Timber Passive House Technologies of Slovenian Contemporary Architecture

Manja KITEK KUZMAN
University of Ljubljana, Biotechnical Faculty
Department of Wood Science and Technology, Slovenia
Mirko KARIŽ
University of Ljubljana, Biotechnical Faculty
Department of Wood Science and Technology, Slovenia
Martina ZBAŠNIK-SENEGAČNIK
University of Ljubljana
Faculty of Architecture, Slovenia

Abstract

Energy efficiency is essential in the efforts to achieve a 20% reduction of primary power consumption by 2020. It is widely recognized that the potential of energy saving in buildings is large. Considering the tendencies of energy production and price, it is becoming urgent to reduce energy consumption in buildings. The choice of materials for a building with a high energy efficiency becomes much more important and strategies for reducing the use of primary energy for the production of materials and components becomes key. Renewable building materials should already be integrated into the early phases of building planning. The positive trend towards wooden construction is dictated by international guidelines, where a wooden building is an important starting point, not only for low-energy, but also low-emission building with exceptional health and safety aspects. In Europe, the most comprehensive and widely used is a concept of ultra-low energy house, more precisely, the passive house concept. Most Slovenian buildings combine contemporary styling with a degree of energy efficiency that comes close to passive house standards. It is widely recognised that the Slovenian construction industry is relatively advanced in the field of low energy buildings. In the light of the growing importance of energy-efficient building methods, it could be said that timber passive house would play an increasingly important role in the future.

Keywords: timber construction, energy efficiency, passive house, sustainable development, Slovenia.

1 Introducton

Timber as a material for load bearing construction represents a future challenge for residential and public buildings. Being a natural raw material, timber represents one of the best choices for energy efficient construction since it also functions as a material with good thermal properties if compared to other construction materials. In addition, it plays an important role in reduction of the CO_2 emissions (Natterer, 2009), has good mechanical properties and ensures a comfortable indoor living climate. Timber construction has better thermal properties than conventional brick or concrete construction methods, even with smaller wall thickness. Considering the growing importance of energy-efficient building methods, timber construction will play an increasingly important role in the future.
The dominating methods of timber construction in Slovenia include a timber-frame construction, balloon and massive construction (Figure 1).

Fig. 1 Panel construction, Wood frame construction, Solid wood construction

Currently, most Slovenian companies offer houses with timber-frame construction. Timber panel construction has had its own production in Slovenia for more than 35 years. Over the past thirty years, timber construction has undergone major changes. The most important (Žegarac Leskova and Premrov, 2013) are the following introduced changes: transition from on-site construction to prefabrication in a factory, transition from elementary measures to modular building and development from a single-panel to a macro-panel wall prefabricated panel system. All of these greatly improve the speed of building.

In timber-frame buildings the basic vertical load bearing elements are panel walls consisting of load bearing timber frames and sheathing boards. Dependant on the wall dimensions, one can distinguish between single-panel and macro-panel wall systems. The single-panel was based on the individual smaller elements in dimensions of 1.30 m (1.25 m) x 2.5 m to 2.65 m (Figure 2a). The height of the wall elements was meeting the height of the floor and the length of the ceiling elements the span of the bridged field. The macro-panel system was developed from the single-panel system in the last two decades and represents an important milestone in panel timber frame building. The aim of the system is that whole wall assemblies, including windows and doors, are totally constructed in a horizontal plane in a factory from where they are transported to the building-site. Prefabricated timber-frame walls as main vertical bearing capacity

elements, of usually typical dimensions with a width of 1.250 m and a height of 2.5–2,6 m, are composed of a timber frame and sheets of board-material fixed by mechanical fasteners, usually staples, to one or both sides of the timber frame (Figure 2c).
Between the timber studs and girders a thermal insulation material is inserted the thickness of which depends on the type of external wall. Composition of wall elements is in detail presented in Table 1(Premrov and Žegarac L., 2013) .

a.) b.) c.)

