CROSS-LAMINATED TIMBER: TOWARDS A CONSISTENT STRUCTURAL INSULATED PANEL FOR PASSIVE BUILDINGS IN BELGIUM

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ABSTRACT: Nowadays, it is possible to build zero-energy houses or even positive energy buildings. Nevertheless, many incoherencies exist if we attach importance to the embodied energy of its constructions. The present paper lays on the logic of structural insulated panel which is used in many low-energy and passive houses and go further in order to reduce the global greenhouse gases emissions. For this purpose, cross-laminated timber is used instead of oriented strand board and the insulation used is made of wood wool. The structure, the technology and the thermal aspects are discussed as well as the fire resistance in order to show if its new product is economically and technically interesting. Results show that the embodied energy can be drastically reduced compared to the structural insulated panels. A wood consumption reduction of thirty percent can also be obtained compared to the classical cross-laminated timber construction.

KEYWORDS: Cross-laminated timber, embodied energy, passive house, timber construction, Structural insulated panel

1 INTRODUCTION

In the early 21st century, an international treaty leads to control and reduce emissions of greenhouse gases (GHG). In this context, Belgium would reduce by 7.5 percent its GHG. Laws has been edited to lead to construction of low-energy houses. Nowadays, it is possible to build zero-energy houses or even positive energy buildings. If it is possible to achieve these standards by different ways, some of them leans on a short term vision marked by many incoherencies with regard to the embodied energy and the objective of GHG reduction. The present paper lays on the logic of structural insulated panel (SIP) which is used in many low-energy houses and go further in order to reduce the global GHG emissions. For this purpose, cross-laminated timber (CLT) is used instead of oriented strand board (OSB) and the insulation used is made of wood wool.

2 STRUCTURAL INSULATED PANEL

SIP is a high performance building system composed of rigid foam plastic insulation glued between two structural skins. Its dimensions reach generally 2.4m by 2.75m, which represents the maximum dimension that can be moved without the use of crane or lift truck. These kinds of panels are able to bear loads for residential and commercial buildings and are used for walls, floors and roofs. It allows to build more quickly and is cost effective. Therefore, it tends to replace more and more traditional building techniques.

3 CROSS-LAMINATED TIMBER

The CLT has appeared in the industry in the 2000s. It is a panel composed of 3, 5 or 7 layers (sometimes more) of sawn timber. Every layers are crossed and consisting of small planks that are generally glued together [1,2]. The so created panel can have dimensions reaching 24m length and 3.5m wide, the thickness varying generally between 6 to 30cm. Elements are completely custom made by CNC machines and assembled to each other on site. The assemblies are generally made by screws and metal brackets. Plywood strips (Kerto) are sometimes used to connect panels in the same plane.

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4 EMBODIED ENERGY

Embodied energy represents the total energy that is needed throughout the material life. It takes into account the energy needed for the raw material extraction, the manufacture and the transport but also the decomposition or the destruction. Considering this aspect, it is possible to compare the effectiveness of materials with regard to the GES emissions. The embodied energy of SIP is very poor compared to that of wood-framed structures. Panels are glued to the insulation which makes difficult the recycling at the end of life cycle. Furthermore, the insulation used contains more than 3 times embodied energy than fiberglass. Develop a new panel to take advantage of the two methods would therefore be very interesting.

5 PROPOSITION OF A SIP WITH CLT

5.1 CONCEPT & MATERIALS

The principal disadvantages of the CLT concern the insulation and the volume of wood which is used. One solution that reduces these disagreements is studied at the University of Mons (BE). It consists in the creation of a kind of SIP made of two CLT panels and an insulation between them. Developing such a SIP accelerate the construction speed. The insulation can be blown or composed of semi-rigid panels, which allow the use of most eco-friendly materials. Assuming a good connection between the panels, the mechanical behaviour can be improved and therefore the thickness of the CLT panels can be reduced.

For this study, CLT panels with a thickness of about six centimetre are used. Self-tapping screws are used to connect the panels each other. Wood wool insulation is used between the panels. Its thermal conductivity is equal to about 0.04W/m.K as for fiberglass or rock wool. Its manufacture is simple and ecologic.

5.2 CHALLENGES

SIPs have a mechanical behaviour which can be compared with the I-beams. New SIP have to be provided with sufficient screws to be enough stiff and resist to shear forces. The screws can be positioned with different screwing angles, thereby facilitating the passage of efforts. The screw characteristics can be determined thanks to experimental tests and finite element models.

The connections of the new SIP product have to be studied precisely in order to respond to the problematic of air tightness and water tightness. A compromise have to be chosen between thermal efficiency and ease of assembly.

In Belgium, a house is considered passive when it respects three criteria [3]:

- The net energy need of the house should be below 15kWh/m²-year;
- The airtightness should be efficient. This criterion is controlled thanks to a blower door test which should be less than 0.6h⁻¹;
- The possibility for the house to be subjected to overheating is verified. If the house suffers an overheating less than 5 percent of the time and if the two firsts criteria are met, it is passive.

In addition to this, Belgian standards impose a value of thermal conduction of the wall lower than 0.15W/m².K and recommend a value of 0.10W/m².K. This value is supposed sufficient to validate easily the first criterion.

Others challenges will be discussed in the paper, as for example the acoustic comfort and the fire resistance.

5.3 EMBODIED ENERGY

The total embodied energy of the new SIP panel with two layers of CLT and 36cm of wood wool insulation is worth 645MJ/m² [4]. This value is done for a wall which is considered passive with a thermal conduction of 0.10W/m².K.

By the way of an example, the classical SIP of 11.5cm thick and with EPS insulation has a total embodied energy of 308 MJ/m² while is thermal conduction is 4 times higher.

6 CONCLUSION

Currently, the Belgian standards are increasingly hardened towards thermal considerations but they attach importance only to values of energy consumption for heating without looking at what happens before or after the using of the material. The present paper shows that it is possible to develop new construction methods which are more environmentally friendly, considering the embodied energy of the materials. A new SIP is proposed. It is composed of CLT panels, screws and wood wool insulation which allow an easy recycling at the end of the life product. Main aspects of the construction are discussed and show that this new mode of making can be reasonably developed at an in-depth study of each point.

REFERENCES