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Mirosława GÓRECKA, Marek CHALECKI, Gabriela RUTKOWSKA

Katedra Inżynierii Budowlanej, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie
Department of Civil Engineering, Warsaw University of Life Sciences – SGGW

Wooden skeleton constructions formerly and nowadays in Poland
Drewniane konstrukcje szkieletowe dawniej i dziś w Polsce

Key words: building construction, post-and-beam construction, light wooden skeleton
Słowa kluczowe: budownictwo, konstrukcja ryglowa, lekki szkielet drewniany

Introduction

A skeleton construction is an object structure containing of a row of vertical posts which are connected to each other by spandrel beams to make them stiffer. The building stability and strength in such solution is determined by a wooden skeleton. Its filling constitutes mainly an insulation (thermal or acoustic) of compartments, but in some extent plays also static functions – it carries its own mass and transfers horizontal forces at the skeleton (Mrozek, 1996).

The traditions of the wooden skeleton building construction in Poland last invariably from the most ancient to the present times. Its beginnings, connected to the post-and-beam construction, are dated to the end of Middle Ages (Kopkowicz, 1958; Pokropek, 1976). Many terms occur to describe the post-and-beam construction in the literature dealing with wooden building constructions. It is called skeleton construction (Polish *konstrukcja szkieletowa*) (Kopkowicz, 1958), timber framing (Polish *mur pruski*) (Żenczykowski, 1967; Mrozek, 1996; Nitka, 2010), wattle-and-daub construction (Polish *szachulec, fachówka* – from the German *Fachwerk*) (Dulewicz, 1992). This diverse nomenclature occurring in the literature is justified first of all by the ways of filling of free spaces existing within the wooden skeleton. The term timber framing is characteristic for the brick filling, whereas the term wattle and daub – for clay and straw or clay and reed filling (Tłoczek, 1980; Adamczewski, 2004; Soja i Tkacz-Laskowska, 2009). Definitions occurring in the accessible literature unambiguously determine the idea of the post-and-beam construction – they are consistent in its characterization. Mielczarek writes that the houses basing on the post-and-beam construction are made of stiffly joined posts, spandrel beams and angle struts and an insulating material is placed between them. Carrying elements are joined with a ground beam at the bottom and with a girt at the top. Joints of the construction elements are made according the rules of carpentry, usually with mortise and tenon (Mielczarek, 2001). The similar characteristic is given by Michałowski (2011). To sum up, the skeleton of a post-and--beam construction contains of the basic elements as ground beams, posts spandrel beams, angle struts and girts.

The post-and-beam construction has its regional variations, as the Upper Lusatian type house (Polish *dom przysłupowy*, German *Umgebindehaus*) or canopy house (Polish *dom podcieniowy*, German *Vorlaubenhaus*).

In the literature dealing with the wooden building construction, a beginning of the history of the Upper Lusatian type house is dated mainly at the 17th century (Adamczewski, 2004; Gaczkowska, 2011). Gaczkowska writes about the first Polish constructions of this type from the 15th century, but it is sure that the peak development of such constructions falls only on the 19th century because the prevailing part of the Upper Lusatian type houses which survived in Poland up to now comes exactly from this period. Examples of the realization of the Upper Lusatian type houses exist in the whole country but their the highest quantity can be found in Lower Silesia. The Upper Lusatian type house consists of a living quarter built in a log house construction, utility rooms built of stone and a storey built as post-and-beam construction supported by posts adjoining to the walls and constituting a construction which is independent on the ground floor.

The term of canopy house has to be understood as a building with an adjoined, not encased part, covered with the same roof as the house; this part can be a protection of an entry, communication porch, workplace or access road (Tłoczek, 1980). It constitutes an architectural form where a compartment on a storey adjoins to a side or gable wall and is supported at the bottom on posts. A one-storey canopy house could be entirely made as a post-and-beam construction (timber framing or wattle-and--daub), as a log house or post-and-plank construction. Big double-storey canopy houses are in turn characterized by a ground floor made of brick or as the post-and-beam construction as well as a storey as the post-and-beam construction. Nowadays the most known canopy houses, preserved in good condition, occur in Żuławy and Warmia.

