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INCREASING THE EFFECTIVENESS OF CIVIL PROTECTION BY THE DESIGN OPTIMIZING: THE REVIEW

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Due to today's conditions, it is necessary to reconsider the purpose of buildings and structures that use a significant number of reinforced concrete elements subjected to complex stress-strain states. The researchers are faced with the task of determining the residual bearing capacity of an element with uneven damage, which will allow choosing the most optimal option for calculating and selecting materials. A detailed analysis of the most common damages to reinforced concrete structures, including protective structures and shelters, from the effects of explosives and weapons of various types was carried out to optimize and maintain strength and durability. It is also important to study the impact of damage that causes a stress-strain state that cannot be predicted by calculation.

Keywords: damage, bearing capacity, stress-strain state, protective structures, shelters, destruction.

Introduction

In the context of the escalating military conflict with Russia and the growing risk of man-made and natural disasters that may be caused by military actions, the problem of providing the population with civil defense facilities is relevant. This article analyzes the existing approaches to protecting the population from shelling and bombing and presents empirical studies on damage to structures from various types of explosives.

To date, civilian emergency shelters have been built in many countries around the world. The shelters are built for different threats and levels of protection and are designed for local rescue procedures. In developing the recommendations, the current legislative and regulatory acts on civilian protection, which are discussed in this article, were taken into account.

Materials and Methods

Civil defense structures and civil protection assets perform very important tasks in both peacetime and wartime. The key challenge is to provide adequate protection against various non-military (e.g., floods, landslides, storms, hurricanes) and military (deliberate military and/or terrorist acts) threats. The need to analyze this issue is due to the growing importance of the phenomenon of terrorism in the context of an unstable situation in the modern world. For the security of the state, it is important to consider and analyze various protective structures that are ready for urgent use in specific conditions. In most European countries, shelters and temporary shelters are used for civil protection and civil defense. A shelter (of a special type), as defined by the fortification literature, is an open structure that protects people or specific equipment from the expected factors of damage only from certain sides. Such structures can be made of improvised elements and materials available (e.g., steel sheets, wood, composite materials), as well as prefabricated elements (e.g., reinforced concrete prefabricated elements).

The functional layout of the shelter reflects the protection concept in terms of solutions.

– local, concerning the entry system, spare exits, stockpiling air, water and energy supply, disposal or storage of waste and sanitary sewage;

– global, including operating regimes (e.g., full isolation), general operating concepts, communication with the outside world. (A. Baryłka a, M. Szota. Material and construction solutions in the construction of civil defence shelters)

This draft DBN establishes codes and requirements for:

-equipment of utility networks of buildings and structures in which the storage facility is built with shut-off devices;

-availability of protective screens on dust filters in ventilation systems with manual fans;

-verification of compliance with the design of emergency mine exits of the repository, earth filling on the repository floor, thickness of the thermal insulation layer of sections of reinforced concrete walls that are not covered with soil and protrude above the ground surface;

-location of air intakes for clean ventilation and filter ventilation.

-compliance of the maximum crack opening width at the joints of reinforced concrete structures with the requirements;

-installation of fittings for injecting cement mortar around the perimeter of the embedded parts of the doors.

Underground reinforced concrete structures are used for military installations protected from conventional weapons. Typically, these structures are box-shaped, partially or fully buried, and covered with a concrete "blast plate" to protect against penetrating weapons. Ground structures serving the same purpose are often modeled using single degree of freedom (SDOF) systems. This formulation offers an efficient method of analysis for preliminary designs, optimization studies, and concept evaluation.

Modeling of structures located underground is thus complicated by the presence of surrounding soil. The success of an SDOF model depends in part on our ability to predict the shape of the dominant mode, which is generally not the case for underground structures that experience an underground blast impact. Here, the response consists of a structure-environment (i.e., soil) interaction that, by its nature, is not amenable to modeling, nor to a modal decomposition approach (Wolf, 1985).

Thus, the choice of an appropriate SDOF model and load function is far from obvious. The literature uses intuitive arguments from relevant physical phenomena such as dynamic bending and added mass (Biggs 1964; Design of Structures 1964). Another approach uses a modification of the free-field stresses in the soil to approximate the pressure load at the interface (Fundamentals 1984). These approximations can be "tuned" by changing the numerical values of the model parameters to obtain an answer that is consistent with experimental data, but their usefulness for preliminary studies is limited because they give unreliable results in some ranges, as shown by Hinman and Weidlinger 1987.

