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Passivhaus Not-Residential Buildings with Wooden Structure

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Abstract: The definition of the different strategies of airtightness and diffusion of water vapor through the envelope acquire fundamental relevance when it comes to meeting the demand and comfort criteria for the Passivhaus Certification. Through a tour of three buildings built with different wooden structural systems, the different airtightness and water vapor diffusion strategies will be explained depending on the different structural systems used.

Key words: cross-laminated timber, passivhaus, air tightness, vapor diffusion

1. Introduction

The analysis and comparison of three buildings projected and constructed according to the criteria of the Passivhaus Standard, with panels of solid structure of cross-laminated and laminated timber, for tertiary or non-residential use, in Navarra (Spain), are intended. The aspects to analyze and compare are: the influence of the structural system in the definition of the thermal envelope of the building, the airtightness strategies, and the vapor diffusion strategies. As these are three buildings with very similar construction characteristics, the aim is to obtain a series of conclusions that help the designer when facing these types of buildings with the objetive of meeting the demand and comfort criteria required for Passivhaus Certification.

The three buildings to analyze are:

- Dotational Building in Mendillorri: 246 m2 SRE building for cultural tertiary use on one floor. Structure of CLT bearing walls and light covering of wooden beams, all on foundation beams and concrete slab. Passivhaus certified building in November 2017 (Fig. 1).
- Dotacional Building in Olloki: 288 m^2 SRE building for cultural tertiary use on one floor. CLT bearing wall structure and light wooden beam cover, all on a concrete foundation slab. Passivhaus certified building in May 2019 (Fig. 2).

Bortiri Refuge in Uztarroz: rehabilitation and expansion of existing building under Enerphit criteria for use of Mountain Refuge. Solid timber structure using laminated timber panels on walls and floors, on four floors high and an SRE of 208 m^2, in a high mountain setting. Work completed in July 2018 (Fig. 3).

Fig. 1 D. B. in Mendillorri.

Fig. 2 D. B. in Olloki.

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Fig. 3 Bortiri refuge.

2. Why in Wood?

The three buildings analyzed have one determining factor in common: their structure is made of wood, and it is visible to the interior in most of the building (Fig. 4). There are many arguments for undertaking a Passivhaus project with constructive or structural systems based on wood, from the purely naturalistic or "green" to the purely economic. Next, we try to synthesize this variety of arguments in 5 sentences:

Minimization of thermal bridges: the thermal and hygroscopic properties of the material itself decisively help to generate continuous envelopes where the presence of thermal bridges is minimized by the configuration of the structural system itself. For solutions based on structural panels, we have the advantage that the structural thickness will contribute a certain thermal inertia to the closings.

Industrialization: The industrialization of wood has spread throughout the construction scene with engineered timber products, providing precision and guarantee of correct execution in critical items such as airtightness and the elimination of thermal bridges, and giving a greater possibility of control both on project and on site.

Fig. 4 D. B. in Mendillorri.

Economy: Speed and ease of assembly are synonyms of timber construction. This lowers hiring costs achieving high productivity. The lightness of the solutions reduces the amount and scope of the auxiliary and transport resources, reducing costs for the builder and therefore for the developer.

Market: construction solutions based on wood-based structural systems optimize the thickness of the envelope, which results in a useful surface/built surface ratio that allows us to have more useful m^2 on less built surface for the same thermal performance of the envelope, resulting in a higher economic return on the operation for the developer.

Ecological construction: Passivhaus is a purely energy standard. Being this one of its great virtues, it could also be considered one of its weak points, due to a lack of ecological or green character, that other labels such as Minergie do contemplate in some of its variants. Wood as material complements the purely energetic component of the Passivhaus Certification with all its "green" nuances. Wooden constructions, both in their life cycle and as CO_2 sinks, are placed at the head of sustainable constructions (Fig. 5).

Finally, wood, if we give it the opportunity through its use in exposed wall structural systems, in addition to allowing and facilitating the execution of extremely energy-efficient buildings, is a material that allows us to create spaces and atmospheres with an environmental quality that guarantees and take the comfort and health of building users further (Fig. 6).

