TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
MECHANICS | MECHANIKA
3-M/2016

RENATA STASIAK-BETLEJEWSKA*

INNOVATIVE WOODEN ENERGY EFFICIENT HOUSES CONSTRUCTIONS

INNOWACYJNE KONSTRUKCJE DREWNIANYCH DOMÓW ENERGOOSZCZĘDNYCH

Abstract

The article presents innovative solutions for wooden energy-efficient constructions which are characterized by low energy power consumption and a high level of performance that ensures a high level of the functional quality and modern design of building interiors. One of the most commonly used modern wooden construction technology is a wooden prefabrication technology whose advantages determine a high level of building energy efficiency. The article presents achievements of selected manufacturers of wooden energy-efficient houses who use prefabrication technology in the context of building construction and interior innovation.

Keywords: the energy efficient buildings, *innovativeness*, *patent*, *wooden prefabricated components*

Streszczenie

W artykule przedstawiono innowacyjne rozwiązania w zakresie drewnianego budownictwa energooszczędnego, które charakteryzuje się niskim zużyciem energii, wysokim poziomem wykonania, zapewniającym wysoki poziom jakości użytkowej i nowoczesne wzornictwo. Jedną z najczęściej wykorzystywanych technologii we współczesnym budownictwie drewnianym jest technologia prefabrykatu drewnianego, którego zalety decydują o wysokim poziomie energooszczędności. W artykule przedstawiono analizę technologii stosowanych przez wybranych producentów drewnianych domów energooszczędnych w kontekście innowacyjności bryły oraz wnętrza budynków.

Słowa kluczowe: budynki energooszczędne, *innowacyjność*, *patent*, *prefabrykaty drewniane*

DOI: 10.4467/2353737XCT.16.119.5730

* Ph.D. Eng. Renata Stasiak-Betlejewska, Institute of Production Engineering, Faculty of Management, The Częstochowa University of Technology.

1. Introduction

The European Directive 2010/31/EU on the energy performance of buildings introduced an obligation on the clean and energy efficient building materials and technologies use. The analysis of the energy buildings standards optimizing methods, carried out by the National Agency for Energy Conservation in Poland (in Polish: KAPE), which took into account economic, environmental and external costs criteria, has confirmed that the increase in energy performance requirements for buildings contributes to the appearance of well--known building materials with improved insulating properties on the market. Materials used for building must provide effective thermal protection using a smaller thickness of the insulation layer [2, pp. 515-520].

An energy efficient building is considered to consume 25–50% less energy than a conventional building. The energy efficiency of a building is not legally defined. Currently in Poland, the demand for heating residential buildings constructed in accordance with building regulations is approximately 65–125 kWh/m^2 of the usable area per year. A building should be energy efficient for heating, ventilation and hot water and to consume no more than 50–70 kWh/m^2 per year [4]. In Western Europe, the technology of energy efficient buildings production with a long-term use of significant house savings in electricity and exploitation of natural environment has a growing popularity. The design process of energy efficient buildings concerns at least construction and materials solutions optimization, taking into account the analysis of building life cycle costs. In accordance with the newest energy efficient constructions, architects have to meet the requirements of customers accustomed to traditional architecture including solutions that provide cost-effective operation and low power consumption [5].

One of the conditions for building energy efficiency is economical operation condition and lower than the average construction costs. These features combine new technological solutions used by contemporary Polish construction companies that experiment with new materials and technologies, so that the buildings can achieve a high level of energy efficiency. However high costs of energy-efficient buildings make consumers/investors look for alternatives, which often provide modern, energy efficient or even passive technologies. Modern technologies of buildings address the following aspects: providing low costs of construction investments, short construction time and cost-effective operation of buildings. Considering these aspects, innovative construction projects involve the use of technologies that ensures: a short construction time, thermal insulation that affect operating costs of the building. Wooden frame construction technology plays significant role in the development of energy efficient constructions. In Germany, there is an increasing demand for energy efficient prefabricated wooden buildings, which results from European energy saving regulations and the popularity of wooden houses [6]. According to the Central Statistical Office, in Poland, in the year 2013, 51 658 new residential buildings in the individual construction were noted, primarily single-family houses built with the application of wooden frame technology (222 buildings), together with 3364 non-individual buildings (1 in the wooden frame technology). According to the Centre for Wooden Construction, there are 750 companies in Poland that deal with the construction of wooden frame constructions and perform each year about 4–5 thousands of buildings in different wooden technologies [1].

