Specifics of multi-storey wood-based buildings

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Abstract. Wood is one of the basic natural renewable materials. Knowledge of its basic properties is the first prerequisite for its proper use in various industries and in human life. Wood is the most versatile and most used material (industry, construction, agriculture, everyday life). Due to its natural character, natural drawing, favorable physical properties, it is an increasingly desirable element of the environment. 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. We are talking about office buildings, non-residential premises, but also wooden high-rise buildings. Multi-storey wooden structures are a promising area of application of wood, which requires much less energy for their production compared to other "classic" materials. The aim of this paper is to present selected aspects of multi-storey wood-based buildings and their application at present.

1. Introduction

Wooden construction according to [1] is a construction or construction work where the main supporting structure consists of elements made of wood. The main building material for timber constructions [2] 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 [3]. 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 [4,5]. Another advantage is the instant bearing capacity, which eliminates the time of acquisition of the strength of the structure.
Supporting structures can be defined as spatial parts of objects, the mass of which is purposefully shaped and distributed in space so as to achieve effective cooperation in the transmission of external forces acting on the object [6, 7]. Depending on the nature of the distribution of the mass of the supporting structure, it is then possible to distinguish between different structural systems [8]. The choice of a specific construction system for a certain object depends on the functional requirements, on the production possibilities and on the overall economic evaluation [9]. There are two basic groups of building structures, and the groups of structural systems belonging to them: multi-storey buildings and hall buildings [10].

2. Multi-storey wooden buildings in the context of height limits
In the case of multi-storey buildings (but also in the case of a number of single-storey buildings) [10] the determining elements of the structural system are vertical load-bearing structures (walls, columns, pillars); Different types of bar glued wooden elements and large-area glued elements (CLT, X-LAM, etc.) are most often used for the construction of wood-based high-rise buildings [11, 12]. A special group of construction systems are systems made of prefabricated spatial units (modules), which are essentially technological variants of wall or column systems.

According to Véghová [13], the trend of wooden buildings is growing in the world, not only in the understanding of cottages, wooden houses and family houses using wooden elements. We are talking about office buildings, non-residential premises, but also wooden high-rise buildings.

According to Sandanus [14], multi-storey wooden structures are a promising area of use of wood, which requires much less energy for their production compared to other "classic" materials. The vast majority of low-energy buildings or buildings with a passive energy balance have a wooden supporting structure. In developed Western European countries, wood is commonly used as a load-bearing material for multi-storey buildings [15],[16]. The limitation of the height of the building is usually related only to the requirements for fire resistance of the building [17]. From the point of view of the mechanical properties of wood with the correct dimension of the elements, it is not a problem to limit the height limits [18]. Regulations concerning the fire resistance of wooden structures in Slovakia are currently probably the strictest of all near (and far) countries.

According to Véghová [13], wood was used less as a building material due to the restrictions stemming from Act 22/1955 on wood inspection, but also due to the fact that before 1990, silicate and steel bases were significantly used. An obstacle was also the slow and inefficient development of fire safety regulations at the time. And so it was much easier to tighten the rules for wooden constructions. In the current technological conditions, we are constantly convinced of the fact that modern wooden buildings are constantly compared with log cabins, or even unimobunks, is not possible. In the context of these approaches, the approaches of EU countries to the issues of fire safety of wooden buildings are constantly being reconsidered.

Until recently, according to Véghová [13], two above-ground floors in buildings intended for housing and accommodation, four floors in non-production buildings, three floors in production buildings were accepted within the Slovak Republic. However, the mentioned limits also brought with them a significant restriction of use from the point of view of the use of the building, related to the highest permissible fire risk. At the same time, high requirements were placed on the fire resistance of structures for this type of construction solution. All significant changes related to multi-storey wooden buildings came into force in 2017 within the revision of STN 92 0201-1: 2017. The most significant change is the possibility to build 5-storey wooden buildings, provided that certain conditions are met. The design and requirements for the construction of timber structures are based on Eurocode 5. It has also begun to consider whether the structural element of a timber structure is protected or not. The
revision did not aim to increase the floor, or the height of the wooden buildings allowed until then, but to grade it on the basis of the level of protection of the wooden structure. This means mainly closing the wooden parts of the structures with non-combustible protective linings and, if they are on the structures, filling the cavities with non-combustible materials. In practice, it is necessary to distinguish between recognized and protected wood in wooden constructions.

