ASSESSMENT OF WOODEN BUILDINGS IN TERMS OF CONSTRUCTION WASTE GENERATION

Eng. Marcela Spišáková, PhD [1]
Prof. Eng. Mária Kozlovská, PhD [2]
Eng. Jozef Švajlenka, PhD., MBA [3]
[1, 2, 3] Technical University of Košice, Slovakia

ABSTRACT

Construction industry creates an environment for people's lives. On the other hand, construction activities have a negative impact on various aspects of the environment. It consumes natural raw materials, significantly contributes to carbon footprint, waste, etc. Appropriate choice of constructional, material, technical, technological and environmental parameters of buildings can partially reduce this negative impacts. By designing, implementing and using wood-based constructions it is possible to reduce the negative impact in the area of construction waste generation. Currently, the construction market offers a large number of construction systems of wooden buildings, which have both strengths and weaknesses. In this paper are identified construction systems of wooden buildings offered on the Slovak construction market. The aim of the paper is a detailed identification of construction waste generation during the realization of particular wooden structures and monitoring of waste generation in production factory (off site) and on construction site (on site) during the construction of wooden buildings. Based on the obtained information, the individual construction systems of wood-based constructions are compared in terms of construction waste generation.

Keywords: *wooden constructions, construction waste, assessment, generation*

INTRODUCTION

Construction affects the environment. We started to recognize this impact in the 1990s. Significant changes were needed to mitigate the environmental impact of building section [1]. The emergence of 'green construction' over the past 20 years has challenged developers and builders to adopt a 'sustainability mindset' towards the design and management of construction projects. Sustainable development in the construction industry has become an important issue, but it seems to be lagging behind other sector [2]. Sustainable development in general is a concept which came today in many spheres of economic and social life. A measure of utilization advantages of each construction systems that reflected in environmental, social and economic areas of sustainability is an important factor in decision of the most customers on choosing the construction system. The evaluation of the construction sustainability consists in the complex evaluation of single period of life cycle of investigated product or process [3]. Authors Udomsapa and Hallinger [4] have define four areas of interest of sustainable construction: alternative materials for sustainable construction, sustainable construction management, recycling and waste reduction, and social sustainability in construction management. The

development of the new construction materials and composites, as well as the basic requirements for construction reflecting increasing its energy and environmental aspects and the development the new methods of construction which have to consider also the aesthetic, architecturally divers and the socio-economic requirements and limitations of costumers [5].

The wooden buildings present sustainable construction approach while meeting all constructional, technical, technological and environmental parameters of modern constructions. Wooden buildings are considered to be energy efficient that is an increased energy standard [6]. Therefore, the costs incurred when building the house are compensated by reduced energy consumption. When constructing buildings using wood-based materials, the cost of its impact on the environment is neglected. It is not only about lower energy consumption for heating, but also a small amount of energy needed during construction. The weight of such a wall is also lower which directly transfers to the cost of transporting construction materials and as a consequence of the final house price. In the case of timber houses the costs of utilizing other materials left following the period of building exploitation are also significantly lower.

Prefabricated building systems (modern method of construction) on the wooden base are the most common in Slovakia. An important factor in deciding the most of the builders in the choice of wooden construction system is a measure of utilization advantages of each construction system that reflected in cost, quality and speed of construction [7].

Modern methods of construction using timber and wood-based materials we can divided into [8]: structural insulated panels (SIPs); cross laminated timber panels (CLT); log wooden construction; wooden blockwork system; wooden column construction; wooden frame construction; wooden volumetric systems.

In general, the construction methods are divided into two basic groups. The first group consists of “off-site” construction methods using the prefabricated elements or parts of wooden constructions, made off-site and then transported and assembled on site. The second groups consist of “on-site” construction methods when the production of construction elements and parts of construction are directly on the site. There belong the traditional construction methods (currently are still the most used the masonry and monolithic reinforced concrete structures) which are currently extended to a number new(modern) methods characterised as “semi-prefabricated” or hybrid construction [9]. There is a part of construction elements produced in the factory (off-site) but its functional location is completed to the site. Many wooden constructions can be constructed of-site or on-site method.

