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FIRE-FIGHTING LEGISLATION FOR WOODEN STRUCTURES: NATIONAL AND INTERNATIONAL SCENE

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INTRODUCTION

Cities are home to an increasing number of people and the problems arising from this intense urbanization also include the growth of precarious housing conditions. The construction of quality housing to serve this marginalized contingent of the population plays a fundamental role in the growth and socioeconomic development of a nation (SANTOS, SANTANA, 2017).

Worldwide technological development has led to a substantial increase in the structural use of wood in recent decades, increasing the industrialization of wooden constructions and the emergence of new wood-based products (ALMEIDA, 2000). What also encourages the use of the material is the environmental crisis facing the planet and the need to build social housing (SANTOS, SANTANA, 2017).

The thermal comfort and aesthetic characteristics of this material distinguish wood from other materials used in construction. Its quality as a raw material can be altered according to the type of plantation and the modern silvicultural techniques employed (ZENID, 2009). Considering the various plantations reported, wood is produced by different species of trees, each with its own physical and mechanical characteristics (ZENID, 2001).

Although wood has favorable characteristics for use as a building material, there is little knowledge of the material among professionals working in the construction sector, and it faces resistance when used in situations where there is a risk of fire. However, Goulart (2011) reports that wood is an insulating material and is considered to be the best in comparison with metals or concrete.

Regarding fire resistance, Pinheiro (2017) explains that robust pieces of wood, when exposed to fire, form a surface layer of charcoal that acts as a kind of insulator, preventing the rapid passage of flammable gases and the spread of heat inside the section, resulting in both heating and degradation of the material at a slower rate, thus helping to improve the load-bearing capacity of the building.

In order to protect themselves, a series of fire-fighting measures have been adopted in buildings, as well as the development of new equipment, new techniques and, most importantly, new legislation and constant updates (GOMES, 2014).

There are currently a huge number and variety of standards and laws that must be complied with, both at federal, state and even municipal level, on the most varied types of buildings, detailing all the necessary equipment, conduct at the time of a fire, maintenance, as well as special precautions when designing and building projects. And this is where our contribution to society comes in as professionals, when we take on the responsibility of organizing the entire Fire Prevention and Combat Project (PPCI), with all its scope, seeking to prevent any incident as much as possible and, should one occur, minimize material losses and avoid human ones.

With the updating of standard 7190 (ABNT 2012) on the use of wood in civil construction and its parameters, the standards for preventing and fighting fires in wooden structures have now been standardized, and this action has several advantages in terms of encouraging the use of the material. The purpose of this research is to present a brief review of the national and international standards on firefighting in wooden structures.

THEORETICAL FRAMEWORK

WOOD AS A BUILDING MATERIAL

Brazil had a total of 7.74 million hectares of forests planted for industrial purposes in 2014, an increase of 1.8% compared to the previous year, but covering an area that does not even correspond to 1% of the Brazilian territory (IBÁ, 2015).

The use of wood in construction has beneficial characteristics, as well as contributing to environmental sustainability, since it is obtained from renewable reserves, its material can be reused and it saves water resources, since water is not used in any industrial process (COPAT, 2014).

In order to choose the species used, it is necessary to evaluate several important characteristics in relation to the environment, such as the availability of raw materials, the environmental impacts on the extraction, transportation, use and demolition process, efficiency, durability, maintenance, reuse and possible recycling of the material (ARAÚJO, 2013).

According to Zenid (2009), it is important to use wooden parts in accordance with the project and in such a way as to avoid loss through unnecessary cuts. Builders should also always check whether the pieces can be reused.

As it has natural characteristics that favor thermal insulation and sound absorption, as well as low specific mass and high mechanical strength, its use is also advantageous in wood structural systems as there is little waste of materials, since the elements are manufactured beforehand (COPAT , 2014).

WOOD PROPERTIES

In order to use wood correctly, knowledge of the material's anatomical and physical-mechanical characteristics is extremely important, as this information enables properties to be determined in order to use the material economically and safely (OLIVEIRA, 2007).

