Modern directions of low-rise housing construction development in the world: economic and technological aspect

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Modern directions of low-rise housing construction development in the world: economic and technological aspect

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Abstract. Today, all over the world, the focus is on the use of the new technologies that would significantly improve the construction quality. The paper considers the low-rise construction development as a whole, analyzes one of the most promising areas of architectural and construction development in the world - modular construction, explores all the positive and negative aspects of modular buildings.

Introduction

Literally all the participants in the construction investment and technological process need the innovative sphere of construction, since outdated technologies do not allow building comfortable and affordable housing, which the majority of the population needs [1, 6].

Low-rise construction is becoming more popular these days. It would seem that now is the time of multi-storey buildings, which arise more and more every year. But this is not so, because the “stone jungle” does not attract everyone. So, in the developed countries abroad, low-rise buildings have long been replaced by residential skyscrapers, which are operated as office, administrative and commercial centers.

Main part

The most important trend in low-rise construction is the increase in this housing construction both in Russia and in the regions. According to the results of various opinion polls, about 57% of Russians would like to live in an individual house, while in a separate apartment - only 35% [5]. The average specific indicators annually for low-rise construction are shown in Table 1.

Table 1. Specific indicators of low-rise construction

1990	1995	2003	2008	2009	2010	2016	2020
10[%]	22[%]	40[%]	43[%]	47,8[%]	50,2[%]	62[%]	71[%]

Several studies of the United Nations Human Settlements Program have emphasized that rapid urbanization is accompanied by burdensome housing problems. Cities are growing disproportionately to the economic development pace, widening the gap between the rich and the poor. In large cities with a population of more than 10 million people, comfortable housing conditions are not available for

all categories of the population. The world community is concerned that 26 of the 34 major cities are located in developing countries. These cities face such challenges as urban sprawl, slums, and spontaneous development. According to statistics, in 2005, every third resident of the city lived in adverse conditions. To meet the global needs for urban housing, it is required to build approximately 35 million apartments per year (approximately 95 thousand apartments per day).

The development of the construction of affordable housing is relevant for many countries. Economically, this can be justified only as a result of the industrial construction modern methods' application, which are based on standardization, integration, typification [2, 3]. Modern materials and construction systems are being introduced in the conditions of the increased energy-saving technologies' use [4]. The specialists' efforts are aimed at finding the ways to reduce construction costs. One of the directions is modular construction. Modular construction is a process in which a building was produced off-site, in the factory, using the same materials, the same norms and standards as in normally constructed facilities, but it was produced and built about twice as fast as usual [12]. The building constructed with modules expresses the same structural concept and technical characteristics in comparison with the most demanding object built on the construction site [8].

A modular low-rise construction type using the structural thermal insulation panels was developed in the USA. This unique technology, in combination with modern requirements for housing, is considered one of the best in the world [11]. Such houses do not require massive foundations. All of their structural elements are factory-made, easy to transport in the kit and quickly erected at the construction site.

In the urban planning code, there is no definition of "modular construction" or "modular building, structure", however, a similar concept is defined as "mobile building" in GOST 25957-83 "Buildings and structures mobile (inventory). Classification. Terms and definitions": "A relocatable building or structure is a building or structure of a complete factory supply, the design of which provides the possibility of its relocation".

It should be noted that today the modules construction is one of the most promising high-tech areas of architectural and construction development in the world [8]. Modular technologies are widely used in low-rise buildings of various functional purposes: office and household, warehouse and sanitary facilities, special purpose premises and so on. However, recently, they have been introduced into multi-story and even high-rise construction.

Modular construction combines various technologies based on the principles of rapid construction [12]. In the modern sense, speaking of the modular components of this system, two main directions can be defined in construction: the use of individual elements of the frame system (beams, columns, floor coverings, wall panels, etc.), which are manufactured at the factories and assembled at the construction site ; the use of 3D elements (block containers), including the necessary internal engineering equipment, interior and exterior decoration and built-in furniture, as well as equipment.

Prefabrication, pre-assembly, wider use of model structures, typical construction and the prefabricated building system are the terms used in combination or separately to describe the advanced technologies in the accelerated construction of buildings, when the structural elements are produced at the factory and the construction site is used only for assembly [7, 13].

BROAD company was founded in China in 1988. This company was the first to use modular construction for the construction of high-rise buildings with more than fifteen floors. In 2008, its subsidiary Broad Sustainable Building (BSB) was established with a manufacturing complex. The seven principles of sustainable development in BSB construction technology are:

- BSB is the only company in the world where 90% of the elements of a modular system are manufactured off-site (production waste – 1%);
- energy efficiency is 5 times higher than in the traditional method of construction;
- unique microclimate inside buildings with specially purified air;
- earthquake resistance (withstands earthquake with magnitude 9);
- saving land (focused on high-rise construction);
- material saving (metal structures made of recycled steel);

- durability.