SMI analysis is performed on mainframe computer systems using large finite element models that include both the structure and part of the surrounding soil mass (Nelson 1978).

New technical requirements are also established for air purification equipment for civil In the context of the escalating military conflict with Russia and the growing risk of man-made and natural disasters that may be caused by military actions, the problem of providing the population with civil defense facilities is relevant. This article analyzes the existing approaches to protecting the population from shelling and bombing and presents empirical studies on damage to structures from various types of explosives.

To date, civilian emergency shelters have been built in many countries around the world. The shelters are built for different threats and levels of protection and are designed for local rescue procedures. In developing the recommendations, the current legislative and regulatory acts on civilian protection, which are discussed in this article, were taken into account.

To regulate legal issues that cannot be included in the state building codes, it is planned to develop a draft "Procedure for Acceptance of Completed Civil Defense (Civil Protection) Facilities" (hereinafter - the "Procedure").

"The Procedure will establish the forms of such documents:

-Declaration on the readiness of civil protection (civil defense) facilities for operation, including the procedure for its submission and registration;

-Act of readiness of a civil protection (civil defense) facility for operation;

-Application for acceptance of the completed facility into operation and issuance of a certificate;

-A certificate certifying the conformity of the completed facility, including the procedure for its issuance and the grounds for refusal to issue the certificate; a Certificate of acceptance of special equipment after testing (Yu.Chaykovskiy, V.Mogilnichenko, O.Fursenko, Cand. of Sc. Tech., 2012).

Defensive structures are distinguished (Skrypnik K. I.; Civil defense structures.):

-by their purpose - for the protection of the population, the location of control bodies (control point - CP, command post - CP, communication center - CC), and medical facilities;

-by the construction period - erected in advance, prefabricated;

-by location - built-in, detached, underground, in mine workings;

-by protective properties - the simplest shelters (open and closed cracks), radiation protection shelters (RPS), and shelters.
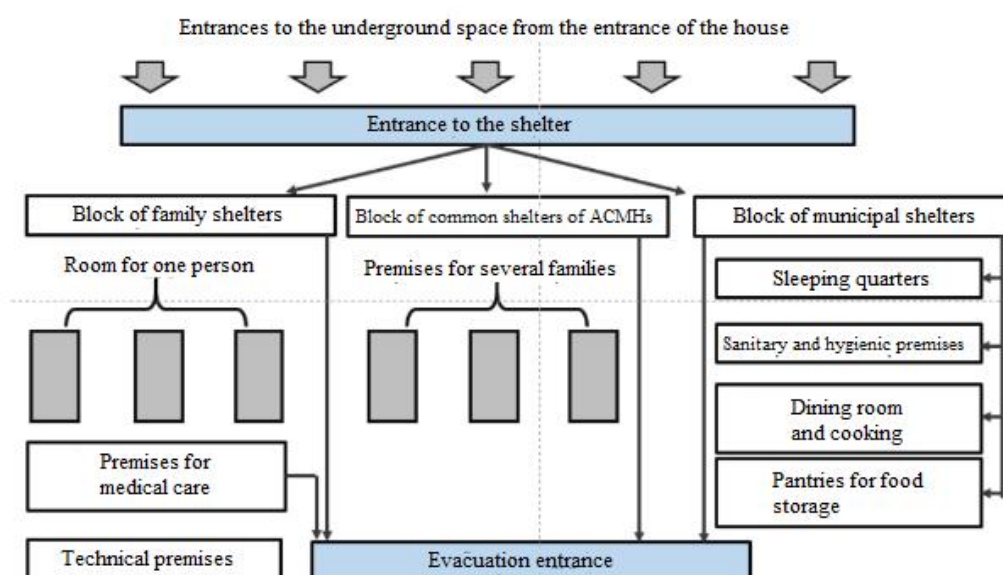

Fig. 1. Underground shelter for a group of residential buildings (Zhydkova T. at all., 2023)

The realities of modern warfare have shown the need to stay in shelters for a long time. Not only to hide but also to live in such premises. Several types of shelters are offered for long-term stays, depending on the level of comfort and form of ownership: private, collective, and municipal. All of these types of shelters should be divided into several blocks, which are divided by ownership.

