Wooden low-rise construction. New constructive and technological solutions

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Abstract. Currently, Russia is in dire need of a large-scale expansion of the construction of low-rise residential buildings, both in urban areas and in rural areas. As of today, various technologies are used in low-rise construction, including those with the use of wood. The feasibility of expanding the choice of wood as the main building material is due to a number of known advantages over other building materials. However, upon a detailed examination of the territory of the Russian Federation as a whole, it should be noted, despite the fact that our country has huge reserves of forest resources, forests are distributed over the territory of our country extremely unevenly. In order to increase the efficiency of wood consumption for the needs of low-rise housing construction, it is proposed to improve the panel construction technology from wood and wood materials by simplifying the structural scheme of the building, increasing its spatial rigidity and reducing the labor intensity of installation. This improvement is realized due to the organic combination of the advantages of frame and panel technologies with the elimination, if possible, of their main structural, installation and operational shortcomings. The proposed technology for erecting a building from wooden panels makes it possible to simplify the design scheme, increase its spatial rigidity and reduce the labor intensity of installation, which gives impetus to further improvement of design solutions for residential buildings, industrial buildings and public facilities designed on the basis of wood and wood materials, ensuring the rational use of material in sparsely wooded areas of our country.

1. Introduction

Russia is in dire need of a large-scale expansion of the construction of low-rise residential buildings, both in urban areas and in rural areas. This is due, in particular, to a significant change in supply and demand in the housing market, which has made a tilt towards individual construction. So over the past 25 years, the share of commissioning of low-rise housing has increased more than 10 times. Today this figure is 60% on average in the country, and in 1990 it was just over 6%.

As of today, technologies are used in low-rise construction that can be divided into two large groups: production of a house in a factory and on a construction site. The main difference between these two groups lies in the answer to the question: where and in what proportion do the main stages of house installation take place (except for the construction of foundations). The most widely used technology for the production of houses from element-by-element blanks (frame technology) and panel construction technology are used in the factory. Technologies at the construction site are repre-
sented by a wider range, for example, masonry technologies (brick, block or stone), permanent formwork technology, monolithic housing technology, etc. [1].

2. The expediency of choosing wood as a building material

Almost all technological schemes provide for the use of basic building materials in the form of concrete, steel and wood. All of the above technologies go through their evolutionary path and have their own advantages and disadvantages due to both the technology itself and the material used. Thus, the key task is to choose the optimal technology for the construction of a low-rise building.

The expediency of choosing wood as the main building material lies in the fact that wood has a number of well-known advantages over other building materials, these primarily include the positive aspects of wood, which create a comfortable environment for a person, and the design features of wood products, which provide low thermal conductivity of walls, saving resources during the construction of foundations, ease of transportation to the facility, including assembled, as well as increased resistance to foundation settlements, seismic loads [2]. Moreover, wooden houses are traditional for Russia. It is on wooden houses that great hopes are pinned as a solution to the problem of affordable housing [3,4]. At the same time, a stimulating factor in the growth of the share of wooden housing construction is the program for subsidizing mortgages for citizens who buy apartments or build their own house using wood materials, which will start operating in 2018. In accordance with the proposed program, it is planned to subsidize 5% of the mortgage loan rate for buyers of wooden housing. On average, a mortgage subject to a subsidy will have a rate of 9-10% per year with an initial payment of 10%.

However, upon a detailed examination of the territory of the Russian Federation as a whole, it should be noted, despite the fact that our country has huge reserves of forest resources, namely, one inhabitant of Russia has ten times more forests than an average inhabitant of the Earth, forests are distributed over the territory of our countries are extremely uneven. The main forest areas are located in large and relatively sparsely populated regions of the North, Siberia and the Far East, while in the most densely populated regions of the Middle Belt and the south, forest areas are small. In terms of the area of forest per inhabitant, the most wooded region of our country (Yakutia) is more than four thousand times larger than the least wooded region (Stavropol Territory). In 27 constituent entities of the Russian Federation, the forest area per each permanent resident is less than the world average.

Thus, in most of our regions, the forest area per capita is not so large, and it certainly does not allow the use of these forests irrationally, without due concern for their protection, protection and reproduction. In this regard, the rational use of forest resources in sparsely wooded areas is becoming an important national economic task and the choice of an effective constructive and technological solution for the construction of a building using wood is one of the ways to solve it.

