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Manuscript submitted 2019.01.17 – revised 2019.02.20,
initially accepted for publication 2019.03.07 published in June 2019

THE MAIN DIRECTIONS OF PREFABRICATED LARGE-PANEL SYSTEMS' IMPROVING

GŁÓWNE KIERUNKI DOSKONALENIA PREFABRYKOWANYCH SYSTEMÓW WIELKOPŁYTOWYCH

DOI: 10.30540/sae-2019-008

Abstract

The article discusses the features of the formation and development of prefabricated large-panel systems in civil engineering. Their advantages and disadvantages are given taking into account a variety of urban planning, architectural, structural and technological solutions. The directions of their improvement are determined and considered, the main of which are: optimization of parametric characteristics of building typing elements using modern computer technologies; increasing the steps of bearing walls with the introduction of large-span systems; improvement of technical solutions for enclosing structures and their joints; the use of combined panel-block systems based on local materials; improvement of aesthetic qualities and means of architectural and spatial expressiveness.

Keywords: prefabricated large-panel systems, the main directions of systems' improvement, housing construction, architectural and technical solutions

Streszczenie

W artykule omówiono cechy tworzenia i rozwoju prefabrykowanych wielkopłytowych systemów w budownictwie. Ich zalety i wady przedstawiono z uwzględnieniem różnych rozwiązań urbanistycznych, architektonicznych, konstrukcyjnych i technologicznych. Zidentyfikowane i omówione zostały kierunki ich doskonalenia, z których główne to optymalizacja charakterystyk parametrycznych elementów typowania budynków przy użyciu nowoczesnych technologii komputerowych, zwiększenie kroków ścian nośnych dzięki wprowadzeniu systemów o dużej rozpiętości, doskonalenie rozwiązań technicznych konstrukcje ścian zewnętrzne i ich połączeń stykowych, stosowanie kombinowanych panelowych i blokowych systemów na bazie lokalnych materiałów, poprawa walorów estetycznych i środków wyrazu architektoniczno-przestrzennych.

Słowa kluczowe: prefabrykowane systemy wielopłytowe, główne kierunki doskonalenia systemów, budownictwo mieszkaniowe, rozwiązania architektoniczne i techniczne

1. INTRODUCTION

Systems are considered to be prefabricated large-panel (PLP) if the vertical load-bearing elements are the walls, built and assembled of large panels, as a rule, no less than the size of the room. The main area of application of PLP systems of construction is the mass residential construction. They have also been used for construction of a number of public buildings without large halls (Fig. 1).

After large-scale construction in the early 1960's in Eastern Europe typical five-storey large-panel and

brick apartment houses with narrow step of bearing walls, since 1965 the block principle has become substantially prevalent, including block-cell method, that provides a comparable variability of space-planning and composition solutions. To overcome the monotony of development, instead of typical building the science of Architecture offered for the designers a set of different block sections, that provides them with some relative variability of individual residential formations in length, configuration and number of storeys. Offering at the first stage as the main element



Fig. 1. Prefabricated large-panel systems

Rys. 1. Prefabrykowane systemy wielopłytowe

of the typing the block section, the authors of this trend continued to go further by downscaling it with the use of semi-block sections, block elements, structural cells, etc. [1, 2].

At the same time, existing mass-scale, prefabricated industrial systems need further improvement, because in many respects they do not meet modern and perspective requirements and do not always allow to obtain complete architectural and urban-planning solutions. These systems often are oriented on outdated architectural, planning and technological requirements and in many cases do not allow to take into account numerous local conditions and factors.

