Methodological approaches to designing biophilic rehabilitation buildings

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Abstract. The article aims to analyse current architectural and engineering research and developments in the treatment of post-traumatic disorders. The study thoroughly explores the aspects which are the basis of the development of rehabilitation buildings. It deals with a comprehensive series of theoretical and experimental studies aimed at devising and validating innovative, inclusive, trauma-informed architectural and landscape solutions, as well as eco-oriented, resource-efficient structural solutions. The article delineates the fundamental principles of spatial organization grounded in the concept of biophilic design. The study developed a conceptual design solution for a rehabilitation building with elements of biophilic design, as well as designed modular elements such as wall panels, floor panels, and roofing panels, which proved to be effective. To substantiate the proposed functional-planning and architectural-engineering solutions, a spatial model of the building has been constructed, and static calculations have been performed.

1 Introduction

The hybrid war of Russia against Ukraine, which has been ongoing since 2014, escalated into an open large-scale military attack in February 2022, which continues to this day. The consequences of this aggression include the destruction of housing and infrastructure, the emergence of internally displaced persons, refugees, and casualties among both military personnel and civilians. Equally significant are the consequences related to psychological and behavioural disorders - strong reactions to minor stimuli, various degrees of mental disorders, including post-traumatic stress disorders (PTSD) as an extreme human reaction to threats. Post-traumatic stress disorder (PTSD) is characterized by constant fear, panic attacks, and intrusive thoughts about traumatic events. It is considered that the average prevalence of PTSD among the population in wartime conditions ranges from 15 to 30%.

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Ukraine may soon face a wave of PTSD, which will have a significant impact on the socio-economic sphere and the healthcare sector. Since trauma affects the body through the environment which a person is surrounded by, the space can play a key role in mitigating the stress response, creating a favourable environment for recovery. Alongside traditional medical approaches, tools, and medications, the development of innovative solutions in the related fields is crucial today. Through a synergistic effect, these innovations will effectively rehabilitate veterans and civilians with PTSD caused by military actions.

An example of this approach involves crafting biophilic rehabilitation buildings, which go beyond mere architectural structures, to create specially designed environments to enhance the physical and psychological well-being of individuals afflicted by PTSD.

In the context of this research, biophilic rehabilitation buildings refer to structures designed with principles of biophilic design and oriented towards enhancing the physical and psychological well-being of individuals, including veterans and civilians, suffering from PTSD. These buildings entail the use of innovative solutions in architecture and design that contribute to creating a favourable environment for rehabilitation and health restoration while reducing the impact of stressors on people's mental well-being.

The aim of the research is to present a methodology for designing biophilic rehabilitation buildings for veterans and civilians affected by the Russo-Ukrainian war, as well as to propose specific architectural and planning principles, techniques, and structural solutions for such buildings.

2 Materials and Methods

2.1 Definitions and Terms

To achieve the research goal, it is necessary to establish a clear understanding of the key terms this article is based on.

The term ‘biophilic design’ refers to a concept used in architecture, landscape, and interiors. This concept focuses on creating spaces that have a positive impact on humans by incorporating elements of nature. These elements can include actual living natural elements such as plants, water features, natural lighting (direct nature); elements representing nature but not living, such as natural and biopositive materials (indirect nature); and spatial mechanisms for connecting with nature, such as maximizing natural light, creating biomorphic forms, and providing access to open spaces.

In the context of architecture, this term encompasses not only the use of natural building and finishing materials but also ecologically clean ‘green’ technologies, approaches to minimizing electromagnetic radiation from technological equipment and building engineering systems, noise control, ventilation, temperature-humidity control, and reducing anthropomorphic impacts on the environment. In our understanding, a ‘biophilic structure’ is aimed at taking into account the physiological and psychological needs of humans and creating a comfortable environment.

As mentioned earlier, in biophilic design, along with natural materials, biopositive materials are also used. Biopositive materials, on the one hand, refer to building materials of natural origin. On the other hand, these are materials that have minimal negative impact on human well-being.

