

UDC 699.85:728.22]-027.521

Olena Filonenko

National University «Yuri Kondratyuk Poltava Polytechnic»
<https://orcid.org/0000-0001-8571-9089>

Dmytro Nikolaienko *

National University «Yuri Kondratyuk Poltava Polytechnic»
<https://orcid.org/0009-0002-9906-2078>

Design of civil defense protective structures in residential multi-story buildings for individual use

Abstract. The military actions in Ukraine, which daily create a threat to the civilian population, necessitate the development of new technical solutions for new construction and the reconstruction of existing buildings and structures. A large number of civilian casualties are residents of multi-story residential buildings. A typical protective shelter is considered to be a basement or cellar floor, the structural features of which are designed for utilities, pipelines, and technical equipment. They lack an emergency exit and proper ventilation, and do not provide for long-term stay with specific conditions in full compliance with the current regulatory requirements for the protection of the civilian population. As a result of the analysis of architectural and planning solutions, there is a need to improve premises where it is possible to integrate individual protective shelters, which are intended to provide proper protection in case of an emergency. The work examines the fundamental principles of approaches to designing individual protective shelters within the housing stock. The proposed recommendations can be used in designing new residential buildings, reconstructing existing buildings, and forming a system of individual protective shelters aimed at increasing the level of public safety in modern conditions.

Keywords: civil defense structures, protective premises, design of civil defense facilities, housing stock.

*Corresponding author E-mail: dmitriynikolayenko3185@gmail.com



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License. (<https://creativecommons.org/licenses/by-nc-sa/4.0/>)

Received: 23.09.2025

Accepted: 09.12.2025

Published: 26.12.2025

Introduction.

Emergencies against the backdrop of prolonged war highlight the problem of reliable design of civil defence structures within the housing stock. Residential multi-storey apartment buildings remain the most vulnerable to enemy strikes. This necessitates the development of new architectural and structural solutions that include a comprehensive approach to the creation of individual protective spaces. The purpose of such a room is not only to fit harmoniously into the architectural and planning composition of the designed building, but also, most importantly, to ensure the necessary level of comfort in accordance with the structural system on which the building will be constructed. A mandatory factor in the design of such a room is to ensure resistance to shock waves, debris, radiation, and to provide conditions for life support in autonomous operation for up to 2 days, as standardised by DBN V. 2.2-5 [1].

Experience of other countries.

Precautionary measures to protect civilians in emergencies were not only applied during military operations. They began to be implemented in the United States in the early 1990s in individual residential buildings, known as ‘safe rooms’, for coastal and central states as protection against natural hazards [2].

The main drawback of building ‘safe rooms’ in the United States is the lack of a unified, systematic quality control system, performance certification, and regulatory requirements for building design methodology (wall thickness, materials, area, ventilation, electricity, etc.). As a result, even a structure that formally “complies” with the recommendations may fail to provide the expected level of protection in a real emergency situation if the execution was poor or if local risks were not even considered during the design of that particular facility. [2, §3, 4, 5].

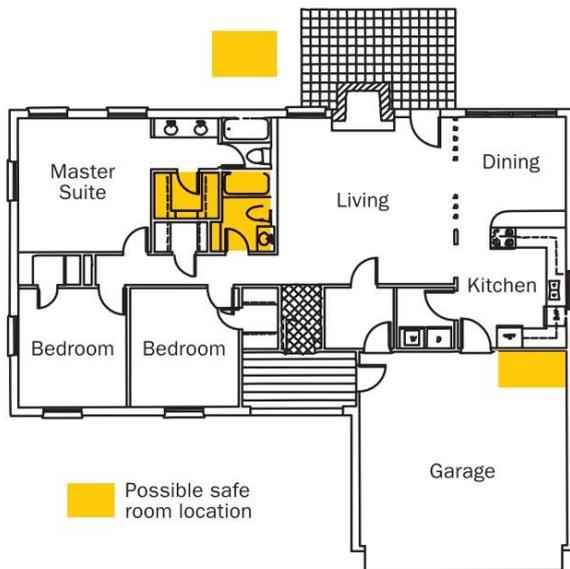


Figure 1 – Possible safe room location [2, p.32].



