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WOODEN HOUSING IN THE PILLAR-BEAM CONSTRUCTION SYSTEM

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Abstract: Building in wood with rationalized components is an alternative to meet the demands of the buildings sector, especially regarding the use of environmentally friendly materials and low energy wood biomass for final uses of civil construction. In addition, wooden construction systems have advantages such as short construction time and low solid waste production. These aspects and the opportunity to encourage the use of wood as a building system favor studies and research on these systems in the academic sphere and in the training of professionals committed to sustainable development, quality, and performance of wooden buildings. This work seeks to show the column-beam timber construction system and an application. Literature and deepening in taxonomic studies on the construction system in wood and the material - uses, advantages, disadvantages- supported the development of a rationalized design process for a dwelling in wood structure of the column-beam type and wood fence with tongue and groove horizontal panels. The built house resulted from a process that associated constructability, multiple performances, and safety.
Keywords: Wooden dwellings; construction system; pillar -beam system; prefabricated houses; wooden architecture.

INTRODUCTION

Wood, a renewable natural resource, is a material that can be used as fuel, food, and shelter for human beings. Differently from other materials whose obtaining the raw material requires highly polluting industrial processes, a differential of wood lies in the possibility of its sustained production in native and planted forests and in modern silvicultural techniques for obtaining and adapting the raw material for the desired final use. (ZENID, nd). Ramage *et al*. (2017, p.333-334) argue that

> [...] Construction-grade timber and engineered forest products are some of the highest value products from trees. This suggests that structural use is important for economies that rely on forestry. Furthermore, following primary use as structure, there are many secondary or tertiary uses for timber construction waste that retain its value. [...] Timber can have economic benefits for construction, as modern timber is largely factory prepared and brought to site for rapid assembly. [...] The environmental benefits have been demonstrated on some projects but are not always easy to quantify or generalise.

As a usable material in the production of buildings, the conscious incorporation of wood is a way to reduce the generation of waste from polluting building materials that impact the environment.

An important step to produce wooden buildings, in terms of constructability, habitability, and durability, is to observe the main aspects to meet user requirements, exposure conditions and performance criteria in projects, through a careful choice of materials and execution processes, operation, use, and maintenance (TORRES, 2010; SILVA; GUIMARÃES, 2006; NUMAZAWA, 2009; RODRIGUEZ; HEINECK, 2003; NOVAES, 1997). In the case of projects with predominant use of wood in multiple subsystems of the building, ABNT NBR 7190:1997 - Design of wooden structures is a reference document together with ABNT NBR 15575:2013 - Residential buildings - Performance. In that regard, an important requirement is professional training with an emphasis on constructability to develop designs for wooden building systems.

Meirelles (2007) points out that buildings made with inadequate construction techniques, without the necessary evaluations of the wood material for application in the built environment, have induced the idea that wooden houses are synonymous with

sub-housing or low durability. That is, the design process of a wooden building demands understanding the functionality of each constituent part and their interrelationships (systemic approach), aiming to guarantee durability, performance, safety aspects and environmental comfort in the building.

Considering a potential market and the sustainability of incorporating wood as a permanent material in a building, this article addresses the production of a wooden house using a pillar-beam structure and vertical fences in tongue-and-groove planks. The elaboration process of the projects for the production and use of this constructive system, particularly regarding the subsystems of structure and vertical fences, were consubstantiated through taxonomic deepening on the building.

WOODEN CONSTRUCTIONS

Historically, the development of the use of wood as a structure has been focused on the construction of houses, bridges, machines, boats, etc. Constructively, and from the point of view of sustainability, Zenid (2015, p.1) points out that

> Wood has several properties that make it very attractive compared to other materials. Among these, the low energy consumption for its processing, the high specific resistance, the good thermal and electrical insulation characteristics are commonly cited, in addition to being a very easy material to be worked manually or by machines.

Demarzo and Porto (2007, p.3) carried out life cycle analyzes in the manufacture of parts produced with wood, steel, and concrete. They took the quantities involved in wood processing as a reference base for the variables energy consumption (*X1*), CO_2 emissions (*X2*), air pollution (*X3*), solid waste generation (*X4*) and environmental impact (*X5*); obtained for the other two materials the following corresponding quantities for these variables: a) for steel, 2.40.*X1*, 1.45. *X2*, 1.42.*X3*, 1.36.*X4* and 1.16.*X5*; and b) for concrete, 1.70.*X1*, 1.81.*X2*, 1.67.*X3*, 1.96.*X4* and 1.97.*X5*. This indicates and reinforces that the conscious design and use of wooden building systems is a favorable factor for the environment.