3. Basic technologies of wooden housing construction

Currently, several basic technologies of wooden housing construction are used: with walls made of solid solid or glued timber (rounded logs, solid timber of various cross-sections, glued timber); with frame walls; panel technology; combined options. In all the variety of wood construction technologies, low-rise buildings made of solid and glued beams occupy a leading place. Each of these technologies is not devoid of both positive and negative aspects. At the same time, a detailed analysis of the normative and scientific and technical domestic and foreign literature showed that at present, as monotechnologies, they have exhausted themselves and their further improvement leads to an improvement in technical and economic indicators by no more than 10%, although there is a need for much greater savings [5, 6, 7].

It is impossible to obtain a qualitative leap in the field of improving building structures without a comprehensive analysis and synthesis of the best known options, without studying the experience of scientists and engineers in the field of research. In this regard, without denying any of the known technologies, at the Department of Construction Production of Irkutsk National Research Technical University, together with specialists from Orenburg State University, it is proposed to improve panel construction technology from wood and wood materials by simplifying the structural scheme of the
building, increasing its spatial rigidity and reducing labor intensity of installation /8/. This improvement is realized due to the organic combination of the advantages of frame and panel technologies with the elimination, if possible, of their main structural, installation and operational shortcomings [9, 10].

The task is solved due to the fact that in a building consisting of external and internal panels, Mauerlat, rafter legs, purlins and a roof (Figure 1), the external and internal panels have one-sided sheathing and are interconnected by means of vertical beams, to which, when by means of through tie bolts are fastened to the open side of the panel ribs. In this case, the panels are interconnected by a Mauerlat made of boards paired in height, butted apart and laid in corner joints in a bandage.

![Figure 1. General plan of the building with marking of wooden panels: 1 - external panels; 2 - internal panels; 3 - vertical bars.](image)

In addition, the vertical beams located inside the building can be brought out into the attic space, while the upper edge of the vertical beams is a support for the rafter legs.

The cross-section of the developed building is shown in Figure 2, and the layout of the boards of the lower and upper rows of the Mauerlat is shown in Figure 3.

The building's consignment marks include outer 1 and inner 2 panels, vertical beams 3, Mauerlat 4, rafter legs 5, through tie bars 6, girders 7 and roof 8. Wooden panels 1 and 2 include one-sided cladding 9 and longitudinal ribs 10, which with the help of through tie ties 6 from the open side of panels 1 and 2 are attached to the vertical beams 3. Vertical beams 3 located inside the building can be brought out into the attic space, while the upper edge of the vertical beams 3 will be a support for the rafter legs five.

Panel cladding can be made in various design options: glued board, OSB, plywood, inlaid tongue-and-groove board, fiber cement board, etc.
Additional external insulation is carried out in the thickness of the frame of the lathing made of wood and bars or steel profiles. Its thickness is taken into account the climatic characteristics of the construction area. Hinged ventilation facade systems in the form of siding, planking, fiber cement slabs, etc. are offered as the main option for facade decoration.

Figure 2. Typical cross-section of the developed building: 4 - Mauerlat; 5 - rafter legs; 6 - end-to-end coupling ties; 7 - roof purlins; 8 - roof made of sheet materials; 9 - one-sided cladding; 10 - longitudinal ribs.

Figure 3. Layout diagram of the boards of the lower and upper rows of the Mauerlat: 11 - boards of the lower row of the Mauerlat; 12 - the same, top.