A family storage unit is a complex of rooms connected by a common corridor. These are high-comfort storage facilities privately owned by one family. Each storage unit resembles a smart apartment with everything you need to stay for a long time. For a family of 2, a sofa bed is offered as a sleeping place. For a family of 4, an additional bunk bed is available.

The second block consists of collectively owned condominiums. These are separate blocks for several families with separate sleeping and shared sanitary facilities accessible to people with limited mobility, and a room for cooking, socializing, and relaxing.

The municipal shelter block should have shared dormitories with bunk beds and accessible sanitary facilities, dining rooms with space for cooking, socializing, and relaxing, and a pantry for storing food.

However, the most affordable and common options for shelter are basements and basements of residential buildings.

In developing the recommendations, the current legislative and regulatory acts on the protection of civilians, as well as the requirements for accessibility for people with limited mobility were taken into account (used in the introduction). In the residential environment, it is proposed to create a safe space consisting of domestic shelters and shelters in the underground space under buildings or the adjacent territory of a group of buildings. Domestic shelters are separate rooms, storerooms, and elevator halls in the part of the building that is bounded by capital walls with increased protective properties. Such premises may not always protect against a direct missile strike, but they are guaranteed to protect against a blast wave. In this solution, the protected space is within a minute's reach. It should be added that, according to the war experience, part of the building in monolithic structures can withstand even direct missile attacks. An example of this is the elevator shaft and part of the premises next to it in a destroyed high-rise building in Mariupol. The next link in the protection of the population should be sheltered in the underground space under buildings or the adjacent territory of a group of buildings.

The premises of the shelters should protect people not only from the blast waves and debris but also from a direct missile strike. A shelter located on the second floor from the ground under a parking lot will receive additional protection in the form of a ceiling over the parking lot (Zhydkova T., Hleba V. & Chepurna S., 2023).

Recommendations for the majority of the population to take shelter in basements and ground floors were developed in the mid-twentieth century. Since then, the power of weapons has increased significantly, and housing requirements have changed. The main structures of most modern buildings do not meet the requirements for reducing the destructive effect of munitions such as artillery shells, aircraft bombs, and missiles. Ceilings over basements cannot withstand the weight of building debris.

At the time of the development of the regulatory documentation, in the mid-20th century, the main housing stock consisted of houses built in the 19th and early 20th centuries and the so-called "Stalinist" buildings, which in fact had basements with robust walls and partitions. These houses had basements completely buried in the ground, unlike their successors. The walls of these basements are brick or concrete with an inner layer of bricks, usually at least 0.77-0.9 metres thick. These houses can be used as simple shelters during the war. However, as of 24 February 2022, most of the structures were in an unusable condition due to their age and inadequate maintenance. Also, unfortunately, some of the surviving units were converted and rebuilt into storerooms and for other purposes by the residents themselves, rendering them unusable in wartime. The vast majority of residential panel houses built in Ukraine after 1956 do not have basements at all. There are only technical rooms designed to accommodate engineering equipment and utility lines. After even a single shell hits, panel houses "fold" completely, because the weight of the destroyed structures cannot withstand the floors of the basement. People hiding in such rooms are almost guaranteed to die. These rooms cannot be used even as the simplest shelters due to the insufficient bearing capacity of the walls and ceilings; insufficient height of the existing rooms; and a developed network of water supply and sewage utilities, including the main ones, located in these rooms.

Among the existing ways and means of protecting the population, the most effective is the use of civil defense (civil protection) facilities. However, with Ukraine's independence, the denationalization of enterprises and privatization of real estate, the general economic depression, and the lack of funds to maintain protective structures, their condition has deteriorated significantly. Most of the shelters and RPUs have been looted, flooded with groundwater or sewage, lack proper life support systems, lack sealing, and have had their evacuation exit covers completely or partially destroyed. About 16% of the protective structures have been privatized, which calls into question the possibility of using them for their intended purpose, while the rest are in state and municipal ownership (Zhydkova T. al., 2023).