Figure 2 – Construction of a safe room with hollow blocks filled with concrete mortar and reinforced with vertical rods from the foundation to the concrete slab (New Smyrna Beach, Florida, 2007) [2, p.27].



Figure 3 – Aboveground residential safe room that was in the garage of a home hit by an EF5 tornado in Joplin, MO (2011) [2, p.31].

The main drawback of building ‘safe rooms’ in the United States is the lack of a unified, systematic quality control system, performance certification, and regulatory requirements for building design methodology (wall thickness, materials, area, ventilation, electricity, etc.). As a result, even a structure that formally “complies” with the recommendations may fail to provide the expected level of protection in a real emergency situation if the execution was poor or if local risks were not even considered during the design of that particular facility. [2, §3, 4, 5].

Israel's experience in designing shelters in apartments is of the utmost value. A safe room, also known as a protected or fortified space, is called a “Mamad” [3]. Against the backdrop of the war with Iraq, the Israeli leadership gave preference to individual shelters in basements, as responding to an alarm or a missile launch limits the time available to descend into the basement. Thus, new buildings had to be constructed with a protective room called a “mamak” in individual residential buildings, or “mamad” for multi-storey buildings, which were built one above the other and formed the core of the building's rigidity.

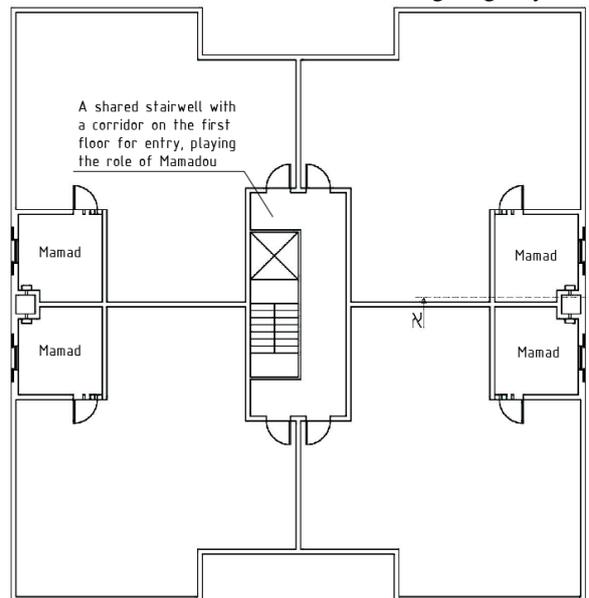


Figure 4 – Floor plan showing the location of risers (without apartment layouts) [4].

This solution, thanks to the vertical grouping of ‘mamads,’ increased spatial rigidity and evenly distributed the load, creating a dissipative element capable of counteracting the air shock wave. The location of the ‘mamad’ within the apartment reduced the evacuation route to the protected area to 30-60 seconds, which is typical for missile threats in Israel. Such integration of protected spaces into the planning and design of the building was not only a safety requirement but also an element that increased the overall stability of the building.

This transition to protective shelters of individual significance was continued with a programme of reconstruction for multi-storey buildings constructed between 1980 and 1992. The key approach to this was

the mass completion of concrete blocks to the exterior of the buildings. Most often, they were installed near balconies with stationary emergency ladders that provided evacuation to the lower floors. The peculiarity of such a vertical structure lies in its self-supporting nature, built on its own separate foundation. It did not significantly increase the overall rigidity of the building, if we disregard the technical condition of the building's structures, which, according to the results of the survey, can be used to determine whether it is necessary to reinforce and connect the metal frames to the walls or the entire building. On the contrary, their separate, albeit not significantly remote, location was an advantage, which in turn ensured human safety in the event of an enemy shell hitting the building itself, and evacuation via emergency ladders from the mamads.



Figure 5 – Annexes to the balconies of Mamady [5].