Among the properties of wood, the basic specific mass, retractability and resistance to static bending stress can be considered. As it is an anisotropic material, wood can change dimensionally and unevenly in relation to the planes of orientation, depending on the equilibrium humidity of the environment. The variation in physical and mechanical properties is also different in relation to the anatomical planes and must be assessed to determine the dimensional stability of the material (Oliveira, 1988; Durlo; Marchiori, 1992; Oliveira; Silva, 2003; Vicente et al., 2005).

The basic specific mass is an important parameter for characterizing wood, mainly because it is related to its strength and rigidity, varying according to the cell wall, dimensions, cell types and, to a lesser extent, the amount of extractive components present per unit volume (Panshin; Zeeuw, 1980; Haygree; Bowyer, 1982; Mattos et al., 2011).

The natural moisture content of wood is an important physical property to consider when using the material, expressed as the ratio between the weight of the water contained in the freshly cut wood and the dry weight of the material (Panshin; Zeeuw, 1980; Haygree; Bowyer, 1982; Mattos et al., 2011).

With regard to mechanical properties, modulus of rupture (MOR) and modulus of elasticity (MOE) are two parameters usually determined in static bending tests and are important in the technological characterization of wood, as they both provide a good approximation of the material's resistance and , in practice, classification criteria (Serpa et al., 2003).

Despite its advantageous characteristics, due to the lack of adequate sizing of sections, fires in different sizes of buildings occur with high frequency and are started by ignitions of other materials present in the building, such as gas leaks, short circuits in electrical installations and appliances connected to energy sources (OLIVEIRA, 2012).

COMBUSTIBLE PROPERTIES OF WOOD

Wood performs well when used in properly designed, constructed and maintained buildings, but its use as a building material is restricted due to prejudice regarding its behavior in the face of fire, since it is a combustible material and when it is heated, it releases combustible gases which, when exposed to heat, burn and produce flames. Through these hot gases and the flames, part of the wood is heated, and that which has not yet been affected by the heat releases more flammable gases, causing a chain that feeds combustion (FIGUEROA; MORAES, 2009).

Wood has a set of physical and mechanical characteristics that, despite being an organic material, are rarely found in other materials and it also has countless variations in aesthetic patterns. The constitution and organization of the xylem tissue in wood are responsible for the physical characteristic of low thermal conductivity, as the cells that make up wood have a high proportion of cellulose, which is a poor conductor (MADY, 2016).

The wood is slowly heated during the interval up to 200°C, and first releases water vapor, gases and uniform mass loss. Even if carbonization occurs at a temperature above 95°C, the wood does not ignite (PINTO; JUNIOR, 2011).

Between 500°C and 1000°C, the wood enters degradation process, when the flames disappear and the luminous burning of carbon monoxide and hydrogen begins. This stage is called incandescent combustion because the remaining charcoal glows brightly (PINTO; JUNIOR, 2011).

When larger diameter parts are exposed to fire, a surface layer of charcoal is formed, acting as a kind of insulator that prevents gases from escaping

This reduces the heating and degradation of the material, favors the load-bearing capacity of a building and preserves the physical properties of the wood even when exposed to high temperatures for a certain period of time (PINTO, 2004).

The specific weight and moisture content of wood affect thermal conductivity for any species. As the specific weight and moisture content increase, the wood's ability to conduct heat will also increase, with wood dried to a stable moisture content having a better insulating function (MADY, 2016).

In Brazil, there is a lack of knowledge about the behavior of wood under the action of fire generates uncertainty and insecurity, because the possible risks related to fires are factors that limit its use in the construction of wooden buildings and structures, in which they do not receive support from national banking institutions for the construction of this material (FIGUEROA; MORAES, 2009).

Therefore, the lack of knowledge about the physical and mechanical behavior of wood under the action of fire has led to less use of this material in structural parts of buildings. Knowledge about the behavior of wood as a result of its reduced mechanical resistance to the high temperatures of fires allows us to clarify doubts about the use of this material in construction and improve safety conditions in buildings (OLIVEIRA, 2012).

DISCUSSION

THE INTERNATIONAL LEGAL SCENE

Around the world, several governments have realized these benefits and have instituted public policies that encourage the responsible use of wood in construction. For many nations, building with wood is nothing new, especially in countries that have a culture of using this raw material and have the appropriate technologies for this purpose. Even countries without this tradition are showing a willingness to transform the way cities are built.