A protective structure is considered "not ready" or "partially ready" if it has at least one of the following deficiencies:

-presence of unprotected openings in the enclosing structures through which the interior of the structure may be exposed to the atmosphere;

-damage to the main building structures of the structure that reduces their load-bearing capacity;

-improper installation of protective and airtight gates and doors, taking into account the direction of their opening and protective properties, their loose fit to the combs, malfunction of the closing mechanisms; absence or malfunction of anti-explosion devices and expansion chambers at air intakes;

-absence of shut-off valves on water supply, sewerage, heat supply networks, gland, and other devices in the places where cables and pipelines are laid;

-non-compliance of ventilation and emergency exit system headers with DSTU;

-flooding of structures with groundwater or wastewater; malfunctions in life support systems;

-absence of sealing rubber on protective devices (fully or partially);

-Lack of special teams to maintain protective structures; and other shortcomings.

As of 2016, according to the SES of Ukraine, on average, 40% of civil protection structures in the country were assessed as "not ready" for their intended use, 50% as "partially ready" and only 10% as "ready" (Voskobiynyk et al., 2016).

Civil defense shelters will be of several types:

a. Family shelters in houses or apartments.

b. Common shelters in buildings, basements, or between buildings.

c. Dual-purpose shelters in public buildings.

d. Public shelters in underground structures.

Generally, civil defense shelters are designed for cases where there is sufficient warning and time for people to get to the shelter. For situations with a short warning time or no warning at all (as in the case of terrorist attacks). People in buildings need to be protected in different ways, for example, using nearby protective rooms or strong enclosing structures. It is very important to take into account the need to provide shelters in existing buildings, as well as designing shelters to allow for easy retrofitting in the future if needed.

The impact of small arms on buildings is relatively low. Protective measures for this type of small-scale armed attack are as follows:

a. External protective elements such as blast and shrapnel-resistant

protective walls surrounding the building, protective shielding in front of windows, etc.

b. Use of blast and shrapnel-resistant materials for the building envelope, such as exterior walls and roofs.

c. Use of explosion-proof windows in the exterior walls.

d. Construction of protected interior spaces.

Protective measures to ensure full protection against direct hits from large-caliber weapons do not apply to "conventional" structures. Protective structures that can withstand such direct hits are special structures, such as underground structures with protective layers, structures in rocks, caves, etc (Reuben).

Prefabricated shelters are also a good solution if there is no time to prepare for martial law. Prefabricated storage facilities (hereinafter referred to as PSF) of modular type should protect against:

- excessive pressure in the front of an airborne shock wave, not less than 100 kPa ($\Delta Pf = 100$ kPa (1 kg/cm2));

- local and general effects of conventional munitions (small arms, fragments of hand grenades, artillery ammunition and aircraft bombs);

- exposure to poisonous substances, radioactive substances, and bacterial agents; - exposure to penetrating radiation with a degree of attenuation of 1,000 ($Kz = 1,000$);

- thermal impact in case of fires.

In a modular-type prefabricated civil protection structure (PCSF), it is recommended to equip folding seats and lying down places that are fixed along the perimeter of the walls of the main premises.

The height of the premises of the protective structure should be at least 2.0 m. If the height of the premises is from 2.3 m to 2.9 m, a two-tiered arrangement of seats and lying down is recommended, and for a height of 2.9 m and more - a three-tiered arrangement.

The height of the seats and lying down places from the floor level should be: the first tier - 0.45 m, the second tier - 1.4 m, and the third tier - 2.15 m. The distance from the top tier to the ceiling or protruding structures should be at least 0.75 m.

Seating in the premises for persons to be sheltered should be provided at a rate of at least 0.45 m × 0.45 m per person, and lying down places - 0.55 m × 1.8 m.

In modular-type SSSFSCs of full factory readiness, separate structures (block modules), entrances, and exits, including protected ones, openings, and passages must meet the requirements of fire safety regulations and be at least 0.8 m × 1.9 m.

The room for the placement of backup (autonomous) power supply sources (batteries, diesel power plant) of the LSS should be located near the outer wall and separated from other rooms by a fire partition of type I. Entrance to such premises of the LSS shall be through a vestibule equipped with two hermetically sealed doors opening in the direction of evacuation (DSTU 9195: 2022).

