BASIC CONTEXT OF DESIGN METHODOLOGY FOR TESTING WOOD-BASED ELEMENTS

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Abstract: Timber-based constructions are increasingly becoming increasingly popular within Slovakia. This provides the ability for many manufacturing and manufacturing companies to offer different wood-based construction systems. In the framework of the offer in Slovakia, most frequently realized are panel, column and log-based construction systems based on wood. While the manufacturers and implementation companies themselves declare the thermal properties of their products only on the basis of computational methods, there is a need to verify the thermal-technical properties of the offered structures even in laboratory conditions. Therefore, the aim of this manuscript is to present a selected context of the methodology for verifying the thermal-technical properties of selected structural variants for assessment under laboratory conditions.

Keywords: Methodology, Thermal-technical properties, Wood, Wood construction

1 Introduction

Wood as one of the oldest building materials is by no means obsolete for use in construction. In recent decades, wood as a building material has become increasingly popular for architects, designers and potential investors. The great potential of this building material is due to developments in both production and the construction of timber buildings [1]. Separately or in combination with concrete, glass or steel, wood can be adapted to all types of construction projects: new buildings or renovations, residential or tertiary use, low-rise or high-rise buildings. Especially through prefabricated and solid wood products, which also represent cross-glued laminated timber products, modern timber construction is an interesting and sustainable construction technology [2]. Statistics on the proportion of timber buildings show that the construction of wooden buildings is becoming increasingly important. Possible ways of producing and constructing wooden buildings are diverse. At the beginning of the planning process, the main issue for the investor is the choice of building technology and materials for its construction. With this investment decision, it is not enough to take into account only economic criteria such as construction, operation and maintenance costs or financing costs [3]. They are also building-physical, technical and environmental criteria that affect the overall success of the building. In accordance with the trend of efficient management of energy resources, the energy performance of buildings is increasingly discussed [4,5]. It is therefore important to address this issue. Certain thermal-technical parameters are declared within the framework of the wood-based construction systems offered, but they are most often derived from theoretical calculations. That is why we chose to design and analyze selected contexts for the purpose of this article, which should be taken into account when checking the structural parts of wooden buildings in laboratory conditions in terms of thermal and technical properties.

2 Energy efficiency and heat protection of buildings

Requirements for energy efficiency and thermal protection of buildings are constantly changing, and the legislative requirements of individual countries at both regional and global levels are being tightened. This is also evidenced by the European Union (EU) Directive on energy efficiency in buildings, which defines that in the EU Member States all new buildings will have to meet almost zero energy consumption by the end of 2020. Nearly zero consumption should mainly be mediated by renewable energy. energy sources at the site or its surroundings [6]. Thermal protection also has a significant impact in reducing energy consumption in residential buildings. This is often associated with the heat transfer coefficient, which expresses the degree of thermal insulation properties of structures. It indicates what amount of heat is lost over 1 m2 of building surface area at the unit temperature difference of the surrounding environment, ie. between the external and internal environment. Its mark is "U" and unit W / (m^2.K). For passive houses, this value should be less than or equal to 0.10 W / (m^2.K) for roofs and walls.

In terms of thermal protection, wood is a very good thermal insulator. For example, the coefficient of thermal conductivity of spruce wood is 0.18 W/m^2.K. Another advantage of wood-based structures is that their walls achieve the desired thermal properties in a much smaller thickness than silicate-based masonry structures. For example, to achieve a thermal resistance of R = 3 m^2.K/W, a wall thickness of about 170 mm is sufficient when using a conventional sandwich shell construction, and a wall thickness of at least 400 mm in combination with a thermal insulation plaster is required for a lightweight ceramic wall. In the legislation of the Slovak Republic, the classification of houses according to the Energy Standard [7] is defined as follows:

Low-energy house:
- the annual heat demand for heating is less than 70 kWh/m2 of floor space.

Energy passive house:
- the annual heat demand for heating is less than 15 kWh/m2 of floor space
- uses passive solar gains and heat recovery by forced ventilation.

Zero House:
- a house with zero energy consumption,
- uses only renewable energy sources.

3 Construction systems of wood constructions

Current wood-based construction methods are very diverse and can be individually tailored and combined. In principle, the current wooden buildings for housing can be divided according to the nature and nature of the vertical load-bearing structures into massive, skeletal and elemental structures [8]. The individual groups differ considerably from each other by the used construction method, appearance and possibilities of production of their structural elements. The foundations of the massive buildings are log buildings, which are still being built today, but nowadays they have also come up with modern massive buildings. Skeletal and elemental building groups have evolved from timber-framed buildings and represent wickerwork. The classic wooden construction methods can be supplemented by so-called. hybrid methods developed in recent years that combine wood as a building material with other building materials.