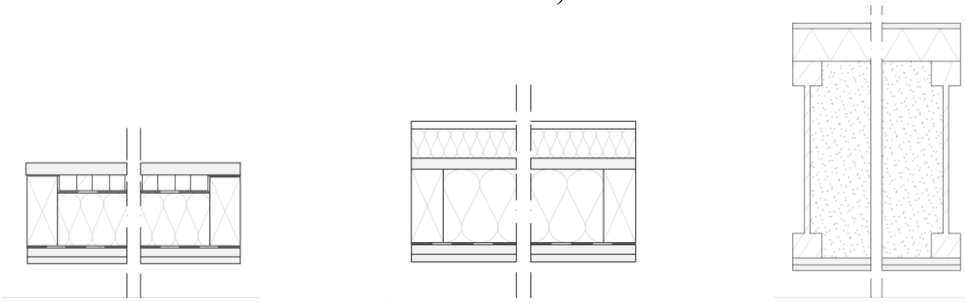

Fig. 2 a.) Single-panel system (TFCL2); b.) Renovated single-panel system (TFCL 3), c.) Timber-frame wall element with I-studs (TF 3).

Table 1 Composition of analysed macro-panel (TF 3) and single-panel (TFCL 2, 3) timber-frame wall elements.

TF		TFCL 2		TFCL 3 – renovation	
material	d[mm	material	d[mm	material	d[mm
rough coating	10	wooden planks	22	rough coating	10
wood fibreboard	60	/	/	mineral wool	40
/	/	TSS*** /open air	0.5	gypsum fibreboard	15
cellulose fibre / TF*	360	TSS*** /open air	20	mineral wool / TF*	100
		bitumen sheet	0.5		
		mineral wool / TF*	80		
OSB**	15	aluminium foil		aluminium foil	
gypsum	12.5	particleboard	13	particleboard	13
		gypsum plasterboard	10	gypsum	10
total thickness	457.5	total thickness [mm]	146	total thickness	188
U_{wall}–value [W/(m^{2}K)]	0.102	U_{wall}–value [W/(m^{2}K)]	0.48	U_{wall}–value [W/(m^{2}K)]	0.30

*timber frame, **oriented strand board, ***timber sub-structure.

The first single-panel systems in Slovenia were used by company Marles and company Jelovica. Those first pre-fabricated houses built in the early 70's had very good thermal properties of external envelope. Thermal transmittance of the best panel types was always much lower than it was defined by the regulations; for example thermal insulation was nearly three times better from 1963 to 1972, and after the year 1992 almost four times better than it was defined by the current national regulation (Figure 3).

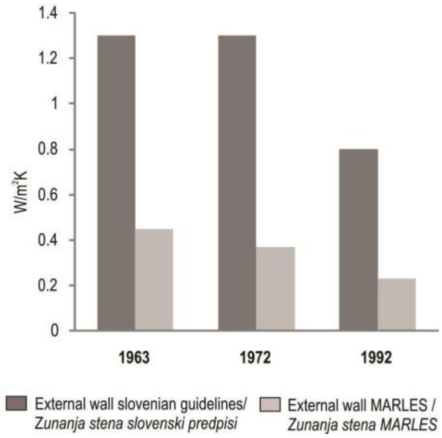

Fig. 3 Thermal transmittance of external wall elements - U-value comparison of the Marles' wall with the Slovene legislation in the period from 1963 to 1992.

Because of the reduction of energy losses in the newly built residential objects, the first measure introduced by the producers was gradual reduction of the thermal transmittance of the external wall elements, resulting in the increase of the timber-frame wall elements thickness, thus enabling thicker thermal insulation instalment. Detailed composition of the older single panel external wall elements construction, as well as newer macro-panel system, are explicitly presented in the Table 1, with additional graphic presentation in Figure 2.

Figure 3 shows data only till the year 1992, when external wall elements for the first time, even at any rate, met nowadays Slovene legislation regarding energy efficient construction, so that the thermal transmittance of external walls was for the first time lower than now prescribed limit value U=0.28 W/(m²K), i.e. it has nearly reached the value for light constructions, which is U=0.20 W/(m²K).

Therefore, all prefabricated timber framed objects set up before the year 1992 are considered as a fund needing energy efficient renovation till the year 2020. The latter refers to the wide-ranging package on climate change adopted by European Union, the overall 20-20-20 targets, which are binding for buildings as well. Therefore, energy performance of existing buildings has to be improved through a complex process of energy efficient renovation, likewise the sustainable new construction of energy-efficient buildings with the use of renewables has to be performed.