Problem statement.

In new construction of multi-storey apartment buildings where protective rooms of individual significance are envisaged, the core of the building must first be designed to ensure rigidity and resistance to air shock waves. [6, 7, 8, 9, 10]. The problem lies in determining the optimal planning and design solutions, where the decision made must integrate such a structure. The core of rigidity, together with protective rooms, should include a common distribution space and, as far as possible, the main stairwell. The reconstruction of the building, to which the extension of protective rooms is planned, as mentioned earlier, should first undergo a technical inspection by relevant specialists in this field, since the current technical condition of the building's structures can predict how much the stability of the building will increase after the extensions of protective rooms, and whether it will be necessary to additionally reinforce the walls, foundations and other structures with metal frames.

The main decision that determines the planning of a new building is the functional purpose of the building, the number of people who are constantly present at the facility, and the location of technical elements.

Taking into account residential buildings, the basic configuration shall consist of consists of the mutual position of a rigid core and residential apartments with

full use of living and usable space. This approach involves placing a protective room within the apartment. The protective room, like the rigid core, must be constructed of reinforced concrete. The foundation may be locally reinforced. An important condition is its use in everyday mode without losing its protective properties.

Community buildings require greater capacity for such structures and a comprehensive approach to engineering ventilation systems, planning sanitary zones, and organising evacuation, as provided for in the planning solution. The configuration of the stiffening core can be in the centre or along the central axis of the building, which represents a frame-trunk structural system, where commercial or office premises, entrance groups, and sanitary blocks can be located along the outer contour of the building's external load-bearing walls. This solution increases the overall safety of the core itself due to the additional external walls.

For critical infrastructure facilities, protective rooms of individual importance, depending on the technical specialisation and focus of the enterprise, must ensure the autonomous, uninterrupted operation of vital systems, power substations, oil and gas production, food warehouses, etc.

Research on the problem.

Questions regarding extensions the construction of individual protective shelters in Ukraine, within the existing housing stock, involves assessing a number of aspects related to structural features. These features determine the limits of technical solutions for the full implementation of Mamadiv. In particular, the degree of permissible interference with load-bearing structures.

Panel houses of typical series, which are common throughout most of Ukraine, limit the possibility of intervention due to their interconnected structural system of external and internal load-bearing walls. Thin external panels with a thickness of 200-300 mm are interrelated with internal partitions with a thickness of 100-200 mm, sealed joints and metal rod connections. The structural system does not provide adequate explosion protection, but interference with the prefabricated panel building system compromises its spatial load-bearing capacity. The addition of 'mamads' requires separate reinforcement of the external and internal load-bearing walls and foundations beneath them, as the overload of the added reinforced concrete protective rooms may affect the load-bearing capacity of the building itself.

Brick multi-storey buildings, due to their massiveness, allow for the construction of a vertical protective structure. The disadvantage is the additional costs for reinforcing thin walls with metal frames and cutting openings for utilities and doors to access the structure with appropriate reinforcement.

For new and old buildings, to extension a vertical self-supporting core with protective rooms is to be added, the materials from which the building is constructed, the technical condition of the enclosing structures and the structural features must meet a

number of requirements in order to be able to have such a structure. This is due not only to safety considerations, but also to a comprehensive approach to ensuring the safety and comfort of the building's residents.

For new construction, "mamads" should be laid at the stage of forming a spatial planning solution, where the structural system of a rigid core is interconnected with the accessibility of apartments to protective rooms in residential and public buildings. For example, in Lviv, back in 2023, the first concept appeared at the preliminary design stage for a protective room in a multi-storey office building, where protective rooms are located vertically one above the other [11].

