Instant shelter: contemporary architectural solutions for disaster management

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Abstract. The article considers the systematization of contemporary solutions to eliminate the consequences of anthropogenic, natural and man-made disasters. The purpose of the article is to classify modern approaches to the implementation of shelters. The article considers modern built and conceptual projects. As a result of a systematic analysis of project examples, 2 major groups of approaches were identified: *specific* and *non-specific*. *Specific* approaches are supposed to be used within one particular sort of cataclysm (tsunamis, floods, earthquakes), *non-specific* approaches are suitable for different extreme conditions. The study will be useful for practical and theoretical research in the field of combating the consequences of cataclysms.

1 Introduction

Natural and technogenic disasters lead to significant destruction, which can be eliminated providing new architectural solutions. According to the UN Report on the Global Assessment of Disaster Risk Reduction 2022, nothing undermines the sustainable development of society as much as natural disasters and the recovery process takes years [1]. These include rapid-onset events (typhoons, earthquakes, flash floods) and slow-onset events (droughts, desertification, soil erosion) developing over months or years.

In February 2023, earthquakes in Turkey and Syria caused the destruction of entire cities, leaving several thousand people without housing and infrastructure [2]. Currently, all forces are thrown at the restoration of housing stock. Tornadoes are one of the disasters that claim 69 lives each year in the United States [3]. In March 2023, more than 600 people were injured due to tornadoes in the state of Arkansas. In June 2019, floods in the Irkutsk region affected more than 100 settlements [4]. For several months, the victims were forced to live on the remains of destroyed buildings.

The devastating consequences of disasters serve as an impulse for finding new effective solutions to eliminate the damage. Currently, new approaches are being developed that use contemporary structures, materials and technologies for sustainable living.

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2 Materials and Methods

Disaster Management includes both predictive and reactive scenarios relating to urban planning strategies and the improvement of building construction technologies.

Thus, the study by S. E. Shah describes urban infrastructure planning techniques that use multiple data collection technologies to form a Disaster resilient smart city (DRSC), informing and preventing the consequences of destruction due to intelligent systems in construction [5].

A. Bashawri et al. consider classifications of shelters depending on the duration of use [6]. In the study by F. C. Karaoğlan and S. Alaçam, scenarios for combining the functional areas of a shelter using computational design were created [7]. Some examples of organizing a shelter made of cardboard and tent fabric for refugees are described by J.F. Latka [8]. In connection with the constant modification of the requirements for disaster-resilient housing, the very concept of "shelter" is being rethought, which is perceived not as an object, but as a process of forming a certain environment [9].

In addition to the organization of individual shelters, approaches for integrated earthquake protection systems have been proposed, where a reserved capsule is built into the standard building layout and is used as a safe unit during collapse [10]. There are new studies on the architecture of shelters aimed at developing requirements and scientific specifications for certain climatic zones [11].

As instant solutions for the consequences of natural disasters, prefabricated folding structures based on rod systems are proposed [12]. In the research by A. Mesrop, an innovative form of textile shelter is generated by using computer algorithms [13]. G. Celentano et al. note that the trend towards the use of local materials in the construction of shelter settlements is gaining popularity [14]. Researchers E. Z. Escamilla and G. Habert also outline that local materials have a higher potential for low environmental impact [15]. Aspects of social, economic and environmental sustainability of shelters were considered in the study by L. Alshawawreh et al. [16]

Along with the concepts that eliminate the consequences of disasters, N. A. Saprykina describes approaches that use the natural geological and ecological processes of the Earth in order to prevent a cataclysm [17].

This study analyzes current and futuristic approaches to dealing with the consequences of several types of disasters, including tsunamis, floods and earthquakes, as well as approaches that provide experience in organizing shelters in general.

3 New approaches to disaster handling

3.1 Tsunami

The most vulnerable to tsunami impacts are Chile, Haiti, Indonesia, Japan, Peru, Samoa-Tonga and the Solomons, where multiple incidents have occurred in recent decades [18]. The "X2Shelter" was proposed by Geotectura in 2019 as a response to the South Asian tsunami. The refuge can be air-dropped into hard-to-reach disaster areas and is powered by renewable energy sources. The pre-fabricated structure can be used as a stand-alone housing tent, sanitary block or medical station. It can also be easily combined with other modules to provide shelter for many people at a time.

"Tsunami Convergenics" underwater skyscrapers were designed for the offshore installation by the Onagawa coastline in Japan. The residential modules are connected to the power plant via offshore channels and convert tsunami wave vibrations to generate electricity. Skyscrapers are installed in regular rows, colliding with which, the underwater

tsunami wave slows down. Each skyscraper consists of residential and technical cushioning modules that expand vertically in response to wave action to provide structural flexibility.

