ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Influence of the age on specific gravity and janka hardness in the wood of teak (*Tectona grandis* L.F.) for floor

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ARTICLE INFO

Article history:
Received 10 October 2015
Accepted 30 November 2015
Available online 24 December 2015

Keywords:
Teak;wood quality;wood floors.

ABSTRACT

Background: The age of the tree is a factor that has a strong influence on the technological properties of wood, among them the specific gravity, which´s considered one of the most important properties because it defines almost all wood uses. This work aimed to evaluate the influence of three ages in apparent specific gravity and janka hardness of teak wood (teak) aiming its use in the manufacture of floors. They Were determined the apparent specific gravity at 12% of moisture for ages 10, 13 and 17 years, according to the NBR (11941) and COPANT Standard 465 for the janka hardness test . To analyze the results we used a completely randomized design. The specific gravity and the Janka hardness showed an increasing trend with age increase. Both properties have shown correlation. The properties meet the requirement for floor, and may probably be improved with increasing age.

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To Cite This Article: Victor Gonçalves Cremonez, Linéia Roberta Zen, Ricardo Jorge Klitzke, Marcio Pereira da Rocha and Morgana Cristina França., Influence of the Age on Specific Gravity and Janka Hardness in the Wood of Teak (Tectona Grandis L.F.) for Floor. ***Aust. J. Basic & Appl. Sci.,*** *9(35): 300-305, 2015*

INTRODUCTION

The wood varies widely in their chemical, physical anatomical and mechanical properties, which vary between species and within species due to various features, but mainly the age. Within the same species, the wood undergoes significant variation in height and pith bark, being influenced by the intrinsic characteristics of the species with respect to formation of heartwood and sapwood, juvenile and mature wood, growth rings, among others.

Klock (2000) states that the wood quality studies should take into account mainly the variations in age and position in the tree and those such variations imply large differences in the properties of wood. To Malan (1995) the radial variation is more important, by the presence of juvenile wood and its share in the trunk. According Dadswell (1972); Bujtenen and Zobel (1989), tree growth period leads to variation in the structure and properties of wood.

The specific gravity of wood is an easy property to be obtained and is an excellent parameter for assessing the feasibility of its use for various purposes (Panshin; De Zeenw, 1980). Padilha *et al*., (2006) noted the need to determine the physical and mechanical properties of wood, for use in floors.

Kolmann and Côté (1968), researching the influence of specific gravity on the Janka hardness, noted that there is a strong relationship between these parameters. Caixeta (2003) found a high correlation between janka hardness and wood specific gravity. The regression analysis between the mean values of specific gravity (SG) and Janka hardness (JH, presented the following equation JH = 2472 (SG) - 1102, with a coefficient of determination (R^2) = 0.80, with not biased distribution of residues.

Various methods have been adopted for determining the hardness of materials such as: Janka hardness, Brinell hardness and Chalais -Mendon (KOLLMANN; CÔTÉ 1968). However, the Janka hardness test has been adopted in Brazil with the aim

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of determining the hardness of wood. Gerard *et al*., (1995) and Chimelo (1980) stated that the hardness of the wood has direct correlation with the specific gravity.

Poletto *et al*. (2006) affirm the importance of determining the hardness of the wood, in parallel and perpendicular to the fiber direction. They note that Janka hardness has been gaining attention in all the essential information used to assess the quality of wood and its technological potential.

Global demand for lumber tends to grow 22% between the years 2005-2020, with an estimated increase of 94 million cubic meters, mainly with encouragement of large timber-producing markets such as Asia, Europe and North America. Thus, the wood from fast-growing species is gaining an important role to supply the international market in view of the high rates of deforestation worldwide (FOOD AND AGRICULTURE ORGANIZATON OF THE UNITED NATIONS – FAO, 2015).

The teak (*Tectona grandis* L. f) is one of the most attractive and promising species in the world, being of great interest in the major industries of the timber industry. The area of forests planted with teak in Brazil reached in 2013 an estimated area of 67,300 ha, while in 2008 the total was 58 810 ha. Such areas represented growth of 14.4 % in planted area this group of species in the country, indicating the growing interest in such species, mainly due to expectations of their financial return on timber projects (ABRAF, 2013).

According to Pérez and Kanninen (2005), several studies have demonstrated the similarity between the mechanical properties of soft wood of 21´s and timber 65´s which provides a margin for lowering the age of spin, without affecting significantly the resistance wood. Studies by Angelo *et al.* (2009) determined the financial maturity of teak from 14 to 20 years and suggest that this timber generates a profitable investment for producers with growth rates , depending on the financial environment, in return of 12 %.

With this, should be better to understand the teak wood behavior with respect to their intrinsic characteristics, considering the age, origin, spacing, genetic variability and especially their technological properties, expanding their use and generating higher value -added products.

The floor is used worldwide for this reason alternative species and rapid growth should be studied for this purpose.

Given the above, this study aimed to evaluate the influence of three ages in specific gravity and janka hardness of the wood of *T. grandis* in order to use on wood floors.

MATERIALS AND METHODS

For the determination of specific gravity and Janka hardness was used teak wood with three different ages (10, 13 and 17 years) coming from plantations located in São José do Rio Claro - MT, Brazil.

The tests for the determination of specific gravity at 12% of moisture were performed according to the recommendations of the Brazilian Standard- NBR (11941) of the Brazilian Technical Standards Association - ABNT (2003). For this, we used 25 repetitions for each age. The samples were stored in a climatic chamber at 20 + 2 ° C and 65 ± 3 % of relative moisture until stabilization in 12 % of moisture.

