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A wooden house in the Holz100 technology as an example of a residential building

Aleksandra STACHERA [1] (*ORCID ID: 0000-0002-7424-8223*)
Dariusz ZYSK [2]
Mariusz OWCZAREK [1] (*ORCID ID: 0000-0003-3510-1664*)

[1] Faculty of Civil Engineering and Geodesy, Military University of Technology, 2 gen. Sylwestra Kaliskiego Street, 00-908 Warsaw, Poland
[2] Sole proprietorship - Dariusz Zysk
Corresponding author: aleksandra.stachera@wat.edu.pl

Abstract: The development of human civilization was and is now dependent on wood. Wood was used not only to build houses, fences and furniture, but also for heating in ancient times. Currently, wood is considered one of the basic sources of heating homes, it is also used in many industries. As part of the constant changes and development of construction, the technology of building houses only from wood was developed. Wood is a natural, healthy and fully renewable material. These houses are characterized by very good properties. The article describes a wooden house which is an example of a building made in the Holz100 technology. Such a building can be built with relatively little effort, cost and workmanship. Characteristic construction solutions and building physics solutions used in the building were presented. The object can be an example of sustainable construction, because wood is a widely available raw material and completely reproducible by nature, and its utilization does not disturb the balance of the ecosystem. Used for the construction of houses, it creates a unique microclimate inside the building, difficult to obtain in other technologies.

Key words: sustainable construction, wooden house, Thoma technology.

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1. Introduction

In the era of continuous technological development, many people dream of having their own house in the countryside. This is due to the desire to maintain health and general well-being. Therefore, the choice of a building material that does not harm health is so important, [1].

The beginning of the rapid development of building materials technology can be dated back to the 1970s. However, since then, a constantly growing number of health problems can be noticed, the causes of which can be found in the immediate living environment of man. Building materials and furniture can release toxic substances for many years. They are considered a potential cause of allergies and other diseases. The interaction of fume-releasing plastics, metals, solvents, adhesives and other chemicals on our health continues to challenge physicians and scientists [1]. Wood is a gift of nature. It is a material known as an element of nature, fuel or as a material for making various things. We owe the ability to use wood to the knowledge passed down from generation to generation. The possibilities of wood technologies really have no limits, it is only a matter of imagination of each person, rule and standard have no place here.

There are many technologies for the construction of wooden houses, [2], they can be roughly divided into log, plank or mixed technologies.

1.1 Full log houses

The structure of solid log walls, also known as tie beam, corner or log structure, consists of horizontally arranged wooden logs, which are connected in the corners by the so-called corners. The corners can be with an offset, i.e. a connection protruding beyond the outline of the building, or without an offset, [2].

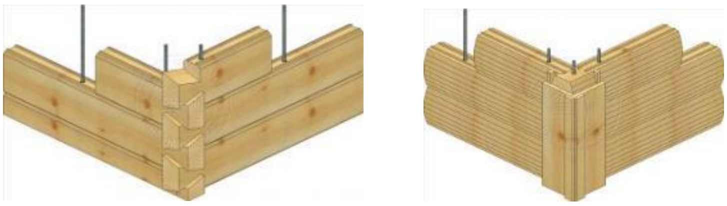

Fig. 1. Exemplary coals without remnants, [2].

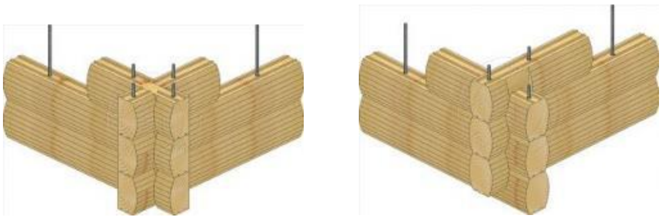

Fig. 2. Examples of coals with remnants, [2].

1.2 Insulated bales

A wall made in the technology of insulated logs usually has wooden logs from the outside, the thickness of which varies from 5 to 20 centimeters. The principle of their connection is the same as in the case of a solid log wall, but it requires additional thermal insulation to meet the insulation requirements of the partition. An additional insulating layer, which is made of glass wool, mineral wool or cellulose fibers, is used on the inside of the wall, and the thickness of the insulation depends on the thickness of the logs, [2].

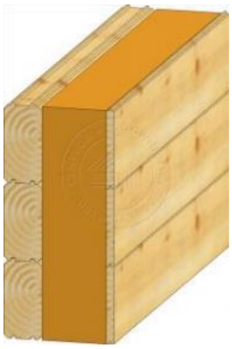

Fig. 3. Insulated log wall, [2].