The beginnings of the modern skeleton constructions in Poland are dated to the end of 1970s. A group of men fascinated by the light skeleton constructions in the USA and Canada started to popularize this type of buildings' realization in Poland. In 1980s and 1990s, this technology was introduced on a larger scale. The modern skeleton constructions include:

– light wooden skeleton constructions, so-called Canadian or American skeleton, as well as a prefabricated skeleton commonly known as ready-built house, Swedish or Finnish house,
– modernized post-and-beam construction alluding to traditional solutions.

The Canadian skeleton is a rib system constructed of linear composing elements as boards or balks, directly on a construction site. Individual parts of the construction are joined by nails or metal joints into characteristic construction frames (Buczkowski, 2009). Two types of the rib systems are distinguished: platform and balloon construction. The unquestionable feature of the Canadian houses is their short montage time, nowadays amounting around three months (Nitka, 2010; Kaczkowska, 2012).

The prefabricated house is defined in the accessible literature as a house mounted on a building lot of prefabricated elements which had been prepared previously in a factory (Buczkowski, 2009; Nitka, 2010; Kaczkowska, 2012). Depending on a degree of prefabrication, three types of prefabrication systems can be distinguished:

– open prefabrication,
– partly closed prefabrication/closed prefabrication,
– closed prefabrication/fully closed prefabrication.

The open prefabrication consists in the factory assembly of a skeleton of walls, roof and ceilings as well as external sheathing made of wood-based plates with increased moisture resistance. Remaining works are carried out on a construction site. The partly closed prefabrication/closed prefabrication consists in the factory assembly of a skeleton of walls, roof, ceilings and thermal insulation as well as external and internal sheathing. Remaining works are carried out on a construction site. The realization of a house to a building shell lasts over 10 days in this prefabrication system. The closed prefabrication/fully closed prefabrication is a very advanced prefabrication system. It consists in the factory assembly of ready walls with built-in windows, doors and necessary installations. Preliminary finishing works are also carried out. The realization of a house to a building shell lasts several days in this prefabrication system.

Nowadays more and more often the return to traditional solutions is observed. Despite these wooden houses are being built mainly in the light skeleton technology, the traditional post-and--beam construction also finds its supporters, though in a lesser degree. They discern its advantages – both functional and esthetic. The return to the post-and-beam constructions is noticeable in the regions where they originally were developed what proves a great attachment of the inhabitants of these regions to their history and tradition. The post-and-beam constructions modernized in our days are designed of elements having smaller cross sections and with increased spans between the posts. Such change is possible due to the application of mechanic joints instead of traditional carpentry joints (Romanow, 2008). In the currently erected post-and-beam houses, the formerly applied straw and clay or brick filling is usually replaced by mineral wool, backfill or another insulation material and the walls are usually planked on both sides.

However, the wooden skeleton combined with clay has become popular and is developed in modern technologies in the countries of the Northern Europe. The buildings erected in these technologies come into existence in Scandinavia, Denmark, Belgium, France and especially in Germany. Already in the 1980s a lot of single-storey and multi-storey individual houses were erected in Darmstadt and Mannheim as wooden constructions filled with clay and straw. At the same time it must be emphasized that a part of the Polish architects (i.a. M. Hyła and D. Kupiec-Hyła), basing on the known technologies of clay building, being applied for ages, worked out their original constructive solutions, adapted to the binding requirements on energy saving (Kupiec-Hyła, 2008). An example can be a skeleton construction technology with filling of wooden ceilings and skeleton walls with light clay, both in the form of blocks and as a mass casted in shuttering. Moreover, near Wrocław, in a small country settlement, established several houses realized in the technology of straw–clay blocks. The skeleton construction of round timbers was filled with the blocks produced on the spot from the raw materials acquired in the surroundings (Górecka, 2011).