3.1 Massive log buildings

The term "massive structures" is used to refer to constructions whose load-bearing structure is made of solid wood, either solid or cross-sectioned, or bonded to one another according to the product system. Massive structures are characterized by the separation of supporting elements and insulating parts. The carrier is not reduced to the individual supports, as is the case with light wood timber systems. Nowadays, because of the increased demands on thermal protection, solid wood-bearing load-bearing walls are supplemented with thermal insulation layers. The traditional representative is log buildings [8].
Log buildings belong to the original methods of realization of houses, which are basically all massive wood buildings. The construction of log buildings is based on massive logs (logs), beams, or horizontal stacked (stacked) beams connected by carpentry joints in corners. However, there are also logs with vertical beams, or a combination of vertical and horizontal beams [8,9].

3.2 Modern massive buildings

Modern solid timber wooden buildings are becoming a current trend that tries to get as close to nature as possible while maintaining a functional and modern design. According to Kobl [11], they have been created by the introduction of new construction systems, also thanks to the industrial manufacturing capabilities of large-scale elements. The structural systems are predominantly composed of solid wood construction elements, or rarely of wood-based panels (e.g. OSB and particle boards), solid or composite cross-sections. The main part of these elements is formed by closed, in particular massive plate cross-sections, or so-called. box components assembled in planar structural members. These elements always form the main bearing of the system - the so-called. supporting core. A characteristic feature of these systems is the carrier system exclusively operating the flat, which uses a reinforcement plate to transfer the load. A common feature is the construction of an additional insulation system on the outside of the structure [11].

3.3 Skeletal structures

The supporting structure of skeletal structures is according to Vaverka et al. [8] assembled from rod members which transfer the applied load to the foundation without the interaction of walls or stiffening casing. They have more than 3000 years of tradition, and from the constructional point of view, they can be used for the construction of frame, column and modern skeleton structures.

3.3.1 Half-timbered buildings

The historical structures of the timbered buildings can be included among the first buildings that have evolved from the historical skeletal system of buildings as the first skeleton system buildings. The architecture of half-timbered buildings has been extended in all regions of Europe, where it was necessary to limit the consumption of wood for construction. Alternative use of rather short deciduous wood elements was also preferred. A large number of timbered buildings, which are still preserved in many historic towns, but also in rural areas are mainly in Central and Eastern Europe, but also in the Netherlands, northern Germany, Denmark and Anglo-Saxon countries. Four- and more-storey buildings of this type have been preserved from the past, and multi-storey, but also commercial, half-timbered buildings have been shown to have a long tradition in Central Europe. In the territory of present-day Slovakia such constructions were made in mountain and spa areas [8,11].

3.3.2 Modern skeletal structures - heavy skeletons

The influence of American construction methods has been reflected in the construction of the half-timbered buildings by omitting the horizontal and oblique reinforcement elements (struts and rails) with the modern skeletal structures. To preserve the massive elements of the construction, these structures are also called heavy wooden skeletons - TDS. In addition to struts and cross members, horizontal elements (threshold and skid) were excluded from the structure, eliminating the unfavorable planting of the structure caused by volume changes in the transverse direction of the wood. In the case of non-settling of the lower threshold, it is also necessary to provide structural protection of the columns anchored directly on the base in order to avoid degradation of wood due to possible permeable moisture [10,11].

3.3.3 Pillar systems - light wooden skeletons - frame structures

The concept of timber-frame construction is based on the use of posts in the supporting structure. As mentioned in the historical review of columnar structures, they have evolved from timber-framed timber houses in North America and have gradually expanded to Europe, where they have been modified over time to form a variety of systems under the frame structure name. The term frame structures does not relate to the static action of the house, rather it is based on the construction of the individual frame walls of the rectangular shape formed by the lower and upper frame and the vertical posts. Also due to the use of small cross sections of the wicker elements, the name light wood skeleton - LDS [8] has also been used for these buildings in some countries.

4 Context of the methodology of testing construction systems on the wood basis for thermal technical characteristics

As already mentioned above, there are many variations in the text of wood-based construction systems, and the combination of them in terms of design solutions implements the aces in practice. That is why it is important to check their design and other properties. On the basis of already realized research, the requirements to create a methodology of investigation and verification of thermal-technical parameters of structural parts of selected construction systems of wooden constructions under laboratory conditions emerged. Such verification of thermo-technical properties with an important basis for analyzes and possibilities of innovation of individual construction systems. In addition, such screening and real measurement can also be used to confront the computational methods most commonly used in practice to declare the properties of individual wood-based structural systems.

