Constructions of buildings based on solid wooden elements

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Abstract. Wood has excellent physical, technological, aesthetic and utility properties. Thanks to them, wooden buildings are very popular and allow to build economically advantageous and modern wooden buildings with long life and durability and thus a positive impact on the ecological and so-called clean future. Knowledge of its basic properties is the first prerequisite for its proper use in various industries and in human life. In the world, but also in our country, the trend of wooden buildings is becoming more and more widespread, not only in the understanding of cottages, wooden houses and family houses using wooden elements. Massive prefabricated log buildings are a typical representative of wood-based buildings. Massive log buildings have undergone some development and currently in construction practice, this system for the construction of wooden buildings in various more modern modifications. The aim of this paper is to present selected aspects of traditional but also blue log constructions and their application at present.

1. Introduction

Depending on the availability of wood, wooden load-bearing structures are widespread in some parts of the world, especially for single and two-storey housing construction [1,2]. The low bulk density of wood enables the production of elements and larger parts of structures in factories, their easy handling, relatively inexpensive transport to the construction site and quick assembly on the construction site. Easy disassembly and recycling of the material also allows for faster replacement of the structure physically or morally.

Wooden construction is a construction or construction work where the main supporting structure consists of elements made of wood. The main building material for timber constructions [3] as well as possible superstructures of already existing buildings or hall buildings is the mentioned wood. The widespread use of woodworks is increasingly being used in almost all segments, for example in individual, residential, administrative, public, industrial, sports or commercial construction and others [4]. It is a natural building material that does not harm health, and thanks to its excellent properties and advantages it has gained an excellent reputation in the area of construction, which has been verified by many generations. By its properties and price, wood has not been overtaken to date by any material. Buildings made of wood and materials on its basis are now able to compete with steel and concrete structures and overcome them in many ways. The wood is considered environmentally friendly, for
several reasons. Wood is a health-conscious material that regulates moisture and provides a pleasant climate at all seasons. Last but not least, the processing of wood and wood-based products is far more environmentally friendly than the production of cement or steel. In construction, unlike concrete structures, the wet process of construction is degraded, which accelerates the construction time [5]. Another advantage is the instant bearing capacity, which eliminates the time of acquisition of the strength of the structure.

According to AWPSR [6], the following types of wooden buildings and structures are currently the most implemented in the Czech Republic and Slovakia: almost all types of buildings (especially administrative and multifunctional buildings, residential buildings and the most realized family houses), truss constructions, roof constructions for middle and large spans, wooden bridges and footbridges, smaller buildings (garden houses, sheds, gazebos). Each of these constructions places specific demands on project preparation, production capacities, logistical support (subcontracting of lumber, warehousing, transport, etc.) and assembly security.

2. Historical context of wood-based buildings
According to Kolb [7] and Kuklík [8], modern wooden buildings are based on the original wooden buildings and structures that have undergone a certain development to meet the current requirements and needs of man. Until the first half of the 19th century, the wooden structures of buildings were realized in two basic ways, namely log and half-timbered structures, which were characterized by demanding carpentry joints. The beginnings of the construction of log houses are connected with Russia, from where this system got through Finland to Sweden and Norway. The occurrence of log structures in Europe in the past was mainly related to the extensive forest wealth. In areas where wood was not available in such large quantities, half-timbered buildings were widespread. They have gained sympathy in Eastern and Central Europe, England, Germany, Denmark and the Netherlands. In different geographical areas, the buildings were characterized by different regional features. The houses from the end of the 19th century and the beginning of the 20th century were characterized by a pillar construction (Balloon-Frame) characterized by lighter materials made of wood, mostly planks and boards. Another method adopted around 1930 was the construction of a platform (Platform-Frame) using even shorter lengths of lumber. This construction system is currently used by most American households. In the mid-1970s, the reassessment of man’s place in nature and in society revealed the need to return to a more traditional way of life and more environmentally friendly. Thanks to new innovative possibilities for the implementation and maintenance of buildings, wooden buildings have also become an attractive alternative for housing. A new perspective for the realization of wood-based constructions has become a frame or column structure specific to simple construction, economy and architectural freedom. The load-bearing frame of the frame structures consists of slender standardized cross-sections made of grown or glued wood, which are reinforced with a cladding of large-area material on both sides. Modern construction systems today use wood material more optimally, so specific construction systems based on column systems use only a fraction of wood compared to their predecessors. Thus, the use of wood is usually only for the load-bearing part of the building and the other elements are combined from different material bases for the best possible properties of the structure.

