BUILDING CONSTRUCTIONS, BUILDINGS AND ENGINEERING STRUCTURES

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Design Features of Volumetric Blocks Made of Lightweight Fibrotorcrete with Non-removable Formwork

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Abstract
Introduction. This article analyzes the design features of volumetric blocks made of fibroblast concrete using a formwork made of moisture-resistant drywall. The basic principles that describe the characteristics of the design with the shaping of these volumetric blocks implemented using shotcrete technology are also outlined. This is especially true for low- and medium-rise buildings.
Materials and methods. To form the construction of fiber-reinforced concrete volumetric blocks with formwork based on moisture-resistant drywall (hereinafter referred to as GCLV), it is suggested that a system of basic principles is used that increases energy efficiency, reduces costs, and promotes the disposal of safe industrial waste.
The application of the basic principles underlying the development of a volumetric block made of lightweight fibrotorcrete with non-removable formwork enabled a systematic approach to a constructive solution to be implemented.
Results. The introduction of an effective innovative method made it possible to develop a reinforced concrete volumetric block created using shotcrete technology. This approach has made it possible to reduce labor costs, increase strength characteristics, and enable the production of bulk blocks both in the factory and directly on the construction site.
Discussion and Conclusion. The multilayer structure of new-generation bulk blocks made of fibrotorcrete created by the authors is based on the key principles that emphasize the effectiveness of their use in the construction of buildings with small and medium storeys.

Keywords: fibroblast concrete volumetric blocks; non-removable gypsum-cardboard formwork; wet shotcrete technology; basic principles of shaping

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Оригинальное эмпирическое исследование

Особенности конструктивных решений объемных блоков из легкого фиброторкретбетона с несъемной опалубкой

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Аннотация
Введение. В данной статье приводятся конструктивные особенности объемных блоков, изготовленных из фиброторкретбетона с использованием опалубки из влагостойкого гипсокартона. Также изложены основные принципы,

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которые описывают характеристики конструкции с формообразованием данных объемных блоков, реализованных с помощью технологии торкретирования. Это особенно актуально для мало- и среднеэтажного строительства.
Материалы и методы. Для формообразования конструкции фиброторкретбетонных объемных блоков с опалубкой на основе влагостойкого гипсокартона (далее ГКЛВ) предлагается использовать систему базовых принципов, позволяющих повысить энергоэффективность, снизить затраты и способствующих утилизации безопасных отходов промышленности.
Применение базовых принципов, положенных в основу разработки объемного блока из легкого фиброторкретбетона с несъемной опалубкой, позволило осуществить системный подход к конструктивному решению.
Результаты исследования. Внедрение эффективного инновационного метода позволило разработать железобетонный объемный блок с использованием технологии торкретирования. Этот подход позволил уменьшить затраты труда, повысить прочностные характеристики и обеспечить возможность производства объемного блока как в заводских условиях, так и непосредственно на строительной площадке.
Обсуждение и заключение. Созданная авторами многослойная структура объемных блоков нового поколения из фиброторкретбетона основывается на ключевых принципах, которые подчеркивают эффективность их использования при строительстве зданий малой и средней этажности.

Ключевые слова*:* фиброторкретбетонные объемные блоки, несъемная гипсокартонная опалубка, технология мокрого торкретирования, базовые принципы формообразования

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Introduction. There is an enormous demand for modern technologies in the construction industry, as in order to increase the volume of construction of buildings, it is essential to cut down construction costs and the types of work to be performed. The key is increasing the energy efficiency of design solutions while reducing material and energy costs [12].

Innovative modular structures are being represented by three-dimensional modular buildings. In domestic practice, the strategic approach to developing house-building complexes focuses on designing quick-to-assemble modular facilities helping to reduce the final housing costs as well as the construction time [4–11].

The objective of the study is to create a system for designing and manufacturing volumetric blocks accounting for the features and specifics of the industry. While developing such systems, it is essential to rely on principles accounting for the advantages and effectiveness of using bulk blocks in the construction sector. It is important to bear in mind that architectural and engineering solutions must comply with the unique requirements and conditions associated with the use of these materials. Effective design calls for an integrated approach accounting for not only technological aspects, but also economic and environmental factors. Proper implementation of methods and technologies would help improve quality and reduce construction costs ultimately resulting in improved overall design and production performance. The key is thus to harmonize all design stages, starting from the idea and ending with the actual construction ensuring maximum efficiency and durability of the final product in construction practice.