Furthermore, considering rehabilitation buildings for veterans and civilians with PTSD resulting from military actions as the object of study, a biophilic structure is endowed with specific functional characteristics while still considering fundamental ecological requirements.
2.2 Methodology

The development of biophilic rehabilitation buildings represents a pressing task that requires a comprehensive approach using various scientific methods. One of the key directions in this field is empirical research, based on observation, experimentation, and analysis of real practical situations. The application of empirical methods provides an opportunity to gain a direct and objective understanding of the impact of architectural and design solutions on the sensory perception and effectiveness of rehabilitation for individuals with PTSD. A set of empirical methods, such as observation, case studies, and experimentation, has allowed for the exploration of the comfort and functionality of rehabilitation buildings (space allocation, natural lighting, room zoning, as well as interaction with the surrounding natural environment).

The application of theoretical research methods, such as analysis of existing theories, concepts, and models, integrative analysis, as well as examination of scientific literature and publications in this field, have allowed for a deeper understanding of the problem and the identification of theoretical foundations for the design of biophilic rehabilitation buildings [1, 2].

The method of analysing architectural concepts and models has facilitated the exploration of various architectural concepts and models prevalent within the framework of biophilic architecture and green building. This has enabled the identification of key principles and approaches conducive to creating buildings capable of positively impacting the emotional and physical well-being of individuals.

The literature review method helped synthesize the obtained data through the analysis of scientific articles and research dedicated to effective treatment and rehabilitation methods for patients with PTSD in the fields of psychology, psychiatry, and medicine. This method allows for the identification of factors (aspects) influencing the recovery process, as well as the needs of the target audience when designing rehabilitation buildings.

The method of innovative structural solutions is used to analyse modern technologies and innovative developments in the field of eco-materials, constructions, and engineering approaches in the design of biophilic rehabilitation buildings.

The study employed specialized architectural planning methods aimed at analysing and designing specific architectural solutions considering the characteristics of rehabilitation facilities and the needs of their future users. These methods included architectural modelling and experimental design.

In designing biophilic rehabilitation buildings for military personnel and civilians with PTSD, the method of architectural modelling was applied. This method involves creating virtual models of buildings, their interiors, and surroundings using specialized software. The developed models allowed visualizing various aspects of a future building, such as its form, spatial organization, distribution of light and air, as well as the use of green technologies and natural elements. This method enabled the exploration of different design options and room layouts to optimize their ergonomics and user-friendliness while considering requirements for mobility-impaired population.

In the context of this study, the method of experimental design involves the creation of prototypes (or pilot projects) to test and evaluate various architectural and design solutions in a specific architectural and urban planning situation (Ukraine). Experimental design included the development of building models or prototypes, virtual tours of the future facility, and the use of specialized simulators to assess the impact of architectural solutions on user sensitivity.

The presented methodological framework of the study represents a combination of various methodological approaches, which allowed for the development of the most successful biophilic rehabilitation building design as a conceptual architectural and planning and structural-engineering prototype.
2.3 Analysis of Existing Research

It should be noted that modern research on the development of architectural and planning solutions for medical institutions is based on the needs and comfort of patients. An emerging area of architectural practice aimed at creating a supportive environment to alleviate the physical, psychological, and emotional consequences of severe illnesses and associated pathologies is trauma-informed design [3].

Trauma-Informed Design is an approach to environmental and architectural design that considers the needs and characteristics of individuals who have experienced traumatic events. The core idea of trauma-informed design is to recognize the impact of trauma on people's perception and behaviour, creating an environment that promotes their healing and well-being. This may involve aspects such as using soft and natural materials, creating spaces for self-soothing and recovery, reducing triggers and potentially traumatic stimuli, as well as providing a sense of safety and control.

In the field of architecture and design, there are several specialists actively engaged in researching and applying the principles of trauma-informed design, such as Michael Murphy, Anna Pinkerton, and others. Foreign authors note the positive effect of implementing design solutions aligned with the principles of ‘green’ construction (energy efficiency, resource efficiency, indoor environmental quality, use of eco-friendly materials, etc.) on reducing stress and anxiety levels [4].