2. Contemporary trends in energy efficient wooden constructions – a short review

One of the most interesting construction solutions related to energy efficient constructions is the construction of a building with the wooden dome of Timothy Oulton, which is unique in terms of architecture and a technology. The construction is a result of meticulous planning and design. The space in the dome is made for the interaction between humans in very modern and comfortable conditions. The whole architecture has a minimal impact on the surrounding environment. The dome of the presented house is constructed of prefabricated elements created by Oulton's company and is completely self-supporting, without any columns and pillars. The entire structure has been created by means of wood FSC certified panels and it is built according to the German passive house standard, which is the highest in the world [7]. All the components used in construction of the dome well, keeping extremely tight and well-insulated structure. All the mentioned requirements have been met by architects from the French Studio Djuric Tardio Architects who built a house in a French district with the surface of 262 m^2. Designers experiment with wood and prefabricated structures. They developed a building system that allows for minimizing environmental costs and construction time, but also gives the result of a permanent home and relatively low operating costs. The design of the house consisted of prefabricated elements of the larch Finnish wood. All the components included warming wool and cellulose external facade panels. All technical and interior arrangements were prepared in accordance with energy saving construction trends.

3. Innovative solutions in Polish wooden energy saving constructions – research results

According to CEED Institute report data (Central and Eastern Europe Development Institute), Poland's economy has the potential to become regional leader in terms of innovation. New trends, fashion and customer expectations are forcing manufacturers of building materials, architects and designers to seek innovative solutions. There are two determinants of the construction industry development: energy efficiency and construction ecology. The construction has already been assimilated with solutions-based solar energy [3]. The use of renewable energy sources applied in connection with energy saving sources is concerned to be innovative solution in the construction industry. An analysis of the innovativeness level of Polish enterprises confirmed 95% of domestic applications with patented solutions that include approximately 4500 of patented solutions submitted by construction enterprises in 2010–2015 (e.g. Fakro).

3.1. The characteristics of selected leading construction technologies in Poland

Wooden prefabrication is one of the most popular construction technology in Poland and it enables the realization of a house construction in a few weeks. MultiComfort is one of the Polish enterprises dealing with the production of prefabricated houses that operates in Poland, Germany, Sweden, Switzerland, Latvia, Cyprus and Italy. It is the first company