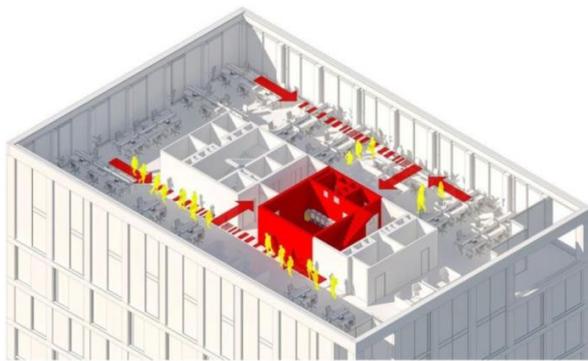


Figure 6 – The shelter is located in the center of the building on every floor [11].

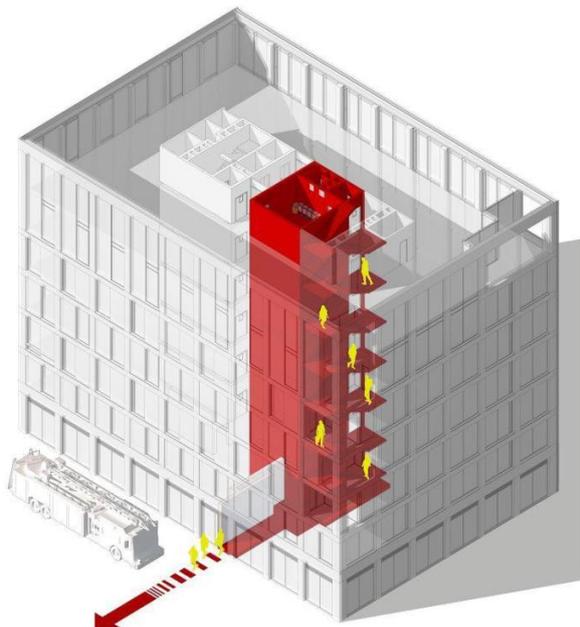


Figure 7 – The shelters are connected by a secure stairwell for evacuating people directly to the street [11].

Large-volume buildings with a large area, such as shopping centres, office buildings, administrative buildings, etc., allow for the provision of civil defence structures at the early stages of design and their integration into the building's structural system, with all the necessary engineering equipment and facilities for long-term stay, in compliance with all necessary and mandatory norms, rules and standards.

Results.

Based on preliminary analysis, the optimal placement of civil defence structures within the building was determined, and a nine-storey residential building with dimensions of 34.8 x 17.8 m and a ceiling height of 3.0 m was designed. The building's structural system is a trunk-wall system, with external walls made of 400 mm thick expanded clay concrete and a reinforced concrete core, with internal and external walls 500 mm thick. The reinforced concrete core of the building contains civil defence shelters located vertically one above the other, which are accessible from each individual apartment. Corridors leading into the building, a staircase and two lifts, see Fig. 8. The project is a new construction.

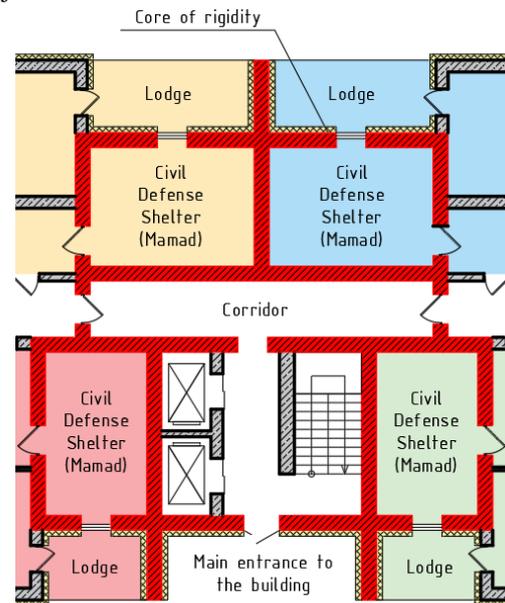


Figure 8 – General view of the reinforced concrete core of the building.

The main entrance is located in a reinforced concrete core, which serves as the main evacuation route in case of an emergency via a staircase. On each floor, there is a common distribution vestibule for two apartments located on the left and right sides of the building. Civil defence shelters are located directly at the main entrance to the apartment, see Fig. 9 and Fig. 10.