As for the viability of housing construction in Brazil, Vivan, Paliari and Novaes (2010) consider that the Civil Construction industry needs to insert large-scale production into the manufacturing process that meets the objectives of serial production and the needs of the subsector. buildings. Augustin (2008) recommends the alternative of building houses with wood as the main building material, due to its attributes of high strength, easy handling for manufacturing components and pleasant aesthetics.

On the other hand, Zenid (sd, p.1) points out that:

> [...] the lack of knowledge of the properties of wood by many of its users and the insistence on old-fashioned construction methods are the main causes of the unsatisfactory performance of wood compared to other materials. This situation, combined with the tradition inherited from Spanish and Portuguese colonizers, generated, in Latin America, a generalized prejudice in relation to the more intensive use of wood in the construction of buildings.

That is, the basis for guaranteeing the performance levels of a wooden house is knowing how to reconcile the knowledge of the physical, mechanical, and biological properties of this material with the levels required in the intended use and potential uses (Figure 1).

Zenid (2009, p. 87-89) and ABNT NBR 7190:1997 mention that it is necessary to ensure a minimum durability compatible with its purpose and with the investment to be made, because the components of a timber construction may be exposed to different

classes of biodeterioration risk as a function of the xylophagous organisms present in the site and the environmental conditions that may favor them to attack the wood. In this sense, observing wood resistance classes is a basic factor in specifying the species and contributes to the appropriate use of wood as a construction material (IPT, 2009). For the execution of a wooden building system with male-female joint sealing components, this is important because the necessary components exert different types of stress and are subjected to different environmental exposure conditions, all these aspects must be analyzed together. The building must be understood and conceived in a global way, because the system formed by the set of parts and or elements (pillars / columns, beams, walls, purlins and ridges, rafters, laths, siding, frames, handrails, baseboards, skirting boards, fillet, ½ board, floor) must ensure the static conditions, safety, and comfort (MANDOLESI, 1981), in perfect integration with each other (CHING, 2010).

BUILDING SYSTEMS IN WOOD

A constructive system comprises the methods and procedures necessary for the execution of the structure and closures of a building. In the case of a wooden house, this material predominates as a structural component and as a seal (KOKUBUN, 2018). This author reinforces that "The implementation of prefabricated wooden construction systems presupposes a paradigm shift, moving from construction to assembly".

RAMAGE et al. (2017) point out that

> Structural timber is most commonly used within a dry building envelope but can be exposed to excess moisture on-site during the construction phase. To ensure equilibrium moisture content relative to its anticipated service environment, structural timber is dried to between a 12–20% moisture content. (p.343). [...] A critical element of the design of most timber structures is the design of the connections between load-bearing members. The dimension of the member required to accommodate the connection may define the size of the structural member as a whole, since edge distances from connectors are set to prevent splitting. These requirements have the potential to add material to a structure simply to accommodate connections. The efficiency of a connection is defined as the ratio of the strength of the connection to the strength of the member it connects. (p.350).

In general, wooden building systems follow a basic classification that divides wood building techniques into traditional and contemporary.

Regarding traditional techniques, systems based on stacking pieces of solid, round or sawn wood, initially predominated in northern Europe, in regions with a great abundance of wood and intense cold. From this constructive system, the lafte technique emerged with fittings for the abutments of walls, exactly in the most vulnerable points of this type of construction. Bittencourt (1995, p. 94-97) mentions that these fittings reduced sealing problems but did not eliminate issues resulting from dimensional variations of the sections of the wooden pieces. Constructions with structural frames (half-timbered) arose from the need to optimize the use of forest resources in regions with less wood availability, their main feature being the fixing of pillars directly to the ground; this building system is the forerunner of contemporary timber construction techniques.

As for contemporary techniques, structurally (Figure 2) stand out the pillar-beam systems, modern lattices (balloon; platform) and constructions in industrialized wooden panels.

