Aspects of designing shelters in Georgia

Teimuraz Melkadze, Giorgi Skhirtladze
Georgian Technical University, Tbilisi, Georgia, 77, M. Kostava St. 0160
t_melkadze@gtu.ge, g.skhirtladze1@gmail.com

DOI: https://doi.org/10.52340/building.2024.70.08

Abstract: In the article is considered the importance of protecting the population in possible emergency situations and during hostilities in Georgia using collective defense means. Necessary recommendations for the reconstruction of the existing shelters in Georgia and the construction of new ones based on the analysis of the current war in Ukraine and the study of the weapons used by Russia against the civilian infrastructure.

Keywords: shelter, civil defense, civil safety, collective protection of the population.

1. Introduction

Due to the geopolitical location of the country, the existence of civilian shelters is a critically important issue to ensure safety and protection of the population in case of possible foreign aggression. In this context, it is appropriate to focus on the comprehensive study and analysis of possible threats, which is an integral part of the shelter construction process. A detailed study of different types of weapons systems used in military conflicts, their destructive potential, impact radius and destructive factors is a necessary prerequisite for the design and construction of shelters that fully respond to protection and safety requirements.

Analyzing the current war in Ukraine and studying the weapons used by Russia against civilian infrastructure is very important for Georgia. This gives us the opportunity to study in detail and understand the radius of impact and the destructive potential of the weapons that Russia is using extensively against the civilian population and infrastructure. Russian occupation forces widely use missile weapons in their military operations against Ukraine.

Georgia's strategic location in the Caucasus region and its propensity for regional conflicts create the need to develop solid civil protection measures. By understanding and adapting to these threats, Georgia will be able to strengthen national safety and ensure the safety of its citizens.

In modern history, Georgia, depending on its geo-political location, faced various types of aggression several times. The last military conflict with the direct participation of Georgia took place in 2008, between Russia and Georgia. In this war, 412 Georgian citizens died, including 228 civilians, 170 military personnel and 14 policemen (Arabuli, 2023). The war exposed significant weaknesses in Georgia's civilian infrastructure, including the failure of the early warning and evacuation system. This historical context creates a good basis to prove the need for shelters in Georgia, which will protect citizens during conflicts.

A study of today's Russia-Ukraine conflict reveals the impact of modern wars on civilian populations and infrastructure. Analyzing this conflict allows us to identify specific weapons systems and tactics that could be used against Georgia and accordingly plan to design shelters that can withstand such threats. This chapter aims to identify the basic design parameters of shelters that will effectively deal with these hazards. This includes structural strength, capacity, accessibility, life support systems and communication infrastructure.

2. **Existing regulation frameworc**

According to the Law of Georgia on Civil Safety, a shelter is a building or structure that can be used to protect people from various damaging factors during an emergency or war. The shelter can be a dual-purpose, civil or industrial building and/or a special hermetic protective structure, which is designed taking into account damaging factors;

According to the same law, it is the duty of executive authorities, self-governments and organizations to provide in the areas assigned to their governance in the manner established by the legislation of Georgia:

- during an emergency situation, if necessary, creating a shelter for people, mobilizing collective protection means and other material resources;
- providing assistance in organizing the evacuation of people and, if necessary, placing