2 Energy-efficient buildings

Researching energy efficiency of buildings is not a matter of the last decade only, since the first intensive studies related to energy and buildings were already carried out in the seventies and eighties of the last century. Many studies focusing on the research of specific parameters influencing energy performance of buildings, such as Johnson et.al. (1984) and Steadman and Brown (1987) have been performed since then. From the existing research findings we summarize that the process of defining the optimal model of a building is very complex. The most important parameters influencing energy-

performance of buildings are listed below: location of the building and climate data for the specific location, orientation of the building,
properties of installed materials, such as timber, glass, insulation, boards etc., building design (shape factor, length-to-width ratio, window-to-wall area ratio, building's envelope properties, windows properties), selection of active technical systems.
According to the Slovene legislative framework, particularly to the Energy Act, the system of energy performance certification is defined in *Rules on the methodology of construction and issuance of building energy certificates (2009)*. On the basis of these rules, the classification of energy-efficient houses was carried, which is listed in Table 3.

Table 3 Classification of energy-efficient houses on the basis of "Rules on the methodology of construction and issuance of building energy certificates".

Degree / Classification in accordance with the rules	Generally used classification in practice	Q_h* (kWh/m^{2}a)	Variation of execution
Class C	minimal requirements for low-energy house	35 – 50 (60)	classical prefabricated construction, conventional heating system, contemporary windows (doors), no central ventilation system
Class B2	low-energy house	25 – 35	thermally improved building envelope conventional heating system, contemporary windows (doors),
Class B1	very low-energy house	15 – 25	thermally improved building envelope + HRV** + improved U-value of windows (doors)
Class A2	passive house	10 – 15	additionallythermally improved building envelope + HRV + improved U-value of windows (doors)
Class A1	passive house	≤ 10	additionally thermally improved building envelope + HRV + improved U-value of windows (doors)

* specific annual heating demand, **heat recovery ventilation

Table clearly shows that energy efficient objects can be constructed only by adequate combination of external envelope efficient insulation and high quality glazing installation. Respecting climate change conditions and the subsequent European directions related to energy performance of buildings, which are forcing the building industry into constructing a nearly zero energy house by 2020, searching for the optimal model of an energy-efficient house has therefore become of major importance.

2.1 Passive house

In Europe, the most comprehensive and widely used concept of ultra-low energy, more precisely, the passive house concept was developed by Dr. Wolfgang Feist of the Passive House Institute (Feist, 1998, Galvin and Sunikka-Blank, 2012). It sets forth the maximum permissible energy consumption for the heating of the building and limits the total primary energy consumption. In its essence, it is an upgrade of the low-energy house standard. Passive houses are buildings that ensure a comfortable in-door climate during summer and winter without requiring a conventional heat distribution system (Feist, 1998). The passive house standard means that the space heating peak load should not exceed 10 W/m^2 living area in order to use supply air heating. The resulting space heating demand will approximately be 15 kWh/m^2 but will vary depending on climate (Feist, 2005).

The term 'passive house' refers to a construction standard that can be met through a variety of technologies, designs and materials such as solid (masonry, concrete, and aerated concrete) and wood structures. Different timber passive house technologies are presented in Figure 4.

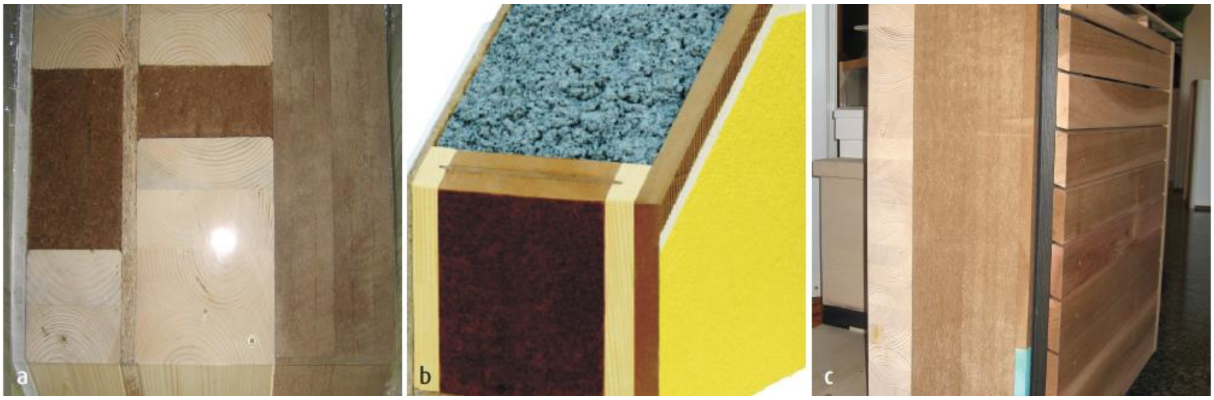

Fig. 4 a) Panel construction (Jelovica houses), b) Timber-frame wall element with I-studs I-joists (Lumar), c) Solid wood construction (Riko houses).

