Current approaches to the modeling and calculation wood frame building, taking into account the joint work of the load-bearing elements of the frame and cladding

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Abstract. The analysis of the current state of issues related to the construction of design models of building structures based on wood. The main software systems are presented, in which the calculation of wooden structures is realized. The need to develop software for timber frame buildings was identified, which would allow an engineer to select sections, check structural units of spatial models of various geometric configurations and take into account the joint work of supporting structures and cladding.

1. Introduction
The modern construction market offers the widest selection of building materials, and wood rightfully belongs to all this diversity.

Wood is a high quality building material. Despite its low density, wood is highly durable. This allows it to be used in the construction of load-bearing structures such as sports complexes, bridges and entertainment halls.

Timber frame houses belong to the classic options for the construction of buildings. If you look into history, then it was wooden frame structures that became the first artificial dwellings of our ancestors. Timber frame houses are built from natural materials and I am one of the most affordable solutions. Timber frame house structures consist of a wall panel, covering and roof, which are filled with thermal insulation material and sheathed on both sides. This timber frame house technology is ideal for the construction of low-rise residential buildings.

Installation of wooden frame structures is done quickly enough. Manufacturing, transportation and installation of construction timber parts require minimum energy consumption and, accordingly, minimum material costs.

Glued wooden structures meet the requirements of modern construction to the greatest extent. They allow to improve the quality of construction and widely use prefabricated parts of any shape and size. Glued structures are the most economical in terms of timber consumption [1, 2].

The use of this material has a wide range - in accordance with the general construction classification, the following functional purposes of construction products are distinguished, primarily structures and parts:

- load-bearing elements and structures subject to the main operational loads and ensuring the reliability and safety of the building (frame racks, floor beams, girders, joists);
enclosing elements and structures that protect the building from temperature changes, wind, precipitation, etc.;
- protective and decorative details used as elements of the interior and exterior of buildings (plattbands, cornices, etc.);
- auxiliary parts - structural elements ensuring their integrity (linings, liners, bosses, wind ties, etc.).

At the moment, standard timber frame construction is a complex structure consisting of load-bearing elements (upper and lower strapping, frame posts and floor beams), structures that provide spatial rigidity and stability (struts, stiffening ties and struts), and directly the internal and external skins (Figure 1).

![Figure 1. Traditional construction of a frame house.](image)

The basis of the walls is a load-bearing wooden frame, on one side sheathed with oriented strand board (OSB) or plywood. The inner space of the frame is filled with insulation. On the inside of the wall, a vapor barrier is installed, which prevents moisture from the room air from entering the heat-insulating layer. Then, from the inside, an inner lining is made, which has a decorative role. Such cladding can be both lining and blockhouse sheets of GVL. On the outside of the wall, an external facing layer is made.

This technology has its pros and cons. The indisputable advantage is the high installation speed and lightness of the structures. The disadvantages include durability, which directly depends on the quality of raw materials, the degree of protection of structures, as well as low sound insulation and fire safety, which is solved by using special impregnations and insulators.

2. Work of wooden structures under seismic load
Software systems make it possible to evaluate the performance of a structure from various types of loads, including dynamic ones. One of the main dynamic loads that can act on a timber structure is seismic loading. Wooden buildings and structures have a high degree of protection against seismic effects, which allows them to be used in high-rise and unique construction.

The work of Zh. V. Ivanova "Ensuring the reliability and safety of wooden buildings used for construction in seismic regions" [3] is devoted to the study of the issue of the work of wooden structures in seismicism. The article considers the analysis of the behavior of wooden buildings during earthquakes.
and the reasons for their destruction, and also presents the following methods for increasing the seismic resistance of wooden buildings by increasing the overall spatial rigidity of the building, which is achieved by the following measures:

- the layout of the building should provide for the introduction of a sufficient number of longitudinal and transverse walls, located as symmetrically as possible about the main axes and at limited, equal or close distances from each other;
- the fastening of walls and racks to the foundation must be sufficiently reliable;
- increasing the overall rigidity of walls and floors in their plane, strengthening the connection between walls and floors, as well as the interconnection of elements of walls and floors;
- the presence of a lower and lighter roof;
- increasing spatial rigidity and connection with walls.
- use of lightweight materials as a wall filler, setting braces and oblique sheathing in the plane of the walls, ensuring a strong and permanent connection with the foundation, connecting the frame elements to each other, etc.

Thus, timber structures need to be reinforced, which will lead to increased load-bearing capacity and rigidity. For this, various combinations of wood and metal are used. One of the latest research in this direction is a comparative analysis of standard glued beams, reinforced with reinforcement [4] in the lower zone, with new beams with rope reinforcement curved in the body of the beam. The authors of the article have established the basic principles of a new type of reinforcement. Schemes of different reinforcement paths are given. Mathematical models of the investigated structures are formed. The stress-strain state of several beams with different options for the trajectories of reinforcement of beams in the SCAD software package has been investigated. The results of the work are presented in the form of indicators of deflections of beams and stress isofields. A comparative analysis of the investigated structures with unreinforced beams and the traditional method of reinforcement is carried out. Conclusions are made about the increase in the strength characteristics of beams in which steel cable reinforcement is used. The optimal trajectory of the reinforcement groove movement has been selected. The competitive advantages and prospects of using a new type of reinforcement are determined [5]. This study has shown another important plus of wooden structures - their complex mutual work with metal.

