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HISTORY OF DEVELOPMENT OF BLOCK-MODULAR CONSTRUCTION: WAY TO SOLVE THE HOUSING PROBLEM

Abstract. *The article discusses modular construction, which is a reasonable alternative to classical capital construction. Modular buildings have a number of advantages, such as: high speed of erection of a modular structure, low cost of construction work, versatility of the structure, the possibility of superstructure, the possibility of dismantling, transportation and assembly at a new location, all-season construction. In modern conditions, when speed and versatility are important, this topic is relevant in the construction market.*

Keywords: *block-modular construction, light construction, mobility, block-modules, rapid construction, affordable housing.*

Introduction

Back in the 20th century, along with large-panel housing construction, construction from three-dimensional blocks began to spread widely, not only buildings of a small number of storeys, but also residential high-rise buildings. It all started with wooden blocks of premises, over time, changes were made, additions to structures in housing and civil construction.

Monolithic load-bearing ribbed blocks, also called "recumbent glass", were common. In Ukraine, work on a monolithic reinforced concrete block of the "cap" type has been widely used. An experiment was carried out on the manufacture of blocks of the “cap” type using the “movable cores” method, which has a number of design features. In Almaty, the so-called Bogodukhovskoe direction was used, the construction of blocks in rural construction (with dimensions up to 8 tons) [1].

For this construction, various materials are used, but such as reinforced concrete, steel, asbestos cement, wood, aluminum, and plastic have become very popular. Buildings from three to five floors predominate. Almost everywhere, constructive solutions from heavy or light concrete are used to create blocks. For example, with a frame structural system, a load-bearing frame is made of heavy reinforced concrete, and the blocks that fill the cells of the frame are made of light. Wooden blocks are popular in the USA, Sweden, Great Britain. Fiberglass, aluminum foil, asbestos-cement sheets, etc. are used for cladding.

The first three-storey block-type residential building appeared in Almaty in 1964-1968. These blocks are three-dimensional block room, manufactured entirely at the factory. The advantages of this construction are in the variety of installation according to the architectural image, purpose, number of storeys, layout. And one of the important criteria: reduction of terms (excluding seasonality in work) and construction costs (due to the loss of materials, as well as an increase in labor productivity, due to the transfer of construction processes to mechanized production, which leads to an improvement in the quality of construction. The cost will be reduced per m^2, which will make this housing affordable for a wide segment of the country's population, solving problems among the middle-income segments of the population.

The effectiveness of volumetric block construction was proven back in the USSR, when it was planned to create a large production base for industrial construction. The Council of Ministers adopted a resolution according to which 25 volumetric block housing construction plants (with a capacity of up to 100 thousand m^2 of living space/year) should be built soon. But experience has shown that the blocks required quite a lot of welded joints, sealing of joints, which turned out to be costlier than monolithic construction [1].

Materials and methods

Structural systems of buildings from three-dimensional blocks.

Depending on the number of storeys, length, geological and climatic conditions, three-dimensional block residential buildings have different design solutions. With regard to spatial connectivity, buildings can be divided into systems: houses with a flexible and rigid scheme.

Flexible scheme. Development from load-bearing blocks with their placement on top of each other, like a "pillar", where the height is equal to the height of the building, with horizontal connections from steel rod reinforcement between the pillars of the blocks. A flexible scheme is rational in construction sites with subsiding soils, mine workings, as this allows the building to follow the deformations of the bases without the appearance of strong additional efforts. But it is very important that the deformations do not exceed certain values, in order to avoid displacements of adjacent blocks in the places where openings are organized between them. Vertical displacements should be no more than 10 mm per store’s height, the values at the bottom of the horizontal deformations in the seams and at the top should not exceed 20 mm. For sanitary wiring, flexible inserts are needed to compensate for any deformations so as not to harm the engineering communication systems. Seal of seams and joints must be closed. This scheme provides a small margin of safety. Since each column is calculated for the action of vertical and horizontal actions, not taking into account the load of neighboring columns.

Spatial scheme. Complete or partial filling of gaps between load-bearing blocks with concrete, forming connections that can take large shear forces between pillars. Thus, it is like a single spatial system of a beam, a console, a box, since the actual connections prevent their shift. The value of the horizontal displacement of a point type is not more than 1/4000 N. The calculated deflection is not more than

1/1000 L. A rigid scheme is used in construction in seismic areas. Also a tower. But in general, when designing three-dimensional block houses, mixed solutions are used [1].

Depending on the structural elements that perceive the existing design loads, 3 structural schemes are conditionally distinguished: block; block-panel; block with a bearing frame.