1.3 Prefabricated logs

These logs are made of wooden cladding giving the appearance of a solid log, while inside there is a filling with insulating material, for example polyurethane foam, which creates a layer of thermal insulation over the entire height of the wall, [2].

1.4 Board buildings

This group includes buildings consisting of various board and post configurations. This creates wide possibilities of shaping the structure of partitions in such a building to obtain the required thermal insulation and water vapor permeability, even without the use of typically insulating layers, [2].

In 1990, the Austrian forester Erwin Thoma founded the Thoma company dealing with the construction of wooden houses, [1].

The company's goal is to build the healthiest homes. No harmful chemicals or adhesives are used during construction. These houses are built of mechanically joined lunar wood - wood at its best, [1].

The basis for proper harvesting of wood is knowledge about what time of the year we can and should harvest it. Another important guideline is also the appropriate age of the felled wood. These recommendations are very important and should not be changed. Currently, unfortunately, tree felling is performed all year round, without restrictions, bypassing the previously presented rules, [1].

Studies on the properties of lunar wood were described in their publication by Kownacki D. and Błaszczyński T., [3]. Wood intended for construction should be harvested in the winter and in the phase of the waning moon. Then this material is characterized by higher strength, lower tendency to crack during drying and higher resistance to insects and fungi, [3].

Basically, the walls of the Holz100 house are erected in the same way as any glued wooden elements. The system of layers of boards arranged in a cross and diagonal manner creates one compact structural system. The breakthrough solution used in the Thoma technology is the fastening material: only wooden dowels are used, [1].

Vertical and horizontal boards and square timber are arranged to form compact building elements without any gaps. A carefully designed grid of wooden pins goes through successive layers along the entire thickness of the wall. The pins in a new place absorb the residual moisture of the wood and swell, joining the individual parts into one massive, durable entity, [1].

The Holz100 system fits well into the requirements of building ecology. Houses in this system are made of 100% renewable raw materials and use modern technological achievements, [1].

2. Sustainable construction

The construction market consumes about 40% of energy in the European Union, [4]. Therefore, a multi-parameter approach was developed to describe the building properties described in Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings, known as EPBD (Energy Performance Buildings Directive), [5,6].

Sustainable construction, combines the three pillars of sustainable development, in a cost-effective and environmentally friendly way and ensures a healthy microclimate inside the building and positively affects the productivity of users, [7].

Sustainable construction includes care for the natural environment and economical management of raw materials throughout the construction cycle, [7].

The most important features of sustainable construction include, [8]:

- efficient use of resources, especially non-renewable energy and water;
- ensuring a healthy and comfortable environment for building users;
- responsibility towards the surroundings and location of the building;
- flexibility and the possibility of re-adaptation of the building as well as installations and devices in the building as a way to protect resources and save money;
- the use of building management systems that monitor and control devices and installations in order to minimize the consumption of energy and other resources;
- minimizing the amount of waste produced and recycling;
- use of environmentally friendly materials for construction, i.e. meeting the min. one of the criteria:
a. made of recycled materials, agricultural waste,
b. natural resources are not exploited in their production,
c. the negative impact on the environment is minimized during their production, destruction or repair,
d. their production saves energy and water,
e. contribute to a healthy and safe indoor environment,
f. locally produced;
- avoidance of toxic and other harmful emissions.

International organizations for the assessment of sustainable buildings have introduced special, multi-criteria ecological certification systems. The most popular are: American LEED (Leadership in Energy and Environmental Design), British BREEAM (Building Research Establishment Environmental Assessment Method) and German DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), [9].

3. Case Study

In Poland, in the town of Otwock, one of the co-authors, a carpenter by profession, inspired by the achievements of generations on wood processing and the technology initiated by Mr. Erwin Thom, after exploring the theoretical knowledge of this technology, decided to build a wooden house himself within 2 years. At the beginning, the contractor obtained a large amount of information on all the details related to the construction of the house using this technology. In the life of the contractor, the construction of this house is the fourteenth repetition of building a wooden house, but the first in this technology.

Thanks to his experience and practical knowledge, the contractor builds the house alone, and thus prepares all the elements for building the house himself. Building in this way extends the completion time, but you have the satisfaction that the house is the result of your own work without the participation of others. A lot of time needs to be spent on processing the material, e.g. you need to make double-sided grooved boards that will be used to build external and internal walls.

