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ANALYSIS OF THE MECHANICAL PROPERTIES OF *PELTOPHORUM VOGELIANUM* POST-ACTUAL FIRE

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Abstract: The present work analyzed pieces of wood from the roof structure of a house that suffered a fire in the city of Itapeva, in the interior of São Paulo. The roof structure was built 25 years ago using wooden beams from the Guarucaia species (*Peltophorum vogelianum*). In general, the surface layer of coal formed in the structural elements subjected to fire preserved the mechanical properties of the core. The values of shear strength (fv), compressive strength (fc0) and modulus of elasticity (Ec0) in compression parallel to the fibers for this species with an average density of 919 kg/m3, according to the Brazilian standard NBR 7190/97, are 15.5 MPa, 62.4 MPa, and 17212 MPa, respectively. In the tests carried out, the twelve specimens analyzed had values close to and even higher than the normalized ones. With an average density of 815 ± 58 kg/m3, the samples had values of 14.8 ± 3.0 MPa for shear strength (fv), 62.6 ± 11.0 MPa for strength values (fc0) and 21751 ± 8230 MPa for the modulus of elasticity (Ec0) in compression parallel to the fibers. Despite the good results, due to the high coefficient of variation observed, it is recommended that wood subjected to fire not be reused for structural purposes.
Keywords: Fire. High temperature. Carbonization. Wood. Mechanical properties.

INTRODUCTION

Fires present a great risk to buildings on the aspect of risk to life and property loss. The risk to life arises due to exposure to smoke, heat and collapse of building elements. Property loss refers to the partial or total destruction of the building and all the belongings contained therein (Figure 1).

No material used in construction is completely safe in fire situations, however, the combustibility of wood is the main factor that generates insecurity in the face of potential fire-related risks.

However, experience has shown that some wooden structures have a fire resistance comparable to, or greater than, many non-combustible alternatives. Robust pieces of wood, when under the action of the flames, form a layer of insulating charcoal that prevents the exit of flammable gases and the propagation of heat into the interior part, thus helping to contain the fire and preventing the entire piece from being destroyed (PINTO, 2001).

In other words, because the temperature gradient formed during the fire is high due to the low thermal conductivity of wood and charcoal, the properties of wood in its cross section are assumed by researchers to be unchanged (SCHMID et al., 2014).

Based on this context, the motivation for this work emerged, which was to seek to establish a parallelism between the information provided by the literature from laboratory tests and a real case, aiming not only at the evaluation of theoretical models, but also at resolving doubts regarding the possibility of reuse. of these woods.

LITERATURE REVIEW

Wood as a building material has the limitation of being flammable. Consequently, wooden structures are viewed by many as a less secure environment than structures constructed of non-combustible materials such as steel and masonry.

In the calculation of fire resistance of structural elements of wood and its derivatives, the most important factor of analysis is the reduction of the cross section due to the rate or speed at which the wood is converted into charcoal (PINTO, 2005; SCHMID et al, 2014; TISO et al., 2018).

This model was described by Schaffer (1984) when he explained that the cross section of a beam exposed to fire can be divided into three parts: (i) a layer of coal with

Figure 1 – Property in a real fire situation.

Source: Own Authorship.

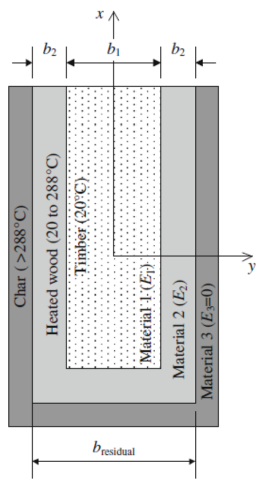


Figure 2– Section of a beam exposed to high temperature according to the model proposed by Schaffer (1984).

Source: SCHMID et al. (2014)

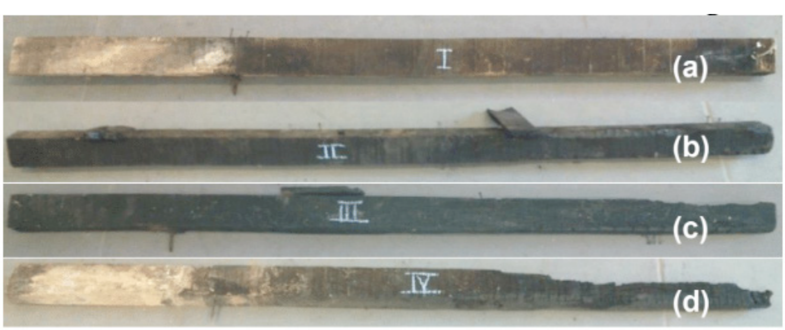


Figure 3: Parts removed from the roof structure that went through the fire.