- In the case of acknowledged wood, the required fire safety is achieved by applying strict height restrictions. In the case of protected wood, it is essential that the wood does not ignite or slowly burn inside the structure under the protective cladding during the required fire resistance period. In addition, the problem of the spread of fire inside wooden structures must be avoided if the structural cavities are unfilled or filled with combustible materials. In the case of multi-storey wooden buildings, today all their structures must be filled with cavities with non-combustible materials that can withstand temperatures of 1,000 °C and cannot settle in or fall out of the cavities. If the cavities in the structures of wooden buildings are not treated in this way, their maximum permitted floor is logically reduced.

- In the case of admitted wood, when the filling of cavities does not meet the mentioned requirements, it is a construction with a flammable structural unit and has a limited maximum permitted height. Non-production buildings up to nine meters of the floor level of the last above-ground floor, buildings for housing and accommodation up to three floors and production buildings up to four floors with protected wood without the required filling of cavities or up to three floors with acknowledged wood. The fire resistance of load-bearing and fire dividing structures in these cases is 60 to 90 minutes. In addition to fire-resistant constructions, it is important to have a suitable solution for escape routes from buildings. Multi-storey buildings mean a longer escape route in the event of a fire. Protected and partially protected roads must be created that provide escaped persons with the required protection for a sufficiently long time. The specific type already depends on the type of use of the building, the number of people and the distance to safety. This is given by the number of floors of the wooden building and their area.

3. Examples of urban agriculture
Multi-storey wooden buildings, which have a long tradition in Scandinavia and North America, still face prejudice in our country. According to ASB [15], investors are mostly concerned about fire protection of buildings. However, the constructions of wooden buildings can also show considerably high fire resistance (up to REI 120). While a year ago we reached the possibility of 5 floors, the first wooden high-rise buildings are already being built abroad. Among the most famous are the projects of the proposed forty-storey (133 m) building in Stockholm (C.F. Møller) or the eighty-storey building in London with a height of 300 m (Oakwood Timber Tower, PLP Architects). According to experts, the fire safety of a well-designed and implemented wooden building is no worse than a well-designed and implemented brick building.

Another example of multi-storey wood-based construction according to Sandanus [14] is the Italian city of L'Aquila, where the tender for the construction of several dozen apartments after the 2009 earthquake won due to construction speed, good fire resistance of the load-bearing structure against seismic loads, suppliers of houses with a wooden supporting structure made of cross-glued wood [19],[20],[21].
4. Conclusions

This paper deals with the issue of multi-storey wood-based buildings. This article outlines the basic aspects of this specific area of construction. Within the specification, segregated breakdowns of these specific structures in terms of technology were presented. As this contribution represents the constructional and technological advantages of the use of wood, there are undoubtedly and wooden and wooden building materials have been used in recent years in the construction of multi-storey buildings. The construction of multi-storey wood-based buildings provides not only the efficiency, speed and quality of the construction process, but also a healthier and greener alternative to construction in the context of sustainability.