them in a shelter;
- maintaining the quality characteristics of the shelter in their use;
In accordance with the legislation, the main measures for the protection of Georgian citizens and other persons on the territory of Georgia from an emergency situation are: their evacuation and/or placement in shelters, implementation of fire, engineering, chemical, radiation, medical and biological protection measures and psychological assistance for them.
The personnel of the facility of vital importance should be protected in the shelter from the emergency situation.
A metropolitan underground structure, cave, bunker and tunnel, as well as the underground floor and storage of a building suitable for shelter (including dual purpose) can be used as a shelter.
The maintenance and intended use of the shelter is ensured by the persons authorized to own, dispose of and/or use the property.
It is possible to change the intended purpose of the shelter and the building and storage suitable for shelter based on the prior written consent of the Emergency Situations Management Service and the Ministry of Defense of Georgia. Alienation of the state-owned shelter is not allowed without the prior written consent of the Emergency Situations Management Service and the Ministry of Defense of Georgia.
According to the law of Georgia "Georgian Code of Spatial Planning, Architectural and Construction Activities", which refers to safety protection during the operation of the building, "during the design and construction of the building, civil safety engineering and technical measures should also be taken into account, the purpose of which is to protect the population from emergency situations, expected losses and reduction of destruction, creation of necessary conditions for promotion of rescue and other emergency works." (Parliament of Georgia, 2018)
Based on the above, according to the Resolution No. 51 of the Government of Georgia of January 14, 2014, regarding the approval of the technical regulations - "Civil Safety Engineering-Technical Measures", the following basic requirements for the design of shelters are defined: the total number of sheltered persons in civil defense protective structures in enterprises is determined by the maximum number of workers per shift. Shelters should provide protection of sheltered people from shock wave, penetrating radiation, radioactive contamination and light radiation of explosion, high temperatures and combustion products during fire, as well as poisonous and bacterial agents. Shelters must provide protection for the sheltered persons for two continuous days and nights.
In an emergency situation, in order to protect the population and ensure the stable functioning of economic objects, priority is given to the utilization and use of underground spaces of cities for the design and construction (placement) of protective structures of civil defense. For the same purposes, it is advisable to transform the ground (semi-recessed) and underground floors of existing and new buildings under construction.
The construction of shelters to be used as a shelter should be considered on the underground floors of industrial and auxiliary buildings under construction, public, residential and other buildings, as well as semi-recessed separate standing buildings. Shelters should be used for household, auxiliary and storage warehouses located in the underground space of the city (except for flammable, explosive, toxic, poisonous and undervalued loose materials warehouses), trade and public catering facilities, cultural-household and sports warehouses, underground parking lots, tunnels, underground passages. and other buildings.
Shelters to be used as shelters should have emergency exits outside the zones of possible explosions as a result of the collapse of nearby buildings and structures.
Protective structures of civil defense (shelters and anti-radiation shelters), which are used in peacetime in the national economy and for population services, should be brought into readiness to shelter people for no more than 12 hours.
In processed underground mines and caves, where it is possible and appropriate, provision of shelters and anti-radiation shields should be provided for the protection of the population.
For the protection of seriously ill patients,

whose evacuation is impossible due to their health condition (non-transportable patients), as well as for their service personnel, shelters should be provided in the basements of newly designed buildings of medical profile institutions (hospitals, clinics) located in the zones of possible strong destruction of categorized cities and objects, which are used in peacetime. will be as needed by the treatment facility.

The number of patients to be accommodated in the shelters of medical institutions is determined to be 10% of the total design capacity of the medical institution in peacetime.

The use of metropolitan areas for the protection of the population is recommended not only in times of war, but also in peacetime emergency situations.

Metropolitan lines and districts should be used as shelters during wartime.

Planning of shelter of people is allowed both on station platforms and in transfer tunnels, alleys, connecting branches, depots and other structures. The number of sheltered people in the metropolitan area is determined by the norm of the area per person: in deep tunnels and stations, it is 1 sq.m., and in tunnels of small depth - 1.5 sq.m.

Employees working in the largest shift of institutions, who do not stop working during the war, and who are within a radius of no more than 500 m from the station, as well as the population, who are in the metropolitan area and within a radius of no more than 500 m from the station, take refuge in the metropolitan area. The filling time of the metro station intended for shelter should not exceed 10 minutes. In some cases, this time can be increased to 13 minutes.

When designing metro lines, connecting metro and railway stations should be taken into account in accordance with the expansion of all types of urban transport and railways.

Metropolitan building constructions and protective devices are calculated for the impact of excess pressure in the front of the probable explosion shock wave, its value is taken equal to 3kHz/sq.cm for deep laying lines, and 1kHz/sq.cm for lines of small depth. Backup power and air supply are provided by a decentralized scheme from diesel power plants and autonomous ventilation units, respectively.

Metropolitan lines and areas that have won special protection orders for shelters should be divided into plots. Those areas of the metropolitan area, which are located under the bed of rivers, in unstable aquifers and will be used as evacuation routes, should be separated by protective walls from the buildings designed as shelters of the metropolitan area.