Source: Own authorship.

zero strength and stiffness; (ii) the heated wood layer with lower strength and stiffness than normal temperature wood (pyrolysis zone); and (iii) an inner part, which exhibits unaltered material properties (sound wood).

For SCHMID et al. (2014) the temperature gradient formed in the residual cross section has a clear influence on the reduction of the mechanical properties of the part, and the heated zone within the cross section, that is, the depth of the layer with 20 C < T < 300 C, depends on the surface temperature caused by a fire and the duration of fire exposure.

This zone beyond the coal line is estimated to be 40 mm deep and is affected by the effects of temperature, whose range according to authors such as Kačíková et al. (2013), Nazerian, Ghalehno and Kashkooli (2011) and Korkut, Akgül and Dündar (2008), cause improvements in rot resistance and dimensional stability, although they have a reducing effect on the mechanical properties of wood.

For Figueroa and Moraes (2010) the permanent effects of heat transfer in wood are observed at temperatures above 65 °C and are manifested by the reduction in the weight of carbohydrates, loss of adhesion water, reflecting in the mechanical properties of the wood, and losses may occur. structural capacity (MANRIQUEZ, 2008; MANRIQUEZ, M. J., MORAES, P. D., 2009; MANRIQUEZ, 2012; WHITE, R. H.; WOESTE, F.E., 2013).

MATERIALS AND METHODS

To carry out this work, wood species from a real fire occurred in the rural area of the municipality of Itapeva/SP were used. The parts were obtained one week after the accident, when four rafters of nominal cross-section of 60 x 50 mm and 1.30 meters in length were collected from the structure of the burned roof (Figure 3).

The species was identified in the Laboratory of Anatomy of Madeira of the Experimental Campus of Itapeva, UNESP and confirmed in the Xiloteca of the IPT (Instituto de Pesquisas Tecnológicas) as being of Guarucaia (*Peltophorum vogelianum*).

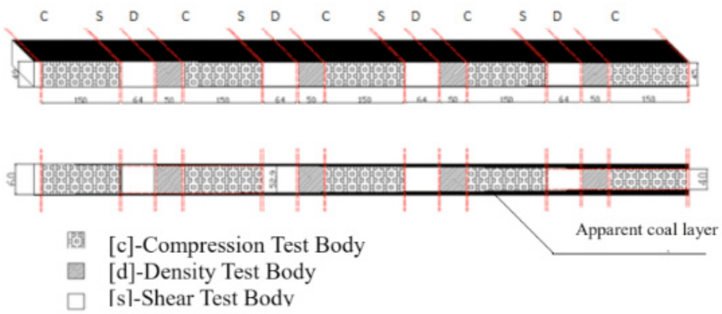
The following steps were carried out exclusively at the UNESP Experimental Campus (Itapeva/SP), including the evaluation of the condition of the parts, making the specimens, taking the final measurements and testing the physical-mechanical properties, with the entire procedure being carried out in a according to the requirements of the normative document NBR 7190/97 in a Universal Testing Machine with a capacity of 30 tons.

Figure 4 is used to illustrate the cutting scheme of the pieces, with a total of 12 specimens being extracted for the tests of apparent density, compressive strength parallel to the fibers and shear. Figure 5 shows some of these specimens.Figura 4 - Esquema de corte dos corpos de prova.

The sections of each specimen were scanned and then imported into the AutoCad 2016 software where these transition areas were demarcated and an estimated area of the pyrolysis and coal zone was obtained to be represented graphically. A sample of the procedure performed can be seen in figure 6 which shows the cross section of two specimens analyzed and their respective area estimates made in the software.

RESULTS

Table 1 shows the values of apparent density at 12% moisture ρap(12%), the properties of strength (fc0) and modulus of elasticity (Ec0) in compression parallel to the fibers and the value of shear strength (fv). In the absence of a standard, that is, of sound wood from the same batch, the value provided by Annex E of NBR 7190 (1997) was used as a control parameter.



Source: Own authorship.