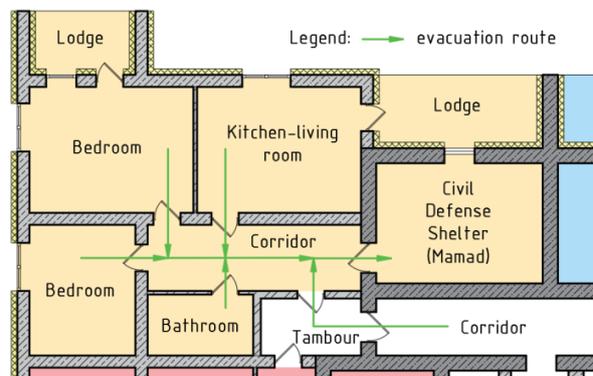


Figure 9 – Planning a three-room apartment (taking into account "mamadu").

The residential apartments are designed as two- and three-room apartments, and civil defence shelters are also included in the residential apartments, as they can be used without losing their protective properties in everyday life.

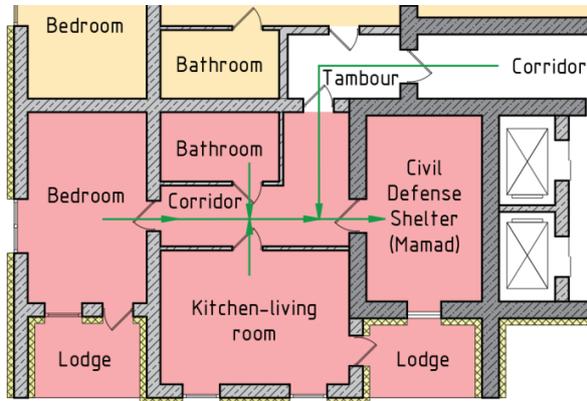


Figure 10 – Planning a two-room apartment (taking into account "mamadu").

Each flat has two lodges, one of which is located near a civil defence shelter and has a fire escape staircase for evacuation to the lower floors in case of an

emergency, which in turn serves as an additional escape route.

The large area of the bedrooms allows the room to be divided into a work area and a relaxation area. The kitchen-living room in each apartment is a central spatial and functional element for residents, combining an area for cooking and relaxation. The open-plan design ensures visual integrity of the space and sufficient natural lighting. The large rooms allow for ergonomic requirements to be taken into account depending on the needs of future residents.

The bathrooms of the apartments are located adjacent to each other, sharing a common engineering wall, which allows for the optimisation of engineering networks, within which ventilation, water supply and sewerage risers can be placed. The location of the bathrooms next to the kitchen-living room provides convenient access to engineering systems and increases the functional feasibility of this layout solution.

Such solutions are typical for multi-storey residential buildings, which in practice contributes to improving the technical and economic performance of the building.

