DOI: 10.18372/2415-8151.25.16790
UDK 699.85

URBAN-ASPECTS ASPECTS OF ORGANIZATION OF ENERGY-EFFICIENT UNDERGROUND SPACE FOR PROTECTION

Zhidkova Tetyana [1], Selikhova Yana [2], Kazachenko Vladislav [3]

[1] Candidate of Technical Sciences, Associate Professor of the Department of Urban Construction and Economy, O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine, e-mail: tavlz9794@gmail.com, orcid: 0000-0001-7903-7073
[2] PhD student, O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine, e-mail: selikhova.yana@ukr.net, orcid: 0000-0002-4435-65573
[3] PhD student, O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine, e-mail: kaza4enko.vlad@gmail.com, orcid: 0000-0002-9568-3136

Abstract: The war in Ukraine has shown a complete failure to protect civilians. The available bomb shelters are designed to stay for several hours or several days. At the same time, in the cities bordering the aggressor state, bombing and missile strikes hardly stop for weeks and months. People are forced to live in shelters, sleep on the floor in rooms unsuitable for long stays without electricity and water supply, sewerage, heating and internet.

This article is aimed at solving urgent, vital problems of protection of the civilian population by creating dual-use premises in the underground space of public buildings.

It is proposed to intensify the development of underground spaces, in particular, with the organization of storage facilities for temporary and long-term stay with the use of energy-efficient technologies that will provide people with the necessary resources during the escalation of aggression.

To achieve this goal, the following tasks are considered in the course of work: identification of the main ways of development of underground spaces, research of types of organization of storages of different purpose for temporary and long-term stay; disclosure of aspects of energy efficient technologies that will contribute to the energy saving use and provision of resources to residents for a comfortable stay in the underground space.

The Department of Urban Construction of the O.M. Beketov National University of Urban Economy in Kharkiv analyzed the underground space of Freedom Square and proposed the organization of a multifunctional shopping and entertainment center connected in the underground passage of subway stations, which will allow access to the complex without access to the ground. On the second floor from the ground should be located dual-use facilities — shopping, entertainment and sports centers, which can very quickly turn into modern bomb shelters.

Key words: war in Ukraine, energy efficiency, underground space, bomb shelters, dual — use buildings, town — planning documentation, dual — purpose premises.

INTRODUCTION

Ukraine has never been destined to avoid a potential threat from an aggressor state with a border length of more than 2,000 km and almost as much as Belarus, which is now an ally of Russia and provides its territories for bombing Ukraine. Therefore, the protection of civilians and urban livelihoods is an urgent task.

Today is another stage of Russian aggression aimed at the final destruction of Ukraine and Ukrainians. The aggressor systematically launches missile strikes on the territory of settlements of Ukraine. The number of civilian casualties, according to analysts, far exceeds the number of dead soldiers. The war in Ukraine showed a failure to provide civil protection. Even if there is shelter, their location does not allow them to be reached in time from the start of the alarm and the start of the shelling. The current legislation and building codes of engineering and technical measures of civil protection did not provide for the realities of war and were not able to provide reliable protection of the civilian population [1; 2]. It turned out that only the underground space is the most suitable for storing civil defense shelters during emergencies. Today, only those who have managed to get a place on the floor of metro stations have reliable protection in large cities.

ANALYSIS OF PREVIOUS RESEARCH

The organization of integrated use of underground space is the most pressing issue of modern urban planning. Prominent scientists of the world are increasingly focusing on and exploring the need to develop the underground space of cities as an integral part of urban planning documentation. The use of underground space in cities has a long history. In the past century, the underground space was used mainly as a defensive and religious buildings and shelter for residents of cities and towns. Underground galleries were used to communicate with the main elements of the environment during the attack of enemy tribes or the occupation of the territory, as well as to access underground water sources and pantries with food supplies.

In countries with difficult climatic conditions, living quarters in the underground space were protected from extreme cold or heat. The world capital of opals is the city of Coober Pedy, located in central South Australia, almost entirely underground. In this area for six months the daytime temperature is about 40 ° C. In the underground space due to the heat-protective properties of the soil layer maintains a temperature of about 24 ° C. Under the ground are living quarters, shops, bars and restaurants, hotels, religious buildings [3]. Energy efficient underground housing is traditional for some provinces of China [4; 5]. UNESCO World Heritage Sites are the Cape Pa Dokia Cave Settlements in Turkey, the Uplistsikhe Cave Fortress in Georgia, Chufut-Kale, Mangup, Eski-Kermen, Kachi-Kalon in the Crimea [6; 7].

Underground galleries have been found in almost all historic cities of Ukraine. Kharkiv has an extensive system of underground galleries created in different historical periods. Some of them are well preserved, but not used for a long time, others are tourist attractions [8; 9]. During World War II, the underground space of cities was a refuge from invaders.