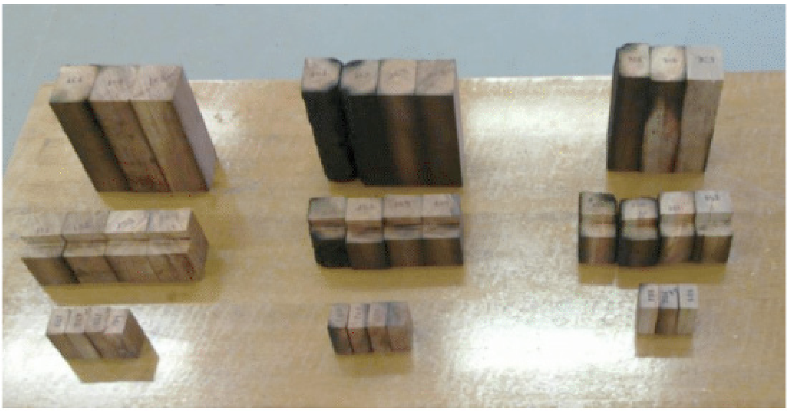


Figure 5 - Specimens used in the test.

Source: Own authorship.

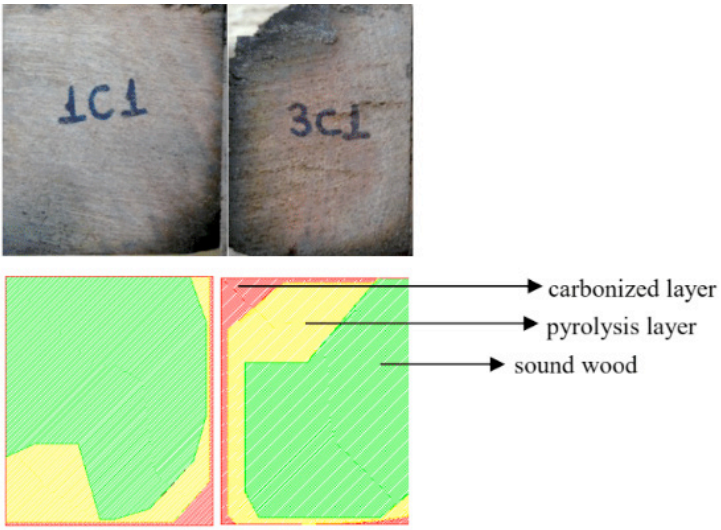


Figure 6 – Procedure for estimating residual section in specimens.

Source: Own authorship.

As shown in the table above, the samples presented an average density of 815 ± 59 kg/m3, which is lower than the usual average provided by Annex E of NBR 7190 (1997) for Guarucaia wood. None of the specimens tested reached the minimum value of 919 kg/m3 referenced, and many of these specimens had regions of coal and pyrolysis (Figure 7). For Pinto and Calil Jr. (2010) the density loss is explained by the thermodegradation process to which the wood was submitted.

Regarding the mechanical properties, even with lower density values in relation to the standardized document, the specimens continued to present good mechanical resistance. The set was characterized as having an fc0 of 62.6 MPa and EC0 equal to 21751 MPa, while the values defined in the reference document were 62.4 MPa and 17212 MPa.

As can be seen, the average values obtained in the compression tests were higher than the provisions of the proposal and with considerable margin for the modulus of elasticity. However, although the results seem acceptable, the samples tested showed high dispersion of results, with this variation being more marked in the modulus of elasticity (coefficient of variation of 38%). The high variability in the results (Figures 8 and 9) was also obtained by Leal (2010) in their studies when analyzing the mechanical behavior of old oak wood from a fire in Portugal.

As can be seen in figure 9, some specimens with a significant area of coal had high elastic modulus, almost double the normalized value. The results presented in this work follow the conclusions made by Esteves; Graça and Pereira (2008) that one of the factors that lead to the loss of mechanical strength of wood is exactly the degradation of polyoses, and the modulus of elasticity is less affected due to the lower degradation of cellulose and lignin.

Regarding the characteristic value of shear strength, the results show that the value of 14.8 MPa represents a reduction of 8% in relation to the average value indicated by the normative document NBR 7190/97, which is 15.5 MPa. The displayed variability, although high (23.8%), was less marked, since it was evidenced that the lowest values came from a single piece – Piece 3 (3C1, 3C2 and 3C3), as seen in figure 10.

Similar results regarding the influence of temperature on the shear strength of wood were found by Oliveira, Mantilla and Carrasco (2017) who studied the shear behavior of samples of wood of the angelim Vermelho species subjected to temperatures in the range of 20 to 240ºC and found that temperature negatively affected both density and shear strength as the temperature increased.

