

2. Gil A. J., Bonet J. Finite element analysis of prestressed structural membranes. *Finite Elements in Analysis and Design*. 2006. Vol. 42, no. 8-9. P. 683–697. URL: <https://doi.org/10.1016/j.finel.2005.10.009>

RETROSPECTIVE ANALYSIS OF GLOBAL EXPERIENCE IN PROTECTING INFRASTRUCTURE FACILITIES

DMYTRO ELISEEV, PhD student

YURIY M. KRUL, Senior Lecturer, PhD in Engineering, Scientific Adviser

OLENA L. ILIENKO, Professor, Doctor of Science in Education, Language Adviser

O. M. Beketov National University of Urban Economy in Kharkiv

Energy security is a key factor for stable economic development and welfare of the state. The full-scale invasion of the Russian Federation into Ukraine in 2022 has been accompanied by significant threats to energy infrastructure facilities, primarily through the use of high-precision air attack weapons. Therefore, building an effective infrastructure protection system is an urgent task that requires a comprehensive approach, using the analysis and application of global experience for infrastructure protection.

The history of use of protective structures by humans spans several millennia. The development of underground space began in deep antiquity. In the period before the 4th millennium B.C., natural caves can be considered prototypes of underground protective structures, which were used by our ancestors as dwellings that protected them from bad weather and predators [1]. Beginning from the 4th millennium B.C., people started to conduct significant underground works. The most important types of underground construction at that time were the digging of tunnels, underground communication passages, canals, construction of water supply systems, and even underground cities.

The next phase in the evolution of underground protective structures is represented by the fortification construction of the medieval period, when the progress of armaments and the introduction of artillery systems, particularly cannons, necessitated the protection of strategic elements of fortification structures during siege operations (water sources, gunpowder depots, military premises, etc.), which led to their placement below ground level or behind massive multi-layered defensive walls. Fortifications and castle complexes performed an essential defensive function in the medieval era, resulting in their often containing developed systems of underground communications and engineering structures [1].

Mining workings and caves began to be actively used for military purposes (as protective structures) only in the 20th century due to the emergence and widespread use of bomber aviation in wars. At the same time, many underground industrial facilities (such as pumping and compressor stations, blast furnace pits, etc.) were constructed at shallow depths. Underground factories, which began to be built in the 1930s, are characterized by great depth of placement.

The fourth phase in the evolution of protective structures can be called the Cold War period [2]. After the development and deployment of weapons of mass destruction, numerous states implemented innovative protection strategies primarily for power generation complexes, as well as military-industrial facilities, public centers, etc. In particular, over 200 hydroelectric power plants and thousands of diesel generator units in Norway have underground locations. Similar protective measures were implemented in Switzerland, Sweden, partially in Canada and other countries. At the present stage, it is in Scandinavia where a significant number of underground infrastructure complexes operate that does not have a direct defensive purpose but are characterized by corresponding engineering protective properties.

Today, we can state the onset of the fifth stage in the development of engineering protection, the prerequisites for which are: the development of high-precision weapons; a significant increase in the speed characteristics of weapons; the need to consider selectivity regarding the targeting of objectives [2]. The modern concept of underground protection of infrastructure facilities began to form in the late 1990s - early 2000s. Underground structures have a number of inherent attributes that make them attractive options for physical protection. They provide increased protection against direct physical attacks, lower energy and maintenance costs, improved environmental control, and more efficient land use by preserving the above-ground environment. Underground structures also have some disadvantages compared to above-ground structures. These include: limited access points and potential hazards, especially from fire; initial costs for small underground structures may be higher than for above-ground ones [3]. Since the 1990s, underground and engineered-protected power plants have been built by Canada, India, Japan, China, South Korea, Germany, Great Britain, Israel, New Zealand, and some other countries.

Thus, the engineering protection of infrastructure facilities on a global scale is characterized by uneven development; it is based on a broad historical foundation, and is implemented primarily through the underground placement of facilities.

References:

1. D. Bryk, V. Narishkin, V. Pchelkin About Global Experience of Underground Mining and Caves as Protective Structures / Civil Security Technology, 2012
2. Koval M.V., Koval V.V., Bilyk A.S., Kotsiuruba V.I. and Kubrakov O.M. Fundamentals of Engineering Protection of Critical Infrastructure Facilities in the Energy Sector of Ukraine Against Means of Enemy Air Attack: Monograph (Kyiv: Lira-K Publishing House). 2023.
3. Linger D. A., Baker G.H., Little R.G. Applications of Underground Structures for the Physical Protection of Critical Infrastructure / North American Tunneling 2002. Ozdemir (ed.) © 2002.