The amount of special protective electrical, air and water supply, control, notification, communication, sanitary-technical and medical provision means is determined according to the number of the population sheltering in the metropolitan area and the duration of their stay in the shelter (no more than 2 days and nights). Air collection and air extraction channels of ventilation systems, gas-air tracts of special ventilation, which exit to the surface of the ground, must have a protective device against penetration of the shock wave into the shelter.

Safety guards placed at the entrances of the stations should ensure that the entrances are locked in a minimum time (2 minutes).

In the normal mode, the power supply of the metropolitan lines and areas should be provided from the source of the external power system, and in the shelter mode - from the protected diesel power plants.

In metropolitan areas, shelters should be supplied with air from both a decentralized and a centralized system, from the existing and to be designed air collectors by means of filter-ventilation devices. The operation of the ventilation system of shelters located in metropolitan areas should be considered in the mode of clean ventilation and filter-ventilation.

Protective devices of ventilation systems, in technologically necessary places, should be equipped with remote control and control signaling devices.

According to the technical regulations "Building Safety Rules" adopted by the Resolution No. 41 of the Government of Georgia on January 28, 2016:

- In the buildings, the area of shelter should be considered, that is, the area where people who are unable to use the road-stairs can temporarily stop before receiving proper

instructions or evacuation.

- According to paragraph 307.7 of the mentioned rules, a group containing a large risk, i.e., enterprise buildings and relevant research areas, where hazardous production substances and substances are used, the total amount of which exceeds the values given in the tables 307.1(1) and 307.1(2) of the same rules, should be classified as CIS-5 group. Accordingly, according to paragraph 307.9 of these rules, at the facilities belonging to the DSS-5 group, for the management group, for the total number of personnel working in shifts, a shelter with easy access should be provided, which should be planned with the provision of airtightness and taking into account special effects and use (operational) requirements.

Analysis of weapon systems used in the Russia-Ukraine war

Analyzing the current war in Ukraine and studying the weapons used by Russia against civilian infrastructure is very important for Georgia. This gives us the opportunity to study in detail and understand the radius of impact and the destructive potential of the weapons that Russia is using extensively against the civilian population and infrastructure.

Russian occupation forces widely use missile weapons in their military operations against Ukraine. At least 12 missile tactical groups equipped with operational-tactical and tactical missile systems are involved in the war. Tactical missile groups mainly use 9K720 "Iskander-M" operational-tactical missile systems equipped with 9M723 quasi-ballistic or cruise missiles. The range of the mentioned 9M728 and 9M729 missiles is mainly up to 500 km, although for the winged version it is possible to have a range of up to 2100-2300 km (Missilethreat, 2024). Russia also uses modern missile variants such as the Kh-101 and 3M-14 (Conflict Armament Research, 2022). In addition, the use of surface-to-air missiles has been reported several times. These weapons are smaller than cruise missiles and are used at a shorter range (about 300 km radius). Tactical "Tochka-U" type missile system 9K79 belongs to a similar type of missile.

The depth of damage of Iskander (9K720) missiles depends on several factors, including the type of charge used, the hardness and specifications of the target. However, in general, Iskander missiles are known for their high penetration and damage capability, especially when using concrete-destroying charges. Concrete shattering charges were designed specifically to damage reinforced structures, such as reinforced concrete shelters and bunkers. A charge of such strength can damage several meters of reinforced concrete (usually 2-4 meters). The depth of specific damage depends on a number of factors, such as the hardness of the target, the type of charge, the angle of impact (if the missile hits the target correctly, the depth of damage will be greater than if it is hit at an angle), the type of surrounding soil, etc. (Cranny-Evans & Kaushal, 2022).

The Tochka-U (SS-21 Scarab) missile, especially in its improved variants, has some capability to damage reinforced concrete structures, although it is less advanced than systems like the Iskander. The Tochka-U can be equipped with a high-explosive (HE) fragmentation warhead or a penetrating warhead. The HE warhead is designed to cause significant burst and fragmentation damage, but is less effective at deep penetration. Penetration warheads designed to fracture reinforced concrete can penetrate approximately 1 to 1.5 meters of reinforced concrete, depending on the specific warhead design and impact conditions.