3.1. General description of the building

The building was designed as a single-storey detached single-family house erected in wooden technology with external dimensions of 13,50 m length and 9,30 m width. The ridge height will be 6,58 m. usable area will be about 100 m^2.

The next part of the article describes the further steps in the construction of this building, and thus the technological details.

3.2. Storage of construction material

The wood used for the construction of this house is not dried in the kiln, but outdoors (fig. 4, 5, 6, 7, 8). During drying, the wood is arranged in the east-west direction.

Fig. 4, 5, 6, 7, 8. Wood during drying (own photos).

3.3. Foundation of the building

First, the foundation was made in the form of concrete piles with a height of 90 cm. The next step was to make a tent to protect the house under construction from the weather. The next stage was the execution of a concrete ring beam measuring 9.30 m by 13.50 m and 30 cm thick on previously made concrete piles. In the surrounding wreath, 160 mm ventilation holes were made for each wall, shown in the photo below (fig. 9).

Fig. 9. Ventilation hole (own photos).

The first layer of the board was made of boards with ribs every 60 cm, joined on the so-called dovetail (fig. 10.11).

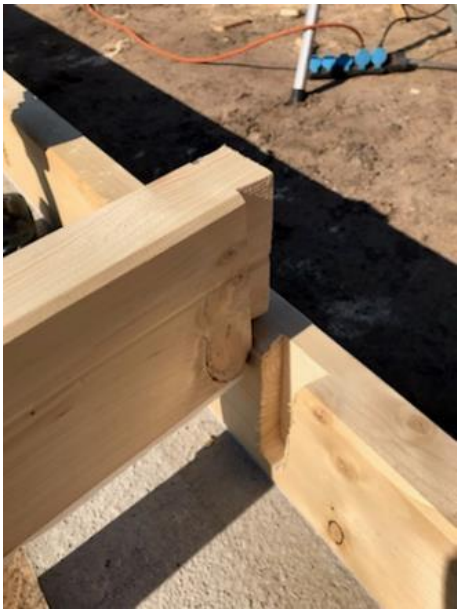

Fig. 10, 11. Dovetail connection in the plate (own photos).

The space between the ribs was lined with paper and covered with sawdust mixed with lime to scare away possible insects and termites. Then it was closed again with paper. The second stage of the slab consists of stacked solid wooden beams 10 cm high and 15 cm wide (fig. 12, 13, 14, 15).