3. Log construction system
According to Štefek and Reinprecht [9], log buildings are among the most attractive and impressive constructions for housing. Log buildings are the successors of the traditional folk architecture of the Slovak countryside, especially in the mountainous parts of Slovakia, where there was plenty of wood. The perimeter walls of these buildings are made of machined tree trunks - log cabins (prisms, pillows, balls). The wall joints are connected by carpentry joints, which ensures the overall rigidity of the structure.
The development of log structures in the world is marked by migration. We can consider Scandinavia as the cradle of log buildings. Medieval experience in shipbuilding has also been translated into the construction of solid and tight log buildings made of wood. The Vikings traded with distant lands and brought home not only traded items, but also various techniques and knowledge, which they sold to people in remote parts of Scandinavia. Norwegian craftsmen developed a construction style that connected the horizontally placed beams with interlocking joints. This construction system, called the "laft", is one of the most sophisticated technologies for the production of log houses [10]. Its production was mostly made of fir, the tip of which was cut off two years before it was cut off to stretch the resin into the wood. The position of log house production technology is still preserved in Norway: the village landscape is dotted with old log structures, many of which are several years old. In North America, we encounter the first log buildings since the first half of the 17th century. This craft technology of production of log houses was brought with them by the new incoming Scandinavians, who took part in the settlement of the east coast of today's United States. Later, these technologies began to overlap with the German influences that German immigrants brought with them to the "new world". Today, we probably owe the Germans, together with the new arriving emigrants from Scotland and Ireland, to expand the production of log cabins on this continent. Wherever there was enough wood, the construction of log houses was economically advantageous. The reason why only a few log buildings have been preserved to this day is their original temporary character. The original log cabins were very primitive and had only clay floors and also the walls were laid directly on the ground, which of course reflected on their short life. This old craft was reborn in North America in the 1970s, and since then the industry has undergone an incredible boom. With the advent of new materials and structures, the technical parameters of log cabins and their utility value have also increased enormously. Today, log cabins are definitely not one of the cheapest buildings available on the market, and their complexity and reworking are unbelievable nowadays. Despite all the conveniences of modern technology, the principle of production of craft log buildings has practically not changed. It must always be based on knowledge of materials and construction and an estimate of both its strengths and weaknesses [11].

According to Štefek and Reinprecht [12], log cabins also fulfill a thermal insulation function. The thickness of the log house ranged from 15 to 30 cm. The joints between the log cabins were filled with screed (a mixture of clay with chaff or shingles - moss with a wooden cover). Novod's log constructions are among the most ecological, because they also process logs of trees, and so during the "production" - the growth of this "building material" no products are produced, on the contrary, pollutants are broken down.

In terms of production technology, we can classify log construction systems as: 1) real log constructions: traditional log constructions made of solid wood, modern log structures made of solid wood or glued wood; 2) false log constructions.

The characteristic features of log construction systems according to Kolb [7] are: high craftsmanship, special selection of wood, high consumption of wood, fixed layout of the floor plan, volume and shape changes of the building, settlement of the building. Log constructions create a unique atmosphere with their architectural expression and provide full use of wood as a natural material (material purity). Compared to light skeletal constructions, they provide a higher heat-storage capacity. This property has a positive effect on the overall energy balance of the log building [13]. From the point of view of environmental and energy load according to Čuláková [14], it is beneficial to use so-called false logs, which use only locally available renewable materials, where the wood is without chemical protection, with minimal possible treatment dried naturally. By using alternative (natural) thermal insulation such as sheep's wool or hemp, the bound energy, i.e. the primary energy needed to obtain the raw materials and process the product, can be minimized. Log constructions according to Houdek and Koudelka [15] react differently to fluctuations in the relative humidity of the
interior. Wood has a considerable ability to absorb and release moisture depending on the relative humidity of the air in which they are located, and therefore the indoor climate in the log cabin constantly reacts naturally and mechanical air conditioning is usually not necessary.