3. Problems of numerical modeling of wooden structures

Wood is a special material that has its own advantages and disadvantages. The main task of design engineers is to develop numerical algorithms for modeling timber frames that take into account the complex and highly non-linear behavior of timber.

In the work of E.N. Serov and B.V. Labudin [1] considers the current state, tendencies and problems of the use of glued structures, reveals the priority directions in the field of Russian design of wooden structures (and glued in particular), as well as the prospects for the further development of these directions.

The problems of numerical modeling of wooden structures were also touched upon in the works of foreign and domestic scientists. For example, in the work of VN Volynskiy [6], the influence of temperature, humidity, speed and nature of loading on the strength characteristics of wood is considered. Also, research was carried out on the work of wood across the fibers, carried out by VN Glukhikh [7], which allows to determine with high accuracy the relationship between the physical and mechanical characteristics of wood and environmental parameters.

Based on the above, we can say that wood, as a building material, justifies its use, allowing engineers to create reliable and durable spatial structures that fit into a wide variety of architectural forms. But the implementation of various architectural and innovative solutions requires, in most cases, an experimental study of a new product. The tests can be carried out on real objects or on special test stands designed for this purpose. The tests are carried out both on structural elements of objects and on connecting elements, the role of which in the structure is becoming more and more important in the case of timber frame structures. Computer software for calculations using the finite element method (FEM) in
these situations turns out to be very effective, because as a result the object can be modeled and tested relatively simply and cheaply compared to experimental tests [8-18].

4. Realization of the calculation of wooden structures in software packages
Similar to the design of steel and reinforced concrete structures, the calculation of wooden structures requires certain professional skills necessary for making decisions, since in the design, manufacture and maintenance of wooden structures and their elements, it is necessary to solve the problem of adequate calculation of strength, stiffness and bearing capacity, taking into account the nature of the work, close to real [5].

Currently, the software market offers many computational systems that allow designing building structures made of reinforced concrete, metal and wood [19].

Below is a list of some software packages (PC) that allow for the calculation and modeling of timber structures:

1. Dlubal Software - allows you to simulate and calculate plane and spatial systems using the finite element method. The complex contains many utilities that allow you to calculate individual structural elements, such as continuous beams, columns and three-hinged frames.

2. SK-Constructor - allows the user to quickly and accurately create a model of the entire building: enclosing structures, trusses and all floor and roof systems. The program can automatically calculate the layout and profile of the required structures for all building systems. Creates profiles for all types of trusses in these systems, performs accurate design of walls, trusses and all parts in accordance with the input information, and also collects information about loads during the entire design process.

For the calculation of individual structural elements, additional utilities are provided that perform not only engineering analysis, but also the selection of the most optimal solution for the choice of materials.

3. Autodesk Robot Structural Analysis - allows you to calculate structures consisting of different types of elements, such as bars, slabs, shells and their combinations, as well as to perform the selection of sections of elements of wooden structures.

4. APM Civil Engineering - allows you to perform the calculation of timber structures and joints of elements in accordance with the current regulatory documents for I and II group of limit states.

5. Decor (PC SCAD Office utility) - designed to perform calculations and check the elements of wooden structures for compliance with the requirements [20]. In addition, the program provides the ability to obtain reference data most often used in the design of wooden structures.

5. An example of calculating a timber frame building in the PC SCAD Office
Consider a timber frame building with dimensions in the plan of 11.5x20.5m (Figure 2). Supporting structures in the form of a riser and crossbars of the building frame are made of glued timber. Along the inclined girders, purlins of coniferous sawn timber are laid. Horizontal and vertical braces are made of pipes. According to the terms of reference, a pitched roof is assumed, as a result of which it was decided to make racks of different sizes.
The distance between the bearing racks of the frame is chosen from the conditions of rigidity and the size of the cladding material used in the construction of the house. The connection of the elements is by means of nails, by staples, ideally by spikes.

The stiffness characteristics of the bars were specified as shown in Figure 3. When modeling a frame building using bar elements, only the elastic modulus along the wood grain is taken into account. It is not possible to take into account the elastic modulus and Poisson's ratio across the fibers, as well as the shear modulus.
Of the shortcomings of the SCAD Office PC, it should be emphasized that there are no tools for specifying the joint work of the inner and outer skin of the building with the load-bearing elements of the frame, that is, modeling the nail connection. Of course, in the work of a real structure, the cladding is included in the work of the building frame and should influence the calculation. You should also pay attention to the absence of a built-in module for the selection of a cross-section of a statically indeterminate system of a frame building as a whole, and not in parts, as it is implemented in the Decor utility (SCAD Office PC).

The listed software systems in paragraph 4 also do not have this feature. As a result, it becomes necessary to develop such a PC that would be able to adequately simulate the operation of a wooden frame and the flexibility of ties in the skins.

6. Conclusion

Construction of computational models of buildings and structures with a wooden frame, as a rule, is limited to the use of bar elements and plates (shells) for the analysis of the stress-strain state. In addition, the correct analysis of the design requires the calculation of the strength of all joints in the structure. The main and main problem of existing PCs is the lack of the ability to take into account the joint work of elements of wooden structures, in particular, the mutual work of the supporting elements of the frame and its cladding. In addition, to perform these calculations, software implementation is required, which would allow the engineer to select sections, check the structural units of spatial models of various geometric configurations. Obviously, in order to efficiently perform such calculations, the design process must be automated.

In the course of the above analysis, the need was identified for algorithmic and software that can adequately simulate the operation of a frame building together with cladding.

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