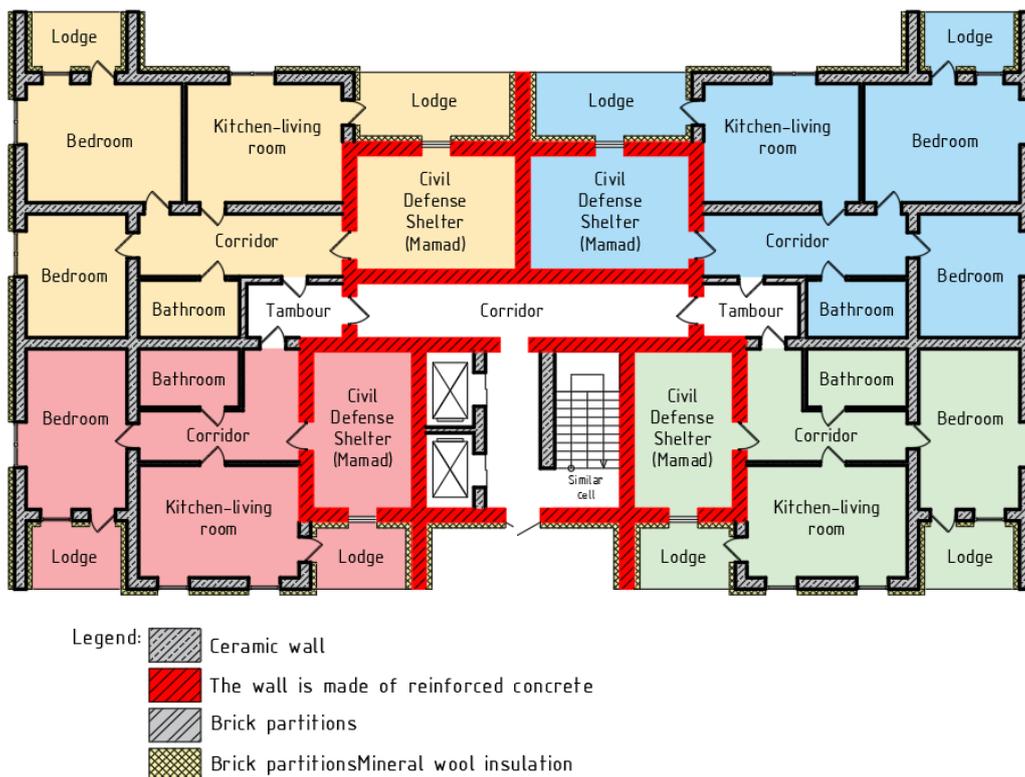


Figure 11 – Typical Floor Plan

Conclusion.

Propriety of integrating civil defence shelters into residential buildings with increased structural rigidity, as a potential basis for the formation and use of such structures for individual purposes, is determined by the architectural and planning solutions and the structural system of the building itself, which at the design stage

will allow for the formation of civil defence structures for individual use.

The proposed planning scheme using civil defense protective structures within a multi-apartment building creates preconditions for local structural reinforcement and provides opportunities for use in peacetime and for rapid transition to protective mode during an emergency situation.

The results of the analysis indicate the feasibility of future development for the design of civil defence shelters as part of residential buildings.

For further development during new construction, the obtained result of the designed building indicates

the advisability of further development of regulatory and methodological rules regarding the design of civil defense protective structures as part of a multi-story residential building for individual purposes.