that has built in Poland a certified passive prefabricated house. Prefabricated houses are manufactured with kiln-dried wood (a wood construction of KVH and BSH type) in German and Austrian sawmills. Properly trimmed elements are arranged in accordance with a detailed design and put together. The stiffness of wooden structure is achieved by building board MFP wood that is nailed to the two sides of the timber frame. The space between posts is filled with mineral wool. On the outer side of the wall external insulation is mounted, which is usually polystyrene, covered in the factory of prefabricated houses with an adhesive and a mesh. The inside wall is attached by a vapour barrier layer and a GKF plate. There are also prefabricated walls, ceilings and roof constructions. Partition walls are covered on both sides with MFP and GKF plates. The accuracy of individual components and advanced prefabrication shortens the construction time. Prefabricated houses are very well insulated. There is a 15 cm thick thermal insulation layer inside the wooden frame and at least 12 cm thick layer on the polystyrene foam facade with the addition of neopor. A U-value below 0.14 W/m^{2}K provides wall insulation. In addition, warm mounting windows (e.g. in the insulation layer), using expansion tapes and flange dealings, eliminates thermal bridges and affects the energy efficiency of a building. An efficient thermal insulation layer is a double layer of mineral wool of minimum 25 cm in thickness. The slab is a plate perimeter with a very low coefficient λ (0.032 W/m·K). Sections of the exterior wall contain: GKF plate, vapour barrier foil (wood construction and insulating mineral wool are protected against moisture), MFP plate (protects a structure against the ingress of moisture, stiffens the structure, strengthens the wall, so that there are no problems with nailing and screwing pins), wooden supporting structure (allows filling the entire space between the joists with insulation material mineral wool), mineral wool (a layer of thermal and acoustic insulation), MFP plate (provides a foundation for the second insulation layer of polystyrene or, optionally, mineral wool and stiffens the structure), glue for external insulation, external insulation (second insulation layer which improves insulating properties), reinforced plaster base grid. Prefabricated wooden houses should be very tight, just as houses constructed in each technology. The tightness of the house is mandatory and must be examined by performing a special leak test – the Blower Door Test. For an energy-efficient house, the leak test should not exceed n_{50} = 1.0. The technology of prefabricated houses applied by MultiComfort obtains test scores on the level of n_{50} = 0.36. It confirms the accuracy of all types of joints in the building: window frames-wall, wall-foundation, wall-like roof structure.

An innovative patented technology for the production of external panel wooden wall elements, absorbing solar energy that can be stored was elaborated on by another Polish construction enterprise Ekoinbud from Gdańsk in Poland. In 2012 it obtained a patent on the performance of wooden structure walls including the assembled system of PE pipes with polyethylene. Pipes receive heat from the walls in the summer, when the sun heats them. Thermal energy is accumulated under the ground, in the land on which the building was mounted. In the winter the stored thermal energy goes back to the walls, providing heating for the house. Ekoinbud production line has the capacity to produce 80 units a year at one shift. Due to the system of a three-shift operation, the production increases to approximately 200 houses a year. The construction of each part of the house – walls, ceilings or roof takes place only in a factory.

3.2. Basic features of the selected energy saving construction

The wooden energy efficient construction is possible thanks to the relatively light weight and modular structure of wooden houses – reconstruction of the attic, construction of an additional floor, removing walls or only modernization that can be carried out simply and practically. The wooden structures offered by Tadeks Fertig Haus enterprise shorten the life of the expansion. Heavy prefabricated wooden elements are created in accordance with the norms and principles of the Polish construction law. However, it is supported by an additional insulation (which is offered by the company Tadeks Fertig Haus as a standard). Energy efficient houses which are based on thoughtful design need 2–3 times less energy than houses built in the traditional way, while providing its users with comfortable living conditions. It is due to the fact that the prefabricated wall of the house is filled in its entirety with an insulator of high thermal parameters. Thermal insulation baffles, determined by the external heat transfer coefficient of partition U [W/m^{2}K], determine how much heat passes through 1 m² within one second at the temperature difference on both sides equal to 1° Celsius. The heat demand of buildings is expressed by the seasonal coefficient of heat demand (EA). In houses that meet the applicable standards of standard EA, it equals approximately 120 kWh/m^{2}a, while the seasonal heat demand for energy-efficient houses ranges between 15–70 kWh/m^2 per year. The analyzed company provides customers with clean and energy efficient wooden houses that combine traditional architectural features with modern technological achievements in the field of construction, which was confirmed by the Technological Certificate DIN-1052 obtained in 1998 and awarded by the MPA LGA Institute in Nuremberg/Germany. While respecting the rigorous rules of technical design and the use of high quality materials, including selected wood KVH and BSH constructions, wooden energy efficient houses provided by the analyzed enterprise are products that meet all European standards. Thermal parameters (heat transfer coefficient $U = 0.15 – 0.07$ W/m^{2}K for the envelope) are synonymous with low energy requirements of our prefabricated houses ($E = 70 – 15$ kWh/m^{2}K).