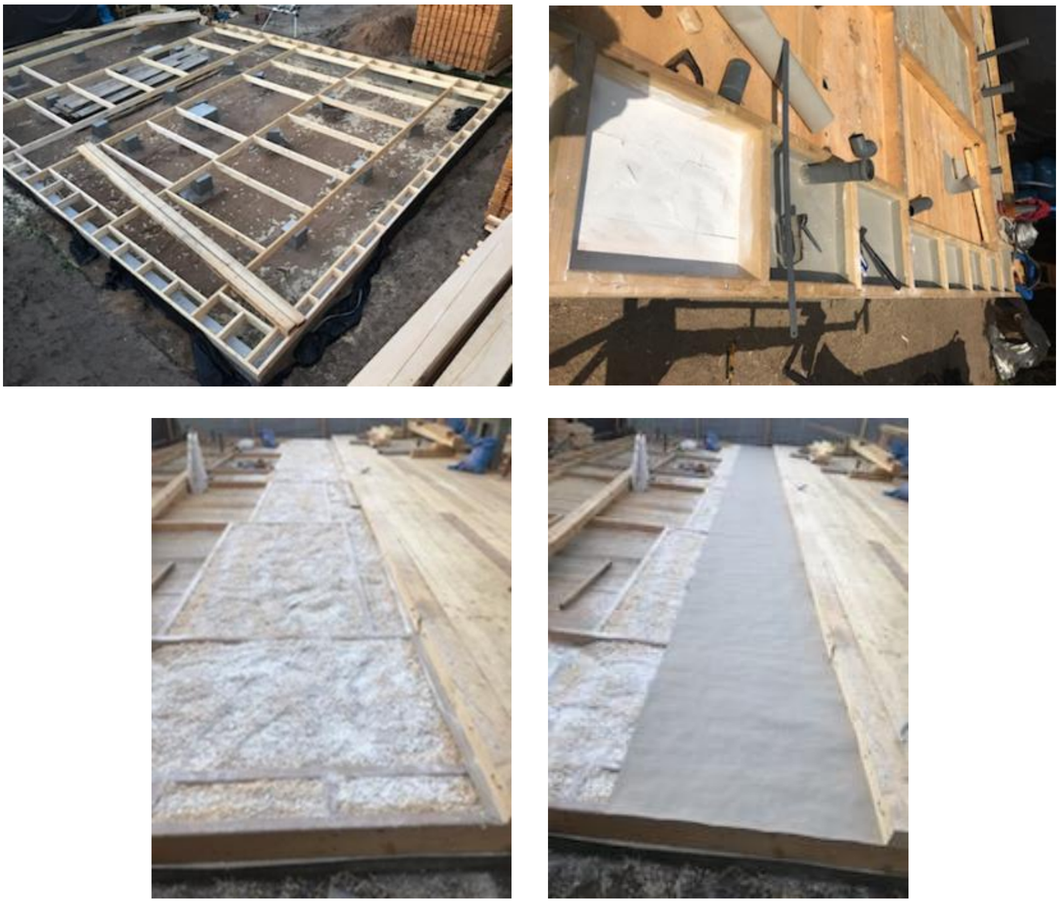

Fig. 12, 13, 14, 15. Filling the board with sawdust, covering it with paper and laying solid boards (own photos).

The next layer is made of 2 wooden boards 28 mm thick arranged diagonally. The last layer of the wooden board consists of stacked solid wooden beams 10 cm high and 15 cm wide (fig. 16, 17).

Fig. 16, 17. Laying layers of wooden board (own photos).

The second and last layer of the slab are the same wooden beams, but arranged alternately.

The thickness of the supporting wooden board is 40 cm. The layers of the board are joined with wooden or beech pins, driven alternately, once at an angle to the left and once at an angle to the right (fig. 18, 19).

In order to facilitate driving the pins in the Holz100 technology, a mixture of cottage cheese and lime is used, while in the analyzed house in Otwock, they are lubricated with beeswax.

Fig. 18, 19. Base plate and wooden support plate (own photos).

The contractor introduced a certain modification, made milling in the last layer of the load-bearing board beams 1 cm thick and the width of the load-bearing part of the wall (fig. 20).

Fig. 20. Supporting the outer wall on the load-bearing board (own photos).

3.4. Bearing walls

Ultimately, the external wall will have the following layers as shown in Fig. 21. The thickness of the external wall together with the façade boards will be 46 cm. The wall without the facade part will be 38 cm thick and will consist of 11 elements.

Fig. 21. Cross-section of the external wall (own photos).

The solid wood posts will be fastened with 5 layers of boards made of grooved wood from the outside and the inside. At this moment, the Contractor has made the following layers of external walls (fig. 22).

Fig. 22. The current advancement of the layers of the external wall (own photos).

The layers of the above wall are arranged as shown in the photos below (fig. 23, 24).

Fig. 23, 24. The method of laying the layers of the external wall (own photos).

The layers of the walls were joined together with dowels. Subsequent corrugated layers in relation to each other are arranged alternately with each other. The first layer is arranged diagonally, the next ones - the inner layers are rotated 45° to the right, and the outer ones to the left.

In this technology, no thermal insulation is made and the building is not heated from the inside. The wooden wall itself has very good insulating properties, according to tests carried out by Mr. Thoma, when the temperature outside is -10°C, the temperature inside the building is + 21°C. This allows you to stop using the heating source. Research also shows that exposure to minus temperatures from the outside can cool down a wall made in this technology to 0°C only after more than one month. Importantly, in the case of a brick wall with an insulating layer, it takes about 10 days, [10].

Walls made in this technology have a heat transfer coefficient equal to that of a wall made of 75 cm thick glued timber, which is confirmed by the results of research conducted by the Fraunhoffer Institute in Stuttgart and the Graz University of Technology [11]. A glued-timber wall with a thickness of 75 cm has a heat transfer coefficient U < 0,23 W/m^2/K.

3.5. Window openings

On the south side, large 5-pane windows with dimensions of 240 cm by 310 cm have been designed on the wall of the house. The windows on the other walls of the building were designed as minimal, measuring 60 cm by 120 cm. All windows in the house are non-openable.

Fig. 25, 26. The smallest windows in the building (own photos).

The Contractor plans to seal the window frame with the wall using his own method, using appropriate channels cut out to ensure the tightness of the window.

3.6. Connection of walls with ceiling and roof

The upper layer of the walls should be cut so that they form an even surface. The weight of the ceiling panel is designed to seal the contact between the wall and the ceiling, which is why it is so important to cut the walls very precisely. It is worth mentioning that wood never changes its dimension tangentially and this property ensures the tightness of the contact between the wall and the ceiling.