An appropriate order of layers in external wall allows currently to reach the optimal overall heat transfer coefficient (*U*). In the countries of the Western Europe, especially in Germany, the houses erected in the technology of light prefabricated elements with the wooden skeleton often represent the standard of passive houses. They are set apart by the application of many solutions minimizing the energy consumption during exploitation. To obtain extremely small energy demand for interior heating (15 $kWh \cdot m^{-2} \cdot year^{-1}$) the basic requirements should be fulfilled, i.a. a good insulating power of external baffles with the overall heat transfer coefficient $U \leq 0.15\ W \cdot m^{-2} \cdot K^{-1}$, what means that the insulation with the thickness of 25––40 cm should be applied and there should not be thermal bridges in the construction. The application of building materials and products of high quality and having extremely favorable heat transfer coefficients in skeleton walls is thus of great importance (Górecka, 2011).

Research methodology

Taking into consideration the issues that have been taken up in the paper, two types of investigations were carried out – direct and indirect.

In the direct investigations, it was applied a method basing on a critical analysis of literature along with propositions of own conclusions. Simultaneously, some methodological assumptions were assumed beforehand whose intention was to define strict frames limiting the scope of the investigations. Those construction which came into existence already in the 16th century and became widespread in particular in the 19th century (post-and-beam construction along with its regional variations) have been called as ancient constructions. As the groundbreaking period between the historical and contemporary skeleton constructions the World War II has been assumed. The constructions which established in the end of the 1970s and to a larger extent started being applied in the 1980s and 1990s (light wooden skeleton – Canadian and prefabricated), have been called as modern ones.

In the direct investigations, a diagnostic survey was applied. The research material was enriched by the information obtained in free interviews with the informers (owners of current skeleton