MATERIALS AND METHODOLOGY OF RESEARCH

One of the drivers to using wooden construction is production of less construction waste compared to traditional construction [10]. The aim of the paper is a detailed identification of construction waste generation during the realization of particular wooden structures and monitoring of waste generation in production factory (off site) and on construction site (on site) during the construction of wooden buildings. Based on the obtained information, the individual construction systems

of wood-based constructions are compared in terms of construction waste generation.

Materials of research

Analysis of construction waste generation was carried out for four selected types of wooden constructions which presents a research material. These four selected types are the most used wooden based construction systems in Slovakia:

1. wooden beam construction
2. log wooden construction
3. wooden panel construction (open panels)
4. wooden volumetric systems

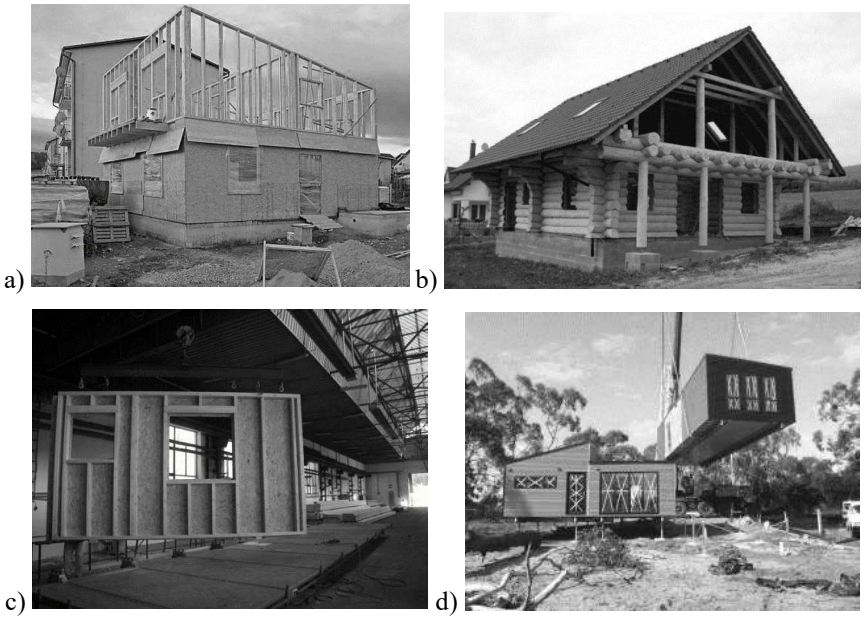

Fig. 1 Types of wooden constructions: a) wooden column construction, b) log wooden construction, c) wooden panel construction – off site, d) wooden volumetric systems [11], [12], [13], [14]

The load bearing system of the wooden beam construction is formed by beams (Fig 1a). This dimension of beams is derived from the static action and load impinging on the structure. Spatial stability of the beams construction can be ensured by the large-format plates used to coat the structures. Nowadays, the use of plasterboard boards is receding in front of the glass fibre boards, which are much more rigid and resistant to impact. As with any type of woodworking, this type of construction requires a good quality of contact with the base joint. Advantage of this system is a simple installation directly on the construction site. It is unlikely that the construction will be influenced by weather conditions. The system is simple, does not require heavy mechanization and makes it possible to respond flexibly to problems and changes in building construction. Log constructions belong to the

oldest buildings used in traditional architecture. In the log constructions, traditional logs made of coniferous trees. The wall of the log house consists of horizontal beams - logs joining in corners with locks (Fig 1b). The basement presents a reinforced concrete foundation slab. The wooden panel construction system has evolved from a wooden beam construction. The difference between these types is in construction technology. The basic part of the structure is a wooden frame. The panel frame is adapted and dimensioned in relation to the panel function (ceiling, wall, partition). The panels can be pre-assembled in off-site (in the production hall) (Fig 1c) or can be assembled on site. Volumetric (modular) wooden structures are characterized by a high degree of prefabrication. The entire facility is manufactured at the factory and transported to the destination. The building can make objects from the cells both vertically and horizontally. Depending on the size of the object, the individual modules are usually individually imported on the means of transport. Cellular structures are used mainly for the construction of temporary buildings, but also for residential and civil construction (Fig 1d).

