Architecture and construction of low-rise buildings from composite wooden modules

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Abstract. Wooden architecture is a significant part of the Russian culture and largely determines its national identity. Wood as a construction material has not exhausted its historical role yet. The reliability of wooden structures can be considered taking into account new processing possibilities. Wooden structures remain important in the face of growing environmental problems, resource-saving. As a renewable building material wood has great prospects. As the decrease in the thermal protection properties of wooden enclosing structures leads not only to heat losses and to the creation of an uncomfortable temperature and humidity regime of residential premises, but also to the decrease in the durability of buildings, increasing the thermal protection properties of enclosing structures in residential buildings should be considered a task of a not only technical, but also social nature. As a result of the analysis, the author of the article suggests using a wooden module for low-rise buildings and wooden temple construction from the well-known construction eco-friendly materials and "Composite Wooden Timber". The factory conveyor modular technology will provide the required quality and characteristics of housing, will allow using the latest achievements of science and technology, provide comfort, energy efficiency, environmental friendliness and economy of living in it.

1. Introduction

The Russian wooden architecture was created by the labor and talent of many generations of architects [1-17]. Selecting and improving all the best, they developed reasonable and logical constructive methods that fully corresponded to the properties of the timber. In addition, they developed an original artistic and imaginative system of architectural forms and spatial organization of towns and villages that corresponded to all practical and worldview tasks of their time, which became the basis for the birth of the Russian national architecture. Academician Igor Grabar called Russia "the Country of Architects". "The feeling of proportions, the understanding of the silhouette," he wrote, "the decorative instinct, the ingenuity of forms - in a word, all architectural virtues - are encountered throughout Russia's history so constantly and everywhere that suggest the utterly exceptional architectural talent of the Russian people..." [18]. It was here that the house building tried to reach the road of industrialization, the production of houses was started in the premises adapted for this purpose, and only then the finished house-kits were transported and collected in the places of residence. So all the talk about the priority of Canadian or European builders in the creation of factory (manufactory)
housing construction is simply ignorance of the history of this issue. The climatic conditions of residence and the natural savvy of Russians determined a similar result.

The theoretical basis of the research was the authoritative works on the general history of Russian architecture and town-planning of such authors as: I.E. Grabar, A.V. Bunin, T.F. Savarenskaya, N.I. Brunov, N.F. Gulyanitsky, A.V. Ikonnikov, A.V. Shkvarikov, E.I. Kirichenko, E.A. Borisova, W.J. Hight, I.A. Bondarenko, A.S. Shechenkov, etc. The Russian wooden architecture, its decoration, are considered in the works of such researchers as: I.E. Zabelin, S.Ya. Zabello, V.N. Ivanov, P.N. Maksimov, E.A. Ashchevik, T.V. Stanyukovich, A.V. Opolovnikov, E.E. Blomkvist, V.V. Kostochkin, A.A. Shennikov, V.P. Orfinskii, V.A. Kroklin, S.V. Bezonov, O.A. Ganitskaya, M.I. Milchik, N.P. Kradin, L.M. Lisenko, S. Ushakov, V.I. Pilyavsky, A.A. Tits, E.N. Bubenov, etc. In recent decades, monuments to the wooden architecture of the provincial cities of Russia, the formation of the space of historical cities have been studied in the works of E.A. Bulavin, L.A. Potapov, S.M. Shumilkin Yu.I. Shepelev, Z.A. Zaitseva, E.M. Valyuta, E.B. Sitnikova, E.A. Spiridonova, A.I. Sazonov, I.V. Kulikova et al.

