of reinforcement of class A-III and A-I.



Pictures 3,4 - Underground pedestrian crossing at the intersection of Mineralna – Ukrainianska streets in Kyiv, 3 - Longitudinal section along the transition with swamps and depression curve; 4 - A pit with walls fastened with a sheet pile

Pictures 5,6,7 - 5 – Trunk part of the transition; 6 - The heads of the elements of the submerged sheet pile and the frontal part, 7 - sumpf reinforcement piles with a water pump

Materials and research results. Instrumental studies established that the causes of cracks in the structures of the trunk part of the underground passage were uneven deformation of the massif of water-saturated soil in difficult engineering and geological conditions, with incorrect water lowering technology. Irregular precipitation deformations were recorded based on the results of instrumental geodetic observation in the mode of monitoring measurements of height marks of the structures of the elevated part of the tunnel.

According to the measurements, in comparison with the design marks, the uneven precipitation of the points of the bottom ranged from 32 mm to 419 mm, which is estimated as an unacceptable condition for the box-reinforced concrete structure of the tunnel part.

It was established that the main reason for the formation of cracks in the structures of the underground passage, the concentration of which is recorded in the walls and covering of the middle zone of the long tunnel of the box cross-section, is: uneven settlement of the slab bottom of the tunnel part of the passage, at the base of which are water-saturated soils with different degrees of compressibility within the con. foundation Uneven deformations of the subsidence of the extended tunnel structure are associated with the process of reducing the strength characteristics (angle of internal friction φ, specific adhesion c) and increasing deformability (decreasing the modulus of deformation E and increasing the subsidence s) of the base soils, caused by the incorrect application of the principle and technology of temporary construction water - sumps located at a considerable distance from each other at the ends of the tunnel being erected (Pic. 6, 7).

The formation of a depression curve between locally located sumps with an uneven lowering of the high level of groundwater along the tunnel trunk created a new stressed-deformed state within the soil massif located under the sole of the bottom.

At the same time, in the middle part, along the trunk of the tunnel, the level of groundwater decreased slightly, therefore the stress-strained state (SST) of the base soil changed due to precipitation as a result of overcoming the reactive pressure in the pore water "Pw" (neutral pressure-resistance), as well as in the soil skeleton "Pstr" (effective pressure-resistance), generally preserving the relative balance of the conditional static equilibrium between the external additional contact pressure "PI" and the sum Pw+Pstr (PI= Pw+Pstr), and therefore the sediment occurs without squeezing of water from soil pores, which corresponds to the classical theory [5,8,9]. In the end zones of the tunnel, where during construction, the level of groundwater was lowered by pumping it out of buried sumps located at a distance of 23.781 m from each other, the amount of measured precipitation "S" from the added additional pressure is much greater.

When water is reduced and the pores are freed from pore water, the value of the pore pressure becomes zero value Pw=0. Therefore, the entire value of external additional pressure "PI" from the tunnel structure is perceived only by the unstable structure of the soil, from the pores of which water is pumped out and squeezed. Therefore, the static equilibrium of the soil massif pressed by the external load "PI" of the soil is ensured only due to the reaction of the soil skeleton "Pstr".

To prevent progressive uneven deformation of the settlement of tunnel structures, including the trunk; one of the stairs; elevator, various options proposed by various organizations were considered.

At the request of the developer, the main criterion for all options should be the scheme of "transplantation" of the foundation slab on piles or supports. In this regard, the option of "transplantation" to reinforcement piles was considered, in which work was carried out from the inner cavity of the tunnel with the cutting of the bottom structure and violation of the integrity of the waterproofing, with all the consequences of its restoration in water-saturated soils with constant groundwater support.

When choosing the most acceptable in specific engineering-geological and hydrogeological conditions, the option of strengthening the base soil, the following factors are taken into account: the level of pressurized groundwater is located 1.5 m above the floor mark of the underground passage; preserving the integrity and tightness of the structure of the vertical and horizontal waterproofing of the tunnel trunk and stairs; the operation of the underground passage should be carried out with the regular switching on of the water pump for pumping out the underground water accumulated in the reinforced concrete pit. Now the deformations of uneven precipitation have stabilized.

CONCLUSIONS and prospects of further research:

1. Constructions of the foundations of underground pedestrian crossings erected on water-saturated foundations in difficult engineering and geological conditions with the use of construction water subsidence, according to technological captures, with the purpose of excluding uneven deformation sediments of the foundations above the zones of depression funnels from water subsidence, use cement-soil reinforcing elements, frontal the part that must be wrapped in the reliable foundations of the base.

2. The sealing of horizontal and vertical technological and sedimentary temperature seams in the structures of foundations, walls, and coverings of underground structures should be supported by modern types of hydraulic plugs that perceive the hydraulic pressure from groundwater and exhibit the property of swelling when in contact with flooding water.

The prospect of further research is: the collection of data based on this work and those already written by the author, for their further processing and bringing them to a common denominator to identify key problematic elements in urban underground structures and structures under the influence of various destructive factors. Compilation of the parametric base of the necessary algorithms for calculating the basic parameters of loads and calculation modules to unify and speed up the process of calculation and selection of materials, modules, types of structures

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ДОСВІД ПІДСИЛЕННЯ ПІДЗЕМНОГО ПІШОХОДНОГО ПЕРЕХОДУ У ВОДОНАСИЧЕНИХ ГРУНТАХ

Мета та завдання. *Мета проаналізувати проблематику осідання вертикальних та горизонтальних елементів підземних пішохідних переходів в умовах міста Києва (Перехрестя вулиць Мінеральна – Українська) з урахуванням обводненої структури грунту. Знайти сучасне рішення даної проблеми з використанням наукового підходу. Завдання: На прикладі підземного пішохідного переходу, виявити найдеформовані ділянки в елементах з'єднань вертикальних та горизонтальних конструкцій для подальшого опрацювання і винесення висновку для ліквідації подібних у майбутньому.*

З метою встановлення причин, що спричинили деформацію споруд, вирішення завдання з інженерного обстеження технічного стану їх залізобетонних конструкцій з інструментальним оглядом фактичної міцності, геометрії та моніторингового спостереження за нерівномірними опадами. За результатами проведених польових та камеральних робіт, з урахуванням вимог був розроблений комплекс підсилювально-відновлювальних інженерно-технічних заходів та рекомендований замовнику до реалізації.

Наукова новизна: *у статті наведено приклад реалізації конструкції фундаментів підземних пішохідних переходів, що зводяться на водонасичених ґрунтах у складних інженерно-геологічних умовах з використанням будівельного водозниження, за технологічними захватками, з метою виключення нерівномірних деформацій осад фундаментів над зонами депресійних воронок від водозниження або штучних основах з вертикальних цементогрунтових армоелементів, лобова частина яких повинна бути загорнута в надійні ґрунти основи.*

Висновки та практичне значення. *Герметизацію горизонтальних і вертикальних технологічних та осадово-температурних швів у конструкціях фундаментів, стін та покритті підземних споруд, доцільно виконувати із сучасних типів гідрошпонок, що сприймають гідравлічний напір від підземних вод та виявляють властивість набухання при контакті з водою підтоплення. Практичне значення: такі технологічні рішення, можна застосовувати при будівництві підземних пішохідних переходів в умовах щільної міської забудови, при наявності значних можливих вертикальних деформацій у водонасичених грунтах.*

Ключові слова: *водозниження, осаду, тріщина, депресійна крива, гірський тиск, гідроізоляція, паля, цементогрунтовий армоелемент, моніторинг.*