The last large-scale construction of underground galleries and repositories, which is widely known, took place in the last century, when the leadership of the aggressor states built a shelter. The most famous of which are the numerous bunkers of Stalin and Hitler.

All these storages are equipped with all the necessary elements necessary for a long stay. At the same time for many people who had to be in the same room, on benches and bunks, providing alternate rest, shelters for the population were designed.

During the Cold War and the threat of a nuclear strike in the last century, bomb shelters were also built and equipped in many countries around the world, including the United States.

In the twentieth century, the greatest use of underground structures to protect the population in the event of an attack by the Soviet Union was recorded in China during the reign of Mao Zedong [10].

Since then, humanity has misunderstood that the threat of a great war has passed, the existing bomb shelters are no longer needed, the premises began to be used mainly as warehouses. Some, for example, in China, are used as cheap housing [11].

Only those bomb shelters that were intended as hiding places for state and municipal authorities have survived.

To date, we have accumulated vast experience in the construction of underground spaces under the central part of major cities around the world. Among them are the most famous underground cities of Montreal, Toronto, Amsterdam, Singapore.

The underground space houses industrial facilities that need protection from external influences or adversely affect the environment, transport facilities, engineering infrastructure, shopping and entertainment centers, trade and

© Жидкова Т. В., Селіхова Я. В., Казаченко В. А. Містобудівні аспекти організації енергоефективного підземного простору для захисту цивільного населення. *Теорія та практика дизайну*: *зб. наук. праць. Архітектура та будівництво*. К.: НАУ, 2022. Вип. 25. С. 140-148. doi: 10.18372/2415-8151.25.16790

catering enterprises, sports facilities, as well as special facilities. appointment.

The most widespread objects of transport infrastructure — pedestrian and transport tunnels, garages and parking lots, interchanges, underground sections of railways and more. It is the transport infrastructure that should connect the elements of the underground part of the city.

The development of the underground space of Montreal began in the 1960s. Today, a network of tunnels, corridors and underground areas connects residential and public buildings, hotels, offices, banks, universities and trade and catering establishments. The underground space provides protection from weather conditions during the long winter months. City residents may not go out in the open for a long time [12; 13].

The largest underground shopping complex in the world is in the city of Toronto. Its area is over 370 thousand m^2, and the total length of pedestrian streets connecting the six metro stations is over 30 km.

The AMFORA project envisages the construction of six underground multifunctional floors under the canals of the city of Amsterdam [14].

The organization of energy-efficient underground space is a direction in urban planning, which is now developing rapidly. A publication for civil engineers, urban planners, architects, and politicians entitled «Underground Spaces: Planning and Building the Cities of the Future» has recently appeared. The book explores the main factors that determine the future of our cities, collects recommendations for the organization and implementation of implemented projects for the development of underground space, which ensure the sustainability of urban structures [15; 16; 17; 18].

PURPOSE

Research of ways to develop energy-efficient underground space, organization of dual-use facilities for temporary and long-term stay of people during rocket attacks and bombings.

Based on the goal, it is necessary to solve the following tasks:

1. Identify the main ways of development of underground spaces.

2. Investigate the main types of organization of bomb shelters for temporary and long stay of people during missile strikes and bombings.

3. Develop recommendations for the use of energy efficient technologies in the design of underground space.

RESULTS AND DISCUSSIONS

Underground passages have traditionally been considered reliable bomb shelters; tunnels, underground warehouses, parking lots, garages, underground shopping centers, catering establishments, metro stations, basements, cellars and ground floors of civil and industrial facilities [2].

Basements, cellars and basements of civil and industrial facilities could not protect the population because they were not designed for the power of modern missiles. Today there are many examples of deaths from missiles.

Metro stations, underground parking lots of large shopping centers, as well as underground production facilities meet the requirements of public protection, but they are designed to accommodate people for no more than a few hours. In case of anxiety in cities, they almost do not stop for weeks and months, people are forced to live in shelters, sleep on the floor in the same room with the sick, pets, small children, etc. [19].

Underground commercial, entertainment and sports facilities have dual-use facilities that can be used as public bomb shelters for long stays provided there are quality ventilation systems, extra beds and drinking places.

Dual-use premises are separate shopping centers, fitness centers, children's rooms in shopping centers, etc. That is, those premises that can be quickly released from the equipment and install two-story folding beds. When designing such premises, additional pantries should be provided for storage of folding chairs, beds and bed linen in peacetime and equipment to be dismantled.

Dual-use premises should be in the municipality, and tenants are warned about their dual use during an exacerbation.

The location of double rooms within shopping and entertainment centers, which include catering establishments, pharmacies, grocery stores, as well as toilets and showers, will solve several issues related to long stays in storage.

The continuous underground space, consisting of enterprises and public facilities connected by transport and pedestrian routes, will allow to safely move residents to places of work, medical, household services, public catering, which will ensure the continuous functioning of the city during military aggression.