The analysis of the research subject has shown a significant positive impact on improving the psychological well-being of patients in a number of healthcare facilities with the implementation of biophilic architecture [5]. Biophilic architecture is an approach to building design and urban planning that seeks to create a connection between people and nature, enhancing the quality of life and well-being of users. The main idea is to integrate natural elements and processes into architectural solutions to create a healthy and supportive environment for living, working and leisure.

In this study, the works of Prof. Stephen Kellert, Judith Heerwagen, Bill Browning, Oliver Heath and others were examined [6-8]. The analysis of the research conducted by these scholars confirms the potential of implementing eco-oriented ‘green’ solutions in rehabilitation buildings. It is also noted that modern practices in energy efficiency and building sustainability, such as technologies for rainwater harvesting, renewable energy (solar panels, wind turbines), and building management systems, allow optimizing energy and resource consumption. The general principles of interior design in the organization of space in biophilic rehabilitation buildings involve creating special areas for relaxation and rest, as well as extensive use of natural design elements such as plants and water features, aimed at creating a calm and soothing atmosphere.

2.4 Integration of Medical, Architectural, and Structural Aspects in Biophilic Design

The study of post-traumatic stress disorder (PTSD) in the context of developing biophilic rehabilitation buildings encompasses medical and psychological aspects of understanding the nature and effects of PTSD, architectural and engineering aspects for designing appropriate buildings, sociological and economic analysis to assess social and economic implications, as well as an ecological approach for developing environmentally sustainable solutions. Thus, researching this topic requires collaboration among experts from various fields for a comprehensive understanding and successful resolution of the tasks at hand.
2.4.1 Medical and Psychological Aspects

The study of post-traumatic stress disorder (PTSD) requires an understanding of both its physiological and psychological aspects. This includes knowledge of the biological mechanisms of stress, neuropsychology, as well as an understanding of the psychosocial and cultural factors influencing the symptoms and development of PTSD [9-13].

The medical aspects of PTSD involve studying the underlying mechanisms of the body’s stress response, such as the activation of stress hormone (cortisol) and changes in the functioning of the hippocampus and amino acid neurotransmitters. Psychological aspects include understanding the emotional, cognitive, and behavioural factors of PTSD (fear and anxiety spikes, recurrent traumatic dreams and memories, as well as avoidance of trauma reminders). Additionally, significant roles are played by psychosocial and cultural factors, such as the presence of social support and cultural beliefs, which can influence the manifestation and recovery timeline of PTSD. Researching these aspects helps to deepen the understanding of the mechanisms underlying the symptoms and the development of PTSD and develop more effective methods for its diagnosis, treatment, and rehabilitation.

For architects, understanding these aspects is crucial when designing biophilic rehabilitation complexes. Firstly, the knowledge of physiological mechanisms of stress and its effects on the body helps architects create environments conducive to stress reduction and health restoration. This may involve creating spaces for relaxation, meditation, physical activity, and other methods known for their beneficial effects on mental and physical well-being. Secondly, understanding the psychological aspects of PTSD helps architects design environments that facilitate the psychological adaptation and rehabilitation of survivors. This can include organizing spaces for therapeutic sessions, psychological support, and social integration, as well as creating a cozy and supportive atmosphere conducive to restoring emotional balance and self-perception. Thus, understanding the medical and psychological aspects of PTSD is the foundation for developing effective and tailored rehabilitation complexes that can significantly improve the quality of life for military personnel and civilians affected by the consequences of the armed conflict.

2.4.2 Social and Economic Aspects

The study took into account the social and economic aspects of this issue, which are necessary for the design of biophilic buildings [14-16]. It was found that sociological aspects, such as stigmatization and social support, have a significant impact on the psychological well-being of the survivors. Biophilic buildings should create a safe and supportive environment that fosters communication and interaction, social integration, and reduces the level of stigma in society.

The analysis of the economic consequences of PTSD emphasizes the importance of efficient resource utilization in the design of biophilic buildings. The costs of treating and rehabilitating survivors can be substantial, and efficient use of resources can reduce the economic burden on society. Biophilic buildings, created with principles of energy efficiency and sustainable development in mind, can reduce operational expenses and cut building maintenance costs in the long term. Additionally, creating conditions for the rapid and effective recovery of the survivors’ health can help reduce the duration of treatment and lower medical service expenses.