In our tests, we observed a strong interaction between the variables fv and density, whose R2 value was equal to 0.8991, concluding that more degraded bodies had lower resistance values, as shown in figure 11.

FINAL CONSIDERATIONS

Having as reference the results found, specifically for the materials and procedures adopted in the present work, it was possible to conclude that:

-In general, it is observed that there is a tendency to reduce the mechanical properties of wood resistance when subjected to a real fire, mainly due to the gradual reduction of the resistant section, replaced by coal and the effect of the thermal degradation of the wood components in the region known as the pyrolysis zone.

- Although the reduction in relation to the properties at room temperature was low in our study, in view of the comparison made with the usual values established by NBR 7190/07, in practice there is a high dispersion of results, showing very different values, the which indicates that it is particularly dangerous to reuse wood from fire as a structural element again.

CP	$\rho_{ap(12\%)}$	f_{C0}	E_{C0}	f_V
1	822	67,9	27129	13,5
2	857	75,5	25608	15,1
3	869	70,9	16005	15,0
4	694	42,9	8837	17,7
5	725	54,0	11525	16,6
6	871	57,6	11197	20,8
7	780	55,5	31821	10,6
8	851	59,4	29705	7,8
9	848	74,6	21371	12,7
10	724	48,6	32699	17,4
11	825	74,1	16933	16,6
12	829	61,6	17954	14,3
Average	**815**	**62,6**	**21751**	**14,8**
Standard deviation	**59**	**11,0**	**8230**	**3,5**
Coefficient of variation (%)	**7,2**	**17,6**	**37,8**	**23,6**
Reference value NBR 7190 (1997)	**919**	**62,4**	**17212**	**15,5**

Table 1 - Results of density tests, compression parallel to the fibers and shear.
Source: Own authorship.

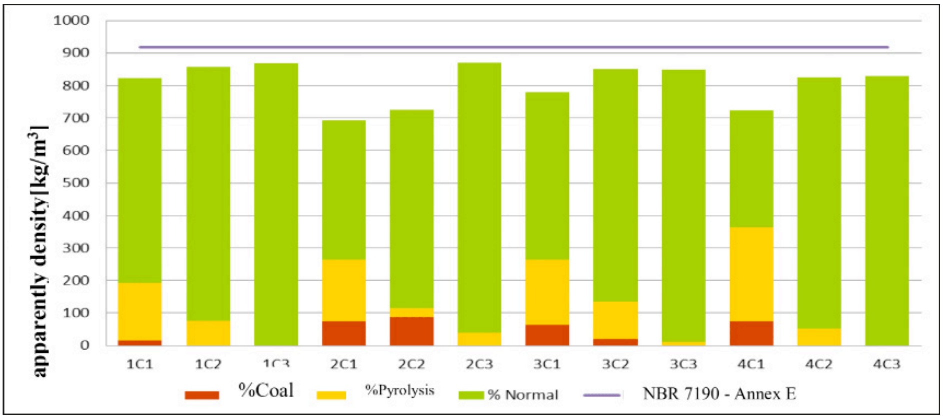


Figure 7 - Density result.
Source: Own authorship.

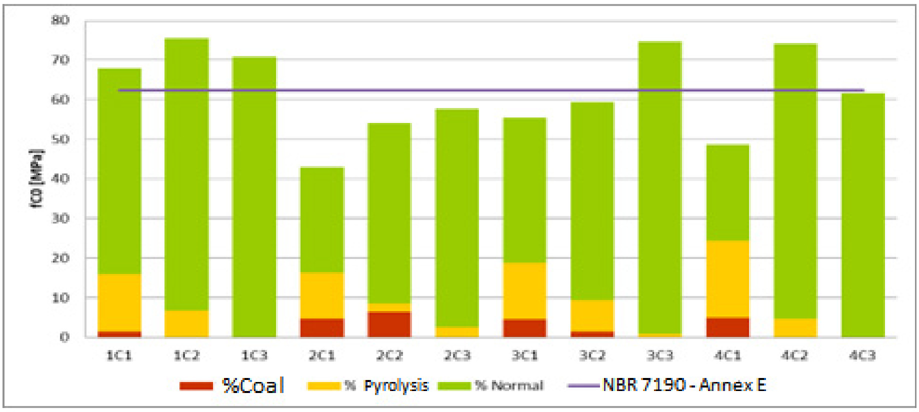


Figure 8 - Compressive strength parallel to the fibers of the specimens tested.
Source: Own authorship.