2. PREFABRICATED LARGE-PANEL SYSTEMS

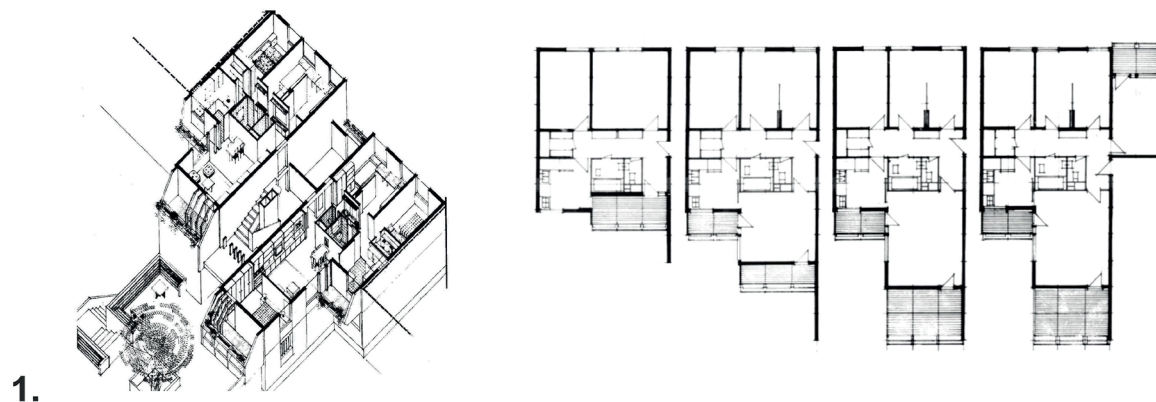
The main structural elements of the PLPS systems are: bearing reinforced concrete panels for interior walls, foundations, floor slabs; outer walls panels, covering slabs (roof construction); partitions (non-bearing panels); constructive elements of transport communications (lift tubing, stairs); engineering equipment and other non-bearing elements of the system [2, 3].

The basis of the prefabricated large-panel system construction is planar (frameless) construction system that has three basic varieties: transverse-wall; longitudinal-wall; cross-wall.

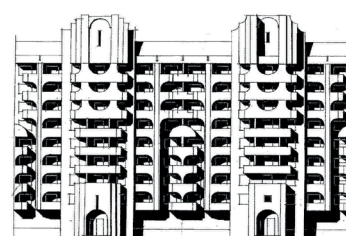
Prefabricated large-panel systems, according to the selected distance between load-bearing walls, are divided into: a narrow span of load-bearing walls – short-run (from 2.4 m up to 4.8 m); the wide span of load-bearing walls (over 4.8 m). Systems with a wide span of load-bearing walls in connection with their development in recent decades can be divided into the system with a mid-span (from 4.8 m to 7.2 m) and with

a wide span (from 7.2 m to 18 m). The formation of a certain type of prefabricated large-panel system and, in particular, its load-bearing system, depends on the functional purpose of buildings and their typological requirements, configuration and size of buildings, of their number of storeys (Fig. 2).

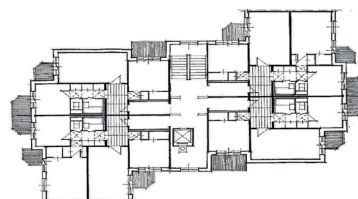
The largest spread in Eastern Europe has acquired a system with narrow transverse load-bearing walls, which has various modification combinations of different parameters of load-bearing walls. Such solutions have a high degree of industrial development, ensuring the high technology level of product manufacture and construction of buildings. Narrow span systems have fine-cell regular layout structure of the buildings, which makes their use for the construction of low-cost housing with small apartment areas, buildings of a hotel type and dormitories, administrative and other buildings without hall premises. For such buildings with fine-cell structure the transverse and cross-wall systems with transverse and longitudinal load-bearing walls and floors of the size of the room are used. Design scheme of the internal transverse load-bearing walls allow to provide the distribution of functions of bearing and enclosing structures. Their application involves the use of lightweight wall panels of the external walls and internal panels of transverse load-bearing walls. Such panels are made of lightweight concrete based on porous fillers, including keramzite, shale porosity, slag pumice.



1.