These four selected types of wooden construction were analysed from the structural, material, technical, technological and environmental point of view. Based on this analysis it was possible to prepare a survey of the construction waste generation (according European waste catalogue) during the construction of particular types of wooden building on site or off site.

Methodology

The analysis of waste generation was based on verification of the specific type of waste generation in the process of production and construction of wooden buildings. Data were processed in tabular form (Fig 2). The arrangement of the data in the table is consistent with the European waste catalogue (EWC). Moreover, this form was used to determine the places (on site, off site) of construction waste generation. Data were obtained through structured interviews of wooden construction producers or constructors.

Analysis of waste generation in wooden construction							
Type of waste		**Place of waste generation**					
		off-site			**on-site**		
		Construction system realization phase					
Number of group, subgroup, type of waste	Name of group, subgroup, type of waste	Foundation structure	Structural works	Roofing	Foundation structure	Structural works	Roofing

Fig. 2 Tabular form of identification of types and place of construction waste generation

RESULTS AND DISCUSSION

Data concerning on the frequency of waste generation and frequency percentage of waste generation were processed in table (Fig. 3). Table provides a summary identification of types and place of construction waste generation. Based on these data were made three conclusions:

Analysis of waste generation in wooden construction							
Type of waste		Place of waste generation					
		off-site			on-site		
		Construction system realization phase					
Number of group, subgroup, type of waste	Name of group, subgroup, type of waste	Foundation structure	Structural works	Roofing	Foundation structure	Structural works	Roofing
17	**CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)**						
17 01	**concrete, bricks, tiles and ceramics**						
17 01 01	concrete				①②③		
17 01 03	tiles and ceramics						①③
17 02	**wood, glass and plastic**						
17 02 01	wood						
	timber		①③④	①③	④	①②③	①②③④
	wooden based material		③	③	④	①②③	①
17 02 03	plastic		③④	③	④	①②③	①②④
17 03	**bituminous mixtures, coal tar and tarred products**						
17 03 02	bituminous mixtures other than those mentioned in 17 03 01						
	asphalt insulation				①②③		
17 04	**metals (including their alloys)**						
17 04 02	aluminium					②	②
17 04 05	iron and steel				①②③		④
17 05	**soil (including excavated soil from contaminated sites), stones and dredging spoil**						
17 05 06	dredging spoil other than those mentioned in 17 05 05				①②③		
17 06	**insulation materials and asbestos-containing construction materials**						
17 06 04	insulation materials other than those mentioned in 17 06 01 and 17 06 03						

	polystyrene						
	mineral wool		③④	③	④	①②③	①②④
	glass fibres						
	natural insulation						
17 08	**gypsum-based construction material**						
17 08 02	gypsum-based construction materials other than those mentioned in 17 08 01		③④			①②③	②④

Notes: ① wooden column construction; ② log wooden construction; ③ wooden panel construction; ④ wooden volumetric systems

Fig. 3 Summary identification of types and place of construction waste generation

1. Less construction waste is generated in the production hall (off-site) than on site

The transfer of wooden construction to the production hall (off-site) provides several advantages, including, time savings on site, reduced workforce on site, independence on climatic conditions. Greater production automation over site production can minimize the amount of unused building material more efficiently with respect to its further processing and utilization.

Based on the obtained data, the hypothesis that less waste was generated in the production hall than on the construction site was confirmed (Fig. 4). While there were 15 (24%) situations in construction off-site production in which construction waste from selected materials is generated, in construction site production it was up to three times more, 47 (76%).