In Brazil, the development of building techniques in wood has its initial reference in indigenous architecture, with centuries-old practices using light wooden structures with a thatched roof (a kind of wooden cage),

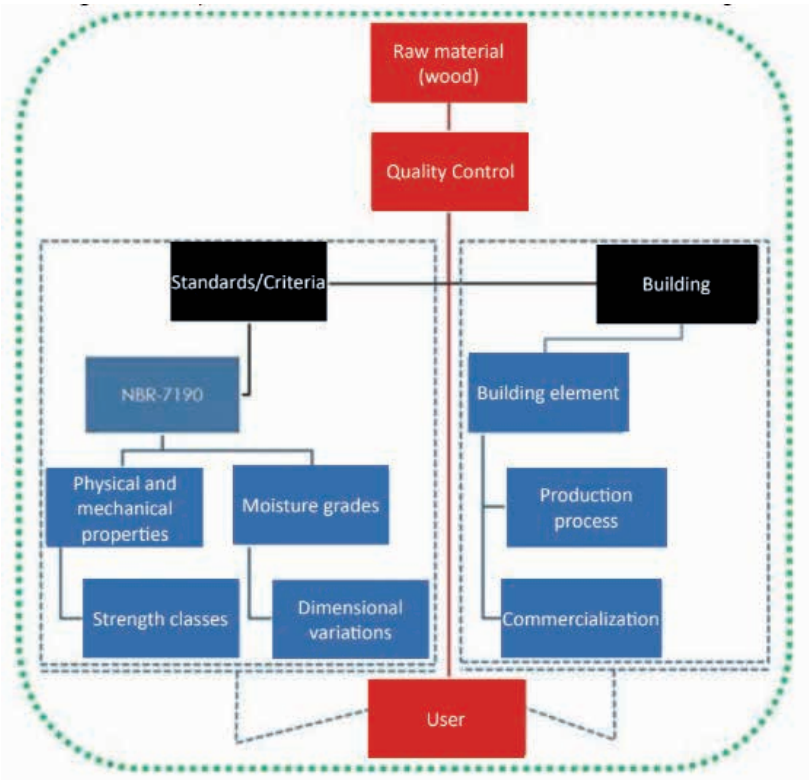

Figure 1 - Requirements for the use of wood in habitable buildings

Source: Authors.

Figure 2 – Examples of contemporary buildings made of wood (left) IBAMA/DF building with pillar-beam system and framed fences in masonry (MELLO, 2004); (right) Typical structure of a house (DON VANDERVORT, 2021).

in often bold compositions that allowed the construction of large hollows for the shelter of several families.

The designation 'wooden cage' can also be considered as a regionalization of the half-timbered system, as it is based on the principle of a wooden structure locked in several directions (crating), and may have its fences in masonry, stone, adobe, or any other material available. The improvement and simplification of this constructive system resulted in the column-beam system, intensely used in wood-structured buildings in Brazil. In general terms, the existing wooden building systems in Brazil are related to wooden houses, according to the classification mentioned above, in general being found the pillar-beam and panel systems.

METHODOLOGY

For understanding and application purposes, an extensive base of scientific knowledge and technological information on the elements and components of a wooden construction system, pillar-beam type, with male-female sealing walls was constituted and analyzed.

In terms of documentation, academic productions (theses, dissertations, and articles) and works and standards of a technical nature were analyzed for the understanding and articulation of taxonomic knowledge about wooden buildings. In terms of decision-making for the design and structuring of wooden houses, a better understanding of the interrelations and connections allowed the planning of a comprehensive project of performance, safety, and environmental comfort compatible with the prefabrication and assembly process for the reality of the place of execution (materials and labor). The elaboration of the project for a wooden house with a supporting structure subsystem of the pillar-beam type and a vertical sealing subsystem of the male-female type, started from a basic ground floor residential unit ($70m^2$), with the possibility of expansions up to 2 floors ($240m^2$).

For the analysis of wood, technological data were obtained from the catalog of Brazilian wood for civil construction (IPT, 2013), which indicates new species on the market, considering the general classification of uses, heavy and light.

The procedures adopted for processing, commercialization, and final use of wooden components in construction (wood used; identification of moisture content; care and preservative treatments) were also studied.

RESULTS AND DISCUSSION

The identification and understanding of the construction system of a wooden house covered the functional parts that make up the pillar-beam type structure and the vertical fence in wall planks with male-female fitting, for the purposes of integration, constructability, and guarantee of conditions of security of the built complex.

For the application, Figure 3 refers to the summary taxonomy of the structural subsystem, for which it was decided to use slats to plumb the pillars and uprights (Figure 4), bracing the parts and receiving the sealing elements.

As for the pillars (Figure 5), there is a variation in their typology due to the fitting of the walls in the channels, thus differentiated: one channel (P1), corner (PC2), parallel (PP2), three channels (P3) and four channels (P4).