Materials and Methods. Building design using three-dimensional block housing construction can be optimized by introducing a system of key basic principles (Fig. 1) which are at its core. These principles help to structure the design and account for all the major aspects, which in turn boosts the overall construction efficiency. The implementation of such standards allows one not only to minimize time and financial costs, but also to improve the quality of the final product. The suggested system includes a variety of elements for making design work and integration of modern technologies more comprehensive. As a result, by means of implementing these principles, it is possible to harmonize functionality and aesthetics, which is in compliance with the modern requirements for building construction. This is imperative to ensure the durability and stability of structures in the future, as well as to cater for of users’ and customers’ needs making design more efficient and adaptable to current conditions.

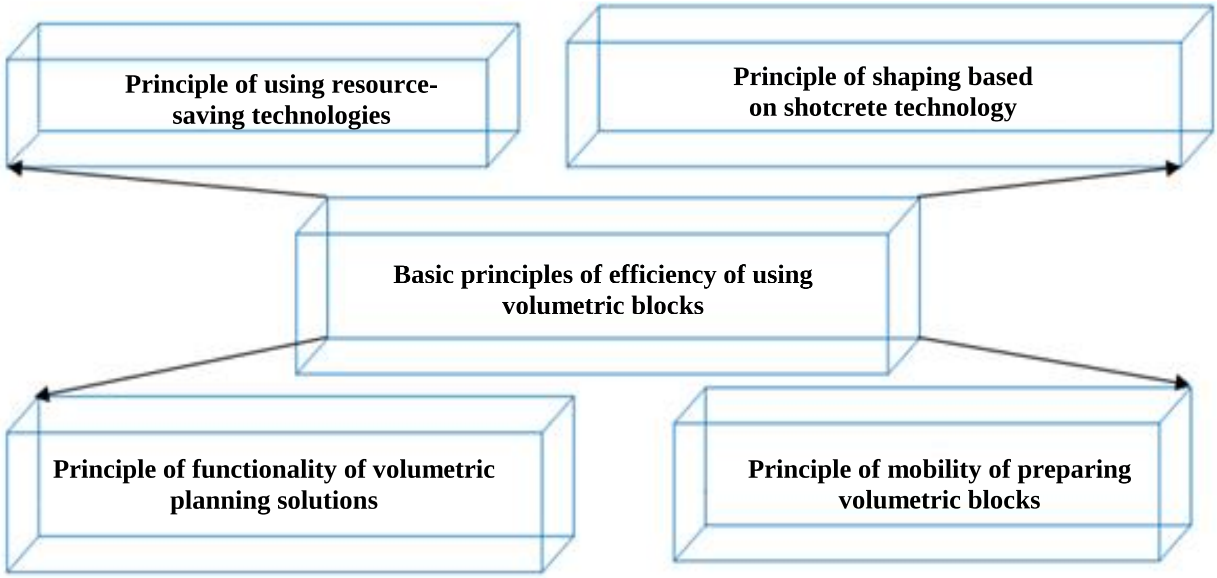

Fig. 1. Basic principles of three-dimensional block housing construction

Principle of introducing *resource-saving technologies* entails the use of regional resources and materials obtained using safely recycled industrial waste. This approach allows not only to optimize the costs of manufacturing building structures, but also to promote recycling of waste from various industries.

Principle of resource-saving is aimed at implementing the state "Strategy for Developing the Industrial Sector in Recycling, Decontamination and Elimination of Production and Consumption Waste until 2030" [1].

Design of a monolithic spatial structure of a volumetric block by means of wet shotcrete technology relies on the *principle of shaping*. A typical feature of the method is the use of non-removable one-sided plasterboard formwork to optimize manufacturing of bulk blocks by reducing labor costs.

The formation of a functional part with the further arrangement of volumetric blocks into various *spatial planning solutions* complies with the *principle of functionality*.

The principle of mobility involves design of production of volumetric blocks not only in a factory, but also directly on a construction site. Based on shotcrete technology, this approach will reduce the cost of transporting heavy structures to a construction site and expand the geographical scope of volumetric-block housing construction. This method will also facilitate the construction process in remote or hard-to-reach areas where traditional delivery methods can be challenging and costly. As a result, the use of mobile production will become a major factor for improving efficiency and cost-effectiveness in the construction sector, opening up new avenues for implementing large-scale block projects. This would not only speed up the construction process, but also make it more accessible to different regions, contributing to the nationwide infrastructure development.

The expansion of the field of use of volumetric blocks designed by means of wet shotcrete technology is due to the fact that they can be manufactured both in an organized production facility and directly on a construction site. This is indicative of the special features of the principle of mobility.

The existing structural solutions of volumetric blocks are entirely ineffective, since they fail to comply with the basic principles of modern volumetric block housing construction, which is in agreement with the state's development strategy in the field of resource conservation. At the same time, the existing forms of three-dimensional blocks do not enable the expansion of the compositional and spatial planning solutions of such buildings. Traditional approaches to design and technology of their construction fail to ensure routine use of three-dimensional block housing in the construction industry. An innovative approach for implementing the basic principles is thus the use of wet shotcrete technology for bulk blocks made of lightweight fibrotorcrete concrete.