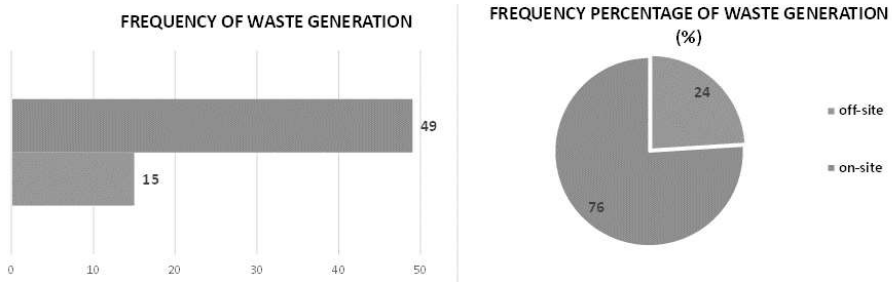

Fig. 4 Construction waste generation off site vs. on site

2. Less construction waste is generated by wooden volumetric system than by other types of wooden construction systems

We assumed that the least waste would be generated by wooden volumetric system than by other types of wooden construction systems. Because of, wooden volumetric systems are largely prefabricated and assembled in factories according to customer requirements.

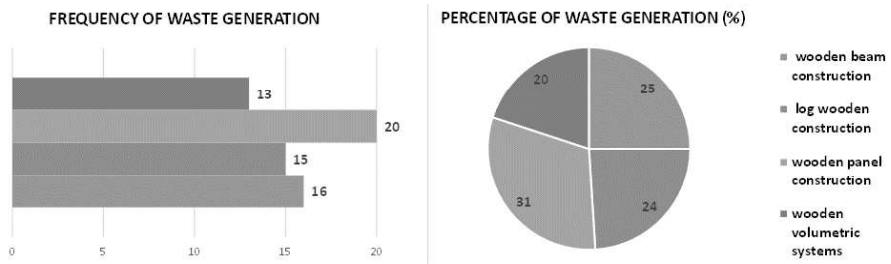

Fig. 5 Construction waste generation considering the construction system

This hypothesis has been confirmed (Fig. 5). Construction waste during the wooden volumetric system manufacturing was generated in 13 situations (20%). Most construction wastes were generated by wooden panel construction – in 20 situations (31%).

3. Wooden waste is the largest part during the production and realization of wooden constructions

The hypothesis of the highest frequency of wooden waste generation can be clearly verified. The summary table (Fig. 3) shows that during the production and realization of wooden construction, up to 37% of wood waste is generated, of which 24% are wooden debris of unused timber and 13% of other wood-based materials, most often OSB boards (Fig. 6). Mineral wool waste accounts for 18% (10 situations) of the total waste generated, followed by 13% (7 situations) with gypsum-based construction materials. According to figure 3, it is evident that the most wooden waste is generated during the construction phase of the structural works, as the largest amount of wood waste is consumed. The lowest waste rate in timber construction is 4% for tiles and ceramics and aluminium.