As for the Kh-101, this missile also has the ability to be equipped with various types of warheads, including high-explosive (HE) and penetration/penetrating warheads. A penetrating warhead is specifically designed to penetrate hardened targets (for example, reinforced concrete bunkers) (Army Recognition Group, 2024). Although the specific penetration depth for the Kh-101 penetration warhead is not officially known, based on similar systems and typical warhead designs, we can conclude that the missile can penetrate approximately 2 to 3 meters of reinforced concrete.

An overview of the main parameters of shelters

In order to ensure the structural integrity of shelters against such weapons, it is necessary to use safe construction materials. As a rule, in

the construction of shelters, reinforced concrete and steel materials are used, which can withstand the strong pressure caused by the explosion and the impact of debris. Reinforced concrete is one of the main materials used in the construction of blast shelters due to its strength and durability. The use of iron mesh (reinforcement) in concrete increases its strength and makes the wall more resistant to the impact of high blast pressure. Steel helps distribute the load evenly on the concrete and increases the overall durability of the structure. It acts as an additional barrier that can absorb and dissipate energy from impact, thereby reducing the depth of penetration. The armature is made of high strength steel and is available in different types. In the US, carbon steel rebar (ASTM A615) and low alloy steel rebar ASTM A706 are most common (iRebar, 2020). In addition to traditional reinforcement, steel mesh and steel fibers can be used to reinforce concrete. These materials increase the concrete's strength, impact resistance, and energy absorption capacity by distributing the reinforcement/strength uniformly throughout the concrete (Sanytsky M., 2023).

Reinforced concrete is effective in reducing both penetration and blast damage. Considering the damage potential of the tools discussed above, several layers of reinforced concrete, at least 2-3 meters thick, should be used in the process of construction of shelters in Georgia. Reinforcement should be located in such a way as to ensure an even distribution of the load. This involves the placement of reinforcement in both horizontal and vertical directions by placing grid-like structures in the concrete. This helps to absorb and dissipate the energy caused by the impact of the penetrating warhead. In addition to reinforced concrete, high-strength steel is used in the construction of shelters. This material is mainly intended for the construction of explosion-proof doors and critical structural components. Blast-resistant doors are designed to protect the interior of the shelter from extreme pressure and blast-related debris. Such doors must be made of steel several inches thick and tested to withstand various levels of blast force (several thousand pounds of pressure per square inch). Also, it must be sealed with a strong seal to prevent blast waves, toxic gases and debris from entering the shelter.

Another important component to consider when designing shelters is the location and depth of the shelter. It is best to build a shelter underground, as the ground has the ability to absorb and dissipate the energy of an explosion and provides good protection against a variety of threats, including missile strikes, conventional explosives, and even nuclear explosions. Based on the missile data described above, it is recommended that the underground shelter be placed at least 5-7 meters deep. In terms of location, shelters are best located near elevated terrain (mountains/hills) as using natural geological features can provide additional protection and avoid the need to dig deep into the ground. Shelters should be located away from primary targets (military bases, industrial facilities, etc.) to reduce the likelihood of a direct hit.

The capacity of shelters is an important issue that affects their efficiency and safety. FEMA recommends that shelters be at least 5 square feet per person for short stays (less than 24 hours) and 10 square feet per person for stays longer than 24 hours. The capacity must also correspond to the capacity of the ventilation system. As a rule of thumb, 10-20 cubic meters of air per hour should be calculated per person (FEMA, 2006).

Support systems in shelters are necessary to maintain living conditions in crisis situations. These systems include basic necessities such as ventilation, clean water, food, medical first aid kits, temperature control and waste management.

As mentioned, in the event of a conflict, the primary threat to Georgia from the potential adversary is expected to be the use of such weapons systems, which are more focused on the destruction of infrastructure and buildings, and not on attacks carried out with chemical, biological or radiation weapons. Therefore, when designing a ventilation system, the focus should be on ensuring air cleanliness and protection against overpressure and debris. Ventilation systems must be equipped with filters for dust, smoke and other harmful particles. It is advisable to have a double ventilation system so that in case of failure of one of the systems, the supply of fresh air continues without interruption. Pressure and

debris protection shall be controlled by means of blow-off valves. These valves are automatically closed during the explosion and protect the shelter from the blast wave and debris. After stabilization of pressure, they are opened and ventilation is resumed. The air intake/exhaust system must be installed in an area protected from direct impact or debris. To catch large particles/debris, there should be a so-called Pre-filters, while filtering of fine particles should be done by means of high efficiency air particle filters. In addition, the shelter must have overpressure relief vents that will automatically open to relieve excess pressure to protect the structural integrity of the shelter and ventilation system.

