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FIRE IN CULTURAL HERITAGE BUILT: THE PARADIGM OF THE WOOD STRUCTURE

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ABSTRACT

This article presents the basic characteristics from the wood in fire situation and proposes an objective vision as for its answer on this type of disaster, specifically when its about constructions protected by the organs of the Brazilian historical heritage. The importance of the care and protection of these edifications is justified by what they represent for the community, for the culture and history of the place that they are inserted, so, this article pretends start a discussion more qualified as for the structural material very present in these buildings: the wood.

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INTRODUCTION

When its about the wood in fire situation, the preoccupation as for the reaction at the fire of this material is made present and palliative solutions emerge in the direction of guarantee the security of the built against this type of disaster. One of the characteristics that proves with such care is the fact of the wood have significant calorific power, 19 MJ/kg (NBR 14.432; Bowman, 2000; Biaoa *et al.* (2012). Other characteristics, such as material anisotropy, deterioration, wood type and part dimensions, are also important for the material analysis about its reaction to fire performance. However, few studies, in Brazil, are made to verify the real wood structures behavior in fire situation. When it comes to buildings protected as cultural heritage, boast about material provides a concern that, on the one hand are justified by the importance that these buildings represent for the culture, the knowledge and the notion of belonging of the population that with it interacts, on the other hand, raises doubts and boast that often leads the focus to other areas that do not necessarily contribute to an increased risk of fire and its spread. A simple example, but easy to understand, is the bonfire from the Brazilian June Festival[1], where are put wood pieces of large dimensions for burn during all party but, for the start of the fire, is necessary to use kindling and drought leafs, beyond some fuel material. In other words, the wood pieces of large dimensions resist to the fire for a long time, hours in the most of the cases. Therefore, this article pretends show the behavior of structural pieces of massif wood, principally for the fact that this type of structure is present in the most of the houses and two-story houses existents in the historical sieges of the State of Minas Gerais, Brazil, and the appropriate knowledge of this material in fire situation it is of basic importance for the correct preservation, rehabilitation and reconstitution of the constructions protected by the preservation organs of the Brazilian cultural historical heritage. The fires in cultural heritage always cause impacts, either by irreparable material loss, either by what this heritage represents for the local, national or even international community, not to mention the possibility of human life loss, main objective of the safety against fire.

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Figure 1. Images of the ancient Hotel Pilão, city of OuroPreto, Minas Gerais State, Brazil (Oliveira, 2003)

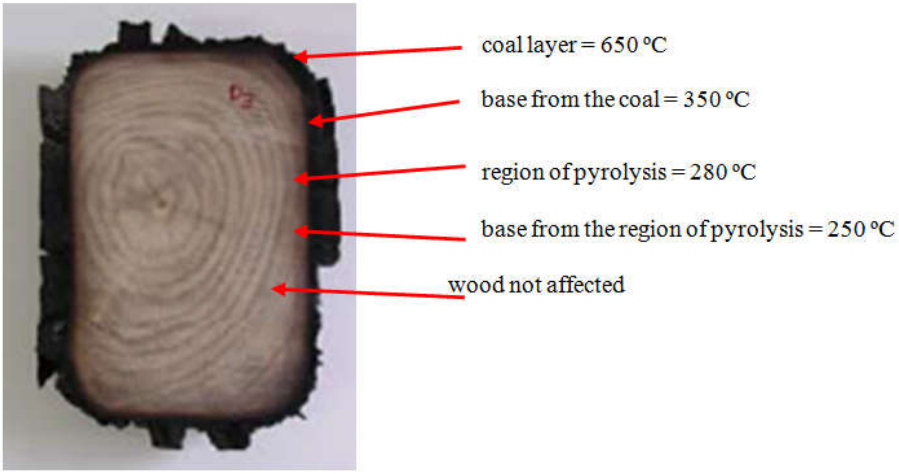

Figure 2. Carbonized section of the wood (Pinto, 2005)