The relevance of using dual-purpose modular shelters is of particular importance in modern conditions, and this aspect is considered in detail in this article (Cennamo, et al. 2012). The variety of such solutions is highlighted taking into account current challenges and needs. The design philosophy emphasizes robustness, starting from architectural modularity and assembly techniques. Many design rules, inspired by nature, such as exoskeletons, parallel systems, redundancy, and compartmentalization, prevent large-scale damage propagation through synergic action. The study concludes that, in addition to traditional advantages like lightness and ease of assembly, the specific capacity-design rules highlighted can ensure high standards of safety, durability, and structural robustness in off-site systems.

The thermal effect on structures from different types of weapons should also be taken into account when designing shelters. For example, the influence on the constructions of rational influence is considered in (Slyusarenko Y. et al. 2023). Traditional comparisons of geodetic results proved insufficient, revealing deformations of up to 20 mm between cycles on the upper tiers and unit measurements on the foundation slab.

Many shelters can be part of low-rise buildings. Although small weights of explosives are not likely to produce significant blast loads on the roof, low-rise buildings may be vulnerable to blast loadings resulting from large weights of explosives at large standoff distances that may sweep over the top of the building. The blast pressures that may be applied to these roofs are likely to far exceed the conventional design loads and, unless the roof is a concrete deck or concrete slab structure, it may fail. There is little that can be done to increase the roof's resistance to blast loading that doesn't require extensive renovation of the building structure. Figure 2 shows the ever-expanding blast wave as it radiates from the point of detonation and causes, in sequence of events, the building envelope to fail, the internal uplift on the floor slabs, and eventually the engulfment of the entire building.

Also important is the combination of materials and their prediction under various influences for further use in shelters, the author (Le et al. 2022). of this article considers compressed elements using external reinforcement that simultaneously serves as formwork.

High-rise buildings must resist significant gravity and lateral load effects; although the choice of framing system and specific structural details will determine the overall performance, the lower floors, which are in closest proximity to a vehicle-borne threat, are inherently robust and more likely to be resistant to blast loading than smaller buildings. However, tall buildings are likely to be located in dense urban environments that tend to trap the blast energy within the canyon-like streets as the blast waves reflect off of neighbouring structures.

Research in this direction with the variability of the flow of the detonation height of the explosive element is considered in the article (Novhorodchenko A. et al. 2023)

Despite the various types of construction, the following protective measures may be used to establish a hardened space that will limit the extent of debris resulting from an explosive event. A shelter is best located within interior space or a building core at the lowest levels of a building or on the ground floor for a slab-on-grade structure. A debris catch system should be installed beneath the roof rafters of a single-story building. The exterior façade should be either reinforced masonry or precast panels and windows should either be laminated or treated with an anti-shatter film that is anchored to the surrounding walls. First-floor steel columns may be concrete encased and first-floor splices may be reinforced. Existing masonry infill walls may be retrofitted by either grouting cables within holes cored

within the walls or with a spray-on application of shotcrete and welded wire fabric or a polyurea debris catch membrane. Hardened interior partitions, such as metal stud blast walls, may be used to enclose the shelter and these walls should be anchored to an existing structure. A stiffened steel panel may be constructed interior to existing load-bearing masonry walls (FEMA 453 / May 2006 Gilbert Gedeon, P.E.; Safe Rooms and Shelters - Structural Design Criteria; Continuing Education and Development, Inc.).
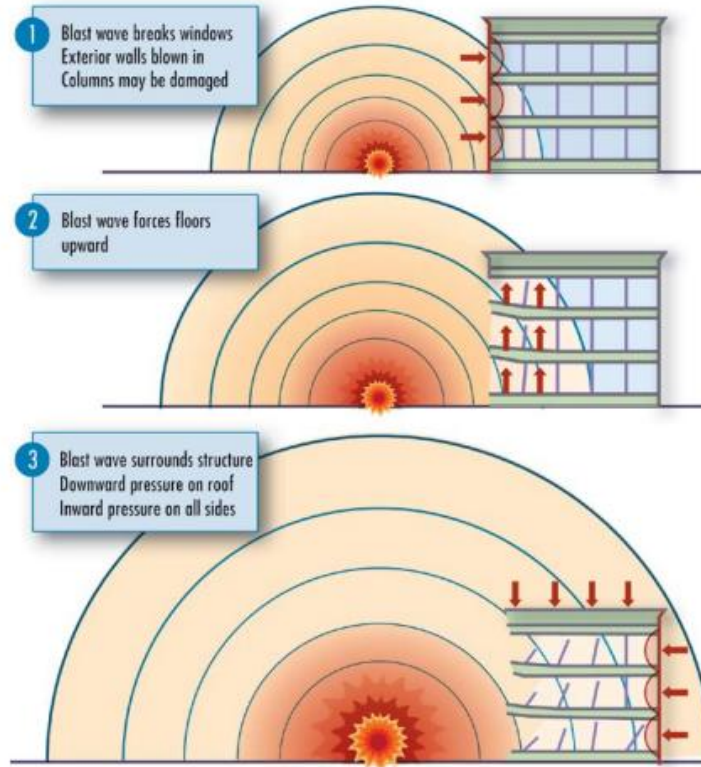