For water supply, large and solid reservoirs should be used, which should be regularly checked for contamination. Filters should be used for water purification and, if necessary, it should be chemically treated. For waste recycling systems, it is better to use secondary water in order to make efficient and long-term use of water resources.

The shelter should have a proper ventilation system to ensure temperature and humidity control. Main and reserve energy sources - generators are used for energy supply. Backup systems provide short-term power supply for critical systems such as lighting, communications, and medical equipment.

The shelter should also have long-term food supplies. Also, medical supplies and equipment, including first aid kits, medicines and basic medical equipment.

It is important for shelters to have good communication infrastructure, which should be used for internal and external communication in emergency situations. For internal communication, fixed and mobile telephone systems are used, which provide fast and reliable communication inside the shelter. Shelters should be equipped with emergency call systems that allow residents to quickly contact the appropriate persons or medical personnel if necessary. External communication in shelters is carried out through radio, Internet, satellite connection. For communication, communication lines protected from cyber-attacks and information leakage should be used, which ensure a secure and confidential connection. Uninterruptible power supply is necessary for communication systems, for which generators and other types of power sources (eg UPS) must be used.

Conclusion

The importance of asylum in Georgia is determined by many factors and is closely related to the country's safety, geopolitical situation and the need to protect the population. The country's geographical location and historical experience determine the importance of the civilian shelter system. The country is located in a strategically sensitive region, where geopolitical tensions often arise. The 2008 Russia-Georgia war and the ongoing occupation underscore the need for civil defense infrastructure.

In this paper, the main parameters of designing shelters in the context of Georgia are discussed. The aim of the paper was to study the military weapons that can be expected to be used by a potential adversary and, based on the analysis of these weapons, to offer recommendations that should be considered in the process of construction/reconstruction of civilian shelters to protect against weapons. As a result of the research, several important aspects were identified, which must be taken into account when creating an effective and safe shelter system in the country.

First, an analysis of the weapons systems used in the Russia-Ukraine war highlights the need for shelters that can withstand the threats of modern warfare, including high-velocity missiles and artillery. The analysis also showed that it is unlikely that nuclear and chemical weapons will be used against Georgia, and therefore shelters should not be counted on such a threat (as was the case in the Soviet Union). In the process of building shelters, emphasis should be placed on the construction of solid underground structures, which will be designed for rockets capable of damaging 3-5 meters of reinforced concrete. Along with sustainability, it is important for shelters to be capacious and have a convenient location. In this regard, Georgia can benefit from its mountainous terrain. In the case of building shelters under elevated ground, the ground becomes a natural shield against blast waves.

Along with the construction of new shelters, it is necessary to survey the existing shelters,

determine their sustainability, reconstruct and put them into operation. It will be less expensive than building new shelters. Such an approach ensures not only the construction of new shelters, but also the effective use and improvement of the existing infrastructure. In this way, it will be possible to ensure maximum safety of the population and optimal use of state resources.

The analysis of international experience has made it clear that for the development of civilian shelters, it is necessary to have a solid legal base that will regulate in detail the issues of construction and operation of shelters. In this regard, Georgian legislation needs to be refined and harmonized with international standards.

By integrating these elements, Georgia can create a comprehensive civil defense strategy that will protect its population from both natural and man-made disasters. The creation of such a system will not only strengthen national safety, but also contribute to the overall sustainability and stability of the country.