The development of multi-purpose underground space is appropriate primarily in large cities, as well as in cities and towns along the border with the aggressor state.

© Zhidkova T., Selikhova Y., Kazachenko V. (2022). Urban-aspects aspects of organization of energy-efficient underground space for protection. *Theory and practice of design. Architecture and construction.* 1(25). P. 140-148.
doi: 10.18372/2415-8151.25.16790

In large cities, where underground space is already used, it is necessary to expand its boundaries by including existing underground facilities and transport communications and the creation of commercial and entertainment sports and training facilities for dual purposes.

In cities and towns along the border with the aggressor state, houses in the city were destroyed after the dismantling and demining of new housing estates with gardens and parks located above the underground structures. All engineering and transport infrastructure, as well as household, shopping, entertainment and sports centers must be reliably protected not only by strong reinforced concrete structures, but also by a layer of soil.

Access to these facilities should be provided directly from residential and public buildings located on the ground.

The use of energy-efficient technologies to ensure the functioning of the underground space will help save energy and further the transition to green energy of people with the necessary resources during their stay in bomb shelters.

This approach will not only ensure civil protection of the population, but also significantly save traditional energy sources through the development of an alternative energy supply system. The use of energy-saving elements and the application of the principles of planning passive development on the earth's surface, geothermal energy of the earth, as well as the heat-protective properties of the earth layer will dramatically reduce the need for traditional energy sources and accelerate the full transition to green energy.

As part of the master's thesis at the Department of Urban Planning of the O. M. Beketov National University of Urban Economy in Kharkiv, an analysis of the underground space of Freedom Square on the organization of multifunctional space. Currently, two metro stations «Derzhprom» and «University» with underground crossings intersect under the square (Fig. 1).

Both stations are shallow. As a result of the analysis, it was found that construction is possible only above the Derzhprom station, as it is located at a height of 13.5 m above the ground.