The structural system is based on the practice of all the elements' typical design: steel columns, beams (transverse beams), floor coverings and curtain wall panels. The most unusual module is a floor section of approximately 12.5 mx 4.5 m in size. They are manufactured and equipped with the necessary engineering equipment and decorative elements: electrical cables, hidden central air conditioning outlet openings and ventilation systems, heating and sound insulation, trim elements, etc. Standard floor height is 3 m. Manufactured modules are delivered to the construction site and assembled with bolted joints and welded joints. The elements' typification, high quality workmanship outside the construction site and perfect logistics (production, storage, delivery, assembly) makes it possible to achieve amazing construction rates.

The panels are distinguished by high energy-saving characteristics (ten times bigger than that of buildings made of brick and concrete), ease of manufacture, low cost, amazing strength and extremely high installation speed. Of these panels, several workers can build a box of a house on the finished foundation in two to three days without the expensive technical means' use. Houses and other buildings using this technology are built in large numbers in the USA, Canada (including beyond the Arctic Circle) in Europe and on other continents, successfully replacing the most common wood-frame technology. The starting materials for the panels' manufacture are oriented as chipboard, polystyrene foam as insulation and a special binder composition, which gives the panel exceptional strength.

At all times, building a house was considered not only costly, but also an extremely long event, but today everything has changed - today it is possible to build a warm and energy-efficient home in just a few days. And all this thanks to the latest construction technology from the structural thermal insulation panels (Figure 1) [9, 10, 11].

Figure 1. General view of SIP panels

The main advantages of SIP-houses.

SIP panels are large building boards consisting of at least three layers: inside - extruded polystyrene foam, and from the outside and inside - OSB-3 (most often), MFP-5, drywall or fiberboard. The thickness of the material is not large (from 160 to 240 mm), however, in terms of thermal insulation, the SIP panel is not inferior to a meter-long brick wall, so the structure is very warm. Accordingly, in the future it is possible to save money on heating in winter and on air conditioning in summer.

Another indisputable advantage of houses made of SIP panels is the low cost, and the point here is not even the material price (it is not so cheap), but the associated costs. So, for example, for the construction of such a house it is not necessary to build a strong and expensive foundation - the walls will be light, and therefore there will be enough shallow tape or pile.

In terms of strength and durability, such a house, of course, loses to a brick one or a wooden one constructed from a natural log house; however, it is quite reliable and will be enough for one human life. The guaranteed service life of SIP panels is about 50-60 years, although there is an opinion that

polystyrene deteriorates faster, but the others claim that it is eternal [5]. It is not possible to make a clear conclusion who is right, since the material is quite new. Another disadvantage of SIP house is poor sound insulation. This is due to the presence in the multilayer structure of the OSB, which "hums". Accordingly, this drawback can be eliminated by isolating the material, for example, using drywall on the walls and screeds on the floor.

The next disadvantage of this type of building is poor ventilation. This is the characteristic of all thermal houses and this problem can be solved only by installing a high-quality, modern system of supply ventilation, as well as more frequent ventilation of the premises.

The features of SIP-panel houses include the high speed of construction, which is a big technology advantage. Since the building will be erected within weeks, it is needed to immediately collect the entire amount for the construction, while the traditional houses are built in parts (the first year - foundation, the second year - walls and roof, third decoration and communications), so it is possible to distribute the expenses over time. The increase in energy prices and the depletion of raw materials causes a growing interest in the energy-efficient houses' construction. By building the prefabricated frame-panel houses from innovative SIP panels, it is possible to save up to 60% of the energy needed to heat a house, while lowering the burden of carbon and greenhouse gases reduces the environmental load.

When comparing the building houses' technology made of heat-insulating SIP panels with traditional ones using such building materials as aerated concrete blocks, hollow blocks, brick, the heat-saving properties of SIP panels are several times better than them (Table 2).

Table 2. Comparison of heat transfer coefficients U

IP panels, thickness	Heat transfer coefficient	Aerated concrete, thickness	Coefficient heat transfer
SIP 117 mm	U ≈ 0,27 [W/m ^{2}]	117 [mm]	U≈ 1,28 [W/m ^{2}]
SIP 167 mm	U ≈ 0,20 [W/m ^{2}]	167 [mm]	U ≈ 0,89 [W/m ^{2}]
SIP 217 mm	U ≈ 0,15 [W/m ^{2}]	217 [mm]	U ≈ 0,69 [W/m ^{2}]
SIP 322 mm	U ≈0,10 [W/m ^{2}]	322 [mm]	U ≈ 0,46 [W/m ^{2}]

As known, the technologies used in the traditional houses' construction are very time-consuming, which leads to a significant increase in costs. Having made the decision to build a house of SIP panels, the future owner can forget about such problems, because this is one of the simplest and fastest methods of walling and roof construction. Figure 2 shows the special laminated walls, the construction of which is based on the use of structural thermal insulation panels. They provide a reasonable level of tightness. The air velocity at such walls is only 0,6 m^3 / hour.