References

1. Міністерство розвитку громад, територій та інфраструктури України. (2023). ДБН В.2.2-5:2023. Захисні споруди цивільного захисту (123 с.). Київ. URL: <https://e-construction.gov.ua/opublikovano-proekt-dbn-v22-52023-zahisni-sporudi-civilnogo-zahistu>
2. FEMA. Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business / FEMA P-320. – Washington D.C.: FEMA, 2014 (publication) / 2021 (updated) – 86 с. URL: https://www.fema.gov/sites/default/files/documents/fema_taking-shelter-from-the-storm_p-320_2021.pdf
3. Збірник наукових розробок планувальних та конструктивних рішень споруд цивільного захисту : монографія / А.В. Гасенко, О.О. Довженко, В.В. Погрибний, О.В. Семко, О.І. Філоненко, О.І. Юрін. – Полтава : Астроя, 2023. – 209 с. URL: <https://reposit.nupp.edu.ua/handle/PoltNTU/17314>
4. Rainbow Beind. אל בית של חירום מ פתרון. URL: <https://surl.li/lrxpny>
5. What is Mamad and why is it needed? / Evacuation.City. URL: <https://evacuation.city/articles/216253/scho-take-mamadi>
6. InterDam B.V. Blast-resistant buildings: concrete or steel – Ridderkerk : InterDam B.V., 2024 (6 June). URL: <https://downloads.interdam.com/wp-content/uploads/2024/06/WhitePaper-InterDam-Blast-Resistant-Buildings-Concrete-or-Steel.pdf>
7. Raikar, R. G.; Kangda, M. Z.; Wadki, V.; Farsangi, E. N. F. Blast mitigation of reinforced concrete structures incorporating shear walls in modern building designs / R. G. Raikar, M. Z. Kangda, V. Wadki, E. Noroozinejad Farsangi. – Buildings, 2023, Vol. 13, № 10, item number 2621. URL: <https://doi.org/10.3390/buildings13102621>
8. Praneeth, C.; Anuradha, P. (Dr.) Analysis of reinforced concrete structure subjected to blast load / Praneeth C., P. Anuradha. – International Journal for Research in Applied Science and Engineering Technology (IJRASET), 2024. URL: <https://doi.org/10.22214/ijraset.2024.64240>
9. Patel, Rajvee; Suthar, Aakash Comparative Analysis of Blast Load on Multi Storey R.C.C. Building at Different Locations / Rajvee Patel, Aakash Suthar. – International Research Journal of Engineering and Technology (IRJET), 2023, Vol. 10, № 06. URL: https://www.academia.edu/104494737/Comparative_Analysis_of_Blast_Load_on_Multi_Storey_R_C_C_Building_at_Different_Locations
10. Luo, Wenzhe; Zheng, Rongyue; Wang, Wei; Ye, Chenzhen Experimental and numerical study on the blast performance of RC shear walls under uniaxial compression / W. Luo, R. Zheng, W. Wang, C. Ye. – Buildings, 2025, Vol. 15, № 12, 1975. URL: <https://doi.org/10.3390/buildings15121975>
11. In Lviv, a developer is constructing safe rooms in offices, as is done in Israel / Official website of the Lviv City Council. URL: <https://city-adm.lviv.ua/news/architecture-and-historic-heritage/u-lvovi-zabudovnyk-v-ofisakh-zvodyt-bezpechni-kimnaty-iaak-tse-robliat-u-izraili/>
1. Ministry for Communities and Territories Development of Ukraine. (2023). DBN B.2.2.5-2023. Civil protection shelters (123 p.). Kyiv. URL: <https://e-construction.gov.ua/opublikovano-proekt-dbn-v22-52023-zahisni-sporudi-civilnogo-zahistu>
2. FEMA. Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business / FEMA P-320. – Washington D.C.: FEMA, 2014 (publication) / 2021 (updated) – 86 с. URL: https://www.fema.gov/sites/default/files/documents/fema_taking-shelter-from-the-storm_p-320_2021.pdf
3. Collection of scientific developments in planning and design solutions for civil defence structures: monograph / Anton Gasenko, Oksana Dovzhenko, Volodymyr Pogribnyi, Oleksandr Semko, Olena Filonenko, Oleg Yurin; edited by Olena Filonenko. – Poltava: PP 'Astraya', 2023. – 209 p. URL: <https://reposit.nupp.edu.ua/handle/PoltNTU/17314>
4. Rainbow Beind. Emergency shelter solutions by Beit El. URL: <https://surl.li/lrxpny>
5. What is Mamad and why is it needed? / Evacuation.City. URL: <https://evacuation.city/articles/216253/scho-take-mamadi>
6. InterDam B.V. Blast-resistant buildings: concrete or steel – Ridderkerk : InterDam B.V., 2024 (6 June). URL: <https://downloads.interdam.com/wp-content/uploads/2024/06/WhitePaper-InterDam-Blast-Resistant-Buildings-Concrete-or-Steel.pdf>
7. Raikar, R. G.; Kangda, M. Z.; Wadki, V.; Farsangi, E. N. F. Blast mitigation of reinforced concrete structures incorporating shear walls in modern building designs / R. G. Raikar, M. Z. Kangda, V. Wadki, E. Noroozinejad Farsangi. – Buildings, 2023, Vol. 13, № 10, item number 2621. URL: <https://doi.org/10.3390/buildings13102621>
8. Praneeth, C.; Anuradha, P. (Dr.) Analysis of reinforced concrete structure subjected to blast load / Praneeth C., P. Anuradha. – International Journal for Research in Applied Science and Engineering Technology (IJRASET), 2024. URL: <https://doi.org/10.22214/ijraset.2024.64240>
9. Patel, Rajvee; Suthar, Aakash Comparative Analysis of Blast Load on Multi Storey R.C.C. Building at Different Locations / Rajvee Patel, Aakash Suthar. – International Research Journal of Engineering and Technology (IRJET), 2023, Vol. 10, № 06. URL: https://www.academia.edu/104494737/Comparative_Analysis_of_Blast_Load_on_Multi_Storey_R_C_C_Building_at_Different_Locations
10. Luo, Wenzhe; Zheng, Rongyue; Wang, Wei; Ye, Chenzhen Experimental and numerical study on the blast performance of RC shear walls under uniaxial compression / W. Luo, R. Zheng, W. Wang, C. Ye. – Buildings, 2025, Vol. 15, № 12, 1975. URL: <https://doi.org/10.3390/buildings15121975>
11. In Lviv, a developer is constructing safe rooms in offices, as is done in Israel / Official website of the Lviv City Council. URL: <https://city-adm.lviv.ua/news/architecture-and-historic-heritage/u-lvovi-zabudovnyk-v-ofisakh-zvodyt-bezpechni-kimnaty-iaak-tse-robliat-u-izraili/>