The first two above are made of bulk blocks and are desirable for the construction of low-rise buildings (up to 5 floors). Provides a high degree of readiness in the factory. When, as at a construction site, only pipelines are connected, sealing joints. So due to the reduction of labor costs, the construction time is significantly reduced. Also, thanks to this scheme, the coherence of architectural and planning solutions is maintained.

Block-panel is common in areas of dispersed construction, when it is necessary to transport blocks, for example, by rail or during the construction of residential complexes in cities, towns, areas of cultural and community significance.

With a height of 12 to 16 floors, heavy or light reinforced concrete is used. The frame-block scheme is assessed as more rational for the use of high-rise construction, since lightweight volumetric blocks are used.

Since in the construction of block-modular buildings the main element is a three-dimensional block, the choice of construction technology, the choice of cranes according to their lifting capacity, the degree of completion of the block under production conditions at the plant will depend on its classification. The mass of the block ranges from 10-40 tons (due to the size, materials, design scheme, this figure varies). For example, for a nine-story house, a block the size of a room has a specific gravity of 700 kg/m^2, where lightweight/porous concrete is used, for a supporting frame - rolled metal products.

According to the manufacturing method, the blocks are divided into monolithic and prefabricated, where the former are produced using bench technology on conveyor lines, and the latter, from separate flat or curved panels. For the production of monolithic formwork systems are required to obtain the desired dimensions and shape, or a stand for high-precision welding of metal beams into a single frame. Then the formation of the outer wall, the ceiling slab, that is, we get a three-dimensional block. After that, he proceeds to the installation of electrical, plumbing, and finishing works. Finally, it is packaged and transported to its destination.

The technical and economic indicators were analyzed, which showed the high efficiency of the method. It has been estimated that the labor intensity of block buildings is approximately 2-4 times lower than the construction of large panels and bricks [2].

The constructive scheme of the building is a three-dimensional block with vertical and horizontal connections between the pillars of the blocks. With hinged outer insulated panels. The main structural element of the building is a one-piece reinforced concrete volumetric 5-plane block of the “lying glass” type (Fig. 1).

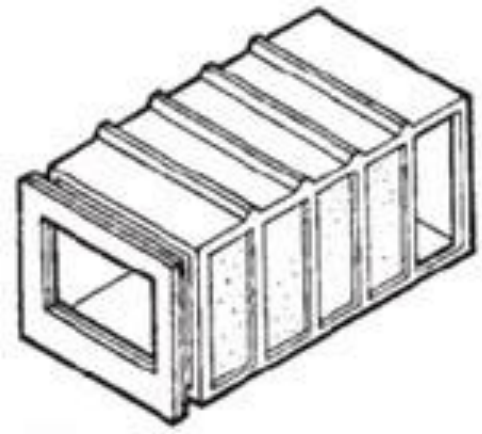

Figure 1 – Block type "lying glass"
[Source: https://saitinpro.ru/glavnaya/nesushchie-konstruktsii/zhelezobetonnye-konstruktsii/obemnye-bloki/]

The volumetric element of the “lying glass” type is a one-piece ribbed 5-plane block consisting of three walls, a floor and a ceiling. It is recommended to use volumetric blocks of the “lying glass” type, provided that they are linearly supported and the load is transferred floor by floor on two sides. This type is considered since this design scheme was used in the construction of residential complex 7Ya in Astana (Fig. 2).

Figure 2 – Residential complex 7Ya in Astana

One of the varieties of spatial design schemes is recommended scheme with the use of spatial finite elements (SFE). SCEs are formed by horizontal or vertical sections. Horizontal sections are recommended to be used for volumetric blocks of the "cap" type, and vertical ones – for volumetric blocks of the "lying glass" type. Sections should be carried out so that the distances between the secant planes are as equal as possible. The total number of SCEs obtained as a result of the section of a three-dimensional block by planes must be at least six. Elements with the same geometric and physical characteristics are considered to be of the same type. A special element is the ceiling slab of the volumetric block, the rigidity of which is taken into account only in its plane [1].

When analyzing foreign experience, the widespread use of light steel thin-walled structures (LSTC) was revealed. During the construction of attic, interroom, interfloor ceilings, townhouses, cottages, warehouses, garages, shops, hospitals, etc. A distinctive feature of LSTK is the minimal impact on the landscape and of course the saved time and minimal labor costs, economically beneficial and what is an important point is seismic resistance. The disadvantage of this method is the impossibility of building more than two floors [3].

Technical and economic indicators.

Evaluation of the effectiveness of design solutions begins with the preparatory stages (transport, installation work). It can be assessed according to four criteria, such as:

– initial (at the design stage, manufacturing of modules at the factory);

– basic (volumes, transportation, construction and installation work, labor costs, economic costs);

– specific;

– additional (level of mechanization, shift ratio, level of manufacturability of structures and processes, degree of combination of work, downtime, skill level of workers).