2. Main part

Currently, the use of wood for the construction of enclosing structures is limited, mainly by low-rise housing construction, but in this area the timber still maintains a leading position, although the traditional log gradually gives way to the beam. This is caused both by economic reasons (rapid assembly of the house and a significant reduction in the proportion of manual labor), and reduced requirements for the qualifications of performers needed when working with the bar. Now in the market of wooden housing construction there are a lot of technologies: armature-frame, armature-panel, panel, volume-modular, from glued profiled beam and round logs. Naturally, each of them, according to the developers of this or that technology, is the best. At the same time, all existing technologies have both advantages and disadvantages. Which is quite natural for any technological process. But quite a large number of those wishing to introduce their own technology already exists. According to what technology to build the house, and what requirements should it meet? The modern house must meet three fundamental principles (Ecology - Economy - Aesthetics) [19]. In the analysis, none of the proposed types of low-rise wooden housing construction (LRWHC) does not meet all the conditions of environmental safety. The most environmentally sound are houses made of rounded logs, massive profiled beams and chopped houses. But thermal engineering calculations for the thermal insulation of buildings, taking into account the new requirements of SNiP, showed that for walls of a beam of 200 and 250 mm thick, the outer wall must be insulated with additional thermal casing [20]. The above data, confirmed in practice, solely illustrate the thermophysical defects of the currently proposed sets of logs and rounded logs, i.e. in this form, they go on sale. One way to increase the heat-protecting properties of the exterior walls of wood is to make them from non-uniform fragments with longitudinal axial holes filled with an effective insulation. Treatment with fire-protective and hydrophobic compounds of the outer and inner surfaces of the fragments increases their operational reliability. As a result of the analysis, the author of the article tried to create a "Composite wooden timber" from patent building materials (patent No. 2008143949/057341). The beam contains the profiled vertical and horizontal walls fixed together to form a longitudinal through hole in them filled with a heater. Horizontal walls made of a multilayer thin sheet material are installed in grooves selected in vertical walls, the vertical walls being made of glued together bars with the opposite direction of the fibers. To ensure the design of high strength and load characteristics on the inside of the vertical walls, the stiffeners are fixed in a plane perpendicular to the planes of the vertical walls. At the same time along the entire length of the beam there are installed cross-section bridges made of thin sheet material and fixed in vertical walls, with the formation of \( n \) chambers, and in the upper horizontal wall technological holes are made. The execution of horizontal walls made of multilayer thin sheet material allows to accelerate the assembly of the finished beam and use it as the third connecting element in the angular vertical and horizontal joints of the beams. Vertical walls are made
of waterproof plywood. This achieves high aesthetic and strength characteristics of the product as a whole.

Having considered the required value of the resistance to heat transfer for a composite wooden beam with a width of 290 mm height of 320 mm with vertical wooden walls of 45 mm and a heater (polyurethane foam) 200 mm as the horizontal walls of the beam a waterproof plywood with a thickness of 10 mm is used. High quality of the inter-packing insulation is achieved as a result of the application of a special insulating liner made of a 5 mm thick jute. The calculation showed that the required heat transfer resistance of the wall from the glued profiled bar is 468 mm, and the width of the wall from the composite wooden beam is 209 mm [21].

Theoretical calculation and testing for vertical compression showed that the construction can be used for the construction of low-rise buildings (Figure 1-4). Considerable preservation of the heat consumption appears only with a layer of thermal insulation from 150 mm. It is desirable to use a composite wooden beam with a heater with a width of 200-350 mm. As a result, heat losses through the enclosing surfaces will not exceed 15 kW from 1 sq.m. heated area per year - this is almost 20 times lower than in conventional buildings. With additional engineering solutions, you can achieve great results.

The prefabricated factory buildings in the second half of the XIX century in Russia and abroad were individual and did not allow to use all the possibilities of prefabricated and modular construction. The house-building enterprise produced, as a rule, a house of one type, since a slight change in its layout could cause a restructuring of the technological processes. The universal shield system was first proposed in 1893 by the Russian engineer Shcherbakov [22,23]. Based on the adopted conventional module, Shcherbakov's skeleton-and-shield house system had a significant advantage over the then widespread in Russia Danish and Finnish prefabricated buildings and allowed, using a small set of shields, to collect houses of different layouts. The main ones in Shcherbakov's system were the shields of a specific size and special design. The construction of energy-efficient buildings is now widely implemented all over the world. Especially impressive in this respect are the successes of the countries of Western Europe and Scandinavia.
Figure 1. Testing of timber.

Figure 2. Angular composite wooden modules.

Figure 3. Draft outline of the corner of the temple.

Figure 4. Model of the assembled corner of the temple.