Some significant examples, presented below, represent the losses occurred in cultural heritages in Brazil. There are two explanations for the origin of the term "festa junina" (Brazilian June Festival). The first explains that emerged on the bases of the festivities, mainly religious, that happened, and still happen, during the month of June. Those festivities were, and still are, in homage of three catholic saints: Saint John, Saint Peter and Saint Anthony. Another version says that this festivity name has its origin in catholic countries of Europe and, therefore, would be in honor only to Saint John. In principle, the festivity was called Joanina. Accorded to historians, this festivity was brought to Brazil by the Portuguese, even during the colonial period. In 1968, a large fire destroyed a large part of the library collection of the College of Caraça, in the country of Catas Altas and Santa Bárbara, in the state of Minas Gerais. A stove forgotten lit in one of the bookbinding rooms caused the accident, and thanks to the students of the institution, were saved approximately 15.000 of the 50.000 books (Werneck, 2013). In 1994 there was a fire at the offices of the *Hospital de Caridade*, Florianópolis, in Santa Catarina State, whose building is a chapel built in 1762, and the hospital opened in 1789.This building is one of the main references landscape urban center of referred to City (Serpa, 2009). Already in 1999, a fire broke out in the Church *Nossa Senhora do Carmo* in Mariana, also in Minas Gerais, where the ceiling of the ship, two side altars and part of the wood floors were totally consumed by fire (Serpa, 2009).

Completed in 1784, was going through a restoration process had four years, and problems in temporary electrical installations for aid restoration works were the probable cause of the fire (Silva, 2011). The fire at the Church *Nossa Senhora do Rosário* of Pirenópolis, Goiás State, occurred in 2002, had probable cause inadequate adaptations of electrical installations and sound, use floor wax (highly flammable) and lighted candles. Built in the first half of the 18th century, was restored in 1999, being completely destroyed by fire (Serpa, 2009). In 2003, a fire in a commercial building (former hotel Pilão), Figure. 1, in Tiradentes square, in the city of Ouro Preto, Minas Gerais, caused his total loss, threatening the surrounding historical buildings. Could have been an accident of similar proportions to the Chiado quarter if not for the existence of a side alley to the building, providing a clearance in relation to other buildings near the fire. In 2005 it was the turn of the Public Market of Florianópolis, State of Santa Catarina, built in 1898. Part of the internal area of the building was destroyed by the flames, the likely cause was the alterations of premises to house new activities (Serpa, 2009). On 21 December 2015 a large fire struck the Museum of the Portuguese Language, located in the building of the *Estação da Luz*, in São Paulo. Despite the total destruction of the premises, there was no great prejudice to the collection for be, mostly, digital, being subject to recovery through backups. However, the biggest damage occurred was in the building, architectural heritage opened in 1867 and restored in 2006 to receive the facilities of the Museum. Other examples of fire in buildings protected can be cited, such as occurred in the

Church *Nossa Senhora das Mercês*, in Sabará, Minas Gerais, in 2003; in the chapel of São Pedro de Alcântara, Rio de Janeiro, in 2011; in the Public Market of Porto Alegre, Rio Grande do Sul, 2013; and the fire in the Church *Nossa Senhora da Conceição*, Ouro Preto, in 2015. To analyze the risks and consequences of the occurrence of a fire in heritage, particularly in buildings called historical, some characteristic aspects of this type of building may increase the risk of a fire, hindering or even preventing their extinction, and causing the collapse of the building. Serpa (2009) lists these aspects can be: the constructive characteristics of the building; the deployment of buildings in urban centers, which often do not have gaps between buildings or expansions or irregular occupations in the brains of the blocks, allowing the rapid spread of the flame; the lack of proper maintenance of buildings and facilities; the type of occupation that is, sometimes, changed without the necessary adjustments to its adaptation to new use; and installations, to the adequacy of the building to the current use, adjustments are made to the electrical installations and liquefied petroleum gas. Within the constructive characteristics, Serpa (2009) points to constructive elements (floors, ceilings, stairs) consisting of wood as one of the factors that hinder the extinction of a fire.