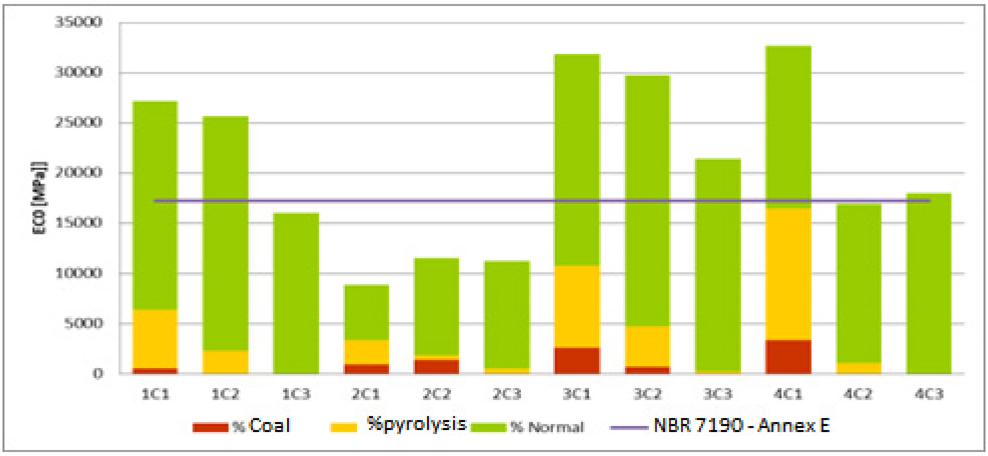


Figure 9 – Result of the elastic modulus at compression parallel to the fibers of the test specimens.

Source: Own authorship

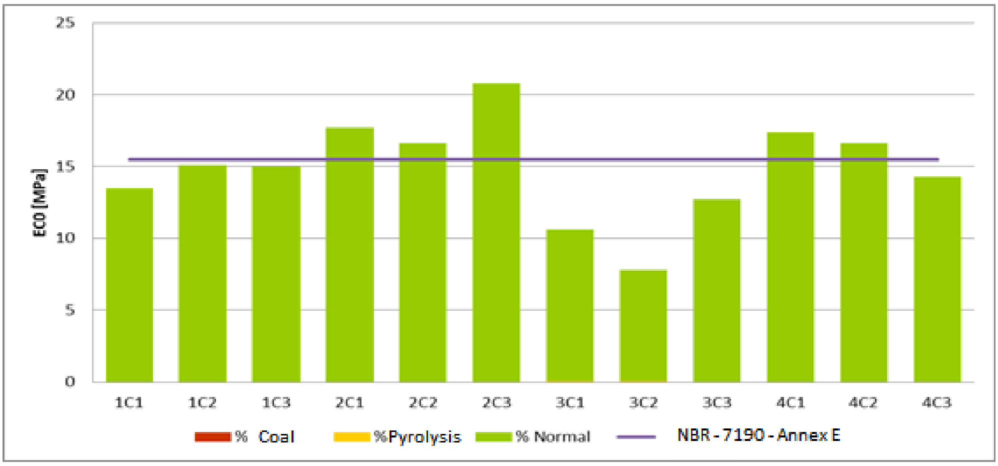


Figure 10 - Result of shear strength.

Source: Own authorship.

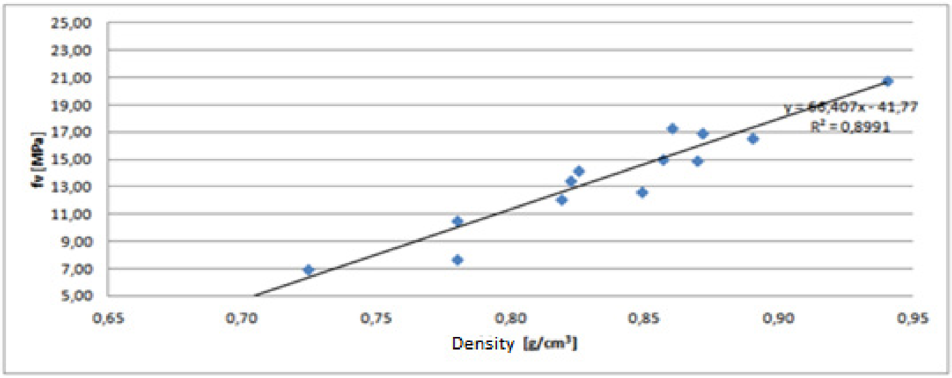


Figure 11 - Correlation of shear strength and density.

Source: Own authorship.

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