References

1. Army Recognition Group. (16 May 2024 r.). armyrecognition.com. Retriewed from armyrecognition.com: https://armyrecognition.com/military-products/army/missiles/cruise-missiles/kh-101-advanced-stealthy-long-range-subsonic-cruise-missile-data#:~:text=The%20Kh%2D101%20features%20advanced,difficult%20to%20detect%20and%20intercept.
2. Conflict Armament Research. (December 2022 r.). storymaps.arcgis.com. Retriewed from storymaps.arcgis.com: https://storymaps.arcgis.com/stories/81bc6b71fdc64361a05a21020c3d6d5e
3. Cranny-Evans, S., & Kaushal, S. (8 August 2022 r.). www.rusi.org. Retriewed from www.rusi.org: https://www.rusi.org/explore-our-research/publications/commentary/iskander-m-and-iskander-k-technical-profile
4. FEMA. (May 2006 r.). www.fema.gov. Retriewed from www.fema.gov: https://www.fema.gov/sites/default/files/2020-08/fema453.pdf
5. Fornusek, M. (5 June 2023 r.). kyivindependent.com. Retriewed from kyivindependent.com: https://kyivindependent.com/almost-third-of-checked-bomb-shelters-in-ukraine-not-suitable/
6. INSTITUTE FOR THE STUDY OF WAR. (22 February 2024 r.). www.understandingwar.org. Retriewed from www.understandingwar.org: https://www.understandingwar.org/backgrounder/russian-offensive-campaign-assessment-february-22-2024
7. iRebar. (2020). www.irebar.com. Retriewed from www.irebar.com: https://www.irebar.com/USCommonBarGrades.html
8. Majumdar, P. (5 July 2023 r.). medium.com. Retriewed from medium.com: https://medium.com/@AirPra/dominating-the-seas-the-naval-supremacy-of-3m-series-kalibr-cruise-missiles-e4a5b5d12c9c
9. Missilethreat. (23 April 2024 r.). missilethreat.csis.org. Retriewed from missilethreat.csis.org: https://missilethreat.csis.org/missile/kinzhal/
10. Reynolds, J., & Fitzpatrick, J. (1963). Shelter building mandatory in six european countries. Madison, Wisconsin: Bureau of Civil Defence.
11. Sanytsky M., K. T. (2023). HIGH STRENGTH STEEL FIBER REINFORCED CONCRETE FOR FORTIFICATION PROTECTED STRUCTURES . Theory and Building Practice , 37-42.
12. THE INTERNATIONAL INSTITUTE FOR STRATEGIC STUDIES. (2020). RUSSIA'S MILITARY MODERNISATION. London: The International Institute for Strategic Studies.
13. UNDP. (19 June 2023 r.). www.undp.org. Retriewed from www.undp.org: https://www.undp.org/eurasia/stories/breaking-barriers-building-hope-ukraine
14. Williams, I. (2023). Putin's Missile War: Russia's Strike Campaign in Ukraine. Center for Strategic & International Studies: London. Retriewed from

https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023-05/230505_Williams_Putin_Missile.pdf?VersionId=0rahER.P81oo5ispb8.UGcT_90DmLoSb

15. Arabuli N. (7 August 2023 r.). www.radiotavisupleba.ge. Retriewed from www.radiotavisupleba.ge: https://www.radiotavisupleba.ge/a/%E1%83%90%E1%83%92%E1%83%95%E1%83%98%E1%83%A1%E1%83%A2%E1%83%9D%E1%83%A1-%E1%83%9D%E1%83%9B%E1%83%98%E1%83%A1-%E1%83%A8%E1%83%94%E1%83%93%E1%83%94%E1%83%92%E1%83%94%E1%83%91%E1%83%98-%E1%83%A0%E1%83%98%E1%83%AA%E1%83%AE%E
16. Melkadze, T. (2012). Fundamentals of critical infrastructure protection in emergency situations. Tbilisi: Technical University.
17. Parliament of Georgia. (29 June 2014 r.). matsne.gov.ge. Retriewed from matsne.gov.ge: https://matsne.gov.ge/ka/document/view/2363013?publication=10
18. PGovernment of Georgia. (14 January 2014 r.). https://matsne.gov.ge. Retriewed from https://matsne.gov.ge: https://matsne.gov.ge/ka/document/view/2195780?publication=0
19. Parliament of Georgia. (29 May 2014). matsne.gov.ge. Retriewed from matsne.gov.ge: https://matsne.gov.ge/ka/document/view/2363013?publication=10
20. Parliament of Georgia. (2018). Code of Spatial Planning, Architectural and Construction Activities of Georgia. Tbilisi.