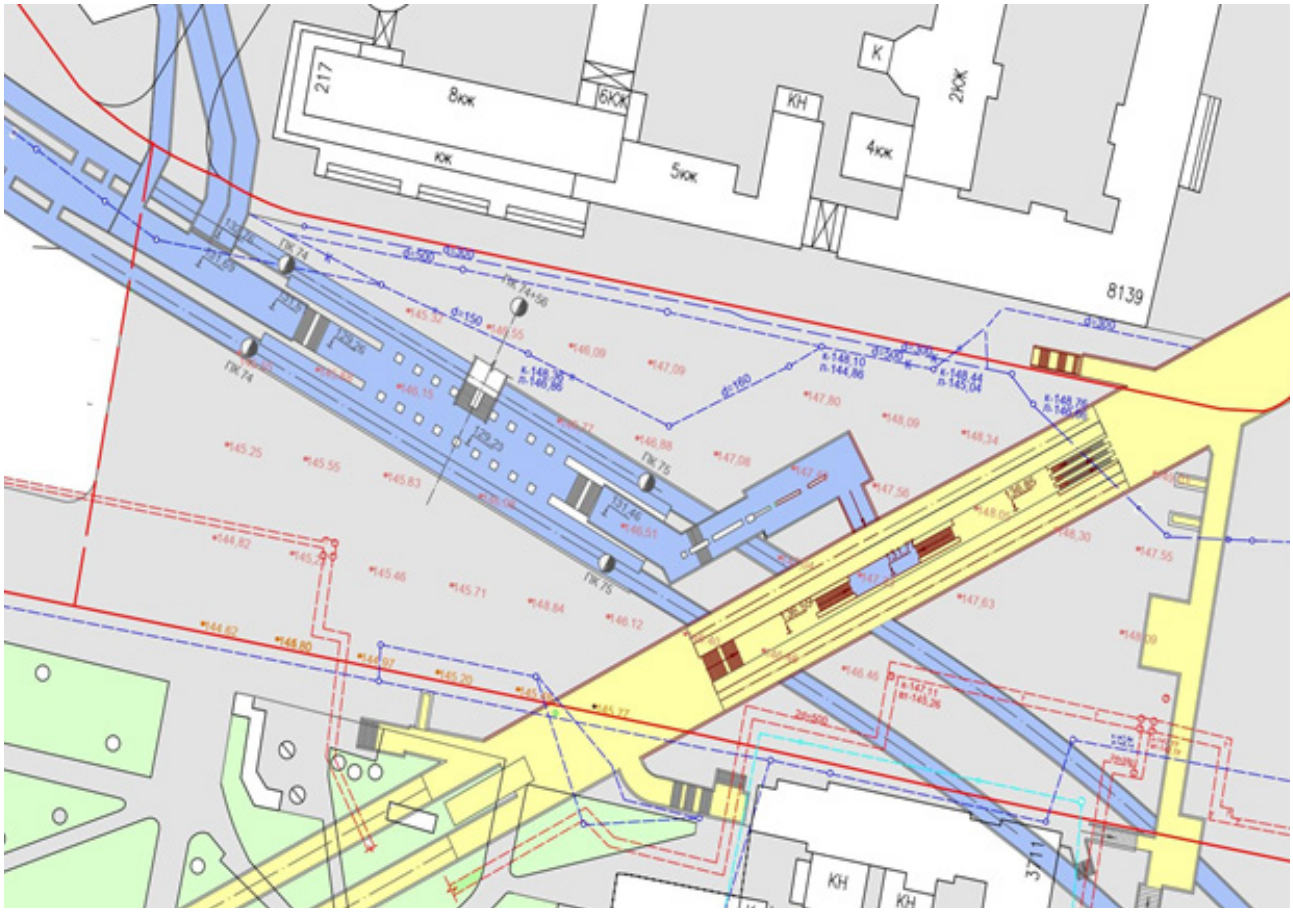

Fig. 1. Diagram of the intersection of metro stations in the underground space of Freedom Square

© Жидкова Т. В., Селіхова Я. В., Казаченко В. А. Містобудівні аспекти організації енергоефективного підземного простору для захисту цивільного населення. *Теорія та практика дизайну*: *зб. наук. праць. Архітектура та будівництво*. К.: НАУ, 2022. Вип. 25. С. 140-148. doi: 10.18372/2415-8151.25.16790

It is proposed to install an underground two-level multifunctional complex with parking on the lower level. There is a right lane under the entrances to the underground car park for the construction of a ramp.

The first underground level of the complex is used for public functions and includes a hall, catering establishments, shopping areas, bank branches, an exhibition hall, administrative premises. The first level of the complex belongs to the metro station «University», which will allow pedestrians to visit the complex without access to the ground (Fig. 2).