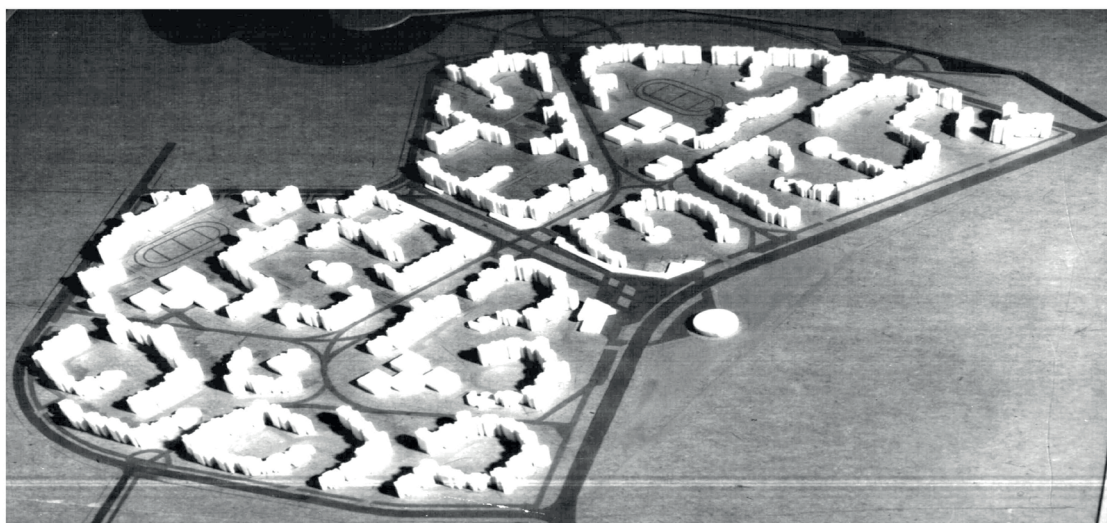


facade



the nomenclature of half-block sections of a series of dwelling houses

rotary block section



2. a project of a residential area "Pivnichny" development in the city of Zhytomir based on the series

Fig. 2. Projects of prefabricated large-panel systems, designed by the architect Vadym Abyzov (in a group of authors): 1 – project for a series of dwelling houses for low-rise and high-density development, 2 – series of dwelling houses for the city of Zhitomir on the basis of local house-building plant

Rys. 2. Projekty prefabrykowanych systemów wielkopłytowych, zaprojektowanych przez architekta Vadyma Abyzova (w grupie autorów): 1 – projekt dla serii budynków mieszkalnych o niskiej zabudowie i wysokiej gęstości zagospodarowania, 2 – seria domów mieszkalnych dla miasta Żytomierza na podstawie lokalnego zakładu budownictwa mieszkaniowego

However, these systems of prefabricated large-panel construction have a significant disadvantage in regard to their moral and operational durability. The fact is, that the narrow span of transverse load-bearing walls is not able to conform a functional-typological structure of buildings in compliance with the typological requirements that are changing, and the conditions of their operation. Strict regular rational structure of short-span PLP systems in many ways limits the ability of layout transformations that are inevitable in connection with the change of socio-demographic, urban, functional, technical, economic and aesthetic conditions and factors. So, a strict constructional and layout structure of prefabricated large-panel residential buildings of the 1960s is now quite obsolete. At the same time, the dynamics of the coming changes on various conditions of housing threatens by a massive reproduction of deficiencies of prefabricated large-panel construction system with narrow span of transverse load-bearing walls [1].

Longitudinal-wall systems feature the mandatory inclusion of enclosing structures of panels of outer walls of bearing system of buildings. Transverse walls in these systems are the supporting elements and not included in load-bearing systems. Unlike transverse-wall, longitudinal-wall systems are characterized by greater layout freedom and flexibility and the possibility of transformation of architectural and spatial structure. However, they are used for buildings with a small number of storeys (up to 9 floors) in connection with a limited load capacity of enclosing structures. In addition, the use of these systems, compared with transverse-wall systems, requires the creation of a wider range of industrial products.