The analysis of the socio-economic and medical-psychological aspects provided understanding and direction for the architectural and engineering activities in this study. The development of biophilic rehabilitation buildings requires the participation of specialists in architecture, interior design, and engineering. An important aspect of architectural and engineering work is the selection and use of environmentally sustainable building materials,
which ensure safety and comfort for building users, as well as minimize negative environmental impact. This should include the use of natural materials that do not cause allergies or toxicity, as well as maximizing natural lighting and ventilation to create a healthy and comfortable indoor environment [17, 18].

These aspects provide the basis for the development of biophilic rehabilitation buildings, considering both the physical and psychological well-being of users. They have provided the opportunity to develop fundamental architectural and engineering principles for designing biophilic buildings in real-world wartime conditions, which have been taken into account in this research.

2.5 Key Design Principles

The aspects described above have led to the formulation of the key architectural and planning principles for biophilic rehabilitation buildings:

- the principle of harmony with nature: intertwining the building and natural landscape elements to create a natural and appealing exterior and connect with the surrounding environment, using natural environmentally sustainable materials that promote the health and comfort of users while minimizing negative environmental impact;

- the principle of accessibility and convenience: creating a friendly and convenient architecture that considers the needs of all users, including those with disabilities, using natural lighting and ventilation to create a healthy and comfortable indoor environment;

- the principle of harmonious spatial solutions: developing functional layouts and aesthetic designs of the building to ensure harmony and comfort in internal spaces, designing special zones for relaxation and recovery of physical and psychological well-being;

- the principle of innovation and sustainability: incorporating innovative technologies and sustainable architectural solutions to create an energy-efficient and environmentally friendly building;

- the principle of adaptability and flexibility: designing architectural forms and solutions capable of adapting to changing needs and conditions of building use over time.

These principles formed the basis for designing rehabilitation building.

3 Results and Discussion

3.1 Architectural Solution

Currently, architectural design approaches based on trauma-informed criteria and biophilic design principles are focused on addressing the consequences of prolonged isolation during the Covid-19 pandemic, improving the well-being of cancer patients, etc. Post-traumatic stress disorders related to wartime events have their own specificity and significantly differ in triggers and reactions compared to those experienced by individuals in other traumatic situations. Practical recommendations for designing biophilic rehabilitation buildings should also consider the anthropometric characteristics of people with disabilities (amputations, anatomical defects, visual and hearing impairments, irreversible organ and system dysfunctions) and the psychophysical perception of patients who have experienced combat actions.

When developing architectural, landscape, and structural solutions, special attention should be focused on local authenticity and culture, aspects of natural landscapes, and the local resource base, which will help create a sense of home, safety, and comfort, significantly contributing to the patient's recovery process [19]. All the proposed solutions for biophilic
buildings should comply with the requirements of the European Green Deal regarding climate and environmental issues.

The conducted research on the aspects and development of the key principles for designing biophilic buildings, along with the authors’ own architectural and urban planning experience, helped develop a conceptual design solution and design a rehabilitation building in the city of Dnipro, Ukraine, located in a frontline area that has served as a rear hub and recovery building for military personnel since 2014.

The conceptual design of the biophilic rehabilitation building is based on integrating the presented principles with a focus on creating a harmonious environment conducive to the physical and psychological recovery of civilians and military personnel who have experienced traumatic events. The main idea is to use natural materials and elements of nature to create a favourable and tranquil atmosphere, facilitating stress relief and improving the well-being of patients.

Fig. 1. The result of experimental modelling of the rehabilitation building

The developed building features a simple and functional form, actively incorporates environmentally sustainable materials, and integrates the surrounding environment into the interior, which are the key aspects of biophilic architecture. Clean lines and minimalist design create a calm and cosy atmosphere, aimed at relaxation and psychological recovery of patients (Fig. 1).
The distribution of natural light within the premises is one of the important aspects of the project. It provides not only sufficient illumination but also activates biological rhythms aimed at promoting visitor activity, alertness, and mood enhancement. The use of natural colours and textures in the interior underscores the connection with the surrounding nature and contributes to creating a harmonious environment for patients.