Філоненко О.І

Національний університет «Полтавська політехніка імені Юрія Кондратюка»
<https://orcid.org/0000-0001-8571-9089>

Ніколаєнко Д.М.*

Національний університет «Полтавська політехніка імені Юрія Кондратюка»
<https://orcid.org/0009-0002-9906-2078>

Проектування захисних споруд цивільного захисту в житлових багатоповерхових будинках для індивідуального використання

Анотація. Воєнні дії в Україні, які щоденно створюють загрозу для цивільного населення, зумовлюють необхідність розроблення нових технічних рішень як для нового будівництва, так і для реконструкції наявних будівель і споруд. Значна кількість жертв серед цивільного населення припадає на мешканців багатоповерхових житлових будинків. Типовим захисним укриттям зазвичай вважається підвальний або цокольний поверх, конструктивні особливості якого переважно призначені для розміщення інженерних мереж, трубопроводів та технічного обладнання. Такі приміщення не мають аварійного виходу та належної вентиляції, а також не забезпечують можливості тривалого перебування людей зі створенням специфічних умов у повній відповідності до чинних нормативних вимог щодо захисту цивільного населення. За результатами аналізу архітектурно-планувальних рішень встановлено необхідність удосконалення приміщень, у яких можливе інтегрування індивідуальних захисних укриттів, призначених для забезпечення належного рівня захисту в умовах надзвичайних ситуацій. У роботі розглянуто основні принципи підходів до проектування індивідуальних захисних укриттів у межах житлового фонду. Запропоновані рекомендації можуть бути використані під час проектування нових житлових будинків, реконструкції існуючих будівель, а також при формуванні системи індивідуальних захисних укриттів, спрямованої на підвищення рівня безпеки населення в сучасних умовах.

Ключові слова: споруди цивільного захисту, захисні приміщення, проектування об'єктів цивільного захисту, житловий фонд.

*Адреса для листування E-mail: dmitriynikolayenko3185@gmail.com

Надіслано до редакції:	23.09.2025	Прийнято до друку після рецензування:	09.12.2025	Опубліковано (оприлюднено):	26.12.2025
------------------------	------------	---------------------------------------	------------	-----------------------------	------------

Suggested Citation:

APA style

Filonenko, O., & Nikolaienko, D. (2025). Design of civil defense protective structures in residential multi-story buildings for individual use. *Academic Journal Industrial Machine Building Civil Engineering*, 2(65), 77-83. <https://doi.org/10.26906/znp.2025.65.4192>

DSTU style

Filonenko O., Nikolaienko D. Design of civil defense protective structures in residential multi-story buildings for individual use. *Academic journal. Industrial Machine Building, Civil Engineering*. 2025. Vol. 65, iss. 2. P. 77–83. URL: <https://doi.org/10.26906/znp.2025.65.4192>.