The planned roof covering will be a ceramic ventilated tile.

3.7. Installations in the building

At the design stage, the installations must be designed very precisely. Electrical installations are laid in conduits, which allows for non-invasive installation of wires or changing them if necessary.

Sanitary installations must be run in a lagging, as leakage is possible, and this may result in wood degradation. Ventilation in the building is advisable only in the bathroom and in the kitchen, where there is high humidity, in other rooms such an installation is not needed. Thanks to the fact that the wood is not varnished, it remains natural and, thanks to its structure, allows free air exchange.

3.8. Material parameters

Wooden elements for the walls and load-bearing board should have a moisture content of 12%. The dowels used to connect the elements should be made of wood with a moisture content of 6%. Thanks to this, a pin with such humidity, driven into wood with a moisture content of 12 - 14%, absorbs moisture and increases its volume. This ensures proper connection of the layers with each other.

The pins are made of the following elements and using the machine shown in the photos.

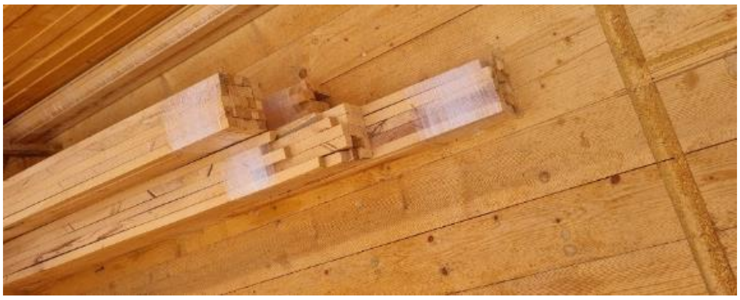

Fig. 27, 28, 29. Wood prepared for making dowels, a dowel making machine and already made dowels (own photos).

An interesting fact is the fire resistance of the house structure made in this way is high. The Holz100 system has obtained the highest fire safety certificate, [11]. It is worth mentioning that the Holz100 wall was tested at the Institute for Fire Protection Technology and Safety Research (IBS) in Linz, Austria. In a flame of 1000°C, after 90 minutes of continuous fire on the other side of the wall, a temperature increase of only 1.8°C was recorded [14].

Tests carried out by the Technical University of Graz determine the fire resistance class REI 120, [12]. The European Technical Approval ETA-13/0785 states that the elements intended for use as wall, roof and ceiling elements comply with the fire resistance class D-s2 and d0 for the PN-EN 13501-1 standard, [13].

Another interesting information is the fact that the walls made in this technology ensure the stopping of various types of waves, they shield EM waves, e.g. from 5G mobile telephony, to a depth of about 20 cm of the wall. Thereafter, the so-called a buffer that prevents this wave from entering the building, [10].

3.9. Work progress

The current progress of the works, estimated by the contractor at about 50%, is shown in the above photographs and was achieved after one year of construction. 170 m^3 of wood is needed to build such a house.

Table 1 summarizes the differences in the construction of the house between the Thoma technology and the house in Otwock.

Table 1. Comparison of Thoma's technology and the house in Otwock.

Item	Thom technology	House in Otwock
Outer wall	Thickness 36.5 cm	Thickness 38 cm
Pin lubricant	A mixture of cottage cheese with lime	Beeswax
Embedding of the external wall	Installation of the wall contour strip, the section of the strip is 5x5 cm	Milling in the wooden floor panel at a depth of 1 cm and a width of 10 cm is the thickness of the core

4. Summary

The described building is an example of a sustainable building. The concept of sustainable construction assumes that all stages of a building's life are taken into account, from its design, through use, to demolition and disposal of materials. It is worth noting that a building with a building area of 125,55 m^2 can be built by one person. Extensive experience in the field of carpentry work and qualifications are needed, it is not a building that can be built by every investor, however, the lack of the need to employ many people and equipment will reduce costs. The reinforced concrete foundation on piles is a stable base. After the construction is completed, research in the field of building physics should be carried out to check the presence of thermal bridges, the actual heat transfer coefficient through the partitions and the tightness of the building. The use of innovative walls with air gaps gives prospects for increased thermal insulation, confirmed by tests according to the authors of the Holz100 technology. The tests planned to be performed would make it possible to check how the modifications introduced by the Contractor affected the declared parameters of houses built in the Thoma technology.

The information presented above allows us to hope that the built house will be a fully safe living space.

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