The suggested block cap made of lightweight fibrotorcrete is a multilayer structure. Such a block can be used for constructing small and medium-rise buildings. Unlike the classic factory manufacturing technology, the wet shotcrete method is used here suggesting taking the construction of bulk blocks to a new level, as they will be produced directly on a construction site. This will not only expand the geography of construction, but also develop a new range of products of the type, as well as reduce the cost of transporting finished factory products.

The suggested design method relies on the principle of shaping involving the simultaneous formation of a structure in terms of design and production. This approach enables a complete monolithic spatial element to be designed.

Research Results. The basic principle of designing spatial blocks made of fibrotorcrete is the concept of shaping focusing on creating a new space with functional zones.

The patented design of the volumetric block includes transverse walls, window and door openings, and a П-shaped longitudinal load-bearing structure. The general view of a three-dimensional block of the "hood" type is shown in Fig. 2 [2].

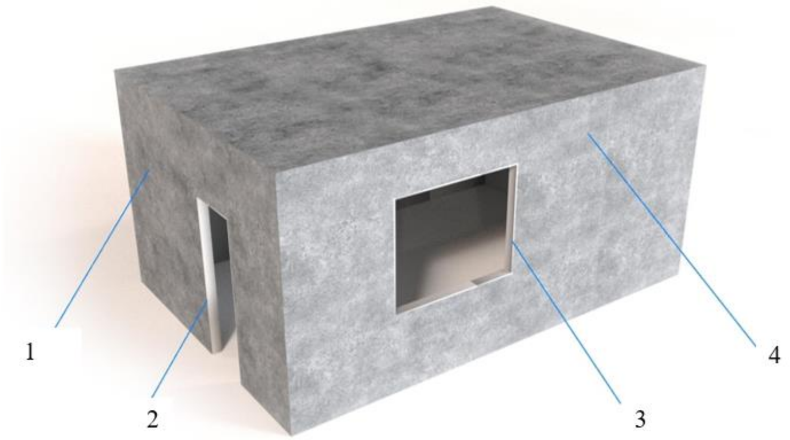

Fig. 2. Structural solution of fibroshotcrete concrete volumetric block:
1 — transverse wall; 2 — doorway; 3 — window opening; 4 — П-shaped longitudinal load-bearing structure [2]

The fibrotorcrete volumetric block modeled according to the basic principles (Fig. 1) is characterized some distinctive features:

– a one-sided plasterboard formwork acting as an interior cladding;

– use of resource-saving concrete compositions with industrial waste ;

– minimization of technological steps within an organized production by means of wet shotcrete on a construction site.

The high efficiency of the constructive solution using lightweight fiber-reinforced concrete based on industrial waste for producing load-bearing elements has been proven by means of the authors' experimental work [3]. The high effectiveness of their use (including fibrotorcrete volumetric blocks) has been confirmed. This enables the principle of resource conservation to be implemented in practice within the framework of the state's development strategy.

A distinctive feature of the design solution is the use of volumetric blocks of multilayer construction as load-bearing walls (Fig. 3). The size of the load-bearing layer varies depending on the construction region and the energy efficiency of the design solution.

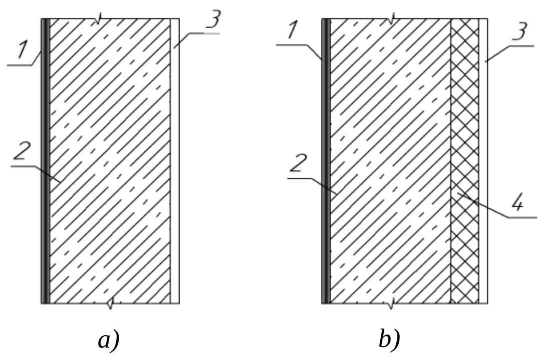

Fig. 3. Supporting structure of the developed volumetric block:
a — a one-layered one, *b* — a two-layered one
(1 — non-removable plasterboard formwork; 2 — fibro shotcrete bearing concrete layer; 3 — shotcrete-plaster; 4 — a layer of plate insulation)