The project incorporates elements of biophilic architecture, manifested in the integration of greenery (gardens, inner courtyards, plant walls) into the architectural design of the biophilic rehabilitation building. Internal gardens and courtyards provide patients with the opportunity to interact with nature directly within the building. Plant walls and green elements in the building's interior complement the overall biophilic concept, enriching the internal space with natural elements and creating a kind of “green oasis” within the premises. This not only adds aesthetic appeal to the building but also improves air quality and reduces noise levels.

Thus, the integration of greenery into the architectural design of the building not only reflects the principles of biophilic architecture but also serves as a key component in creating a unique and therapeutic environment for the rehabilitation of civilians and military personnel suffering from PTSD (Fig. 2).

**Fig. 2.** Applying the principles of biophilic design to the architectural solution of the rehabilitation building

According to the authors' concept, the project envisages the use of technological solutions to enhance patient comfort and safety: smart building management systems, automatic
regulation of temperature, humidity, and lighting, as well as shelter, modern security systems, and monitoring of patients' health.

Overall, the conceptual design of the biophilic rehabilitation building aims to create a unique and functional environment conducive to the comprehensive recovery and well-being of patients who have experienced combat conditions.

3.2 Structural Solution

The architectural style of the building is characterized not only by minimalism and functionality but also by the embrace of nature as an important design component.

Regarding the structural solutions of load-bearing and enclosing structures, they must meet the requirements of load-bearing capacity and operational suitability, as well as create a minimal volume of harmful emissions throughout the entire life cycle, maximize the efficient use of material and energy resources, be suitable for recycling into secondary materials or for reuse, and have no harmful impact on human health [20].

Existing research in the field of environmentally friendly building materials is mostly devoted to studying thermal insulation properties. However, when designing buildings in the medical field, isolation from external noise is no less an important comfort parameter. To create healthy conditions for biophilic buildings indoors, it is also necessary to consider criteria for selecting eco-materials based on environmental and sanitary-hygienic characteristics (thermal performance, harmful emissions, toxicity, flammability, microflora).

Maintaining the necessary microclimate indicators in individual rooms and the rehabilitation building as a whole should be achieved through the development and implementation of engineering solutions for heating, ventilation, air conditioning, and lighting using renewable energy sources and smart control technologies. The target indicators of the systems should be minimizing energy consumption, autonomy from centralized networks, and an individual approach to the needs of each patient.

The peculiarity of the structural solution of the biophilic rehabilitation building is in the use of massive timber for all load-bearing structures. According to the architectural and planning decision, the building of the rehabilitation complex has a simple form in plan and cross-section. Regular dimensions of the coordinate grid allowed for the proposal of modular prefabricated structures, which will contribute to the precision and high quality of assembly, reduce construction time, and provide the opportunity to erect similar buildings in different regions of the country.

The proposed structural system is illustrated by the example of a residential block of the rehabilitation complex. Load-bearing walls and columns are located around the perimeter of the residential block. Wall panels are designed to be one floor high. The width of each panel is assumed to be 3.1 meters. The structure of the wall panel consists of three layers and an effective insulator: the first layer is internal (load-bearing structure made of CLT timber); the second layer is intermediate (thermal and sound insulation made of an effective environmentally friendly material); the third layer is external (decoration and protection of the insulating layer from the influence of the surrounding environment) [21]. In the case of using CLT timber for the external layer, its thickness is 60 mm. The thickness of the internal layer is determined by calculation and preliminarily set at 120 mm. Environmentally friendly thermal insulation from natural materials is assumed as the intermediate insulating layer. Considering the value of the thermal conductivity coefficient and the minimum permissible thermal resistance for the Dnipro region, the thickness of the thermal insulation intermediate layer was accepted as 100 mm. Based on all of the above, the total thickness of the wall panel is preliminarily estimated to be 280 mm [22].
The use of CLT timber offers several advantages. These panels have high visual quality, do not require external finishing, and create a sense of authenticity and unity with nature due to the attractiveness of wood as a natural material.