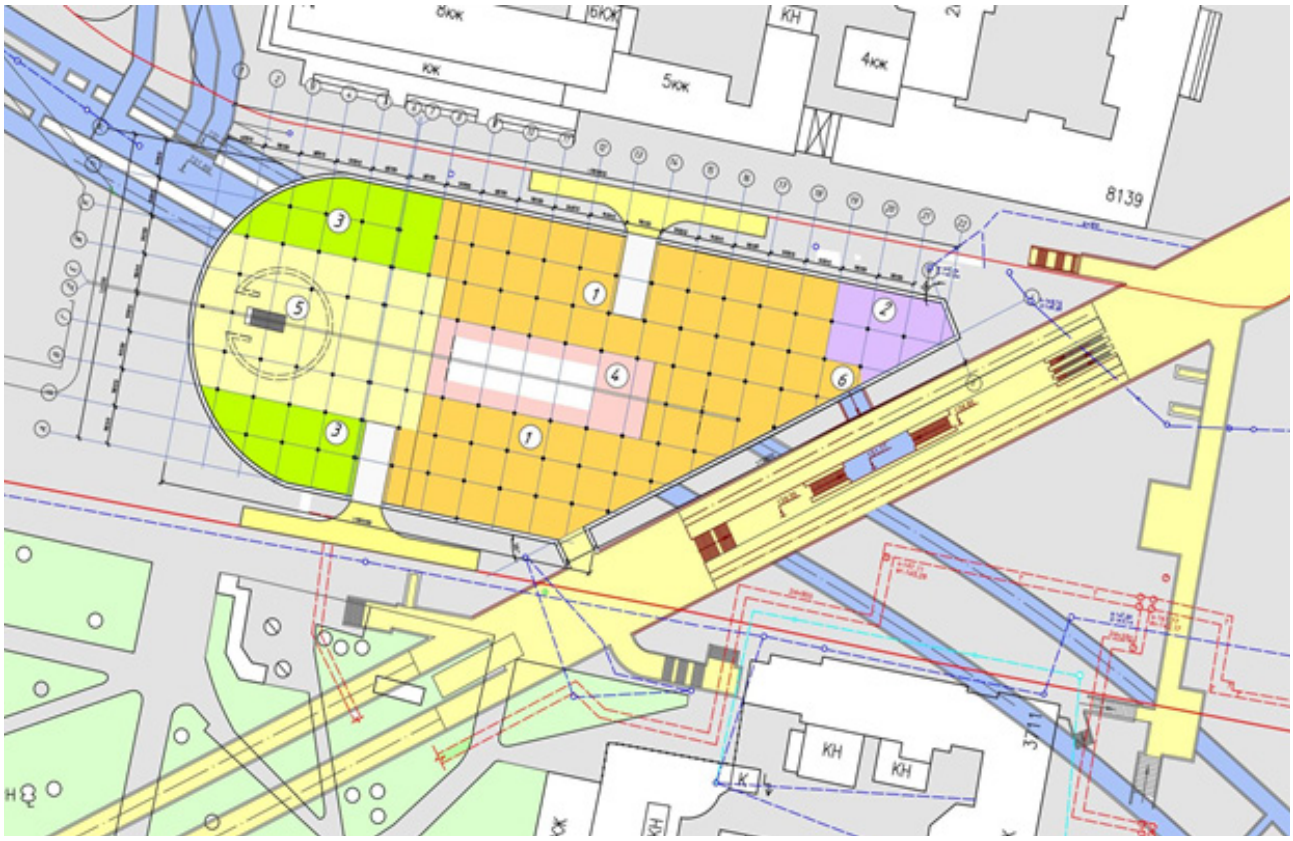

Fig. 2. Scheme of arrangement of the shopping complex in the underground space of Freedom Square: 1 - zone of trade and entertainment establishments; 2 - administrative and economic zone; 3 - Zone of public catering establishments; 4 - zone of sports and training institutions; 5 - Communications between floors of the building; 6 - connection with the metro station

Dual-use premises can be separate shopping centers, fitness centers, children's rooms in shopping malls, etc. That is, those rooms that can be quickly freed from the equipment and install bunk beds.

When designing such premises, additional pantries are provided for storage of folding chairs, beds and bed linen in peacetime and equipment used for the relevant function, and during the aggravation of the situation is subject to dismantling.

Dual-use premises must be in communal ownership, and tenants are warned about their dual use.

The location of double rooms within shopping and entertainment centers, which include catering establishments, pharmacies, grocery stores, as well as toilets and showers, will solve several issues related to long stays in storage.

The main criteria for selecting the area for further development of underground spaces should be natural resources, such as — relief, engineering and geological conditions, soils, vegetation, groundwater and surface water, climate, wind, insolation — the amount of solar radiation per square meter of surface, here also includes the level of able-do (the effect that occurs when sunlight hits the earth's surface, part of this solar radiation is reflected back into the atmosphere by clouds, the other is retained in the atmosphere by greenhouse gases and

© Zhidkova T., Selikhova Y., Kazachenko V. (2022). Urban-aspects aspects of organization of energy-efficient underground space for protection. *Theory and practice of design. Architecture and construction.* 1(25). P. 140-148. doi: 10.18372/2415-8151.25.16790

the rest -Rhnu [20]); lack of high surface water levels; geological characteristics of soils, for the possibility of implementing the necessary utilities and the use of alternative energy sources, one of which is geothermal heat pumps, climatic zones. The characteristics of these components affect urban planning processes, creating the preconditions for the location of such activities in such areas, which determine the conditions of development and affect the planning structure of settlement systems.

Underground premises can be built up with underground single buildings, which are located separately from each other, they can be the same or multi-story, have different purposes, use different methods of construction (one or more spans, frame or frameless). Most often, materials such as concrete, reinforced concrete or even compacted soils are used in the construction of such buildings, which differ depending on the geology of the site and the type of structure).

The selected materials must provide good waterproofing, durability, fire resistance and most importantly - withstand the load of the earth's surface. Underground construction and installation of underground facilities has several practical advantages, including energy efficiency, cost savings and reduction of natural resources, protection from cold winters and huge equipped and comfortable bomb shelters in case of aggression by the Russian Federation. Large-scale underground spaces in cities with large populations will receive more diverse functions of the underground space. Due to the limited urban geological conditions, geographical environment and technology of underground development, the development of urban underground space has also undergone appropriate changes. In addition, human psychological factors and the formation of urban underground space affect the viability of underground space, thereby influencing the development of urban underground space [21].

The social bomb shelter should consist of blocks of minimum comfort and contain barrack-type rooms with bunk beds, bathrooms and showers. Several such units are grouped near the unit with kitchen equipment, dining room and pantries for food storage.

In this unit, everyone in the bomb shelter can prepare food for themselves and their families according to their own needs. Inside the dining room it is possible to communicate with those who are in the bomb shelter, distance learning of children and more.

The main task in the development of underground space is to choose the optimal terrain and design solutions for buildings that will be located on the territory. Buildings should be designed to receive as much sunlight as possible in winter and retain heat through thermal insulation. First, you need to think about how to keep warm and not lose it due to ventilation, which should be in every room.

Various constructive solutions are used for energy saving of underground buildings, enclosing constructions taking into account climatic conditions, creation of new types of bio coatings, maintenance of thermal regulation through external coverings of buildings.

The following technological solutions are used in underground buildings, including passive solar heating systems, installation of solar panels on protruding roofs for hot water supply, geothermal heat pump systems, introduction of a double sewer system together with a roof water storage system, heat accumulator and storage system. basements, natural ventilation and cooling systems, additional daylight systems, introduction of wind turbines, use of bio accumulators for buildings.

CONCLUSIONS

The use of underground space for individual objects is one of the main tasks of urban planning. It is very important today that the underground space can provide effective protection for civilians and urban livelihoods. The development of multi-purpose underground space is appropriate primarily in large cities, as well as in cities and towns along the border with the aggressor state.