In the column-beam system, pillars/mounts support the roof loads and receive the parts of the vertical sealing subsystem, through slots in their faces. Thus, they transmit the loads from the wooden superstructure to the infrastructure. Horizontal and inclined beams have the function of receiving loads from the

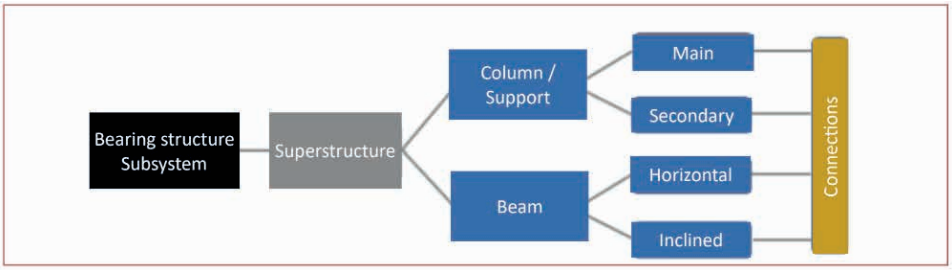

Figure 3 - Simplified taxonomy of the bearing structure subsystem

Source: Authors.

Figure 4 - Supporting structure subsystem: pillars and beam

Source: Authors.

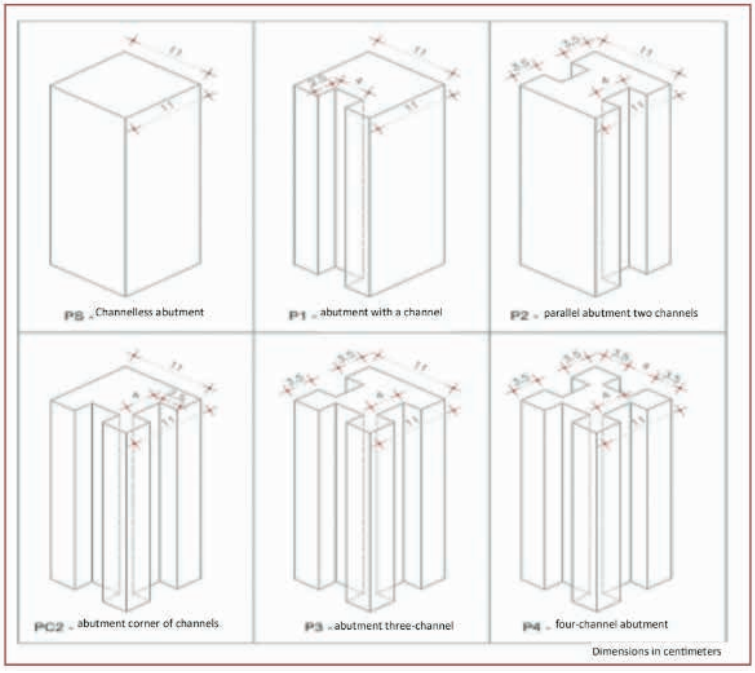

Figure 5 - Typology of pillars/uprights for fitting the sealing parts

Source: Authors.

parts that make up the vertical fences and the roof and transmitting them to the pillars.

After executing the supporting structure, the connection between the pillars and the vertical sealing elements was made without using connectors, by fitting, which can facilitate interventions and allow greater durability for the components. As a result, the constructive system makes it possible to disassemble the woodwork and facilitate its disassembly so that it can be installed elsewhere, allowing its use in line with the principles of sustainability.

The vertical sealing subsystem (Figure 6) constitutes the facades and vertical divisions such as walls, frames, doors, and windows.

The wall planks of the vertical sealing subsystem (Figure 7) are connected by fitting, dispensing with the use of glue or nails for their fixation. The purpose of the fence walls is not structural, but to support the pillars (Figure 8), in addition to receiving the openings for the installation of door and window frames. In this constructive system, solid woods are used as sealing components.

For the execution of door and window openings, the doors have slots for fitting wall planks (Figures 9 and 10), which allows locking at all ends.

Figure 11 shows the front facade of the finished building of a house made of wood, for which we sought to combine less time for manufacturing, architectural modulation, and minimization of material waste. Due to the planning process, pre-fabrication, and the definition of the installation site in the project, the standardized parts arrived at the construction site to compose the construction system and assemble the house.

CONCLUSION

The taxonomic study made it possible to deepen the identification of the constituent parts of the building system for the use of wood as the predominant material and a functional analysis to define the performance levels of each part and globally.