3. Conclusion
The composite wood modules considered are energy efficient. Modules can be used in the construction of walls and ceilings of wooden low-rise buildings and temples (Figure 5, 6). When using these bars, no additional work is required to insulate the premises, as well as internal and external finishing of the house. Onto the construction site, it arrives in a finished form ready for assembly. The
installation of this beam can be carried out without the participation of lifting machines, as the weight of the beam has decreased by more than 80%. Modules can be manufactured on woodworking machines using standard equipment in conditions of both small handicraft workshops and large woodworking plants. Conveyor factory assembly will provide high quality work, construction speed and low prices, with very high quality products. The total effect of heat savings in newly built residential and commercial buildings here is 50 - 70%. Such a significant saving will allow you to quickly recoup costs from the use of energy-saving technologies.

**Figure 5.** Draft outline of a wooden temple using composite wooden modules. View from the east.

**Figure 6.** Draft outline of a wooden temple using composite wooden modules. View from the south.

**References**

[1] Maltsev V V 2006 Low-rise wooden house construction: the concept of a new century *Journal: Timber*. 6 p 135

[2] Pilyavsky V P, Tits A M, Ushakov Yu S 1984 *History of Russian architecture* (Moscow) pp 34–67

[3] *Wooden architecture of Tomsk* 1975 (Moscow: Soviet Artist) p 18
Alekseev Yu V, Kazachinsky V V, Bondar V V 2004 History of architecture, urban planning and design: lecture course (Moscow: Publisher ASV) p 448

Alekseev Yu V, Somov G Yu 2003 Urban planning of settlements. Vol. 1 The evolution of planning: textbook in 5 volumes (Moscow: ACB Publishing House) p 336

Ashchepekov E A 1950 Russian wooden architecture (Moscow: State Publishing House of Architecture and Urban Planning) p 34

Baranov D A, Baranova O G, Madlevskaya E L 1999 Russian cottage: illustrated encyclopedia (St. Petersburg: Art) p 76

Borisova E A 1979 Russian architecture of the second half of the XIX century (Moscow: Nauka) p 38

The general history of architecture: in 12 volumes. Vol. 10 1972 (Moscow: Stroyizdat) p 92

Ikonnikov A V 1990 Thousand Years of the Russian Architecture. Development of traditions (Moscow: Art) p 384

Kirichenko E I 1978 Russian architecture of the 1830s-1910s (Moscow: Art) p 40

Lisovsky V G 1988 National traditions in Russian architecture of the XIX-beginning of the XX century (Leningrad: Knowledge) p 32

Opolovnikov A V, Ostrovsky G S 1970 Russia is a wooden one. Samples of Russian wooden architecture (Moscow: Children's Literature) p 199

Preservation of monuments of the wooden architecture: collection of scientific papers 1989 (Moscow: Publishing House of NMS MK USSR Union "Restoration") p 184

Ganeshin A 1983 Historical environment: research and design Architecture of the USSR (Moscow) 2 pp 37–39

Pribytkova A 1955 Wooden architecture of Tomsk Architectural heritage 5 pp 101–114

Ashchepekov EA Gorbachev V T 1978 Monuments of wooden architecture in Novosibirsk Monuments of the history and culture of Siberia (Novosibirsk) pp 95–102

Grabar I E 1969 On the Russian architecture (Moscow) p 49

The concept of development of low-rise wooden housing construction in Russia in the XXI century. Developer Agency for Industry (ROSPROM) Russian Academy of Natural Sciences. Federal State Enterprise "Scientific Research and Design Institute" Nauchnstandart - Giprolesprom " 2006

SNiP SP 23-101-2000 Designing of thermal protection of buildings (Moscow) 2001

SNiP SP 23-101-2004 Design of thermal protection of buildings (Moscow) 2004

Gladkov B V, Karl sen G G, Pronevich V P 1948 Low-rise apartment buildings of factory manufacturing (Stroiizdat) pp 23–78

Moro zov N A 1952 Factory building construction (State Publishing House for Architecture) pp 27–56

Acknowledgment
The work was supported by Act 211 Government of the Russian Federation, contract No. 02.A03.21.0011.