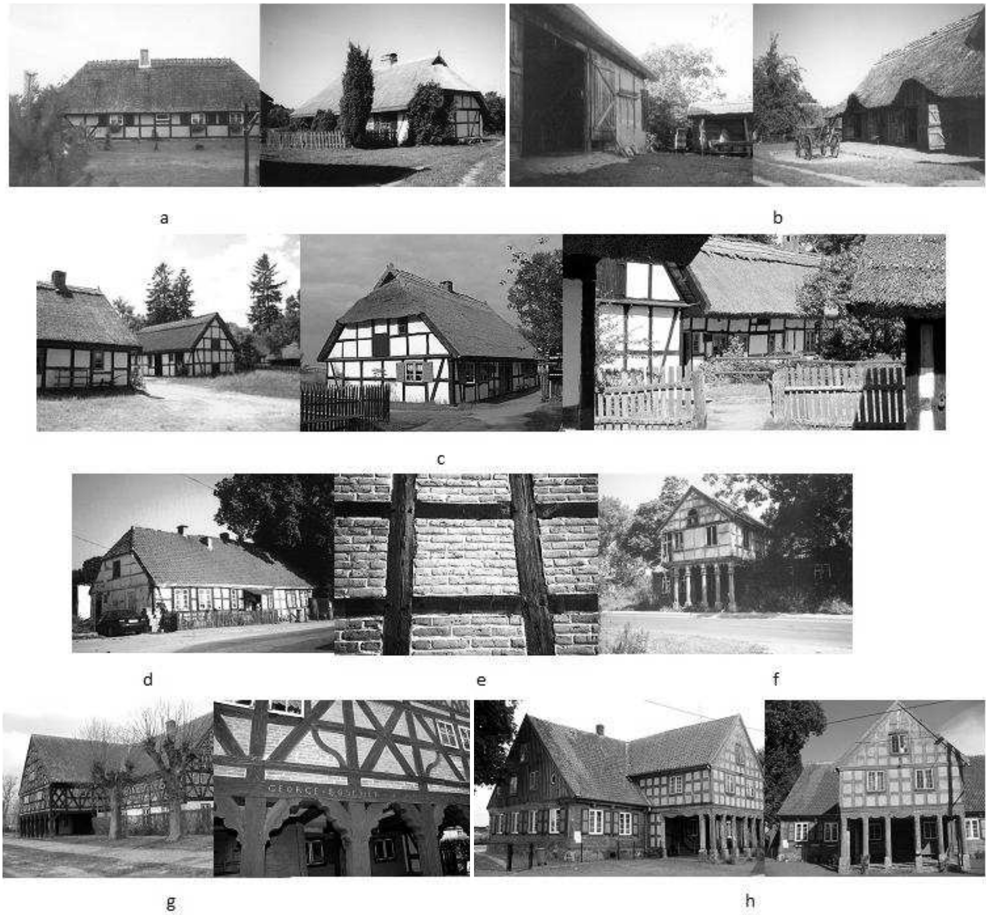

FIGURE 1. Selected examples of the ancient skeleton construction: a – Cassubian hut from 1802 rebuilt in 1984, Karwieńskie Błota; b – Cassubian hut, barn and cowshed in an antic rich farmer's farmstead, Nadole; c – farmstead buildings, Kluki; d – dwelling house, Smolno; e – a detail of a post-and-beam wall filled with ceramic brick in a farm building from the end of the 19th century, Darżlubie; f – canopy house from the beginning of the 19th century, designed by a Gdańsk architect Piotr Loewen, Żuławki, Warmia; g – canopy house from 1720, Trutnowy; h – canopy house from 1840, Nowa Kościelnica (photo by Mirosława Górecka)

RYSUNEK 1. Wybrane przykłady dawnych konstrukcji szkieletowych: a – chałupa kaszubska z 1802 roku odbudowana w 1984 roku, Karwieńskie Błota; b – chałupa kaszubska, stodoła i obora w zabytkowej zagrodzie gburskiej, Nadole; c – budynki w zagrodzie, Kluki; d – dom mieszkalny, Smolno; e – detal ściany ryglowej wypełnionej cegłą ceramiczną w budynku gospodarczym z końca XIX wieku, Darżlubie; f – dom podcieniowy z początku XIX wieku, zaprojektowany przez gdańskiego architekta Piotra Loewena, Żuławki na Warmii; g – dom z podcieniem z 1720 roku, Trutnowy; h – dom z podcieniem z 1840 roku, Nowa Kościelnica (fot. Mirosława Górecka)

FIGURE 2. Selected examples of modern skeleton constructions alluded to traditional post-and-beam solutions in Cassubian huts – dwelling houses, Karwieńskie Błota (photo by Mirosława Górecka)
RYSUNEK 2. Wybrane przykłady współczesnych konstrukcji szkieletowych nawiązujących do tradycyjnych rozwiązań ryglowych w chałupach kaszubskich, domy mieszkalne, Karwieńskie Błota (fot. Mirosława Górecka)

houses and inhabitants of the seaboard northern Cassubia and Żuławy). Additionally a thesis written under the author's supervision (Molenda, 2013) was used in this part of investigations. The seaboard Cassubia was chosen mainly due to the fact that there are open-air ethnographic museums, i.a. in the villages Kluki and Nadole, where the spatial layout of a 19th century village was reconstructed with preserved authentic post-and-beam huts. At the same time, a special attention must be paid at the buildings characterized by a regional post-and-beam construction, erected at the beginning of the 20th century in Karwieńskie Błota. It is one of few enclaves of the northern Cassubia where the architectural esthetics is being continued, which retains the advantages of the building constructions of this region with the application of traditional and modern material and constructive solutions. A special attention was paid particularly at: the sort of construction wood, the dimensions of cross sections of the separate elements, the ways of their joining, the distance between posts, the type of walls an way of their filing, the ornamentation and decorativeness. However, Żuławy was chosen due to the significant number of the preserved canopy houses. The attention was paid mainly at the multiplicity of decorations, the ways of joining of the elements as well as at the characteristic canopy – at the distance of the supporting posts, their quantity and the dimensions of their cross sections. The appropriate illustrative material (photographs) enabled to depict the issues presented in the paper (Figs 1, 2).

In the direct investigations, an empirical method was also applied; it allowed to make, in the main part of the paper, a comparative analysis of the selected elements of construction and architecture of the ancient and today's skeleton buildings, basing on the literature review and the own investigations.