On the second floor from the first floor there should be dual-purpose premises as part of shopping, entertainment, and sports centers, which can very quickly turn into modern bomb shelters.

Access to these facilities should be provided directly from residential and public buildings located on the ground.

This approach will not only provide civil protection for the population, but also significantly save traditional energy sources.

© Жидкова Т. В., Селіхова Я. В., Казаченко В. А. Містобудівні аспекти організації енергоефективного підземного простору для захисту цивільного населення. *Теорія та практика дизайну*: *зб. наук. праць. Архітектура та будівництво*. К.: НАУ, 2022. Вип. 25. С. 140-148. doi: 10.18372/2415-8151.25.16790

ЛІТЕРАТУРА

[1] Кодекс цивільного захисту України. Документ 5403-VI, чинний, чинна редакція від 03.04.2022 р., основа - 2081-IX. URL:https://zakon.rada.gov.ua/laws/show/5403-17#Текст

[2] ДБН В.1.2-4: 2019 Інженерно-технічні заходи цивільного захисту (цивільної оборони) [Чинний з 01.08.2019]. – Київ, Мінрегіон. URL:https://dbn.co.ua/load/normativy/dbn/1-1-0-754

[3] Condello, A. 2018. Opal Entrepreneurship: Indigenous Integration of Sustainable Luxury в Кубер-Педі, в Gardetti, M. and Muthu, S. (reds), Sustainable Luxury, Entrepreneurship, and Innovation. Екологічний слід та еко-дизайн продуктів і процесів, стор. 131-146. URL: https://link.springer.com/chapter/10.1007/978-981-10-6716-7_7

[4] Li Zhang, Peng Lu, Raymond Lau, Lijie Yan, Xiang Li, Ruixia Yang, Ho Hon Leung, Panpan Chen & Xia Wang Unique traditional villages on the Loess Plateau of China: historic evolution and challenges to sustainable development of silo-caves Herit Sci 9, 118 (2021). https://doi.org/10.1186/s40494-021-00591-4

[5] Göreme National Park and the Rock Sites of Cappadocia (Turkey). URL:https://whc.unesco.org/en/documents/118157

[6] HanAdmiraalaAntoniaCornarob. Why underground space should be included in urban planning policy – And how this will enhance an urban underground future. Tunnelling and Underground Space Technology. Volume 55, May 2016, Pages 214-220 URL: https://www.sciencedirect.com/science/article/abs/pii/S0886779815302935

[7] Underground Earth-Sheltered Homes URL: https://www.energy.gov/energysaver/efficient-earth-sheltered-homes

[8] Укрінформ. Підземний Харків: 300 років історії під ногами. 2019. URL:https://www.ukrinform.ua/rubric-tourism/2812958-pidzemnij-harkiv-300-rokiv-istorii-pid-nogami.html

[9] How the US has prepared for nuclear Armageddon – in pictures. URL: https://www.theguardian.com/us-news/gallery/2018/jun/22/nuclear-armageddon-us-preparations-doomsday-war-in-pictures

[10] Inside China's huge underground city dubbed 'The Dungeon' URL: https://nypost.com/2020/08/05/inside-chinas-underground-doomsday-city-dubbed-the-dungeon/.

[11] Yingjuan Qiao Review on the Legal System Unban Underground Space in China: International Symposium for Intelligent Transportation and Smart City (ITASC) 2017 Proceedings pp 225–233. URL: https://link.springer.com/chapter/10.1007/978-981-10-3575-3_23

[12] Jacques Besner Cities Think Underground – Underground Space (also) for People/Urban Subsurface Planning and Management Week, SUB-URBAN 2017, 13-16 March 2017.Bucharest, Romania January 2017 Procedia Engineering 209:49-55 URL:https://www.researchgate.net/publication/3216_C6412 -Th

[13] Ahmed El-Geneidy, Lisa Kastelberger, Hatem T. Abdelhamid Montréal's Roots: Exploring the Growth of Montréal's Indoor City Journal of Transport and Land Use Vol. 4 № 2 (2011) p/33-46 URL:https://www.jtlu.org/index.php/jtlu/issue/view/10.

REFERENCES

[1] Code of Civil Protection of Ukraine. Document 5403-VI, current, current version from 03.04.2022, basis - 2081-IX. URL:https://zakon.rada.gov.ua/laws/show/5403-17#Text.

[2] DBN B.1.2-4: 2019 Engineering and technical measures of civil defense (civil defense) [Effective from 2019-08-01]. - Kyiv, Ministry of Regional Development. URL:https://dbn.co.ua/load/normativy/dbn/1-1-0-754.