4. The procedure for assembling a building from wooden panels
The designed timber-panel building is assembled in the following order. On a pre-made foundation with anchor rods, at the junction of the outer 1 and inner 2 panels, pre-fabricated at the factory, vertical beams 3 are mounted so that the distance between their edges "in the light" is equal to the width of the panels. This distance is assigned the same over the entire area of the building, which ensures the use of panels 1 and 2 of the same overall dimensions. With the same overall dimensions, depending on the configuration and purpose of the premises of the building, the panels are made with a blank sheathing, with window and door blocks. Alternately, starting from the corners of the building to create rigid sections in space, outer 1 or inner 2 panels are inserted between the vertical beams 3, while the outer edges of the cladding 9 form smooth walls, since their surfaces facing the rooms are pre-processed and finished at the factory. At the locations of the through tie ties 6, holes are drilled in the longitudinal ribs 10 of the panels and in the vertical beams 3, after which through tie ties 6 are inserted into these holes (for example, bolts with nuts and washers). With the arrangement of the through tie-down ties 6 in one unit in mutually perpendicular directions, the holes are made with a shift in height. The holes in the longitudinal ribs 10 of the panels and in the vertical beams 3 can be pre-drilled according to the template at the factory, which will further reduce the labor intensity of installation. Tensile end-to-end tie-rods 6 are carried out up to control values. The diameter of the through tie-down ties 6 is determined by the appropriate design load calculation, which allows without any difficulties to ensure the perception of all possible dynamic loads, for example, seismic. Under the action of dynamic loads, the wood in the installation zone of the through tie ties 6 will work to crush across the fibers, which will provide a damper perception of forces due to the viscosity of the wood and, as a result, a significant increase in the overall spatial rigidity of the building.

Typical joints of panels and beams are shown in Figure 4.

Along the upper edges of wall panels 1, 2 and vertical beams 3, they are made of Mauerlat 4 boards paired in height, while the boards of the lower 11 and upper 12 rows are joined along the length in a run-up and are laid in the nodal junctions in the dressing (Figure 3).

![Figure 4](image_url)

**Figure 4.** Typical building units: a - conjugation of the outer and inner panels; b - interfacing of internal panels; c - fastening the outer panels to the vertical rack: 13 - insulation; 14 - soundproofing; 15 - finishing layer.
Such a constructive technique allows you to create a rigid belt of mutually perpendicular elements at the level of the attic floor, which significantly increases the overall spatial rigidity of the building, especially under the action of dynamic loads.

If necessary, the vertical beams 3 located inside the building can be brought out into the attic space, while the upper edge of the vertical beams 3 will be a support for the rafter legs 5. Thus, the vertical beams 3 within the height of the attic space will be cantilever elements with the lower end pinched at the joints of the panels, which eliminates the need for both vertical cross or brace ties along the lines of the posts, and horizontal ties along the girders 7 in the plane of the rafter legs 5. In addition, due to the lack of vertical ties, it becomes possible to provide free an attic space and can easily be converted into attic spaces.

On the upper edges of the vertical beams 3, located inside the building, with support on the Mauerlat 4, rafter legs 5 are mounted, along which the girders 7 and the roof 8 are subsequently arranged. An insulating layer 13 of the outer 1 panels and a soundproof layer 14 of the inner 2 panels are carried out, followed by finishing layers 15. External 1 and internal 2 panels can be supplied to the construction site with a pre-made heat-insulating layer 13 or soundproof layer 14 at the factory. In this case, in the places where the through tie-down ties 6 are installed, special hollow nests are provided, the sealing of which is performed after the installation and tension of the through tie-down ties 6. In unheated rooms, the insulation of the internal cavities of the panels is not performed.

External insulation and installation of the facade system is carried out after the completion of the assembly of the frame and load-bearing walls of the building (Figure 5).

![Figure 5. Coupling of the outer and inner panels](image)

**Figure 5.** Coupling of the outer and inner panels: 1 - GVL; 2 - OSB board; 3 - Vapor barrier; 4 - Insulation; 5 - Racks of the frame (150x50 and 100x50); 6 - Plywood sheathing; 7 - Horizontal bar 50x50; 8 - Windscreen; 9 - Vertical ventilation bar 25x50; 10 - facade cladding.

5. Conclusion

Thus, in comparison with the prototype, the proposed building made of wooden panels makes it possible to simplify the structural scheme of the building, increase its spatial rigidity and reduce the labor intensity of installation by 15 ... 20%.
This proposal does not exhaust all possible options for modernizing low-rise wooden construction technologies. The considered option gives impetus to the further improvement of design solutions for residential buildings, industrial buildings and public facilities, designed on the basis of wood and wood materials, ensuring the rational use of material in low-wooded areas of our country. There is no doubt that the described technology will contribute to the expansion of the range of wooden structures and increase their competitiveness.

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