The analysis expanded the thematic range of interpretations of the parts of the construction system, compared to the whole (the building), raised the quality of the project and planning and the resulting actions of building under the practical view of systems in the successive stages of the design processes and construction.

Specifically, the application in a building system, all in wood above ground, contributed to consolidate the domain of knowledge and production of the construction system and contributed to improve the qualification of the workforce and the control of the quality of housing.

It must be noted that the durability of the components of the pillar-beam building system with wall planks, male-female fitting, together with the connections of the structural subsystems and vertical sealing of the housing in solid wood is linked to the choice of appropriate dicotyledonous wood species to the conditions of exposure to local environmental agents and is also directly associated with the manufacturing standard and the coupling of the constituent parts of the supporting structure and vertical fence subsystems.

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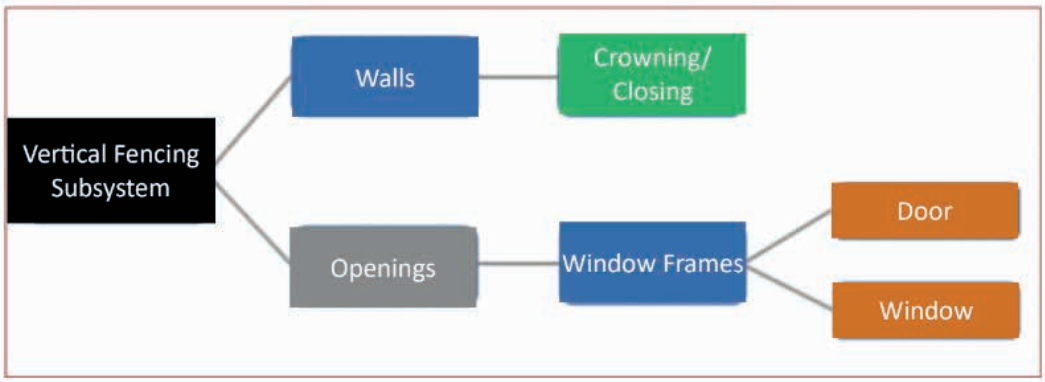

Figure 6 - Simplified taxonomy of the vertical fence subsystem

Source: Authors.

Figure 7 - Sealing parts with male and female fitting

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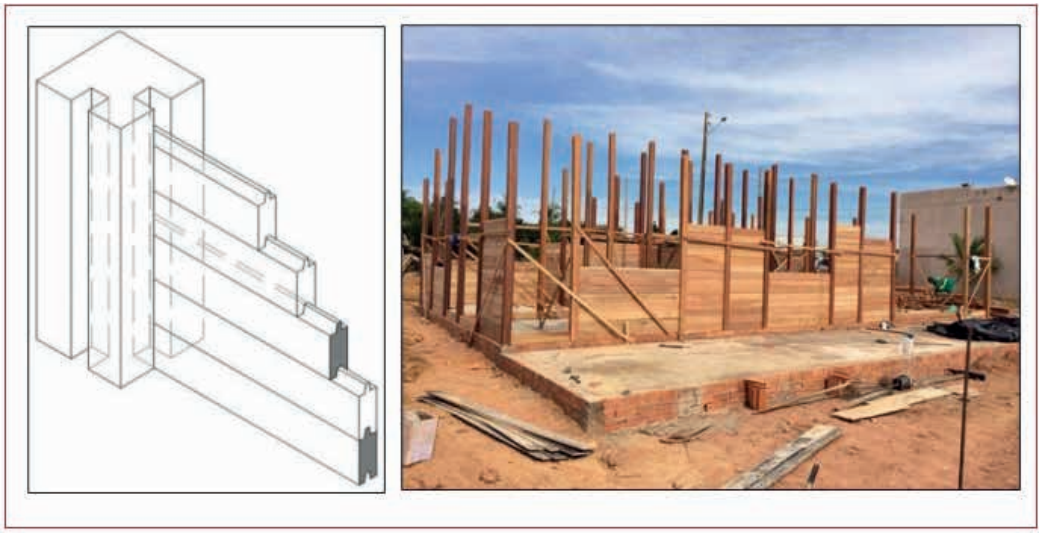

Figure 8 - Connection and bracing of the pillars by means of the sealing parts

Source: Authors.

Figure 9 - Frame stops with slots for fitting wall pieces

Source: Authors.

Figure 10 - Frame stops fitted to the sealing parts

Source: Authors.

Figure 11 – Finished wooden house, in a pillar-beam construction system

Source: Authors

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