Fig. 5 D. B. in Olloki.

Fig. 6 Bortiri Refuge.

Fig. 7 D. B. in Mendillorri.

Fig. 8 D. B. in Olloki.

3. Airtightness Strategies

One of the prerequisites in the three buildings studied is that of being able to enjoy structural timber as an interior finish in most of the walls and floors of said buildings. This, in addition to increasing the environmental quality of the interiors by creating sensitively comfortable atmospheres, helps us to have interesting thermal inertia values despite being light constructions.

The biggest drawback of allowing structural timber to be exposed indoors is that our sealing strategies will always have to occur on the exterior faces of such structural walls (Fig. 7). When we project with wood, we will define all these strategies differently depending on the structural system with which we are working.

3.1 CLT Cross-Laminated Timber Panel Systems (Fig. 8)

The use of massiv wall systems made with cross-laminated timber panels a priori facilitates the implementation of the airtightness strategy, compared to bracing structural board systems. In contrast to the discretization of construction elements that occurs in light-frame systems, where each element has its function, the cross-laminated timber panels usually combines structural, airtightness and water vapor diffusion regulation functions, as it is usually placed indoors of the envelope, covered to the outside with insulation. Therefore, once the airtightness strategy has been chosen, we must take special care in the treatment of the joints between panels, and the different joints with other elements of the envelope, guaranteeing that the joints are durable over time.

In terms of airtightness, the biggest handicap of CLT panels is usually its thickness and composition. Extreme caution should be used with panels less than 12 cm thick, especially if they are made of three layers. The unavoidable perforations to which we will subject the CLT by fixing the different interior or exterior construction layers, as well as those necessary for transport, placement on site, and humidity measurement, can create airways between interior or exterior and the different layers of the wall, so that unwanted infiltrations are generated.

3.2 Panel Systems Based on Tongue and Groove Laminated Timber Profiles

An alternative to CLT panels are tonghe and groove laminated timber profiles. These profiles are tongue and groove laminated timber beams, which can be individually assembled or assembled to form larger panels or walls. In the cases studied, they have been used in the Bortiri Refuge to form the bearing three-dimensional structure, formed by walls and slabs. The structural concept is therefore very similar to that of CLT panels, with the exception that CLT can be understood as a bidirectional element within certain width-to-length relationships, and laminated panels are always unidirectional. Special attention must be paid to the calculation of dimensional losses in laminated timber due to variation of internal humidity, which will determine the evolution of the width of the pieces.

As for the airtightness, laminated timber panels presents some notable differences with respect to the CLT (Fig. 9). As it is usually assembled in the factory, the airtightness between profiles made on the factory bench guarantees optimal and controlled execution. On the other hand, being laminated timber elements, the perforations for fixations that can be made turn out to be less compromising than in the CLT panels formed by cross layers.

4. Vapor Diffusion Strategies

Contrary to social belief, the biggest enemy of wooden structures is not fire, but water. Both the direct entry of water, which is not the object of these reflections, as the pathologies caused by the humidity and interstitial condensations of the enclosures. When designing the airtightness strategies we must take into account the diffusion of water vapor, knowing that, if the humid and hot indoor air accesses colder areas of the building envelope, especially in the cold season, the water vapor in the air can condense, so that the insulating effect will be reduced and the body of the building will be damaged.

In the enclosures used in the analized buildings, the solutions with solid wood inside, with insulation and a ventilated façade on the outside, respond really well to the requirements of vapor diffusion, so the type of insulation used not being influential, having a minimum incidence in the global vapor diffusion of the element. However, complications arise when we apply fire regulations to tertiary or dotational buildings, specifically spanish regulation CTE DB-SI 1 and the requirements regarding Reaction to Fire of the construction elements. Solid wood, whether laminated or cross-laminated, facing the interior as it is being used in analized buildings, presents a reaction to fire D-s2, d0 lower than C-s2, d0 required by the spanish CTE. To comply with said regulations, it is therefore necessary to apply fire-retardant varnishes made from special resins. These technical varnishes withstand the action of fire, being flame resistant, guaranteeing a certificate of reaction to fire according to UNE-EN 13501-1 standard classified as B-s1, d0.