In the interior of the building, there are no load-bearing walls or columns. For efficient use of structural material in the floor slab, with a span size of 9 meters, a solution was developed in the form of ribbed panels of a beam-like cross-section. These panels consist of an upper layer forming the floor plane, made of CLT timber, and glued timber beams. The structural height of the floor slab is determined by the architectural solution and is 580 mm. The preliminary dimensions of the elements of the ribbed slab are as follows: the thickness of the CLT panel is 120 mm, the dimensions of the glued timber beams are 200×460 mm (width and height of the cross-section), and the spacing of the beams is 800 mm. CLT panels and glued timber beams are joined using adhesive.

For the roof construction, it is advisable to use three-layer panels with effective insulation similar to the wall panels, with a thickness of 380 mm [22].

To substantiate the developed structural solution of the biophilic rehabilitation building prototype, research was conducted on the stress-strain state of load-bearing structures forming the building's structural system.

Wood is an anisotropic material in terms of its physical and mechanical properties, which was taken into account when modelling glued and cross-laminated timber. In a classical glued beam, all layers are oriented in one direction. Glued timber of strength class GL28h with characteristics according to table 1 was adopted for modelling columns and perimeter beams [23].

<table>
<thead>
<tr>
<th>Modulus of elasticity, MPa</th>
<th>Shear modulus, MPa</th>
<th>Poisson's ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Along fibres</td>
<td>Across fibres</td>
<td>Along fibres</td>
</tr>
<tr>
<td>$E_{0,\text{mean}}$</td>
<td>$E_{90,\text{mean}}$</td>
<td>$G_{\text{mean}}$</td>
</tr>
<tr>
<td>12600</td>
<td>420</td>
<td>780</td>
</tr>
</tbody>
</table>

Cross-laminated timber differs in that each layer in the panel is oriented perpendicular to the previous one. This allows for a more homogeneous material in terms of overall characteristics but complicates its modelling. Reduced geometric and physical-mechanical characteristics were used to create calculation models of cross-laminated timber [24]. The reduced modulus of elasticity along the panel (E1) is determined by formula (1).

$$ E_1 = 0.096(8.25E_x + 2.17E_y), $$ (1)

where: $E_x$ – modulus of elasticity of the timber along the fibres ($E_x = E_{0,\text{mean}}$), $E_y$ – modulus of elasticity of the timber across the fibres ($E_y = E_{90,\text{mean}}$).

The modulus of elasticity of the timber across the panel ($E_2$) is determined by formula (2).

$$ E_2 = 0.208E_x + 0.792E_y. $$ (2)

In the existing literature on cross-laminated timber, the Poisson's ratio along the panel varies within the range of $\mu_{21} = 0.4-0.5$, while across the panel, it is $\mu_{12} = 0.1-0.22$ [25]. The determination of these Poisson's ratios is based on the condition of the existence of elastic potential of the timber (3).
\[ E_{1}\mu_{21} = E_{2}\mu_{12}. \]  

(3)

The characteristics of cross-laminated timber panels of strength class C24 are presented in Table 2.

**Table 2.** Characteristics of the cross-laminated timber panel.

<table>
<thead>
<tr>
<th>Modulus of elasticity, MPa</th>
<th>Shear modulus, MPa</th>
<th>Poisson's ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Along the local X-axis</td>
<td>Along the local Y-axis</td>
<td></td>
</tr>
<tr>
<td>( E_{1} )</td>
<td>( E_{2} )</td>
<td>( G_{\text{mean}} )</td>
</tr>
<tr>
<td>8789</td>
<td>2581</td>
<td>690</td>
</tr>
</tbody>
</table>

For the analysis of load resistance, a spatial computer model (Fig. 3) was created to reflect the collective spatial behaviour of all elements. Spatial beam elements were used to model beams and columns made of glued laminated timber, with the wood's anisotropy not being considered. The modelling of structures made of cross-laminated timber was performed using rectangular shell elements, taking into account orthotropic properties. Separate material stiffness types were assigned for walls, floor slabs, and roof elements.