Prefabricated large-panel systems with a wide-span load-bearing walls, are primarily used for residential construction, where due to their implementation the total number of sizes and brands of industrial products had reduced and a new architectural quality of the construction was reached. Prefabricated large-panel systems with a wide-span load-bearing walls, which provides the free planning of buildings with large non-divided spaces have found their successful use in residential construction in Denmark, Sweden, Finland, the Netherlands [3–5]. These systems are quite promising for prefabricated large-panel housing construction also in the countries of Eastern Europe.

The range of application of prefabricated large-panel structures for public buildings is limited to organizations and enterprises, educational, administrative, commercial and household, medical

and cultural purposes, which have a fine-cell structure with the same type facilities and small hall premises.

In Western European countries the traditional construction of single-family and sectional houses and based on complete assembly construction of pre-manufactured concrete structures has been withdrawn. Prefabricated large-panel construction that developed fast in the 1950s for solving housing problems after World War II, mostly in France, Denmark, Sweden, the Netherlands, turned out to be warranted for these countries only in the presence of a large and persistent in time volumes of construction. However, in countries where the large production base of PLP systems existed, the selective prefabricated large-panel construction in various combinations with other building systems continues, mostly for low-rise construction and individual apartment houses for people with low levels of income (Fig. 3).



Fig. 3. Large-panel housing construction in the Netherlands (Rotterdam)

Rys. 3. Prefabrykowane budownictwo mieszkaniowe w Holandii (Rotterdam)

Creation of powerful basis for PLP systems with numerous residential building enterprises was crucial in carrying out a large-scale housing program in Eastern Europe, including the countries of the former USSR. Development and mass implementation of common projects of prefabricated large-panel residential buildings accompanied by the constant interdependent improvement of architectural-layout, design and technological solutions with regard to improving their technical and economic indexes. Extensive work was carried out to ensure the reliability of the butt joints, their air and water insulation. Comprehensive development was aimed at increasing the readiness of factory prefabricated elements, reduction of weight and material consumption of buildings, improvement of technologies of their

production and installation, the use of outer panel walls of light and porous concrete with different heat insulators. Three-layer wall panels with mineral wool or polystyrene insulation have become widespread.

The application of the PLP systems for the mass typical residential construction in the view of the high degree of efficiency and industrial capability, adaptability to manufacture of products and installation of the buildings turned out to be economically effective enough. It should be noted that the technical and economic performance of buildings on the basis of prefabricated large-panel structures largely depend on the number of storeys and the configuration of buildings, their layout solution, the level of engineering, degree of factory readiness of products, conditions of construction.

3. THE MAIN DIRECTIONS OF IMPROVING OF LARGE-PANEL SYSTEMS

Studying of various researches and publications [2–9], own project experience, as well as multifactorial analysis of design and implementation of large-panel systems, allowed to identify the main directions of improvement and prospects for the development of these systems. Let us review the following main directions of improving of prefabricated large-panel systems (Fig. 4).

For the conditions of mass construction of residential buildings, the issue of modular coordination and typification of structural and layout parameters of the PLP systems are crucial. The ultimate goal of such development is drastically reducing the number of brands of industrial products, improvement of their circulation, and, consequently, increase the efficiency of production and construction. This approach allows the maximum use of the advantages of streaming technology in the construction of a wide range of residential buildings and a solution for a multi-choice architecture-urban planning tasks. One of the main factors that determine the effectiveness of the development and functioning of architectural systems, industrial construction, is the question of optimizing the range of items of typification (block-sections, flats, etc.) of residential structures. Solving it is aimed at providing the minimum necessary number of source items of typification of maximum architectural composition and urban variations of the residential construction. A key requirement in the development of methods for the formation of prefabricated large-panel ABS is focusing on existing technologies of PLP systems. But the organization of technological process is actual, it ensures the creation

and integration of various parts and products of specified nomenclature with architectural qualities about the sizes, shapes, finishes, etc.