Results

The literature review and own investigations enabled to present differences between the ancient and modern wooden skeleton constructions. Table presents the selected elements of solutions which served to carry out the comparative analysis.

The performed analysis of the ancient and modern wooden skeleton constructions showed many differences between those solutions. The most differences concern the dimensions of cross sections of the carrying elements and the distance between them, the way of their joining, the wall filling and the building foundation as well as the ornamentation and decorativeness.

In the ancient building solutions, the cross-section areas of the constructive elements were about 60% bigger than in the modern ones. Neither did exist the delimitation between the cross-section dimensions for external and internal walls, as it does nowadays. The distance between posts significantly reduced too – in the most extreme case, in the today's solutions, it is about 80% lower. Such evolution of the skeleton constructions was possible due to the introduction of mechanical joints instead of the carpentry ones. Such joints are easier to made compared to traditional solutions, they ensure higher stiffness of the joint and, first of all, allow to apply beams with significantly smaller cross sections, what was emphasized above.

Next significant feature differing the historical and today's skeleton constructions is a possibility of application of modern thermal insulating materials as the filling of the wall skeleton. It affected in a large extent the thermal features of the external components. In the beginning the skeleton was filled with a burnt brick or clay combined with straw or reed. Walls were erected as single-layered. The houses which establish today as light wooden skeleton constructions are usually low energy consuming and even passive houses with high thermal insulating power of the walls.

Differences can be also observed in the ornamentation and decorativeness. The houses erected till the World War II had the exposed skeleton construction what substantially characterized the building façades of those times. The canopy and Upper Lusatian type houses were characterized by effective layouts of angle braces and elaborately decorated posts. Today a wooden skeleton is usually covered with an external facing and internal sheathing.

The constructions being analyzed differ between each other also in a form of foundation and fire protection. Formerly the main form of foundation were stones laid in building's corners or under its whole projection, today this is mainly a concrete foundation. Today the wooden skeleton is protected against fire by various impregnants, formerly walls were merely plastered with clay. The erection time of modern wooden skeleton houses is short. It is equal around three months and in the case of a prefabricated building – even a couple of days. Sawn timber, used today to build skeleton houses, comes from coniferous trees, usually pines, not from deciduous trees as formerly, and it must fulfill appropriate requirements on mass humidity. Differences are stated also in reference to the area where the analyzed constructions were found. The houses with wooden skeleton are presently erected in the whole country, whereas formerly the predominant regions were: Wielkopolska, Lower Silesia, Pomerania, Warmia and Mazury.

Summary and conclusions

In the paper, a comparative analysis of ancient and modern skeleton wooden constructions was carried out. The indirect investigations performed with the use of literature review as well as the direct investigations basing on the

TABLE. Comparative analysis of ancient and modern wooden skeleton constructions (by Mirosława Górecka)

TABELA. Analiza porównawcza dawnych i współczesnych drewnianych konstrukcji szkieletowych (oprac. Mirosława Górecka)

Analyzed element Analizowany element		Ancient wooden skeleton constructions Dawne drewniane konstrukcje szkieletowe	Modern wooden skeleton constructions Współczesne drewniane konstrukcje szkieletowe			
Building timber sort		originally oak wood, from second half of the 19^{th} century pine wood	wood of conifers – pine, fir, spruce			
Cross-section dimensions of construction elements [cm]	spandrel beams	10 × 12–18×18	external wall	4 × 15	internal wall	4 × 10
	posts	13 × 13–21×21		3,8 × 14, 4 × 15		3,8 × 8,9, 4 × 10
	ground beam	12 × 14–21×23		3,8 × 14, 4 × 15		3,8 × 8,9, 4 × 15
	girt	12 × 14–21×23		3,8 × 14, 4 × 15		3,8 × 8,9, 4 × 15
	angle struts	12 × 12–21×21		2,2 × 12, 3,8 × 14		3,8 × 8,9, 4 × 15
Distance between posts [m]		0.8–1.0, 1.0–2.0	0.4 or 0.6			
Thickness of external walls [cm]		13–21	14, 17, 18			
Foundation type		originally stones laid under the building's corners or joined with clay and laid under its whole projection; at the end of 19^{th} century and beginning of the 20^{th} century – shallow stone or brick underpinnings	concrete foundation walls, concrete foundation framework under the posts			
Wall filling		originally clay combined with straw, hay or reed; at the end of 19^{th} century and beginning of the 20^{th} century – burnt brick	thermal insulation in form of mineral wool, wood wool, glass wool or cellulose fibers, Styrofoam; occasionally clay combined with straw (clay and clay–straw blocks)			
Wall type		single-layered	multi-layered – external facing, wind insulation, external sheathing, thermal insulation, vapour barrier, internal sheathing			
Joining of construction elements		carpentry joints: – French lock – mortise and tenon – dado joint	mechanical joints: – nails – metal sheets – angled, T-shaped, spiked – toothed rings			
Fire protection means		plastering of buildings with clay	impregnation with anti-fire agents, application of plaster and cardboard plates for external sheathing of baffles			