In the province of Quebec, Canada, since 2009 there has been a measure aimed at increasing the use of wood products in the non-residential sector and in the construction of condominiums, as well as intensifying the use of exposed wood products. In Japan, the government has adopted several measures establishing a minimum amount of wood use. Called the "Wood First" Law, these measures require wood to be considered a primary building material for any government-funded building up to three stories high and for any privately-owned building used in a public way (RUSSO, 2017).

Along with the laws encouraging its use, construction standards in various countries have been updated with regard to the use of wood as a building material, and some standards are maintained as a world reference.

Eurocodes are seen as the main way forward in structural codes. In Portugal, for example, Eurocode 5 (Part 1-2) is used as a basis for supporting timber structure projects in situations where fire structures are to be calculated. It describes the principles, standards and rules for the structural design of buildings exposed to fire, whose general fire protection objectives are to limit the risks to the individual, society, neighboring property and, where necessary, direct exposure of the property in the event of a fire.

Eurocode 5 applies to the design of buildings and civil engineering works in solid wood, glued laminates and LVL, among others. It is concerned with the requirements of mechanical resistance, maintenance, durability and fire resistance of wooden structures, and does not take into account thermal insulation or acoustic insulation systems.

The document presents specific aspects of passive fire protection in terms of the design of structures, as well as simplified or more sophisticated rules for assessing the fire resistance of a given structure.

All buildings must be designed and constructed in such a way that, in the event of a fire outbreak:

- Fire resistance can be assumed for a certain period of time;
- The generation and spread of fire and smoke within the site is limited;
- The spread of fire to neighboring buildings is limited;
- The occupants can safely leave the site or be rescued by other means;
- The safety of rescue teams is taken into account.

A complete structural fire safety analysis process takes into account the behavior of the structural system at high temperatures, heat exposure and the potential beneficial effects of active fire protection systems, not forgetting the uncertainties associated with these three characteristics and the importance of the structure. Therefore, it is now possible to carry out a suitable procedure for determining performance, which incorporates all these parameters to demonstrate that the overall structure or its components in isolation achieve adequate performance in the event of a fire.

In order to calculate the fire-resistant capacity of wood, as mentioned above, Eurocode 5 (Part 1-2) provides a set of specifications that the project must comply with, through simplified methods as well as advanced calculation methods aimed at determining the mechanical resistance of each construction element. In its annex, a set of flowcharts is provided to help interpret the rules and specifications included in the code, facilitating the designer's task in carrying out the necessary procedures for structural fire calculation in timber structures (EUROCODE, 2004) (ANASTÁCIO, 2010).

As for the tests required to classify wood as a building material, in the United States the ASTM E-119-95a test standard (standard test

methods for fire tests of building construction and material) evaluates the resistance of construction elements or materials used in a building. The resistance index is given in hours or minutes. This test standard is used to evaluate elements made of various materials, not just wood. Exposure temperatures vary between 8150C and 10380C, APA (1993).

Another widespread standard for evaluating resistance is ISO 834 - Fire resistance tests - elements of building construction. The reaction of materials to fire is also evaluated through standardized tests, which characterize materials according to:

- Surface flame propagation;
- Combustibility;
- Flammability;
- Calorific value ;
- Specific optical density of smoke;
- Smoke toxicity.

All the parameters described above were listed for the updating of NBR 7190. Until 2012, the standard, which was previously updated in 1997, did not describe design standards for the use of structural timber in buildings in fire situations

NATIONAL LEGISLATION

In Brazil, due to the lack of major fires and large numbers of victims, until the 1970s the "fire" problem was restricted to the actions of the Fire Brigade. Regulations were scarce, without absorbing international knowledge and exclusive to the building codes of each municipality, and ABNT was only involved in overseeing the production of fire extinguishers. There were no regulations on emergency exits, lighting, signage, escape routes or protected stairways

By the very definition used by ABNT, "a technical standard is a document, established by consensus and approved by a recognized body, which provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, with a view to obtaining an optimum degree of order in a given context."

This recognized body is ABNT itself and these technical standards include the NBRs, which can be mere recommendations made by ABNT based on studies and tests in laboratories, well as the knowledge accumulated over time by professionals in each area, but when they are mentioned by the government in Decrees, Laws or Ordinances, their compliance becomes mandatory (GOMES, 2014).