The disadvantages of log constructions include the fact that the realization of log constructions requires high craftsmanship, they have a higher workload during assembly, during their use there are volume and shape changes of the building. During the construction of log houses, there is a high consumption of wood in comparison with other construction systems of wooden buildings. Mostly wood is imported from areas with higher altitudes, for reasons of better quality raw material. Increasing the transport distance ultimately reduces the environmental efficiency of the building. There are some restrictions on these types of buildings, such as the number of floors and the location of the building (according to architectural and urban planning rules, it is not possible to build these buildings anywhere). At present, from an environmental point of view, some applied sandwich constructions, combinations of wood with synthetic-based thermal insulation materials, are not a very suitable alternative. A more suitable alternative is the use of sheep wool, which after suitable technological treatment does not even burn and has self-extinguishing properties. The combination and use of various modern glued elements undesirably reduces the quality of the indoor microclimate in terms of the release of volatile organic compounds, and glued wood (structural elements) show a relatively high value of bound energy of the resulting structure. Also, the industrialization of individual components and parts of structures increases energy consumption and at the same time releases more unwanted emissions into the ambient air.

3.1. Traditional log constructions made of solid wood
Traditional log constructions are made of log perimeter and partition walls. The log walls are bound from beams, which are either closely placed on top of each other or gaps are left between them. The beams are usually completely or partially edged, or they are just simple balls. Edged log beams are either unmachined or planed on one or both sides. The thickness of the beam depends on the wall load and, in residential buildings, also on the climate, the dimensions of the beam are usually 18/20 - 20/22 cm. It is proven that even 15 cm thick log walls do not freeze, but complete tightness of the load joints is assumed. Sharply angled beams should fit snugly in the load-bearing joints; For this, the joints are filled with a mixture of greasy clay and lime, which is caught on the wood wool and holds well. The joints are white or painted, the buildings arranged in this way are very neat. If the log wall is made of ball joints, the joints are filled with screed, i. clay into which the chaff or sheath is mixed. In order to hold the screed in the joints, wedges are driven into the loading joints. Inside the rooms, the log walls are not plastered, because the plaster on the wood does not hold well, if plastering is required, it is necessary to stretch the grooved cardboard, or nail insulating cork or heraclite boards, and thus plaster [16-20].

3.2. Modern log constructions made of solid wood or glued wood
Modern log structures are structurally influenced by higher thermal-technical requirements of man for housing, higher standard criteria for thermal-technical quality of structures, wide technological possibilities of wood industrial production, research of structures, development of building materials (thermal insulation, cladding), etc. [21,22]. The construction of modern log houses consists of building elements made of solid wood or glued profile wood - glued blocks.

3.2.1. Modern log structures made of solid wood. The basic structural element of modern log structures made of solid wood (Figure 1) is machine-profiled wood [23,24]. The solid log element can be made in one piece in length (round profiles, etc.) or connected in length with various types of joints. The log elements can have the maximum humidity of a freshly cut tree, or they can be partially dried (natural, artificial), or they can be completely dried for the climatic area in which they will be
used for the construction of the building. Sealing of horizontal joints of solid timber structures is solved by means of different types of solid element profile, or they are supplemented by sealing. Thermally and technically, the log cabins are structurally made as single-skinned (thickness 15 - 40 cm), with thermal insulation as sandwich or double constructions.

3.2.2. Modern log constructions made of glued wood.
Log constructions made of glued wood are the most technically modern constructions [25,26]. Log glued elements are made by gluing from several parts. Bonding is practiced on the thickness, height and length of the element. Log glued elements have different dimensions and the shape of the transverse profile. The transverse profile can be square, rectangular or round in shape (glued balls that match the natural roundness of the trunks on the outside). The production of glued log elements is more demanding and they are more expensive than solid log elements. However, they have their advantages, such as higher quality of the wooden element (due to the possibility to choose better parts of the wood mass), dimensional stability of the element, aesthetics of the log without cracks on the exterior and interior, improvement of thermal properties of the log wall itself (the whole thickness of the element without cracks is involved in thermal resistance) and Come. The sealing of horizontal joints is performed by the principles as in the case of log structures made of solid wood [27,28]. Similar to modern solid wood logs, they are structurally made as single-skinned (however, thicknesses are up to 21 cm), or with insulation as sandwiches.

Sandwich log constructions according to Varg [29] imitate real log cabins in different ways and to different degrees. The main reason why they are implemented is the aesthetic aspect - the positive effect of wood and log construction on humans. The sandwich log construction consists of an exterior so-called of a false log construction, imitating a real log and from a statically supporting structure which can be a column, panel, concrete, resp. brick. Thermal insulation is inserted between the outer and inner log construction of the wall.

4. Conclusions
This paper deals with the issue of log houses. This article outlines the basic aspects of this specific area of construction. Within the specification, segregated classifications of these specific structures in terms of technology and their specifics were presented. This paper also presents the design and technological advantages of using wood in massive log structures as ecological and sustainable solutions with the so-called distinctive architectural character.
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