Thermal insulation condition for external walls	not fulfilled	fulfilled, U <0.25
Degree of prefabrication	no prefabrication	open prefabrication, partly closed prefabrication, closed prefabrication
Construction time	no information	light Canadian skeleton – around three months, light prefabricated skeleton – several days
Requirements on sawn bimber humidity	no information	mass humidity below 20% (the best 16–18%)
Ornamentation and decorative-ness	– clearly exposed truss – picturesque drawing made by the layout of separate wall elements, rich ornamentation of posts in canopy houses – elaborate ornamentation of posts and cornices in grand canopy houses – effective layout of angle braces in canopy and Upper Lusatian houses	very rarely met
Region of existence	Wielkopolska, Lower Silesia, Pomerania, Warmia, Mazury	the entire Poland

empirical method and diagnostic survey showed the changes to which the wooden skeleton construction was subjected over the centuries. As the most important differences between the historical and modern constructions were recognized:

– significantly smaller cross-section areas and reduced distances between the elements in the modern buildings,
– mechanical joints being applied nowadays instead of traditional carpentry joints,
– a wooden skeleton exhibited in the ancient constructions of the wooden skeleton constituting a decoration of the building, unlike the modern solutions with the skeleton covered with internal sheathing and external facing,
– high thermal insulating power of external walls of currently erected buildings,
– different ways of wall filling,
– big possibilities of fire protection in the modern constructions,
– short construction time of the modern skeleton houses.

The performed analysis proved that numerous differences exist between the ancient and modern wooden skeleton constructions. It can be concluded that they arise mainly due to the development of new technologies, constant improvement of building materials as well as evolving laws and directives whose aim is to attain as high material savings as possible with as good insulation properties of buildings as possible.

Nowadays the wooden skeleton constructions constitutes about 6% of all one-family constructions in Poland (Nitka, 2012). However, one should hope that in the immediate future a rise of its popularity will come. The short construction time and mainly the high thermal insulating power weighs in favor of such solutions.

References

Adamczewski, J. (2004). *Perły architektury drewnianej*. Katowice: Videograf II.

Buczkowski, W. (2009). *Budownictwo ogólne.* Tom 4. *Konstrukcje budynków.* Warszawa: Arkady.

Dulewicz, A. (1992). *Encyklopedia architektury*. Warszawa: Wydawnictwo Artystyczne i Filmowe.

Gaczkowska, A. (2011). Powrót do tożsamości. Zmiany stosunku mieszkańców do architektury przysłupowej na terenie polskich Łużyc. *Zeszyty Naukowe Politechniki Poznańskiej Architektura i Urbanistyka, 23,* 83-89.

Górecka, M. (2011). *Kształtowanie architektoniczne niskoenergochłonnego domu wiejskiego.* Warszawa: Wyd. SGGW.

Kaczkowska, A. (2012). *Technologia budowy domów z drewna*. Krosno: KaBe.

Kopkowicz, F. (1958). *Ciesielstwo Polskie*. Warszawa: Arkady.

