Modern wood construction realised in CLT technology on the example of Bio-climatic Modular Unit

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Abstract. *The paper deals with the issues related to creating ecologically friendly space with the use of glued timber elements in CLT technology. The discussion is based on the example of a residential and commercial building. Cross laminated timber elements have very good technical properties. Timber construction is ecological and environmentally friendly. The elements are biodegradable and their production does not require much energy input. In addition to being widely available, timber does not need labour-intensive technological processes and generates low CO2 emissions. Cross laminated timber elements can be used to construct low-, medium- and high-rise buildings.*

Keywords: timber; building structures; CLT (Cross Laminated Timber)

Cross Laminated Timber (CLT) elements are large dimensional panels usually composed of three, five or seven layers of structural timber. The cross-laminated arrangement of layers ensures adequate dimensional stability, strength and stiffness. Production of elements in CLT technology requires timber with appropriate moisture content, strength and quality. The elements (boards) consist of longitudinal and transverse layers. In the case of wall elements, the longitudinal layers are arranged parallel to the force applied, while in floor and roof elements they are arranged parallel to the span. The longitudinal layers are usually made of wood of grade at least C24 and the transverse layers of at least C16 [1, 2, 4, 9].

Due to the high heat capacity of wood, CLT buildings provide an excellent barrier against the short-term effects of high external temperatures and adequately maintain the temperature during the short-term drop in external temperature. Cross-laminated timber elements have high load-bearing capacity, insulation and fire resistance at the level of 30, 60 or 90 min (in special cases also REI 120). They allow for designing and construction of energy-saving and passive buildings. In the process of manufacturing construction elements in the CLT technology, no harmful gases or substances are emitted, and the glue used for joining is free from dangerous elements. Moreover, wood is a natural store of carbon dioxide (1m3 of CLT wood stores 1-1.5 tonnes of CO2).It can be used locally and recycled [5 ÷ 8]. Walls in CLT technology do not require additional finishing treatments on the inside.

Wood as a natural material with anisotropic structure and diverse mechanical properties is easy to design and predictable once built into the structure [3, 10 ÷ 15]. By gluing the layers together at right angles, the panel in CLT technology achieves high stiffness in both directions. Glued laminated timber fits into the idea of sustainable construction. It can be used in combination with other materials, also in the case of the underground part of the building, where it is impossible to use a wooden structure. It has good acoustic and thermal parameters. Construction time is even a few days, depending on the complexity of the project. For the production of elements in the CLT technology PEEC or FSC certified wood is used. Cross-laminated timber is resistant to temperature, while the influence of humidity does not pose such a problem as in the case of old wooden structures. In a properly constructed CLT construction no sealing foil, wind or vapour barrier is required. During a fire, a carbon layer is formed on the surface of the wood, which means that it chars on contact with the fire and significantly delays the combustion process. Buildings using CLT technology are characterised by low structural weight and ease of reconstruction and modernisation.

Innovative cross-glued timber structures

Cross laminated timber elements can be used to build low-rise single-family houses as well as medium and high rise buildings. CLT technology enables shaping of various architectural forms and construction of original, interesting buildings with respect for ecological considerations.

The Bridge House realised in 2016 on a lake in Canada, with a usable area of 230 m2, shows the technical and architectural possibilities of CLT technology in designing and realising low-rise buildings. Mjøstårnet is an 18-storey mixed-use building in Norway that was completed in March 2019. It is named after Norway's largest lake. The structure is made of glued laminated timber. Officially, it is the tallest wooden building in the world (height 85.4 m). Its total area is approximately 11,300 m2. The building contains a hotel, flats, offices, common areas and a swimming pool hall. Another building, the 18-storey Brock Commons (opened in July 2017) serves as a dormitory for 404 students from the University of British Columbia Point Grey in Vancouver, Canada. It is the first wooden building in Canada to be constructed as part of the Wood Construction Demonstration Project. The facility promotes timber construction as a model for future years. With a volume of 2,233 m3, it uses an impressive amount of wood that stores 1,753 tonnes of carbon dioxide, avoiding 679 tonnes of greenhouse gas emissions. The cost of constructing such a building in Canada is comparable to a traditional concrete building. The building structure and façade were completed in just 66 days. The building is 53 metres high. It contains offices, conference spaces and on the ground floor there are service areas, leisure facilities and restaurants. Tree is a fourteen-storey building in Bergen, Norway, built between 2014 and 2015, designed to meet current and future social needs with a focus on efficiency and sustainability. The building is entirely made of cross-laminated timber. It has a height of 49 m.