The standard thickness of external walls in the technology applied by Tadeks Fertig Haus maintains $U = 0.13$ W/m^{2}K, which is only 32.5 cm, where a wall made in the traditional way is acceptable for about 45.0 cm (which greatly increases the cost of house construction and minimizes internal space). The components of the external wall structure – prefabricated structure components include: the insulation wool of ISOVER SUPER-MATA (150 mm λ – 0,033), building board OSB or MFP ECO (12 mm), plasterboard or gypsum fibber (12,5 mm), wooden construction KVH and BSH (60 × 140 mm), vapour barrier stabilized ISOVER STOPAIR 0,60 g/(m^2 (24 h), construction board OSB or MFP ECO (12 mm), graphite styrofoam EPS (100 mm λ – 0,033), grid plaster facade, silicate plaster CERESIT/CAPAROL and plaster facade.

4. Conclusion – the newest technological achievement in the building energy efficiency

The analysis of innovative technologies applied in energy efficient buildings shown several different technical and design solutions. There are other technologies that can affects the final energy efficiency level of the wooden construction.

Tadeks Fertig Haus, as one of the few companies in Poland, applies one of the most modern technology – SIPs (Structural Insulated Panels). The SIP technology consists of three-part panels including two portions arranged outside the OSB or MFP and a polyurethane foam layer forming a core wall. Production materials are carefully selected and the whole thing is based on a prefabricated wooden structure that is made directly in our factory. Ecological character and energy savings are the reasons why the SIP technology is becoming increasingly popular and is gaining wider groups of supporters. The properties and technology of structural panel system provide high resistance to fire or water and the advanced technology and the "dry" method of production and assembly eliminate all kinds of insects, rodents and fungi. The main advantages of SIPs are the following: low production, construction and maintenance costs, short lead time, high level of noise suppression, several times higher rate (about 66%) of energy efficiency than in houses built in the old-fashioned way. Walls in the SIP technology can support a load of 3 tons in 30 cm of construction. The SIP technology is recommended in order to obtain high efficiency, high structural resistance and reduce the costs of heating, cooling and ventilation.

Acknowledgements: *I wish to thank Tadeks Fertig Haus for the information materials on the used technology.*

References

[1] Bekas J., *Ile domów drewnianych buduje 750 firm?*, Gazeta Przemysłu Drzewnego, **4** (207), 2014, 35.

[2] Borkowski S., Stasiak-Betlejewska R., *Analysis of Wooden House Construction Costs in the Chosen Company*, Proc. of the 4th International Conference on Contemporary Problems in Architecture and Construction. Sustainable Building Industry of the Future, September 24–27, 2012, Czestochowa, Poland. Vol. 2., Sekcja Wydawnictw Wydziału Zarządzania Politechniki Częstochowskiej, Częstochowa, Politechnika Częstochowska, 2012, 515-520.

[3] *Report Poland's 10 years in the EU*, CEED Institute, Warsaw 2014.

[4] Kasperkiewicz K., *Wybrane zagadnienia oceny i projektowania energooszczędnych budynków mieszkalnych*, Prace Instytutu Techniki Budowlanej, **2** (134), 2005, 23-37.

[5] Płaziak M., *Technologia tanich domów energooszczędnych jako odpowiedź na kryzys w budownictwie mieszkaniowym*, Przedsiębiorczość–Edukacja, **9**, 2013, 214-226.

[6] Stasiak-Betlejewska R., *Innovative Level in the Wooden House Constructions*, [in:] *Majska konferencija o strategijskom menadzmentu*, Studentski simpozijum o strategijskom menadzmentu. Zbornik izvoda radova, 25–27 May 2012, Bor, Serbia, Univerzitet u Beogradu, Tehnicki fakultet u Boru, Odsek za menadzment, 2012, 32-39.

[7] *Timothy Oulton i jego kopuła z prefabrykatów drewnianych*, http://okraglemiasteczko.net/blog/timothy-oulton-i-jego-kopula-z-prefabrykatow-drewnianych/ [date of acc. 26.06.2016].