Kupiec-Hyła, D. (2008). Bliżej natury – zrównoważone budownictwo mieszkaniowe z gliny niepalonej. *Zeszyty Naukowe Politechniki Rzeszowskiej, 47,* 225-230.

Michnowski, Z. (1995). *Buduje taniej. Książka dla prywatnego inwestora*. Warszawa: Arkady.

Mielczarek, Z. (2001). *Nowoczesne konstrukcje w budownictwie ogólnym*. Warszawa: Arkady.

Molenda, A. (2013). *Analiza porównawcza drewnianych konstrukcji szkieletowych dawniej i dziś*. (praca magisterska). Warszawa: Szkoła Główna Gospodarstwa Wiejskiego w Warszawie.

Mrozek, W. (1996). *Podstawy budownictwa i konstrukcji budowlanych.* Część I. *Budownictwo ogólne.* Białystok: Wydawnictwo Politechniki Białostockiej.

Nitka, W. (2010). *Mój dom z drewna*. Warszawa: Centrum Informacyjne Lasów Państwowych.

Nitka, W. (2012). Podstawowe wymagania dla drewnianego budownictwa szkieletowego. *Inżynier Budownictwa, 05,* 81-85.

Pokropek, M. (1976). *Budownictwo Ludowe w Polsce*. Warszawa: Ludowa Spółdzielnia Wydawnicza.

Romanow, J. (2008). Budownictwo ryglowe. Kunszt i tradycja we współczesności. *Dachy 3*, 40-41.

Soja, H. i Tkacz-Laskowska, V. (2009). *Muzeum Wsi Słowińskiej w Klukach. Muzeum Pomorza Środkowego w Słupsku*. Kluki.

Tłoczek, I. (1980). *Polskie budownictwo drewniane*. Wrocław: Zakład Narodowy im. Ossolińskich.

Żenczykowski, W. (1967). *Budownictwo ogólne.* Tom III. Warszawa: Arkady.

Summary

Wooden skeleton constructions formerly and nowadays in Poland. The paper presents issues concerning former and contemporary wooden skeleton constructions. As the groundbreaking period between the historical and contemporary skeleton constructions, the World War II has been assumed. In the introduction, the constructions have been characterized basing on a literature review as well as direct investigations on selected Polish realizations. As one of originally appearing wooden skeleton constructions, the post-and-beam construction was rated with its regional variants, however as one of contemporary ones – the light wooden skeletons: Canadian and prefabricated. In the main part of the paper, a comparative analysis of former and contemporary solutions has been made; it showed a lot of differences resulting mainly from the technology development, continuous improvement of features of building materials and changing laws and directives.

Streszczenie

Drewniane konstrukcje szkieletowe dawniej i dziś w Polsce. Artykuł przedstawia problematykę związaną z dawnymi i współczesnymi drewnianymi konstrukcjami szkieletowymi. Za okres przełomowy między historycznym i obecnym budownictwem szkieletowym przyjęto II wojnę światową. Na wstępie scharakteryzowano konstrukcje na podstawie przeglądu literatury oraz badania bezpośrednie na wybranych polskich realizacjach. Do pierwotnie powstających drewnianych konstrukcji szkieletowych została zaliczona konstrukcja ryglowa wraz z jej regionalnymi odmianami, zaś do nowoczesnych – lekki szkielet drewniany: kanadyjski i prefabrykowany. W zasadniczej części artykułu dokonano analizy porównawczej dawnych i współczesnych rozwiązań, która wykazała wiele istotnych różnic wynikających przede wszystkim z rozwoju technologii, ciągłego ulepszania właściwości materiałów budowlanych oraz zmieniających się przepisów i wytycznych.

Authors' address:
Mirosława Górecka
Marek Chalecki
Gabriela Rutkowska
Wydział Budownictwa i Inżynierii Środowiska SGGW
Katedra Inżynierii Budowlanej
02-787 Warszawa, ul. Nowoursynowska 159, Poland
e-mail: miroslawa_gorecka@sggw.pl
marek_chalecki@sggw.pl
gabriela_rutkowska@sggw.pl