In the following part of the text, selected parts of the methodology are presented, which can be used as a basis for the methodology for use in laboratory conditions. The methodology is devoted to the measurement of thermal-technical parameters of wood-based structural systems in the so-called climate chamber that allows to simulate indoor and outdoor temperature and humidity conditions.

Design of boundary conditions of measurement and requirements for the examined structural parts of the structure

Data on the thermal performance of structural components are needed for various purposes, including, for example, expert judgment on compliance with regulations and specifications, design guidelines, research on material properties, construction, and simulation model validation. In general, there are many different designs of test methods and devices. The variety of structures to be tested can be so great and the requirements of the test conditions so diverse that it could be a mistake to limit the test method more than necessary and limit the measurement to a single possible arrangement [12]. Therefore, such measurement methods cannot be clearly predefined.

Before designing boundary conditions, it is essential to define the purpose for which the measurement is being performed. Another essential aspect is the definition of boundary conditions can be designed either as so-called stationary or so-called non-stationary. As mentioned above for the choice of stationary conditions, it is necessary to be aware of the purpose of the measurement and the data outputs that need to be achieved during the measurement. Therefore, definite marginal values cannot be clearly stated. As far as non-stationary conditions are concerned, this philosophy is similar but it is possible to use long-term observations of environmental climatic conditions when choosing non-stationary conditions. It is ideally based on ten-year observations of the temperature and humidity characteristics of the environment for a given climate area [13].
When measuring the thermo-technical properties of structures in the so-called it is essential to define the size and location of the sample to be tested. Typically, the verified sample is placed between a warm and a cold chamber in which ambient temperatures are known. These temperature and humidity environments reproduce the agreed or defined boundary conditions on a sample between two gaseous media, typically atmospheric air.

By measuring the correct dimension of the measured area, it is possible to avoid measurement errors and avoid misinterpretations of measured values.
The measured area is defined as follows:

a) for a warm chamber protected device from center to center of the measuring chamber, provided that the sample thickness is greater than or equal to the chamber nose width, if the sample thickness is less than the chamber nose width, the area shall be determined by the inner chamber of the measuring chamber,
b) for a calibrated hot chamber test apparatus, the inner chamber of the measuring chamber.

The size of the measured area determines the maximum sample thickness. The aspect ratio of the measured area to the specimen thickness and the width ratio of the area to be protected and the sample thickness are determined by similar principles to that of a hot chamber enclosure. The sample size may also limit the possibility of verifying the representative design time on which the tests are to be performed. This may cause difficulties and errors in the interpretation of the results. Measurement errors in the heat chamber test method are partly proportional to the circumference of the measured area. The relative impact of this error decreases as the area to be measured increases. In a warm chamber protected apparatus, the minimum dimension of the measured area is given by a larger value of three times the sample thickness or 1 m x 1 m. The minimum sample size for a calibrated hot chamber test device is 1.5 m x 1.5 m. Errors due to the circumference of the measuring chamber of the test chamber with the protected chamber are caused by lateral loss of heat flow along the sample surface due to imbalance between the measured and condensed area or due to the occurrence of irregularity. Errors around the circumference of the test chamber with a calibrated hot chamber are due to losses at the edges of the sample, which include a failure to uniformly heat flux at the edges of the sample [12].

The above-mentioned basic contexts are combined within a wider range of contexts, depending on the purpose of the measurement and the method of obtaining data from the measurements through various temperature, humidity and other measurement sensors. The data recording interval is determined by the measurement accuracy. The set of measuring devices is concentrated in a recording device called the so-called data bus for long-term continuous data recording.

5 Conclusion

In the presented article, the basic connections between energy efficiency of buildings as such and their energy savings are presented. As far as timber-based constructions in Slovakia are concerned, there are several construction systems that are currently being applied in the construction market. This article also defines the basic features of the most frequently implemented wood-based design variants. However, the main idea of this article was to evoke contexts that need to be taken into account when developing the methodology for testing the thermal-technical properties of real structural parts of wood-based structures in laboratory conditions. From the analysis of available standard documents, it is necessary to define, before the actual measurement, especially the boundary conditions depending on the required information that will be examined. Also an important element is the design of the sample size to be examined and the positioning of the measuring sensors according to the requirements for the resulting parameters of the structural components under consideration.

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