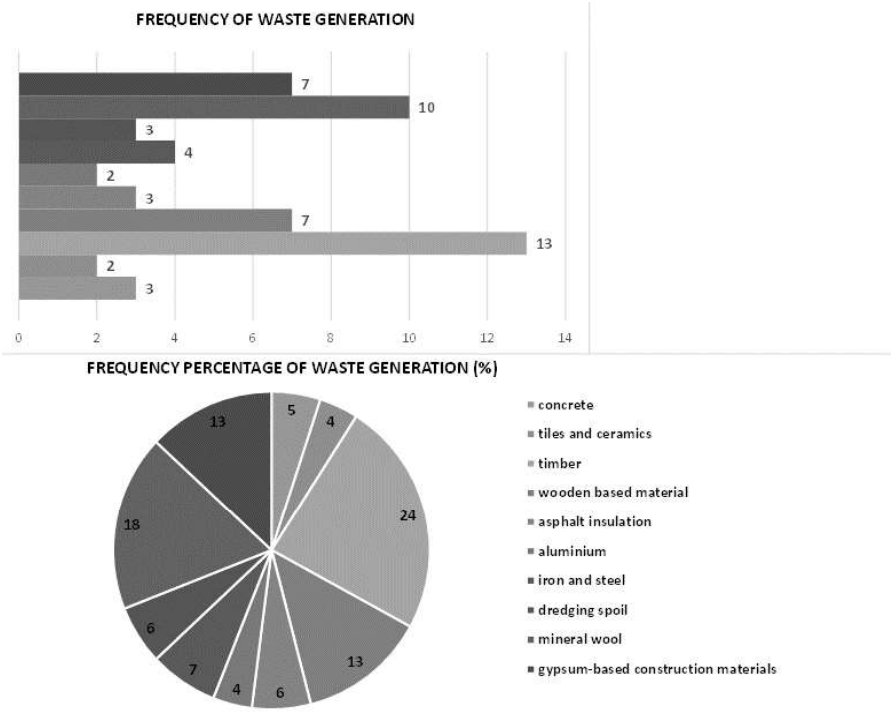

Fig. 6 Construction waste generation in terms of waste type

CONCLUSION

Wooden buildings belong to ecological and environmental buildings that are environmentally friendly during production, throughout their lifetime and also during their removal. Properly selected construction of wooden buildings can eliminate waste, which contributes to the protection of human health and conservation of nature. The paper was focused on detailed identification of construction waste generation during the realization of particular wooden structures and monitoring of waste generation in production factory (off site) and on construction site (on site) during the construction of wooden buildings. The most used (in Slovakia) selected types of wooden construction were analysed from the structural, material, technical, technological and environmental point of view. Three conclusions were confirmed: (i) less construction waste is generated in the production hall (off-site) than on site; (ii) Less construction waste is generated by wooden volumetric system than by other types of wooden construction systems; (iii) Wooden waste is the largest part during the production and realization of wooden constructions.

ACKNOWLEDGEMENTS

VEGA project-1/0557/18 “Research and development of process and product innovations of modern methods of construction in the context of the Industry 4.0 principles”.

REFERENCES

[1] Haapio A., Viitaniemi P., A critical review of building environmental assessment tools, Environmental impact assessment review, vol. 28, pp. 469-482, 2008.

[2] Tsai C-Y., Chang A-S., Framework for developing construction sustainability items: the example of highway design, Journal of Cleaner Production, vol. 20, pp 127-136, 2012

[3] Rajnicova L., Investigating the use of LCA in decision-making in waste management, Novus scientia, vol. 16, pp 489-493, 2007

[4] Udomsap A. D., Hallinger P., A bibliometric review of research on sustainable construction, Journal of Cleaner Production, vol. 254, pp 1-9, 2019

[5] Lesniak A., Zima K., Cost calculation of construction projects including sustainability factors using the Case Based Reasoning (CBR) method, Sustainability, vol. 10, pp 1-14, 2018

[6] Kozik R., Lesniak A., Majka M., Application of multi-criteria analysis method for thermal insulation solutions selection, International Conference on Numerical Analysis and Applied Mathematics 2018, vol 2116, 2018

[7] Kozlovska M., Spisakova M., Mackova D., Modern methods of construction towards adoption in Slovakia, EuroScientia, pp 230, 2017

[8] Hamid Z., et al., IBS in Malaysia: The current state and R&D initiatives, Malaysia construction research journal, vol. 2, pp 1-13, 2008

[9] Modern methods of construction, Evolution or Revolution, BURA, 2005, London

[10] Baldwin A., et al., Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional, Renewable Energy, vol. 43, pp 2067 – 2073, 2009

[11] https://www.asb.sk/stavebnictvo/drevostavby/realizacia-rodinneho-domu-drevenou-stlpikovou-sustavou

[12] https://www.zelenarchitektura.sk/2012/09/drevostavby-zrub-skeletova-konstrukcia-alebo-mobilny-dom/

[13] http://www.nesbau.sk/

[14] http://modularhomeowners.com/do-you-know-the-difference-between-prefab-and-manufactured-homes/