[3] Condello, A. 2018. Opal Entrepreneurship: Indigenous Integration of Sustainable Luxury в Кубер-Педі, в Gardetti, M. and Muthu, S. (reds), Sustainable Luxury, Entrepreneurship, and Innovation. Екологічний слід та еко-дизайн продуктів і процесів, стор. 131-146. URL: https://link.springer.com/chapter/10.1007/978-981-10-6716-7_7

[4] Li Zhang, Peng Lu, Raymond Lau, Lijie Yan, Xiang Li, Ruixia Yang, Ho Hon Leung, Panpan Chen & Xia Wang Unique traditional villages on the Loess Plateau of China: historic evolution and challenges to sustainable development of silo-caves Herit Sci 9, 118 (2021). https://doi.org/10.1186/s40494-021-00591-4

[5] Göreme National Park and the Rock Sites of Cappadocia (Turkey). URL:https://whc.unesco.org/en/documents/118157

[6] HanAdmiraalaAntoniaCornarob. Why underground space should be included in urban planning policy – And how this will enhance an urban underground future. Tunnelling and Underground Space Technology Volume 55, May 2016, Pages 214-220 URL: https://www.sciencedirect.com/science/article/abs/pii/S0886779815302935

[7] Underground Earth-Sheltered Homes URL: https://www.energy.gov/energysaver/efficient-earth-sheltered-homes

[8] Укрінформ. Підземний Харків: 300 років історії під ногами. 2019. URL:https://www.ukrinform.ua/rubric-tourism/2812958-pidzemnij-harkiv-300-rokiv-istorii-pid-nogami.html

[9] How the US has prepared for nuclear Armageddon – in pictures. URL: https://www.theguardian.com/us-news/gallery/2018/jun/22/nuclear-armageddon-us-preparations-doomsday-war-in-pictures

[10] Inside China's huge underground city dubbed 'The Dungeon' URL: https://nypost.com/2020/08/05/inside-chinas-underground-doomsday-city-dubbed-the-dungeon/.

[11] Yingjuan Qiao Review on the Legal System Unban Underground Space in China: International Symposium for Intelligent Transportation and Smart City (ITASC) 2017 Proceedings pp 225–233. URL: https://link.springer.com/chapter/10.1007/978-981-10-3575-3_23

[12] Jacques Besner Cities Think Underground – Underground Space (also) for People/Urban Subsurface Planning and Management Week, SUB-URBAN 2017, 13-16 March 2017.Bucharest, Romania January 2017 Procedia Engineering 209:49-55 URL:https://www.researchgate.net/publication/3216_C6412 -Th

[13] Ahmed El-Geneidy, Lisa Kastelberger, Hatem T. Abdelhamid Montréal's Roots: Exploring the Growth of Montréal's Indoor City Journal of Transport and Land Use Vol. 4 № 2 (2011) p/33-46 URL:https://www.jtlu.org/index.php/jtlu/issue/view/10.

[14] AMFORA Amstel, Amsterdam URL:https://www.zja.nl/en/AMFORA-Amstel-Amsterdam.

[15] Fang-le Peng, Yong-Kang Qiao, Soheil Sabri, Behnam Atazadeh. A collaborative approach for urban underground space development toward sustainable development goals: Critical dimensions and future directions. Frontiers of Structural and Civil Engineering volume 15, pages20–45 (2021) URL:https://link.springer.com/article/10.1007/s11709-021-0716-x

[16] Wout Broere. Urban underground space: Solving the problems of today's cities/Tunnelling and Underground Space Technology Volume 55, May 2016, Pages 245-248 URL: https://www.sciencedirect.com/science/article/pii/S0886779815302923.

[17] Zhi Zhang; Jenny Paulsson; Jian Gong; Ji'E Juan. Legal Frame-work of Urban Underground Space in China. Sustainability 2020, 12, 8297. URL: https://www.mdpi.com/2071-1050/12/20/8297/htm.

[18] Han Admiraal, Antonia Cornaro. Underground Spaces Unveiled: Planning and Creating the Cities of the Future. Institution of Civil Engineers 2018. 284 Seiten 2018 Ice Publishing (Verlag) URL: https://doi.org/10.1680/usu.61453.plates

[19] Liz Cookman. Life Underground in Bomb-Shattered Kharkiv URL:https://foreignpolicy.com/2022/03/11/life-underground-kharkiv-ukraine-russia/.

[20] Xiaochun Hong and Xiang Ji. Spatial Pattern of Underground Space Development in Major Cities in China: Evaluation and Analysis/Mathematical Problems of Multi-Coupling Effect in Geological Engineering. Mathematical Problems in Engineering. 2021. URL: https://www.hindawi.com/journals/mpe/2021/2125776/

[14] AMFORA Amstel, Amsterdam URL:https://www.zja.nl/en/AMFORA-Amstel-Amsterdam.