The following considerations are particularly important when choosing the material and the construction type: the construction type should be standardized; the construction system should be based on natural and environmentally-friendly materials; the thermal envelope should meet the standards of a passive house; the construction should be wind-tight, airtight and diffusion open.

In order to design and implement a high-quality passive house project, attention should be paid to the materials used. The choice depends on personal preferences, in particular on the cost. There is a growing movement especially in Germany, Austria and Switzerland to build passive houses that are based on energy conservation measures and an efficient mechanical ventilation system with heat recovery. Over the past few years, the number of different types passive houses (Figure 5) has been seen a continuous increase in Europe as shown in Figure 6 (The International Passive House Association).

Fig. 5 Different types of passive houses: (a) Single family passive house,(b) Multy storey timber frame passive house, (c) Industrial building.

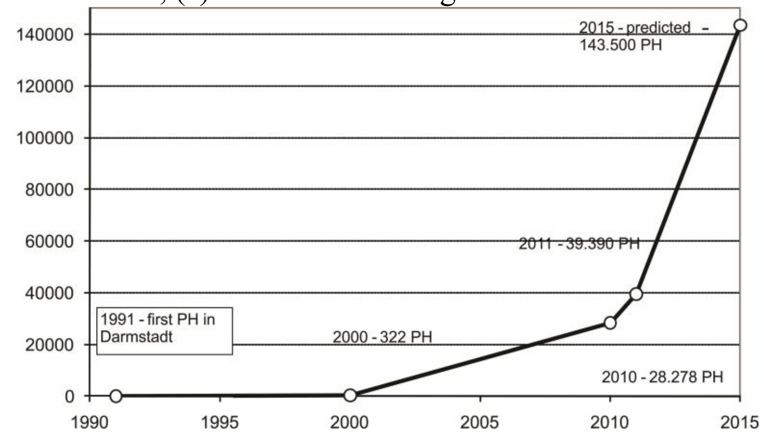

Fig. 6 The number of passive houses in 31 countries of Europe.

The greatest challenge facing civil engineers, wood science and technology engineers and architects today is how mitigate and adapt to climate change. They have recently focused their efforts on finding environmentally-friendly solutions and construction methods that bolster energy efficiency and thus reduce the environmental burden. The choice of a construction material is one of the most important decision with long-term consequences for the owner of the building (Johnson, 1990). The analysis by Kitek Kuzman et al. (2013) showed that wood as a renewable raw material is one of the best choices for energy-efficient construction. because it is also a good thermal insulator, has good mechanical properties, and ensures a comfortable indoor climate.

2.1.1.Certificates

In recent decades several methodologies have been developed to assess the quality of buildings: in the UK there is BREEAM (BRE Environmental Assessment Method) in France HQE (Haute Qualite Environmentale), the USA has LEED (Leadership in Energy and Environmental Design), Germany has DGNB (Deutsche Gesselschaft für Nachhaltiges Bauen) and so on. These certificates demonstrate the environmental and energy indicators of buildings, as well as the economic, socio-cultural and technical aspects of construction. For those buildings in the highest energy class, for instance passive houses, special systems of certification have been developed: in Switzerland the Minergie P and in Germany the Passive House Certificate. In some countries (Germany, Austria and Switzerland), the two certificates are the basis for allocating subsidies for passive houses. Within the profession they are highly valued – as a good promotional tool representing a market advantage.

In the Slovenian market there are already a large number of components bearing the Passive House Certificate. Components with this certificate are most commonly manufactured by large foreign firms that have representatives in Slovenia, but also by a number of Slovenian firms that is growing each year. Currently there are few houses in Slovenia built with the Passive House Certificate and with the Minergie P certificate.

3 Case study: The Active House

Based on the active house concept, this highly energy-efficient structure makes best use of solar energy and offers utmost living comfort. The built-in smart home installations, the ceiling-mounted heating and cooling system, and the rooftop photovoltaic installations and solar collectors in combination with skylights are only one part of the concept. The idea of an environmentally friendly house is completed with an outside rainwater collector; collected water is used for flushing toilets, washing machines and the *automatic* garden *watering* system. The design follows the strict requirements set out by the municipal site plan for this area. The longer side of this two-story house with a symmetrical gable roof faces the southeast, ensuring a maximum gain from sun energy. All blinds, skylights, the watering system, and all mechanical and electrical installations are computer-controlled and automatic, allowing for maximized energy efficiency. Energy consumption can also be monitored online.
(Figure 7 and Fugure 8).