Fig. 2. Blast damage. Source: naval facilities engineering service center,
user`s guide on protection against terrorist vehicle bombs, May 1998 (Gilbert Gedeon, 2006)

Several empirical estimates for predicting and modeling the positive phase of an airburst have been proposed by many researchers and extensively studied. Wu and Hao (2005) proposed the following empirical model to estimate the positive profile of the explosion phase.

$$P(t) = \begin{cases} Po & for\ (0 \leq t < t_A) \\ Po + Pop \left(\frac{t}{t_1}\right) & for (t_A \leq t \leq t_1) \\ Po + Pop \left(1 - \frac{t-t_1}{t_2}\right).exp\left(-\frac{\beta(t-t_2)}{t_2}\right) & for(t_1 \leq t) \end{cases} \tag{1}$$

US Department of Defense, proposed by Kingery and Bulmash (1984). The explosion pressure is calculated using the following empirical relationship.

$$P(t) = \begin{cases} P_r \cos^2\alpha + P_i(1 + \cos^2\alpha - 2\cos\alpha), & \cos\alpha > 0 \\ P_i & \cos\alpha < 0 \end{cases} \tag{2}$$

Siddiqui and Ahmad (2007) investigated the simultaneous effect of air-blast and ground shock on structures and derived the following empirical equations to predict the ground shock wave parameters.

Summary of PPV prediction models proposed by various researchers.

$$PPA = 4.689 S^{-1.3} W^{0.95} \text{ (for saturated sandy clay)} \tag{3}$$

$$t_{A_2} = 580 \frac{S^{1.24}}{c_S W^{0.01}} \tag{4}$$

$$t_S = 5.60S^{0.54} \tag{5}$$

$$T_{lag} = t_A - t_{A_2} \tag{6}$$

where, PPA=peak particle acceleration (g); t_{A_2}=arrival time of ground shock (ms); C_S=seismic velocity of the rock/soil (m/s); t_S=positive phase duration of ground shock (ms) and T_{lag}=time lag between the ground shock and air-blast pressure reaching to the target structure (Anas et al. 2022).The impact of various components of the explosion should also be considered, and this paper (Anas et al. 2020) considers and analyzes this impact in the analysis of military conflicts on buildings. Experimental studies (Anas et al. 2023) consider the proposal of combining reinforcement for slabs in order to improve the impact resistance of slabs against punching.

From a safety point of view, it is important that a concrete structure, apart from necessary load capacity, also can show ductile behaviour that allows redistribution of forces so that a local failure does not lead to total collapse of the structure. A structure's ability to exhibit such behaviour is highly dependent on the reinforcement detailing of the joint connections between its independent members. Accordingly, to obtain sound structural behaviour, the joints should ideally be as strong as the structural members connected to them and show ductile behaviour in the ultimate limit state.
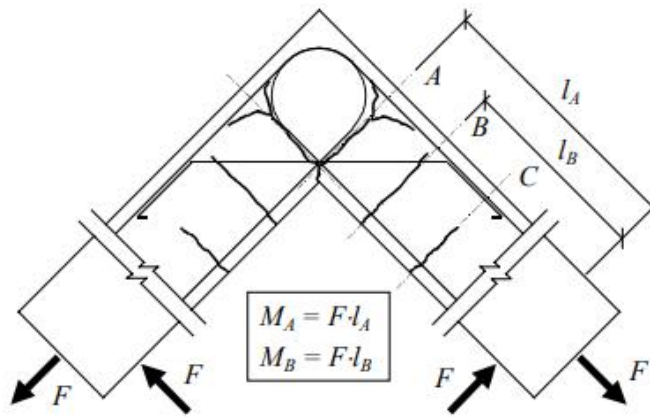