[15] Fang-le Peng, Yong-Kang Qiao, Soheil Sabri, Behnam Atazadeh. A collaborative approach for urban underground space development toward sustainable development goals: Critical dimensions and future directions. Frontiers of Structural and Civil Engineering volume 15, pages20–45 (2021) URL:https://link.springer.com/article/10.1007/s11709-021-0716-x

[16] Wout Broere. Urban underground space: Solving the problems of today's cities/Tunnelling and Underground Space Technology Volume 55, May 2016, Pages 245-248 URL: https://www.sciencedirect.com/science/article/pii/S0886779815302923.

[17] Zhi Zhang; Jenny Paulsson; Jian Gong; Ji'E Juan. Legal Frame-work of Urban Underground Space in China. Sustainability 2020, 12, 8297. URL: https://www.mdpi.com/2071-1050/12/20/8297/htm.

[18] Han Admiraal, Antonia Cornaro. Underground Spaces Unveiled: Planning and Creating the Cities of the Future. Institution of Civil Engineers 2018. 284 Seiten 2018 Ice Publishing (Verlag) URL: https://doi.org/10.1680/usu.61453.plates

[19] Liz Cookman. Life Underground in Bomb-Shattered Kharkiv URL:https://foreignpolicy.com/2022/03/11/life-underground-kharkiv-ukraine-russia/.

[20] Xiaochun Hong and Xiang Ji. Spatial Pattern of Underground Space Development in Major Cities in China: Evaluation and Analysis/Mathematical Problems of Multi-Coupling Effect in Geological Engineering. Mathematical Problems in Engineering. 2021. URL: https://www.hindawi.com/journals/mpe/2021/2125776/

АНОТАЦІЯ

Жидкова Т. В., Селіхова Я. В., Казаченко В. А. Містобудівні аспекти організації енергоефективного підземного простору для захисту цивільного населення.

Війна в Україні показала повну неспроможність забезпечення захисту цивільного населення. Наявні бомбосховища розраховані на перебування протягом кількох годин або кількох діб. Водночас, в містах, що межують з державою-агресором, бомбардування й ракетні удари майже не припиняються протягом тижнів і місяців. Люди змушені жити в укриттях, спати на підлозі в приміщеннях непридатних для тривалого перебування без електро- та водопостачання, каналізації, опалення та інтернету.

Дана стаття спрямована на вирішення нагальних, життєво необхідних проблем захисту цивільного населення шляхом створення приміщень подвійного призначення в підземному просторі громадських будинків.

Пропонується інтенсифікувати освоєння підземних просторів, зокрема, з організацією сховищ для тимчасового та довгострокового перебування з використанням енергоефективних технологій, які забезпечать людей необхідними ресурсами під час загострення агресії.

Для досягнення поставленої мети, в ході роботи розглянуто такі задачі: виявлення основних способів освоєння підземних просторів, дослідження типів організації сховищ різного цільового призначення для тимчасового та довго-

© Жидкова Т. В., Селіхова Я. В., Казаченко В. А. Містобудівні аспекти організації енергоефективного підземного простору для захисту цивільного населення. *Теорія та практика дизайну*: *зб. наук. праць. Архітектура та будівництво*. К.: НАУ, 2022. Вип. 25. С. 140-148. doi: 10.18372/2415-8151.25.16790

строкового перебування; розкриття аспектів енергоефективних технологій, які сприятимуть енергоощадному використанню та забезпеченню ресурсами жителів для комфортного перебування в підземному просторі.

На кафедрі міського будівництва Харківського національного університету міського господарства імені О. М. Бекетова проведено аналіз підземного простору площі Свободи й запропонована організація багатофункціонального торговельно-розважального центру, пов'язаного в підземним переходом станцій метрополітену, що дозволить відвідувати комплекс без виходу на землю. На другому поверсі від землі мають бути розміщені приміщення подвійного призначення — торгово-розважальні та спортивні центрів, які дуже швидко можуть перетворитися на сучасні бомбосховища.

Ключові слова: війна в Україні, енергоефективність, підземний простір, бомбосховища, споруди подвійного призначення, містобудівна документація, приміщення подвійного призначення.

ВІДОМОСТІ ПРО АВТОРІВ

Жидкова Тетяна Володимирівна, *к. т. н., доцент доцент кафедри Міського будівництва та господарства ХНУМГ імені О. М. Бекетова, м. Харків, Україна, e-mail: tavlz9794@gmail.com, orcid: 0000-0001-7903-7073*

Селіхова Яна Вікторівна, *ХНУМГ ім. О. М. Бекетова, м. Харків, Україна, e-mail: selikhova.yana@ukr.net, orcid: 0000-0002-4435-6557*

Казаченко Владислав Андрійович, *ХНУМГ ім. О. М. Бекетова, м. Харків, Україна, e-mail: kaza4enko.vlad@gmail.com, orcid: 0000-0002-9568-3136*

Стаття подана до редакції 11.06.2022 р.
Стаття прийнята до друку 19.06.2022 р..