The next direction of improvement of PLP systems is to increase the span of internal load-bearing walls. This allows to increase the demographic and planned variation of residential cell sections, the level of comfort of accommodation, as well as improve the moral durability of buildings with their flexible layout organisation. However, the economic benefits of the systems with short-span floors come out mostly in solutions of high-rise buildings, designed for the construction in seismic and other difficult geological conditions. The research and project development are actual, relating to the possibilities of the implementation of long-span architectural and building PLP systems with the use of overlapping slabs on two, three or more rooms of 9.0, 12.0, and 15.0 m long. Considering the technical difficulties of creation of spatial rigidity for long-span systems of high-rise residential buildings, these solutions can be successfully applied for low-rise (up to 5 floors) high density building development.

The progressive trend of development of prefabricated large-panel systems in accordance to the modern requirements is to improve technical solutions for outer walls. For the solution of this problem the important issue is the distribution of load-bearing and enclosing functions between internal and external load-bearing structures. The release of the outer wall from the load-bearing functions will facilitate the solution for such requirements, as independence of the elements of enclosures from the support of structural system, their interchangeability and, where appropriate, disassembly, as well as facilitation of the weight of building products. This will, in turn, apply a variety of effective structures, including the multi-layered panels for outer walls using traditional and new building materials with high thermal insulation properties. Along with this should be considered that the low-rise construction and justified use of design schemes with longitudinal load-bearing external walls and the use of effective outer walls are advisable. An important tool for promoting rational use of local materials and construction resources, improvement of the architectural quality of the residential environment, which is formed on the basis of the prefabricated large-panel system of construction, is the use of local construction materials for external walls. In this case in accordance to the resources available the rational step is the application of various lightweight concrete