This assertion is not isolated, and perhaps this is due to the fact that wood is a combustible material, unlike concrete and steel. Like the other solid fuel, wood, in normal conditions, don't burn directly, causing it to decompose first in gases that, exposed to heat, in fires that, in turn, heats the wood has not yet reached and promote the release of more flammable gases, feeding combustion. However, the wood structural elements subjected to fire display in their interiors, after the charred layer, a heated layer, whose mechanical properties are affected by the heat, and a core unchanged. This means that the fire resistance of an element or structure of wood depends on the existence of a protective layer or charred wood layer thickness and the size of the residual section, which depend on the rate of carbonization of wood species used (Figueroa and Moraes, 2009; Bowman, 2000; Kanlia *et al*., 2015). However, the fire affects other construction materials in different ways: the steel loses its rigidity and resistance, while the concrete fragments when exposed to high temperatures due to its hygroscopic characteristic. Therefore, the combustibility of wood cannot be the main criterion by which the fire performance of a construction can be evaluated (A Madeira: um Material Resistenteao Fogo, 2009; Biaoa *et al*., 2012; Kanlia *et al*., 2015). The wooden parts with large sections, when exposed to fire, form a surface layer of coal that, which in turn, acts as an insulator, preventing the rapid departure of flammable gases and the spread of heat to the inside of the section. This behavior allows a smaller heating speed and degradation of the material, there by increasing the time required to fire resistance of composite structures for this material (Biaoa *et al*., 2012; Kanlia *et al*., 2015). When the wood reaches high temperatures, occurs at its depolarization, with the release of volatile gases (flammableor not), the woody material combustion, charring and incandescent carbon burning. When, on the burning, there is not an enough oxygen supply (or this is controlled), occurs the carbonization, whose solid residue is coal.

During the wood heating, many volatile organic compounds are produced and released, such as alcohol and resins. They are the ones which are participating in the chain reaction during the wood combustion process (Figueroa and Moares, 2009). At the heating beginning, when the wood temperature is above 100ºC, the chemical bonds of its components begin to break down. Between 100ºC and 200°C there is the water release, carbon oxides and traces of organic products. Generally, the thermal degradation process is divided into five phases: up to 200°C; from 200 to 280°C; from 280 to 380°C; from 380 to 500°C; and above 500°C (Figueroa and Moraes, 2009). The exothermic reactions begin between 150ºCand 160ºC and increase with the elevation of the temperature. Until 200ºC happens the slow pyrolysis, the liberation of steam of water and gases, the existence of some exothermic reactions of oxidation and the change of the original color from the wood. Meanwhile, the ignition doesn't happen. Between 200 and 280ºC, happen the phase knows by quick pyrolysis, where there is the increase of gases emission and the incident of primary exothermic reactions without inflammation. It is in this phase that the ignition temperature is reached. Between 280 and 380ºC, denominated exothermic phase, it take places large quantities of distilled (methanol, for example) and the production of vegetable coal like final residue. Between 380 and 500^{o}C, also inside the exothermic phase, there is the reduction of the emission of gases, the production of acetic acid, methanol, tar and several other gaseous substances and the loss of mass, which revolves around 70% of the original mass. Above 500^{o}C, there is the end of the carbonization and beginning of the gasification from the coal, being the principal residue. In the interior, the wood remains with the temperature until 380ºC, being this also denominated of exothermic phase (Figueroa and Moraes, 2009).The Figure 2 shows the regions where these phases happens.

The influence of high temperatures in the wood can provoke temporary effects and permanent effects, depending of the degree of degradation of the material caused by exposure to the heat and for the temperature. The permanent effects don't disappear after the cooling from the wood and happen to temperatures superior to 65ºC. They depend on the temperature and on the tenor of moisture from the wood and are originating, probably, from there actions of depolymerization, in which the break of the chemical connections begins to take place in temperatures superior to 100 ºC. The constant effects are shown by the loss of the weight of the carbohydrates, water loss of adhesion and by the softening of the lignin, and think straightly about the mechanical properties from the wood (Figueroa and Moraes, 2009). Before the here presented, it is necessary the further study and goal of the wooden structures, in fire situation, of buildings considered Historic Heritage, to the search for affirmative and effective actions able to protect the structure, without however taking a paradigmatic view of wood taken from the little knowledge of structural material.

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