The "Tsunami Park Skyscraper" project was proposed by architects W. Jue, Zh. Qian, Zh. Changsheng, Li Muchun, Xu Jing for eVolo 2022 Competition. The Pacific region, located at the intersection of four tectonic plates, is significantly at risk of severe tsunamis. The volcanic eruption in Tonga on January 14, 2022 resulted in a tsunami threat for the entire Pacific region. The shape of the skyscraper imitates the mangroves, which act as a biological barrier that softens the impact of tsunami waves (fig. 1).

Fig. 1. "Tsunami Park Skyscraper" by W. Jue, Zh. Qian, Zh. Changsheng, Li Muchun, Xu Jing, Source: https://www.evolo.us/tsunami-park-skyscraper/

The skyscraper has two functional states: a *normal* state and a *distress* state. Under normal conditions, residents can use the space between the high concrete columns for recreation and fishing. Tanks with filters are installed in the columns to collect water, which is transferred to underground tanks for desalination and further use. Underwater turbines are fixed around the columns, converting wave energy. The upper terraces of the skyscraper serve as protected above-water residential and public spaces. The water treatment and storage system in the pillars and the underground part of the skyscraper is connected to the city's water supply network in order to provide drinking water for the entire city in the event of a disaster.

3.2 Flood

Flooding poses a serious threat due to global sea level rise, stimulating the emergence of floating buildings [19]. The extreme water environment impacts the precedents for the construction of unique objects adapted to life on water [20]. The "Airdrop House" project was designed by architect E. Maynard for remote areas affected by floods. The capsule house can be moved from the flooded area to a safe zone using air transport. The material for the sphere capsule is a water-absorbing polymer composite, which deploys a house up to 7 m in diameter when contacted with water.

The project of a shelter on removable supports made of steel sheet was developed by designer D. London for areas affected by natural disasters. The shelter can be fixed on a floating base and moved over remote distances. The interior of the capsule is lined with insulating fabric for climate control and provides a place to relax and work.

The design of the "Duckweed Survival House" floating capsule for the consequences of floods was developed by the architects Zh. Ying and N. Yuntao. Each module is equipped with a stabilizing weight at the bottom of the structure to ensure buoyancy. Signal coloration of the upper part of the module facilitates the search for victims during the rescue operation.

The deployable "Life Box" flood shelter was designed by architect A. Onalan. A collapsible polyethylene container with air holds food, freshwater and sleeping bags. When deployed, the container turns into an inflatable shelter. All shelters provide buoyancy through the 2 inflatable rings around the base. "Life Box" can be deployed in less than one minute. The modules can also be expanded and used to create temporary hospitals (fig. 2).

Fig. 2. "Life Box" flood shelter, Source: https://inhabitat.com/life-box-an-air-droppable-pop-up-recovery-shelter-for-victims-of-natural-disasters/

3.3 Earthquake

A 3D-printed residential building on earthquake-resistant supports was designed by Haus.me architects in 2019. The house does not require a connection to local power grids and uses solar energy to operate the building's engineering systems. The module is also equipped with systems for collecting and bioactive water purification to ensure complete autonomy in case of a crisis. Three models of a typical house are provided: with an area of 400, 800 or 1600 m^2.

A student project for an earthquake emergency module was developed at the Pontifical Catholic University of Peru (PUCP) in 2015. An aluminum self-supporting framework stabilizes the dome structure. A layer of thermal insulation is deployed on top of a solid frame, protecting the interior from extreme conditions. After that, diamond-shaped PVC panels are installed over the entire surface of the shell. Natural air circulation is provided by side openings and a window in the upper part of the dome.

The hemispheric residential module project was developed by industrial designer S. Williamson for areas affected by earthquakes. The hemisphere measures 6 m in diameter, 2 m in height and is designed for 6 people. The material of the shell is a hybrid fabric consisting of aluminized nylon and polyethylene. The material prevents heating of the air inside the living space during the daytime. In the center of the dome is a camp stove with a pipe outlet from the top central hole, which maintains a comfortable temperature at night. In the absence of provisions for a long time, the module can be used as a greenhouse, as well as a desalination plant operating according to the distillation method.

Architect L. Perschl designed a portable shelter for territories of Japan affected by earthquakes. The modules are made on the basis of a folding wooden structure. There are three stages of using the structure: at the first stage, the modules, folded in the form of cubes, are transported to an earthquake-prone area and are stored in a warehouse. After an earthquake, they serve as temporary homes. At the third stage, the modules are grouped to form public spaces.