When comparing various options for the production of works, the most widely used are: specific reduced costs, specific labor intensity, specific cost. Also, the effectiveness of such parameters as manufacturability and operation is affected by the manufacturing process of the blocks themselves at the factory. The influence of design and planning decisions (set by the architect on the basis of data on the area of the building site) is great on the choice of the type of building, technological parameters for the manufacture, transportation and installation of block modules. Choice of materials. Which determine the thermal, functional and operational properties (durability, strength, fire resistance, frost resistance), which must be at least sixty years old.

Results and discussion

Block building examples

Buildings from modular blocks can be used for areas with seismicity of 7–9 points when using not labor-intensive and low-cost special measures in the structural system. Reducing the weight of volumetric blocks is achieved by using modern lightweight innovative materials, which, due to their technological properties, allow the use of structures with a smaller cross section than in capital construction. Such structures can be easily transported to the construction site and promptly mounted at the site of the element's design location.

The project “Tourist center in the foothills of the Zailiysky Alatau”, developed by student A. Temirbekova (supervisor – associate professor of the department “Architecture and Design” G.R. Iskhodzhanova, KazNTU named after K.I. Satpaev) is an example of the use of modular prefabricated structures in high mountains. The center is supposed to be built on a mountain slope in the gorge of the Middle Talgar River for the development of a tourist and high-mountain type of recreation [4].

The main purpose of using block-modular construction is to accelerate commissioning, taking into account not only existing international scientific and technological achievements, but also promising, predicted future trends in the development of architecture. Buildings are rented or leased directly from the factory, and the customer receives a new building within a few days. Modular construction is a new culture of meeting the needs of construction objects and quickly achieving results, which turns the previously heavyweight construction industry into qualitatively advanced technologies of the 21st century.

Due to economic constraints, modular construction provides a solution to many problems for further improvement, and the creation of a regulatory framework for the design of modular technology is very important here. However, at the moment Kazakhstan has only one standard for the design of modular buildings ST RK 3190-2018. Buildings are block-modular. Specifications. But in a rapidly developing market, these technologies are not enough, since from the side of seismic resistance, high-rise buildings, etc. not yet reviewed. This is also indicated by foreign experience in the form of the construction of a five-star hotel in the Huan province of China on the shores of Lake Dongting, with a height of 30 floors and an area of 17 thousand m^2 (Fig. 3). Built in 15 days. With a minimum effort of 200 people. And from the equipment there is only one tower crane. The development and implementation of the project was carried out by BSB (BroadSustainableBuilding), and the work completed in such a short time included finishing work and equipment with electrical and plumbing fixtures.

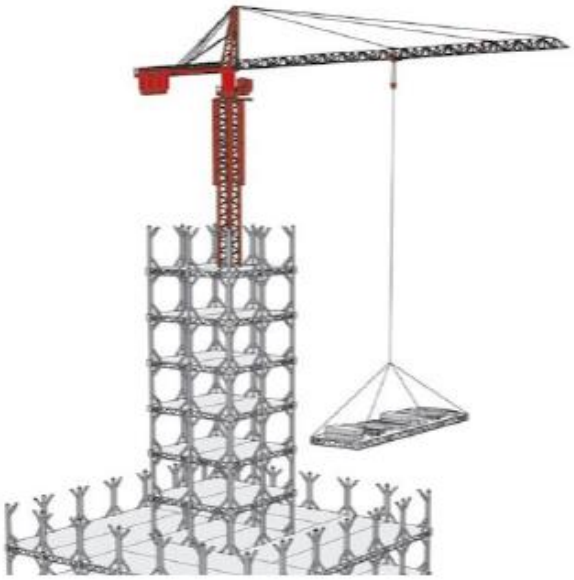

Figure 3 – Hotel assembly process in Huan Province, China

And the most important is the construction of the world's tallest modular house 461Dean in Brooklyn (New York) (Fig. 4). This is a 32-storey building with a height of 109 m, consisting of 930 modules, each of which is fully equipped in the factory. The author of the project is the architectural firm SHoPArchitects [5].