Fig. 9 Bortiri Refuge.

Despite the fact that in the technical data sheets of these varnishes it is usually said that they repel water and environmental humidity, and that they regulate the transpiration of the wood avoiding deformations, it is very difficult to obtain reliable values of the resistance factor to the diffusion of water vapor, commonly known as the μ factor, or thickness of the air layer equivalent to the diffusion of vapor, known as Sd value. That is reason why it becomes interesting in this type of buildings to have envelope surfaces in which we have the Sd value of the enclosure perfectly controlled so that, together with the action of mechanical ventilation in permanent operation, and the hygroscopic capabilities of the wood itself, we can guarantee that the vapor diffusion from the interior atmosphere can be done through these surfaces quickly.

Normally, using laminated or cross-laminated solid timber panels in inclined roofs is structurally disproportionate and inefficient, so the roof will be the wrapping enclosure in which we can often work and define the airtightness by de use of sheets with specific Sd values that, without compromising the good behavior of the component, they allow adequate vapor diffusion as a sink that collects the excess of vapor from the rest of the parts of the envelope of the building that have been compromised and have increased resistance to the passage of water vapor through fire-retardant varnishes.

Thus, in the analyzed buildings, vapor barriers and vapor brakes have been prescribed with vapor diffusion resistance values in accordance with the relative humidity peaks that are expected to occur depending on the different expected uses, always without compromising the correct functioning of each of the elements of the envelope.

5. Conclusions

It is evident that one of the key points when facing a Passivhaus building work is the airtightness and vapor diffusion. In the case of wooden structure constructions, they are even more important due to the risks of structurally severe pathologies that these buildings may suffer (Figs. 10 and Fig. 11). A correct choice of the constructive and structural system depending on the building use, together with adequate strategies of airtightness and diffusion of the overall vapor of the building, acquire special importance to achieve the objectives successfully. The knowledge of the specific rules, and the physics of the construction of the wooden structural systems by the technician or designer, are of vital importance in order to guarantee that the building will function for most of its useful life within the criteria of low energy demand and high comfort that the Passivhaus standard demands.

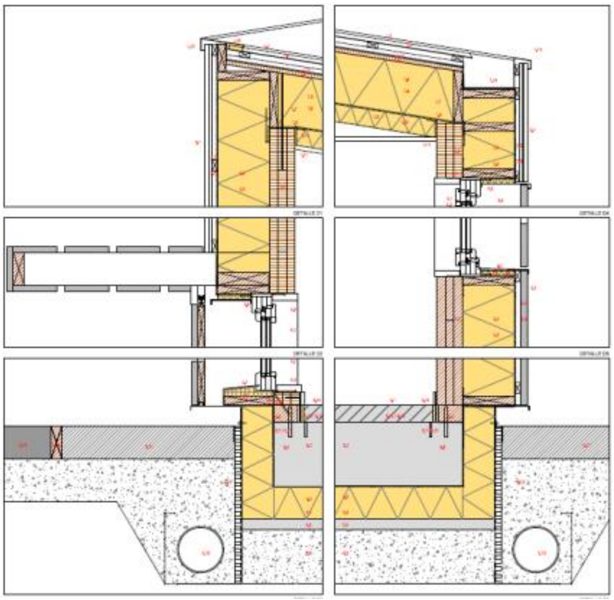

Fig. 10 Constructive detail, D. B. in Olloki.

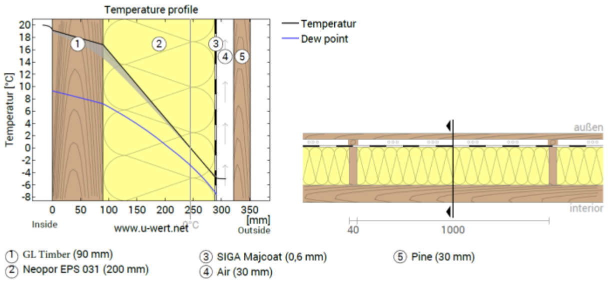

Fig. 11 Condensation study in bortiri refuge.

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