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References

[1] Atrium SK, “Building Dictionary”. [online] [Accessed 2019-01-10], Available at: http://www.atrium-sk.sk/sk/technika/stavebny-slovnik, 2019 (in Czech).
[2] Drevotomka, “Wood constructions”. [online] [Accessed 2019-01-10], Available at: http://drevotomka.sk/drevostavby/, 2019 (in Czech).
[3] P. Hájek, et al. “Konstrukce pozemních staveb – komplexní přehled,” Skriptum, Praha, 2011.
[4] A. Adamuščin, “Economic benefits of green buildings and certificates for sustainable construction,” Nehnuteľnosti a Bývanie, 2014 (in Czech).
[5] D. Westphalen, and S. Koszalinski, “Energy Consumption Characteristics of Commercial Building HVAC Systems,” U.S. Department of Energy, Cambridge, MA 02140-2390, 2001.
[6] M. Veljkovic, and B. Johansson. “Light steel framing for residential buildings.” Thin-walled structures, 44(12), 1272-1279, 2006.
[7] N. Naud; L. Sorelli; A. Salenikovich; and S. Cuerrier-Auclair. “Fostering GLULAM-UHPFRC composite structures for multi-storey buildings.” Engineering structures, 188, 406-417, 2019.
[8] K.S. Elliott, and C. Jolly. Multi-storey precast concrete framed structures. Wiley, 2013.
[9] H. R. Lu; A. El Hanandeh; and B. P. Gilbert., “A comparative life cycle study of alternative materials for Australian multi-storey apartment building frame constructions: Environmental and economic perspective.” Journal of cleaner production, 166, 458-473, 2017.
[10] P. Hájek, C. Fiala, and V. Hájek, “Konstrukce pozemních staveb – komplexní přehled.” České Vysoké Učení Technické v Praze. 2011 (in Czech).
[11] G. Rinaldin, and M. Fragiaccomo. “Non-linear simulation of shaking-table tests on 3-and 7-storey X-Lam timber buildings.” Engineering Structures, 113, 133-148, 2016.
[12] J. Hummel, and W. Seim. „Displacement-based design approach to evaluate the behaviour factor for multi-storey CLT buildings.” Engineering Structures, 201, 109711, 2019.
[13] J. Végrová, “Ako znížiť horľavosť viacposchodových drevostavieb.” [online]. [Accessed 2021-02-27] Available at: https://hnonline.sk/prakticke-hn/1790280ako-znizithorlavost-viacposchodovych-drevostavieb, 2018, (in Slovak).
[14] J. Sandanus, „Drevená nosná konštrukcia pre viacpodlažné domy”. [online], [Accessed 2021-02-28] Available at: https://www.asb.sk/architektura/rodinnedomy-architektura/drevostavby/drevena-nosna-konstrukcia-pre-viacpodlazne-domy, 2010, (in Slovak).
[15] ASB, “Dáme šancu poschodovým drevostavbám aj na Slovensku?” [online], [Accessed 2021-02-27] Available at: https://www.asb.sk/architektura/rodinne-domy-architektura/drevostavby/dame-sancu-poschodovym-drevostavbam-aj-na-slovensku, 2019 (in Slovak).
[16] L. Pozza; M. Savoia; L. Franco; A. Saetta; and D. Talledo. “Effect of different modelling
approaches on the prediction of the seismic response of multi-storey CLT buildings.” Timber Struct Eng, 163, 2018.

[17] A. Polastri; L. Pozza; D. Trutalli; R. Scotta; and I. Smith. “Structural characterization of multistory buildings with CLT cores.” In Proceedings 13th World Conference on Timber Engineering, Quebec City, Canada, 2014.

[18] R. Cvetković; D. Stojić; S. Krasić; and N. Marković. “Innovative structural CLT system in projecting and building of student houses.” Facta universitatis-series: Architecture and Civil Engineering, 13(1), 57-64, 2015.

[19] C. Demirci; C. Malaga-Chuquitaype; and L. Macorini. Seismic shear and acceleration demands in multi-storey cross-laminated timber buildings. Engineering Structures, 198, 109467, 2019.

[20] M. Follesa; I. P. Christovasilis; D. Vassallo; M. Fragiacomo; and A. Ceccotti. “Seismic design of multi-storey cross laminated timber buildings according to Eurocode 8.” Ingegneria Sismica, 4, 2013.

[21] T. Reynolds; D. Casagrande; and R. Tomasi. “Comparison of multi-storey cross-laminated timber and timber frame buildings by in situ modal analysis.” Construction and building materials, 102, 1009-1017, 2016.