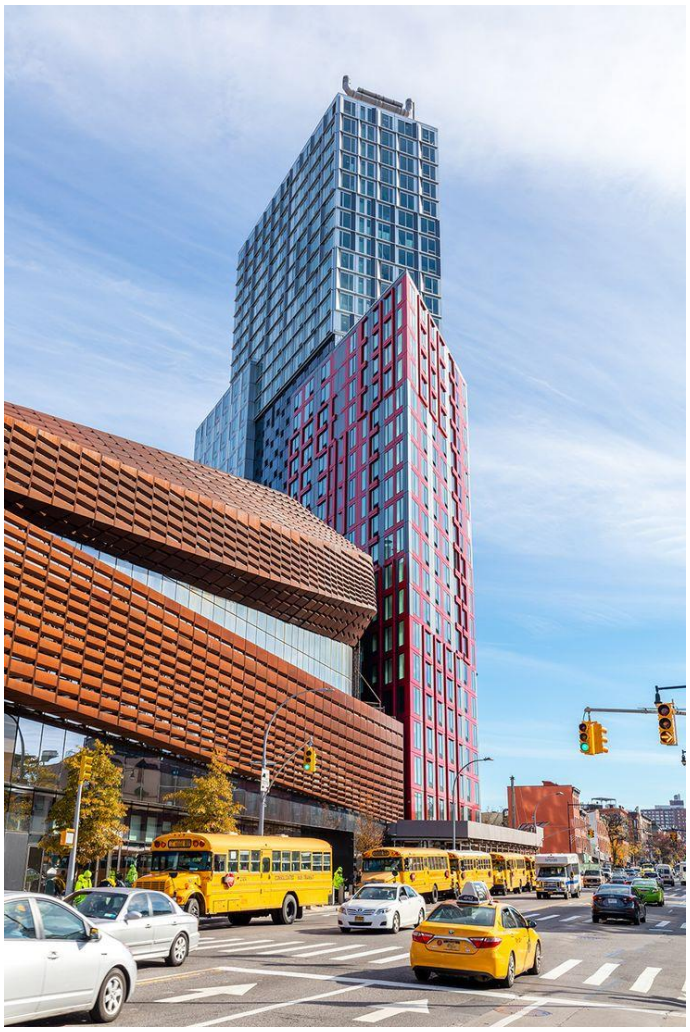

Figure 4 – 461Dean House in Brooklyn

Despite the presence of so many advantages, there are still disadvantages. For example: increasing the carrying capacity of the mechanisms and transport used; the need for a priority purchase of imported blocks-modules; lack of necessary equipment, trained personnel, introduction of special software for the production of modules with strict adherence to design solutions and high quality; absence of the design stage "Factory documentation", quality control standards for the production of modular units and construction and installation works); complexity of transportation of modular blocks [6]. Economists and experts from the UK are less positive about savings and certain design limitations.

Conclusions

As a result of the study, we came to the conclusion that, of course, one of the most important advantages of block-modular construction is time, the speed of construction, where the period of the year does not depend. I would like to note that in case of natural disasters, this solution will be the best solution. Based on the situation, the pros and cons of designs, choose the desired type. At the moment, architects are thinking about creating a unified design for modular structures and buildings. It is al-

so promising in the construction of standard residential buildings, because thanks to it it is possible to provide the population with affordable housing in the shortest possible time, which will increase the quality component. Thus, in order to develop this area in our country, it is necessary to think about production, the construction of factories, and the design of buildings.

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БЛОҚТЫҚ-МОДУЛЬДІК ҚҰРЫЛЫСТЫҢ ДАМУ ТАРИХЫ: ТҰРҒЫН ҮЙ МӘСЕЛЕСІН ШУШУ ТӘСІЛІ

Аңдатпа. *Мақалада классикалық күрделі құрылысқа балама болып табылатын модульдік құрылыс қарастырылады. Модульдік ғимараттардың бірқатар артықшылықтары бар, мысалы: модульдік құрылымды тұрғызудың жылдамдығы, құрылыс жұмыстарының төмен құны, құрылымның әмбебаптығы, қондырманың мүмкіндігі, жаңа жерде бөлшектеу, тасымалдау және жинау мүмкіндігі, құрылыс маусымдығы. Заманауи жағдайларда, жылдамдық пен әмбебаптық маңызды болған кезде, бұл тақырып құрылыс нарығында өзекті болып табылады.*

Түйін сөздер: *блок-модульдік құрылыс, жылжымалы және жылдам құрастырмалы құрылыс, блок-модуль, жылдам құрылыс, қолжетімді баспана.*

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ИСТОРИЯ РАЗВИТИЯ БЛОЧНО-МОДУЛЬНОГО СТРОИТЕЛЬСТВА: СПОСОБ РЕШЕНИЯ ЖИЛИЩНОЙ ПРОБЛЕМЫ

Аннотация. *В статье рассматривается модульное строительство, которое является разумной альтернативой классическому капитальному строительству. Модульные здания имеют ряд преимуществ, таких как: высокая скорость возведения модульной конструкции, низкая стоимость строительных работы, универсальность конструкции, возможность надстройки, возможность демонтажа, перевозки и сборки на новом месте, всесезонность строительства. В современных условиях, когда важны скорость и универсальность, данная тема является актуальной на рынке строительства.*

Ключевые слова: *блочно-модульное строительство, легковозводимость, мобильность, блок-модули, быстрое строительство, доступное жилье.*