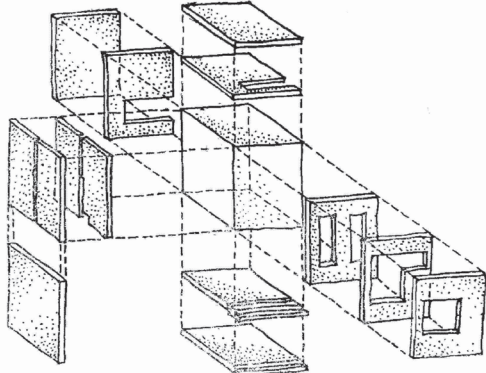
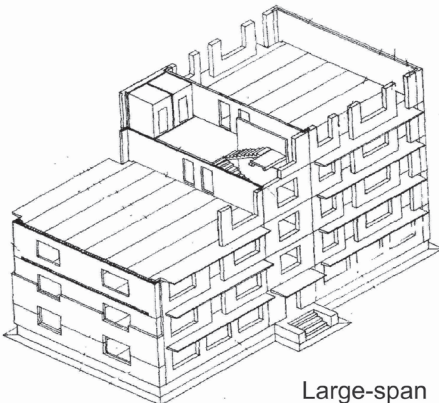
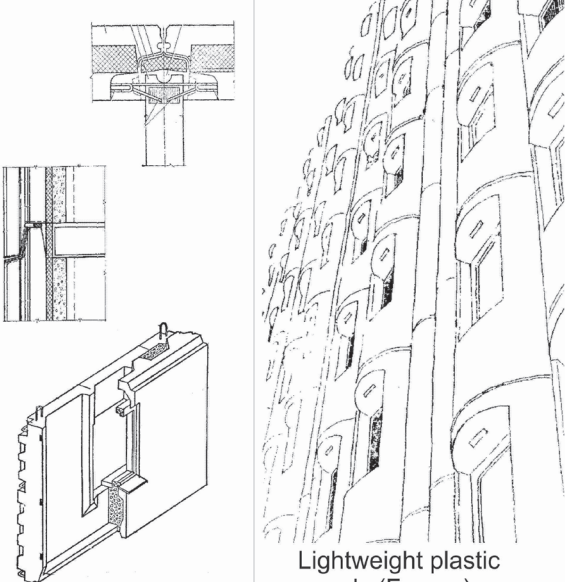
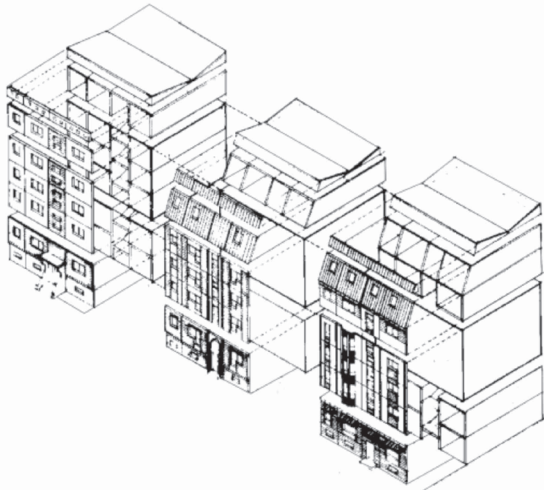
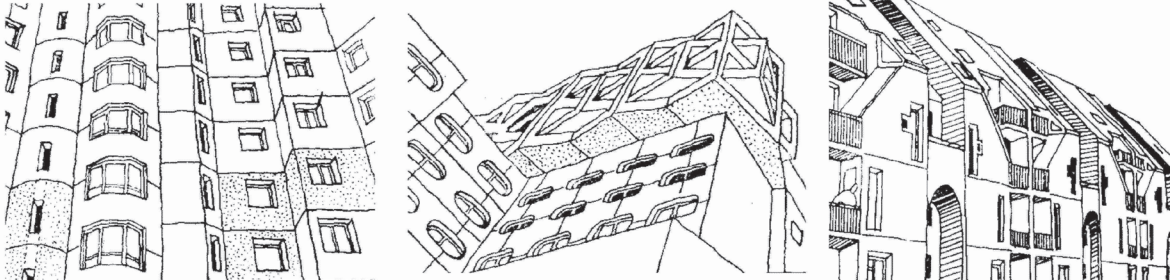
<p>Optimization of parametric characteristics of series of residential houses and elements of their typing</p>	<p>Increasing the steps of bearing walls with the introduction of large-span large-panel systems.</p>
 <p>Formation of the "Mobile" system</p>	 <p>Large-span system "Bars"</p>
<p>Improvement of technical solutions for enclosing structures and their joints</p>	<p>The use of combined panel-block ABS based on local materials</p>
 <p>Lightweight plastic panels (France)</p>	 <p>Large-panel residential buildings in Chemnitz</p>
<p>Improvement of aesthetic qualities and means of architectural and spatial expressiveness of large-panel systems</p>	
 <p>Large-panel buildings of L'Avenir company (France)</p>	

Fig. 4. The main directions of improving of large-panel systems
Rys. 4. Główne kierunki doskonalenia prefabrykowanych systemów

blocks, blocks of limestone, sandstone, and other local materials, including use of waste products of industrial production. It can be widely used as a traditional brick, as well as its various new modifications, such as face, figured, hollow brick, as well as ordinary ceramic modular stone.

This solution with a combination of different load-bearing structures is a combined cell-panel architecture-construction system [5, 6]. For the conditions of low-rise dense building development, as well as mass low-rise individual construction for categories of the population with a low level of income, the conversion of prefabricated large-panel system residential construction to the application of ABS with external walls made of local materials, is quite promising. So, the proof is the development of the existing urban environment in East Germany and in the Netherlands with the low-rise residential buildings based on cell-panel systems, either in the surroundings of historic building development. Besides the possibilities to solve various architectural and artistic problems, this will improve the workability of production structures, produced by construction enterprises, due to the exclusion of the manufacture of panels of external

walls, expand the use of products, and reduce the capital intensity of building production by the rational use of local resources of building materials.