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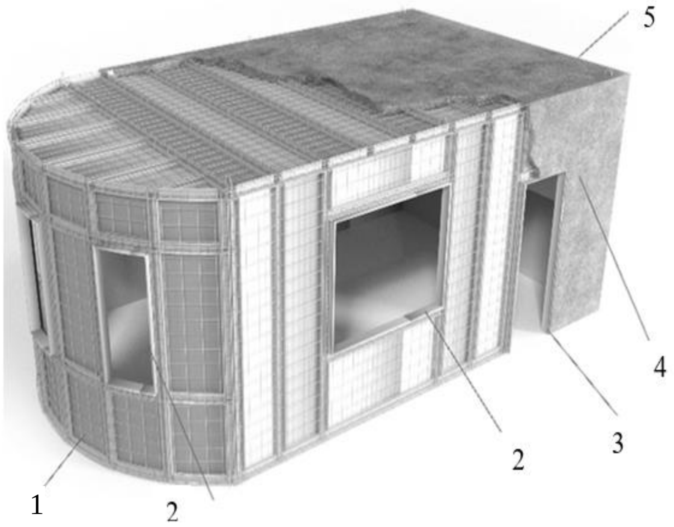
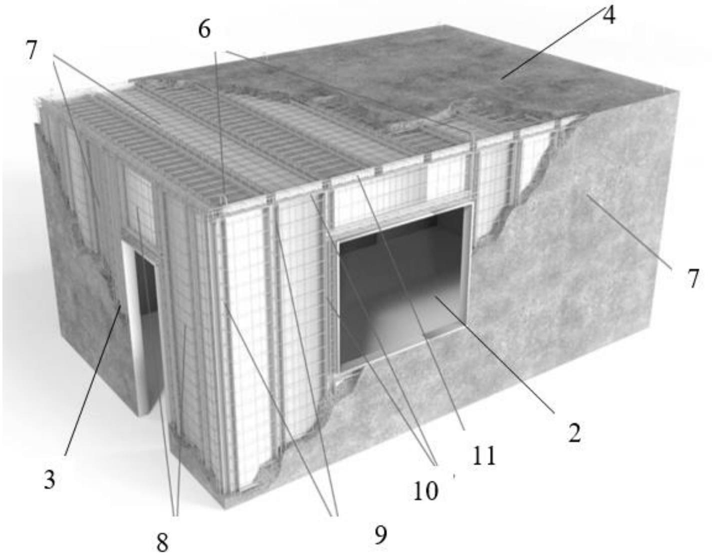
The suggested design solution for a three-dimensional block of a "hood" type configuration expands the possibilities of planning solutions for such buildings. In particular, a volumetric bay window type block cap made of fibrotorcrete concrete is set forth. (Fig. 4, *a*).

The design solution of the "hood" type configuration of a new-generation volumetric block expands the possibilities of planning solutions for such buildings. The article looks at the use of fibrotorcrete concrete to design a three-dimensional bay window-type block hood making it possible to improve the architectural and functional characteristics of buildings. The effectiveness of the use of this material in construction and its impact on the stability and durability of structures is also accounted for.

A new type of volumetric reinforced concrete block of a new generation (Fig. 4, *b*) is a П-shaped load-bearing structure with transverse walls capable of receiving loads with no additional support. Openings for windows and doors are provided in these walls. The block is made of lightweight reinforced fibrotorcrete and is a monolithic spatial element with five faces. In order to increase the bearing capacity, the coupling zones of the supporting frames of the block are reinforced with additional grids along the perimeter. The rigidity of the wall elements with openings is regulated by their width dimensions accounting for the angular sections of the walls.



a)



b)

Fig. 4. Constructive solution:
a — volumetric block with a bay window; *b* — rectangular volumetric block (1 — bay window; 2 — window opening; 3 — doorway; 4 — П-shaped longitudinal load-bearing structure; 5 — transverse wall; 6 — mounting loops; 7 — fiber reinforced concrete layer; 8 — reinforcing grid; 9 — frame reinforcing carcass; 10 — metal profile; 11 — strapping reinforcing carcass [2]

One of the major advantages of the suggested design is the possibility of using non-removable formwork made of high-strength moisture-resistant drywall that is one-sided. This allows smooth surfaces suitable for various finishing works to be obtained.

According to regulatory documentation, moisture-resistant formwork is capable of withstanding a humidity of up to 85%, which in turn is acceptable for use in civil buildings with a relative humidity of up to 60%. When the wet mixture is shotcrete onto the drywall formwork, there is instant adhesion and a contact layer is formed ensuring the integrity of the formwork.

The use of drywall formwork helps to cut down labor costs, because it provides a complete interior decoration of the space.

Discussion and Conclusion. As part of the basic principles for constructing new-generation volumetric blocks shotcrete technology enables non-standard spatial planning solutions to be employed and a technological scheme for producing such structures on a construction site to be changed. The inclusion of acceptable types of industrial waste into blocks, increasing the strength of the starting materials and obtaining an economic effect from substituting conventional materials, accounting for geographical features of construction not only contributes to reducing the cost of structures, but also to speeding up waste recycling. This complies with the principles of rational use of natural resources and minimization of a negative environmental impact [1]. The possibility of producing volumetric blocks on a construction site would enhance the scale of volumetric-block housing construction.

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NV Andreeva: formulation of the conclusions, preparation of the manuscript and graphic materials.

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