3.4 Multi-use

Designed for the aftermath of industrial disasters, the "Exo Shelter" can be folded for compact storage or transportation to remote locations. One cargo ship can deliver 300,000 modules to provide shelter for more than a million refugees. The module consists of a base plate and an outer shell, fixed within two minutes without specialized labor. The living area of the module is 7.2 m^2. The upper shell is made of polypropylene composite fixed on an aluminum frame.

The "Lagoon Folding House" is designed for a wide range of functions, including a disaster survival shelter. The roof of the residential module is equipped with a flexible solar panel, the energy from which is used for the life support of all house systems. The module contains a central square core serving as a common seating area, bathroom and kitchen, and 4 folding units with an isolated entrance. Each block is designed to accommodate 2 people.

A shelter in the form of a folding structure can be erected independently in a few minutes. Stabilized polypropylene, resistant to extreme atmospheric conditions, is used as a shell material. The house is equipped with controlled ventilation openings designed to stabilize the microclimate. The design has the shape of a cube with a height of 198 cm.

The idea of a growing bamboo shelter for the regions of Southeast Asia is reflected in the design of architect R. Tiwari. Modules based on triangular and hexagonal prisms are placed on platforms raised above the ground. The module construction time is 5 hours. It is assumed that the side panels of the shelters will be hinged to allow the connection of individual modules.

The 9 m^2 shelter, constructed from standard plastic boxes and nylon cable ties, was assembled by Lebanese American University (LAU) architecture students. Crates provide storage spaces within the walls of the hideout. In hot and dry climates, a shelter is an alternative to a standard tent: it provides natural light, ventilation and cooling and is structurally more stable. In colder climates, the inside of the drawers can be insulated with standard PVC blocks.

The "EDV-01" shelter, based on a retractable hydraulic structure, was designed by the Japanese industrial company Dawia Lease and Yatsutaka Yoshimura Architects. The shelter is shipped in a folded configuration that is the size of a standard container. A hydraulic lift raises the outer shell, creating a two-story building. Kitchen and bathroom are located on the ground floor, living room or bedroom are placed on the upper floor (fig, 3).

Fig. 3. "EDV-01" shelter, Source: https://www.designboom.com/architecture/daiwa-lease-edv-01-elevates-emergency-shelter-design/

Equipped with solar and lithium batteries, an autonomous dwelling does not need additional electricity from outside. An 800 liter water tank, a drinking water station and a composting toilet are enough for 2 adults to live for a month. Satellite communication devices

allow refugees to live autonomously, which is necessary for partial reconstruction of the surrounding buildings.

4 Discussion

As a result of the research, contemporary approaches to organizing shelters for victims of natural and man-made disasters were analyzed. Modern solutions were conventionally divided into *specific* and *non-specific*. *Specific* solutions include objects for certain emergency situations (tsunami, flood, earthquake) associated with the most typical sorts of danger. *Non-specific* solutions include strategies that can be used to eliminate the consequences of various types of cataclysms. The groups are conventionally presented on a diagram (fig. 4).

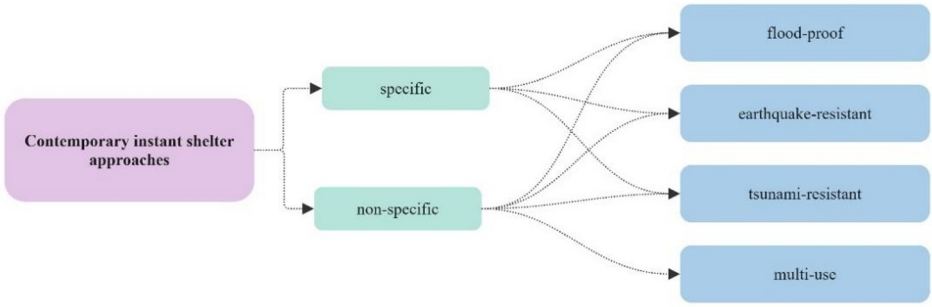

Fig. 4. Contemporary instant shelter approaches.

5 Conclusion

The existing multiple approaches to the organization of shelters were systematized according to contemporary tendencies. The resulting directions can be detailed in further studies on architectural solutions for disaster management. Subsequent research can be aimed at regulating constructive and technical solutions within the described areas.

Acknowledgements

The study was carried out within the framework of the Program of Fundamental Scientific Research of the Russian Academy of Architecture and Construction Sciences and the Ministry of Construction, Housing and Communal Services of the Russian Federation for 2023, grant no. 1.1.6.3. “Formation of artificial living environment for extreme conditions as an alternative ecosystem: innovative approaches”.

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