Fig. 3. Schematic view of potential critical crack sections
in an opening corner. (Johansson M., 2000)

Figure 3 shows a schematic case of a corner subjected to opening moment. Here, crack A corresponds to the critical. Crack B is a crack in the adjacent element closest to the corner, and although it is formed close to the corner in this case, it is assumed that the inclined bars have little effect on the load carrying capacity of the section.
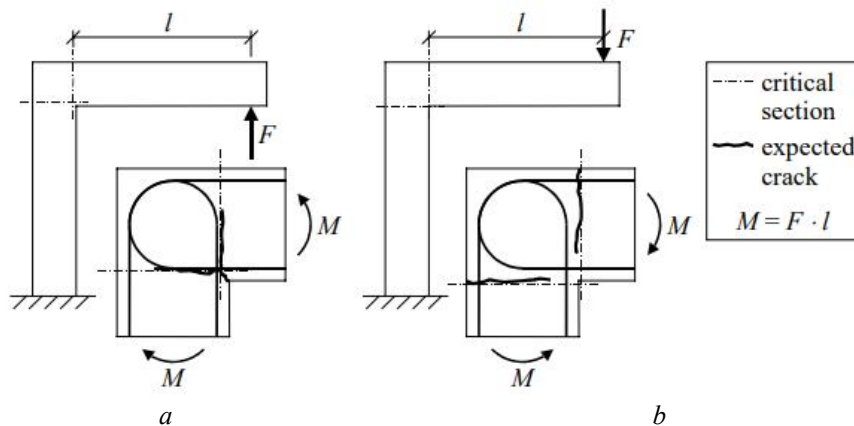

Fig. 4. Definition of critical sections used when determining moment capacity obtained in tests for:
(a) opening moment and (b) closing moment. (Johansson M., 2000)

Depending on the effect of the inclined bars on the load-bearing capacity of section B, crack C may become a critical crack if the final failure occurs outside the corner region. However, if the failure occurs in section B, the moment M_B must reach the section bearing capacity $M_{uc,B}$ before the moment M_A reaches the bearing capacity $M_{uc,A}$ of the corner. The relationship between these capacities can be expressed as

$$M_{uc,A} = \eta \cdot M_{uc,B} \qquad (7)$$

where η is the efficiency for a type 4 detailing. According to Figure 3, it varies between approximately 0.90 and 1.25 for $\omega_g \leq 0.200$. Thus, if a critical crack is formed outside the angular region, the M_A/M_B ratio must be greater than the efficiency η. But since there are an infinite number of possible loading cases, it is difficult to give a general statement about whether this will happen or not (Johansson M., 2000).

No less important is the analysis of damaged structures and the assessment of their real bearing capacity in operation (Vegera et al. 2021), it has been experimentally shown that in some cases the theoretical calculation underestimates the bearing capacity by 3%...21% of the experimental one.

Significant research developments in the design of protective structures taking into account the nuclear load are considered in Krauthammer T. (2008).

When designing a civil defence shelter, it is for practical reasons regarded as a statically loaded structure. However, in reality, a shelter must be able to withstand highly dynamic loading due to, for example, blast waves from a nearby explosion or the impact of falling masses from a collapsing building. When subjected to such loads, the global response of a structure can be considerably different compared to that of static loading. The peak load for transient loads is, for instance, often several times higher than the "equivalent" static load used in the design of the shelter, but their duration is instead very limited in time. Further, if the load is applied fast enough, part of the structure may still not even "be aware" of the external loading when another part reaches failure. Simplified, it can be said that the boundary conditions of the structure change with time. Due to the strain rates obtained in this kind of loading, the material properties of both concrete and reinforcement will also change, making the response of the structure even more complicated to understand (Johansson M. (2000)).