Bioclimatic Modular Unit made of Cross Laminated Timber

An interesting attempt to use cross-laminated timber in the CLT technology in a residential and commercial concept building in the Praga-Południe district of Warsaw [16], in the aspect of pro-ecological considerations, is shown in Figures 1 and 2. The space of the building is a clamp connecting urban green-ecological areas. The building was divided into flexible functional zones, maintaining the balance between the natural environment and the built urban tissue. The structural layout allows flexible interior design. A constant part of the building is the communication core over its entire height. The shape of the building allows for the permeation of internal and external space. Unconventional energy sources in the form of photovoltaic panels, heat pumps and small wind turbines were used. Rational water management consists in the use of rainwater for watering greenery and the use of the so-called grey water cycle [5].

Fig. 1. Bioclimatic Modular Unit made of cross-laminated timber together with ecological open space - green corridor (źródło: A. Hajdenrajch).

Fig. 2. View of the Bio-climatic Modular Unit

The spatial layout of the building allows flexible use of the space depending on changing usage needs. The building includes areas for hydroponic cultivation, the so-called urban farms [5]. The main idea of the presented author's project is to create a place for solving local and global problems. It is an example of an experimental building and a well-known urban procedure of creating green ecological corridors. In order to understand the problems and needs of the place, it was necessary to conduct a thorough analysis and estimate the possibilities that the space and its users could offer. The choice of location was not accidental, as Warsaw is the largest and fastest growing centre, and therefore generates a lot of environmental damage. An attempt to exploit the potential of the Praga-Południe district was to connect existing green areas by creating an ecological corridor linking leisure locations. Important centres characteristic of the area under study are the Warszawa Wschodnia railway station and Skaryszewski Park. In the urban axis, a pedestrian and cyclist route has been created through the designed building, which is characterised by a nearly zero-emission impact on the environment. Among other things, it is equipped with energy-saving power supplies using alternative energy sources. It has been designed in a way that allows the layout of the space to be redesigned. Floors intended for offices can fulfil other functions, and commercial premises can be easily rebuilt. The same applies to the residential part and public facilities such as kindergartens. A small shopping arcade is planned in the building, where communication is designed in a way that allows access to the underground car park, where it is also possible to charge a car with electricity. The floor of the passage incorporates the historical existing pavement. The building meets the requirements of people with disabilities. The applied solutions are simple and intuitive. The interdisciplinary nature of the project is characterised by solving problems on a local and global scale in a comprehensive manner at the sociological level and meeting the needs of individual well-being. The conceptual design shows the direction to take in order to shape a sustainable environment [6].

Conclusions

Pre-project analyses on the optimum choice of building materials for the construction of the Bioclimatic Modular Unit showed that CLT glulam is highly advantageous due to:

- adequate dimensional stability, strength and stiffness;
- an excellent barrier against short-term exposure to high outside temperatures and due to temperature maintenance during a short-term drop in outside temperature;
- high load-bearing capacity, insulation and fire resistance;
- environmental aspects;
- walls using CLT technology can be manufactured in such a way that they do not require additional finishing on the inside.

Buildings made of wood using CLT technology form harmonised ecological complexes, which is an important feature of sustainable development of the built environment.

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