Location | Dragočajna, Year | 2013
Architect | Jernej Gartner, Brigita Babnik, Gregor Košorok, KOŠOROKGARTNER ARHITEKTI d.o.o.
Surface | 151 m^2
Construction time | 1 year
Structural engineer | dr. Luka Pavlovčič, Lumar IG d.o.o.
Energy efficiency | plusenergy (PHPP 15 kWh/m^2a)
U-value ($W/(m^2K)$) | wall 0,1; roof 0,1; floor 0,12; window 0,87: glass 0,6; frame 0,86
Construction system | timber frame
Construction company | Lumar IG d.o.o.
Price | best practice Zeleni svinčnik 2013, ZAPS
House technique | air to water heat pump, floor heating, solar collector, photovoltaic power station, comfort ventilation with heat recovery,rain water collector

(a) **(b)**

Fig. 7 (a) The house is built entirely of environmentally-friendly materials, which have the biggest impact on the environment in the stage of production. The house includes an photovoltaic power station, solar collectors for hot water, skylights, rainwater gathering for sanitary purposes and watering as well as smart installations, (b) The basic idea in the design was to produce a demonstration dwelling house used for the promotion and relevant explanation about 3 topics energy, indoor climate and environment. Active House is a network for knowledge sharing and demonstration of the feasibility of comfortable buildings in the future.

Fig. 8 Ground floor plane and first floor plane.

Conclusion

Most Slovenian buildings combine contemporary styling with a degree of energy efficiency that comes close to passive house standards. It is widely recognised that the Slovenian construction industry is advanced in the field of low energy buildings. In the light of the growing importance of energy-efficient building methods, it could be said that timber passive house would play an increasingly important role in the future.

References

Feist, W. 1998. DAS PASSIVHAUS – BAUSTANDARD DER ZUKUNFT?. Protokollband Nr. 12, Passivhaus Institut, Darmstadt.

Feist, W. 2005. QUALITÄTSSICHERUNG BEIM BAU VON PASSIVHÄUSERN. Protokollband Nr. 18, Passivhaus Institut, Darmstadt.

Galvin, R., Sunikka-Blank, M. 2012. Including fuel price elasticity of demand in net present value and payback time calculations of thermal retrofits: Case study of German dwellings. Energy and Buildings. 50:219-228.

Johnson, K. 1990. Timber Bridge Design, Engineering and Construction Manual. Wheeler Consolidated. St. Louse Park, MN.

Johnson, R. et al. 1984. Glazing energy performance and design optimization with daylighting. Energy and Buildings. 6:305–317.

Kitek Kuzman et al., 2013. Comparison of passive house construction types using analytichierarchy process. Energy and Buildings. 64:258–263.

Natterer, J. 2009. Massivholz-konstruktionen: Herausforderung für eine nachhaltige Ökobilanz. In: Kitek Kuzman (Ed.): Building with Timber, Challenge and Opportunity for Slovenia. University of Ljubljana, Biotechnical Faculty, Ljubljana, pp. 18-21.

Premrov, M., Žegarac L., V. 2013. Energy-Efficient Timber-Glass Houses. Springer, 178 p.

Rules on the methodology of construction and issuance of building energy certificates, Official Gazette RS, 77/2009.

Schnieders, J., Hermelink, A. 2006. CEPHEUS results: measurements and occupant's satisfaction provide evidence for Passive Houses being an option for sustainable building, Energy Policy, 34, pp. 151–171.

Steadman, P., Brown, F. 1987. Estimating the exposed surface area of the domestic stock. Energy and urban built form. Centre for Architectural and Urban Studies, University of Cambridge, pp. 113-131.

The International Passive House Association. Passive house. Darmstadt, Germany. http://www.passivehouse-international.org/.].

BREEAM, http://www.breeam.org/ (Accessed December 2013)

HQE, http://www.interfaceflor.co.uk/web/sustainability/green_building/hqe (Accessed December 2013])

LEED, http://www.usgbc.org/DisplayPage.aspx?CategoryID=19 (Accessed March 2014)

DGNB, http://www.dgnb.de/ (Accessed March 2014)

Minergie P, http://www.minergie.ch/ (Accessed March 2014)

Passivhaus Institut dr. Wolfgang Feist, www.passiv.de (Accessed March 2014)