There are an infinite number of NBRs, especially in the area of Civil Engineering, and it is vital to consult them, especially in the area of Fire Prevention and Fighting, due to their constant updating. Laws are created by the State to establish the rules that must be followed, constituting an order, the highest of which is the Federal Constitution itself. The totality of the laws that govern a society is called legislation (GOMES, 2014).

In the NBR 7190/2012 standard, the updated section appended to the standard in 2012 refers precisely to the structural safety of wood in fire situations, in buildings intended for residential, commercial and industrial use and in public buildings.

For the study of wood exposed to fire, thermal properties and properties related to resistance and rigidity are the ones that most influence its performance. Most of these properties are related to factors intrinsic to the wood, such as density, moisture content, grain orientation, chemical composition, permeability, thermal conductivity and extrinsic factors such as temperature and duration of exposure to fire and ventilation in the environment.

The core of the section remains cold only a short distance from the burnt zone, preserving most of the wood's physical properties. These characteristics contribute favorably to

its resistance capacity, even after being exposed to high temperatures.

> Sizing in a fire situation means checking structural elements and their connections, with or without fireproofing, for their ability to withstand high temperatures, in order to prevent the structure from collapsing under conditions that would hinder the escape of building users and, where necessary, the approach and entry of people and equipment for firefighting actions (NBR 7190/2012, p. 68).

With the amendment to NBR 7190/2012, an alternative is also provided for the use of advanced methods of thermo-structural analysis based on Eurocode 5, part 1.2, provided they are adapted to the structural safety requirements of the Brazilian standard, or the results of tests carried out in a national laboratory or foreign laboratory, in accordance with ABNT NBR 5628 or in accordance with a foreign standard or specification.

Updating the standard now provides users with a great deal of information, thus increasing their confidence in using wood as a raw material in construction.

State and municipal legislation

The Construction Code is the set of municipal laws that control the use of urban land. As described in the Code of Works of the City of Santa Maria - RS in its Article 2: "this Code provides for and is applied to the architectural design, execution, renovation, modification, use, licensing and inspection of buildings, constructions and works in the Municipality of Santa Maria".

The Construction Code includes articles detailing the procedures and standards to be followed when drawing up Fire Prevention and Fire Fighting Projects (PPCIs), often highlighting NBR 9077 and also compliance with municipal and state laws for their approval.

The PPCI is the Fire Prevention and Fighting Project and can only be drawn up by qualified professionals (Civil Engineers and Architects), inspected and approved by the Fire Brigade, through inspections and the granting of permits, and is required by public bodies for any property in order to provide greater safety for people. It is compulsory for all existing buildings, even those that are under construction or renovation (those that have an extension of more than 10% of their total area).

Passive protection measures are those taken during the architectural and complementary design phase, with the aim of preventing a fire outbreak as much as possible and, if it does occur, reducing the conditions conducive to its growth and spread to the rest of the building and to neighboring buildings.

There are also Ordinances and Technical Instructions (ITs) issued by the Military Brigade's Fire Brigade, designed to standardize procedures and define issues where the legislation is vague. The Fire Brigade is the body that plans, studies, analyzes, approves, inspects and supervises fire prevention and protection installations and equipment throughout the state.

In order to facilitate understanding in the study of PPCIs (fire prevention and protection plans), a hierarchy can be observed, which at the same time represents the increasing degree of detail and specificity of the sizing rules for the various PPCI component systems (EUZEBIO, 2011):

- 1st Federal Constitution;
- 2nd State Constitution;
- 3rd State Law;
- 4th State Decrees;
- 5th Norms cited by the Decree;
- 6º Municipal Laws and Decrees;
- 7º Fire Department Ordinances, Technical Instructions and Opinions.

FINAL CONSIDERATIONS

The update of standard 7190/2012 brings several benefits to the wood market in the country, including greater knowledge about the properties of wood in fire situations and more detailed calculations for designers who will be dimensioning wood structures.

As 7190/2012 was drawn up based on the guidelines of Eurocode 5, a standard used in several countries, the document has a very well-founded structure for detailing.

Other regulations, such as those of municipalities and fire departments, must follow the changes to the standard in order to update their governing documents as well.

This will encourage greater knowledge of wood as a building material and consequently its greater use, whether in solid, sawn or prefabricated timber constructions.

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