For buildings of more than 9 floors high with wide span of bearing walls the rational step is the introduction of reinforced concrete monolithic core for spatial hardness. The application of staircase-elevator unit in this vertical core (shaft), combined with prefabricated large-panel build up is a combined panel-monolithic system [5].

The search for various options of facade fragmentation is quite promising, with various location of loggias and balconies, entrances, stair-elevator units that can be used as a turning and connecting elements of block-sections in the compositional structure of residential houses. Formation of architectural-spatial and visual expressiveness of prefabricated large-panel residential buildings is contributed by such tricks as the creation of terrace development, 3D elements of loggias, attic floors, shading, and other structural and decorative items, as well as a variety of solutions to the relief and colour processing of exterior panels, facades, etc. (Fig. 5).

Various techniques of architectural and artistic



Fig. 5. Various options of facade fragmentation of prefabricated large-panel buildings
Rys. 5. Różne opcje fragmentacji elewacji prefabrykowanych budynków wielopłytowych

decisions of assorted elements for personalising the facade are designed by the architects and builders of the countries of Eastern Europe, in particular of Poland. They include the use of triangular loggias and balconies, that vary in length and depth, standing out 3D elements, use of the plastic properties of concrete to create relief panels, etc. Technology of forming the concrete products in fibreglass forms used in Riga (“Rigabeton”), is characterized with the combination of the high technical and economic indicators (low consumption of concrete, increased density, impermeability, frost resistance) with architectural qualities (a variety of shape, plastic, high quality front surface). In France the “artbeton” is widely used, which combines the efficient production technology with plastic properties of concrete mass. Prefabricated concrete products become the independent artistic value. The surface can be smooth or rough, fine-grained or coarse, with marble, granite or other crumbs, covered with shredded ceramics, glass mosaic.

The production and supply of such parts is provided by special companies that in cooperation with architects determine the required range of panels of different options – by shape, colour, and textured finishing and using new building materials [9]. For example, modern decorative plasters ArtBeeton and SaltBeton from the company RM Distribution imitate not only rough concrete structure, but also fading or salt deposits on the surface.

It should be noted that overcoming the contradictions between the architectural requirements and structural and technological features in prefabricated large-panel residential construction must occur in close cooperation of architects, designers and technologists, including modernization of residential construction

enterprises and determining the optimal nomenclature of industrial products. For this issue the experience of foreign and particularly Czech architects and builders is useful, they master the programme of new construction and prefabrication of various parts based on periodic (every 3–5 years) forms, equipment, and products updates.

4. CONCLUSIONS

Due to the cost-effectiveness, the high degree of industrialization, the technological efficiency of manufacturing products and the installation of buildings, the use of prefabricated large-panel systems for social housing construction remains quite effective. The main characteristics of these systems are determined by their differentiation according to the constructive scheme (transverse-walls, longitudinal-wall, cross-wall) and the distance between the bearing walls (narrow span, mid-span, wide span of load-bearing walls). The main directions of large-panel systems’ improvement are the following:

- optimization of parametric characteristics of series of residential houses and elements of their typing, using modern computer technologies;
- increasing the steps of bearing walls with the introduction of large-span prefabricated systems;
- improvement of technical solutions for enclosing structures and their joints;
- the use of combined panel block systems based on the use of local building materials;
- improvement of aesthetic qualities and means of architectural and spatial expressiveness of prefabricated large-panel systems.

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Acknowledgments:

The work was financed by work Kyiev's National University of Technologies and Design

Podziękowania:

Praca była finansowana przez Narodowy Uniwersytet Technologii i Projektowania