The paper (Sobczyk K. et al. 2020) considers the calculation coefficient for taking into account the layers of soil or bulk material in protection against dynamic loads; these studies make it possible to improve the consideration of urite fractures.

A Building Vulnerability Assessment Checklist was developed for FEMA 426 and FEMA 452 to help identify structural conditions that may suffer in response to blast loading. Each building under consideration needs to be evaluated by a professional engineer, experienced in the protective design of structures, to determine its ability to withstand blast loading (Gilbert Gedeon et al. 2006).

Given the above, it can be concluded that there is a significant number of studies investigating the bearing capacity and parameters of the stress-strain state of damaged structures. However, there are a limited number of studies that take into account the load level and the actual stress-strain state of structures during damage. Since all structures operate under a certain level of load, ranging from their weight to the operational load, obtaining data on changes in their bearing capacity and developing a methodology for its calculation is a promising area of research.

Conclusion

Based on a comprehensive study and exhaustive literature review, it is concluded that due to the war with Russia and the threat of emergencies caused by military operations, the problem of providing the

population with protective structures is becoming more urgent. There are about 22,000 protective structures in Ukraine, of which 5,000 are shelters and the rest are radiation shelters located in buildings. Since no shelters are provided for the population, the design and manufacture of rapidly constructed protective structures should be considered a priority. The article describes possible ways to improve existing shelters by creating a fortified space that will limit the amount of debris. The article also mentions the experience of Western countries in using dual-purpose buildings (car parks, warehouses, shooting ranges, gyms, etc.), which are used for their intended purpose in peacetime and converted to shelter in a short time in a special period. This is a possible method of dividing the shelter into blocks for the sake of practicality. It was found that the global response of a structure subjected to a blast load in the initial stage may be very different from that of a static load, an important reason being that the boundary conditions initially can be said to vary with time. The most critical stage for the shelter studied here was during the initial 10 ms (Johansson M. (2000))

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ЦИВІЛЬНОГО ЗАХИСТУ ШЛЯХОМ ОПТИМІЗАЦІЇ ПРОЕКТУВАННЯ

Структури та засоби цивільного захисту виконують дуже важливі завдання як у мирний, так і у воєнний час. Ключовим викликом є забезпечення належного захисту від різноманітних загроз невійськового (повені, зсуви, шторми, урагани) та військового характеру..

У зв'язку з умовами сьогодення необхідно переглянути призначення будівель і споруд, в яких використовується значна кількість залізобетонних елементів, що зазнають складних напружено-деформованих станів. Перед дослідниками постає завдання визначення залишкової несучої здатності елемента з нерівномірним пошкодженням, що дозволить обрати найбільш оптимальний варіант розрахунку та підбору матеріалів. Проведено детальний аналіз найбільш поширених дефектів та пошкоджень залізобетонних конструкцій, в тому числі захисних споруд та укриттів, від дії вибухових речовин та зброї різних типів з метою оптимізації та збереження міцності та довговічності. Важливим також є дослідження впливу пошкоджень і дефектів, які спричиняють напружено-деформований стан, що не може бути передбачений розрахунком.

В умовах ескалації військового конфлікту з Росією та зростаючого ризику техногенних та природних катастроф, які можуть бути спричинені військовими діями, актуальною є проблема забезпечення населення об'єктами цивільного захисту. У цій статті проаналізовано існуючі підходи до захисту населення від обстрілів та бомбардувань, а також наведено емпіричні дослідження пошкоджень споруд від різних видів вибухових речовин. Розглянуті наявні експериментальні та теоретичні дослідження з оптимізації проектування та розрахунку утримання та сховищ.

На сьогоднішній день в багатьох країнах світу побудовані сховища для цивільного населення на випадок надзвичайних ситуацій. Ці сховища будуються для різних загроз і рівнів захисту та розраховані на місцеві процедури порятунку. При розробці рекомендацій були враховані чинні законодавчі та нормативно-правові акти з питань цивільного захисту, які розглядаються в цій статті.

Ключові слова: пошкодження, несуча здатність, напружено-деформований стан, захисні конструкції, укриття, руйнування.