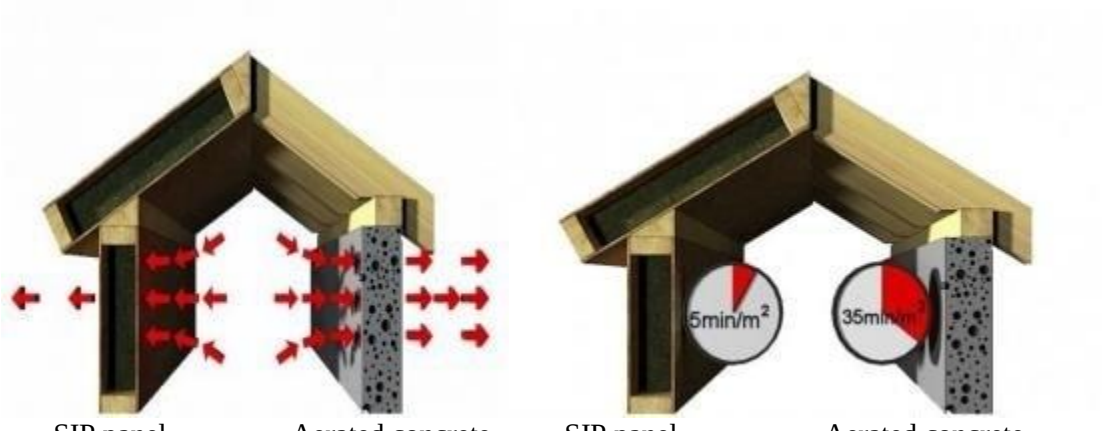

Figure 2. Laminated walls using structural insulation panels

There are two main principles and both of them are several times faster compared to traditional construction. The first involves the use of standard panels, mass-produced at the factory. Using this method, the walls and roof structure are mounted from the standard panels brought to the construction site, which are already adjusted to the appropriate size and shape at the construction site. The second is that ready-made structural elements of the house of the right size, with cut-out openings for windows and doors, for a particular house, are brought to the construction site. Due to the low weight of the heat-insulating panels, building a house up to the basement level can be carried out without the heavy equipment participation. The weight of a heat-insulating SIP panel with a thickness of about 167 mm is only 14.75 kg/m^2.

In Hong Kong, there is another example of the modular structures' introduction in the affordable public housing construction. Large items manufactured at the plant are used in the construction of 40 storey residential buildings. The high-rise residential building "461 Dean Street", erected in the Brooklyn area (New York) is an interesting and illustrative example of the use of modular systems in construction. Upon completion, it will be the tallest modular building in the world (32 floors, 109.4 m). This building is part of the large Pacific Park complex and has 363 apartments. At the same time, 50% of all residential buildings will be rented to the low- and middle-income families as a part of the program aimed at providing affordable housing for such families. In total, 930 modular units will be required for the building construction. For this project, 225 types of modules were developed. They are manufactured at the FC Modular factory, specially built for this purpose. To be more precise, the modules are fully completed at the factory. Steel frames for modular units are transported to New York from Virginia and facade panels are supplied from other plants. The size of the modular block is: width up to 4.57 m; length from 6.10 m. to 15.24 m., height 3 m. The production line, which makes the modular units fully completed, depends on their functional purpose and includes the installation of all engineering systems (electricity, water and sanitation, ventilation and air conditioning), equipment (plumbing, kitchen equipment, etc.) and decorative elements (lamps, switches, floor coverings, ceramic tiles, etc.) [13].

The average production rate is 4 modules per day, approximately 1 floor per week. The most time-consuming and longest process is assembling the bathroom modular units. Therefore, at first bathtub modular units are equipped with subcomponents, and then they are built into the main module. Ready-made modules are delivered to the construction site with special trucks and are installed "just in time" at night. All parts of the building are fixed on steel columns with additional transverse crossbars to strengthen the structure. The architectural solution was developed by the "SHoPArchitects" company. It should be noted that the production speed is not very high, but at the same time it allows to achieve perfect quality, complete equipment and make interior finishing work.

3D modular construction of buildings is a type of prefabricated construction, which is based on the use of 3D blocks pre-manufactured outside the construction site. Their application has a number of advantages: assembly speed, high quality control at the factory, labor safety during short high-altitude work, testing and the rapid introduction of new technologies at the factory, reduction of noise level and the amount of construction waste at the construction site, which has a positive impact on the environment. The material for the structural structure is a reinforced concrete or metal frame.

Summary

In conclusion, it can be stated that modular construction is promising in many respects for the requirements for this construction type. People who build relocatable module buildings are faced with very fast building processes and very simple construction technology. Unfortunately, the modular construction principle, in most cases, is used in the construction of temporary residence, warehouses. Few see this as a whole house. But real experts say that modular construction is our future, since the construction of such houses can be carried out all year round, on almost any type of soil.

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