**Fig. 3.** General views of computer model of the Prototype biophilic rehabilitation building

Connections between columns and perimeter beams, as well as beams of the ribbed floor and wall panels, were assumed to be hinged. Connections between wall panels and the junction of roof panels with wall panels were considered to be continuous. The support node for wall panels and columns was defined as a hinged-fixed connection [26]. To obtain data on stress-strain parameters, a static calculation of the model under load action was performed [27]. Loads applied to the model elements included self-weight, useful loads on floor slabs, wind and snow loads typical for the Dnipro region.

As a result of the modelling, data on deflections, displacements of structural elements, and internal stresses were obtained. Separate contour plots of deflections and stresses for the elements of the floor and wall panels are illustrated in Figure 4.
Fig. 4. Contour plots: of vertical displacements (a) and principal stresses (b) in the floor panel; of horizontal displacements (c) and principal stresses (d) of the wall panels

Table 3. Analysis of the strength characteristics of the biopositive structures.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>tension parallel to the grain</td>
</tr>
<tr>
<td>Calculated strength of timber,</td>
<td>7.84</td>
</tr>
<tr>
<td>MPa</td>
<td></td>
</tr>
<tr>
<td>Calculated stresses in</td>
<td>Roof</td>
</tr>
<tr>
<td>structural elements, MPa</td>
<td>Walls</td>
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<td></td>
<td>Floor</td>
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</table>
The following values were adopted as the design strength characteristics for cross-laminated timber (CLT) of strength class C24 to assess the compliance of the structural solution with the load-bearing capacity criteria:
- tensile strength parallel to the grain: 7.84 MPa;
- tensile strength perpendicular to the grain: 0.224 MPa;
- compression strength parallel to the grain: 11.76 MPa;
- compression strength perpendicular to the grain: 1.4 MPa.

As seen from Table 3, the calculated stresses in the building elements do not exceed the permissible values (the calculated strength of the wood). Thus, the strength criterion is ensured for all structural elements. Regarding the deflections of the floor slab, they amount to 4.3 mm and do not exceed the limit of 45 mm for a span length of 9 m [28]. Since the structural system of the building is wall-bearing, under the condition of ensuring load-bearing capacity, the norms do not restrict the magnitude of horizontal displacements due to wind load. It was calculated that the maximum horizontal displacements at the top of the roof are 44 mm. Relative to the total height of the building, which is 11.4 m, this represents approximately 1/250.

4 Conclusions

Post-traumatic stress disorder poses a significant challenge both to the individual who has experienced a traumatic event and to the society in which the individual is a part. Ukraine is already experiencing this urgent need in finding and developing new comprehensive approaches to PTSD treatment, as well as their practical application.

This study explores the use of innovative solutions in architecture and design to create a favourable environment for patient rehabilitation and health restoration. To achieve this, the article examines medical, psychological, social, and economic aspects of post-traumatic stress disorder, including knowledge of stress biological mechanisms, neuropsychology, as well as understanding of psychosocial and cultural factors influencing the development and manifestation of PTSD. These aspects laid the conceptual foundation and enabled the development of crucial architectural and engineering design principles for biophilic buildings in the real conditions of wartime.

As a result of the research, a conceptual design solution for a rehabilitation building in the city of Dnipro (Ukraine) was developed based on trauma-informed and biophilic design criteria, focusing on overcoming post-traumatic stress disorders. The building's design solution is based on the integration of principles outlined in the article with an emphasis on creating a harmonious and safe environment. Elements of biophilic architecture were incorporated into the project, manifested in the integration of greenery (gardens, inner courtyards, green walls), as well as the use of natural and biopositive building materials and green technologies.

A distinctive feature of the structural solution of the biophilic building is the use of solid wood for all load-bearing structures and modular assembled wooden structures for the assembly of walls, floors, and roofing. The structural solution is driven by the precision and quality of assembly, reduction of construction duration, and the possibility of erecting similar buildings in different regions of the country. Using an analytical approach, the investigation evaluated the stress and strain characteristics of load-bearing structures, adding support to the chosen materials and the structural system's capabilities.
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