The Resistance to Janka hardness was according the standard procedures described in COPANT 465 (1972).

This procedure involves pressing a steel ball having a diameter of 11.284 mm for the specimen at a rate of 6.5 mm/minute. In addition, Janka Hardness is the maximum force required to penetrate the wood with respect to half the ball diameter and the result is, expressed in kilogram force (kgf/cm2).

To this end, in the trials were used 25 repetitions for each age. The tests were performed in the perpendicular direction to the fibers. The samples were stored in a climatic chamber at 20 + 2 ° C and 65 ± 3 % relative moisture until the stabilization in 12 % moisture.

To analyze the results of the specific gravity and Janka hardness at 12% moisture content, we used a completely randomized design. When detected significant differences between treatments, it used the Tukey test at the 5% level of significance for the comparison of means.

RESULTS AND DISCUSSION

The table 1 shows the results of the specific gravity at 12 % of moisture for the three ages.

Table 1: Specific gravity at 12% of moisture (kg/m^3) for three ages of species of teak (*Tectona grandis*).

Ages	Asg (Kg/m^3)	SD (Kg/m^3)	CV (%)
10	538,28 A	31,54	4,85
13	620,99 B	10,22	1,65
17	650,47 C	24,98	4,64
Mean	603.25	50,09	3,71

Asg-12% Apparent specific gravity; SD - Standard deviation; CV - coefficient of variation
Means followed by the same letter are not statistically different from each other (Tukey, $p \geq 0.05$).

It is observed that the specific gravity increased with increasing of age, being observed statistical difference at 5 % of probability for the three ages studied (Table 1).

An increase of 17.24% was observed in specific gravity, showing that the age influenced the property. Low rates of coefficient variation and standard deviation, shows that the number of samples used in the test was sufficient to analyze the property.

In similar studies, Pinto (2007) evaluated the specific gravity of teak with ages of 5, 10 and 30 and obtained results 530, 550 and 670 kg/m^3, respectively. Note that the result for the age of 10 years was close to results of this research, at the same age and the result obtained by the author at the age of 30 years was similar to that obtained in this study to the age of 17 years (Table 1).

Moya and Arce (2003) evaluating plantations of 10 years, achieved a result of 530 kg/m³ in specific gravity for teak, very close also to the value obtained in this research. Already Valero, Reyes and Garay (2005), found a value of 550 kg/m³ for stands of 20 years located in Venezuela, lower than the result for the age of 17 years (650.47 kg/m3).

According Vital (1984), the specific gravity tends to increase with the age as a consequence of increased cell wall thickness and reduced width of the cells. The wall thickness of the fibers is closely related to the specific gravity of wood (MALAN, 1995). Thus, one may say that the increased specific gravity provides an increase in most mechanical properties.

Figure 1, shows the linear regression between the specific gravity at 12 % and the age of the woods, getting a good R^2 ratio of 0.71, confirming a strong correlation between the two variables.

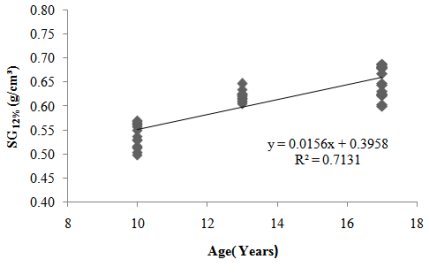

Fig. 1: Relationship of the specific gravity to 12 % of teak with the ages of trees.

In figure 1 can be observed a trend to increase with the age of specific gravity, showing that the species has a potential for lifting such property. Pinto (2007) in their study obtained specific gravity results for teak wood of 0.67 g/cm3 at the age of 30 years.

Souza (2010) observed the variation in the fiber length in the pith-bark, to characterize the transition between juvenile and mature logs with 12 years from the same planting, and noted that fiber length is not It stabilized, deducting that the wood has not heartwood. Moreover, Kokutse *et al.* (2004) found a proportional increase in specific gravity with age and a leveling trend in the specific gravity of wood of *T. grandis* over 23 years. This implies that the teak studied still has the potential for increasing the specific gravity and therefore mechanical properties, among them the Janka hardness.

Janka hardness:

Table 2 shows the results obtained for the Janka hardness to the three ages studied. In the same vein of the specific gravity, the Janka hardness increased with increasing of age , with a significant difference at 5 % among the three ages studied. Thus, it can be said that the hardness of the wood is affected by the age of the tree, and consequently the specific gravity of the wood.

Table 2: Janka Hardness apparent (kgf/cm2) at 12% of moisture for three ages of the species teak (*Tectona grandis*).

Age	JH (Kgf/cm²)	SD (Kgf/cm²)	CV (%)
10	470,41 A	56,72	8,30
13	595,77 B	65,42	10,98
17	683,13 C	50,16	10,66
Mean	583,1	57,43	9,98

JH – Janka Hardness; SD - Standard deviation; CV - coefficient of variation
Means followed by the same letter in the column are not statistically different from each other (Tukey, $p \geq 0.05$).

An increase of 31.14% was observed in the resistance to janka hardness, showing that the age influenced the property. The standard deviation and coefficient of variation indices are considered normal for the wood and show that the number of samples used in the test was sufficient to analyze the property. It can also be affirmed on this study that with a 17% increase in the specific gravity of the wood with age, gave a higher gain in the wood strength reaching 31%, demonstrating strong

influence of specific gravity and the age in resistance of Janka hardness of the wood.

Valero, Reyes and Garay (2005) reported hardness values of 602 kgf/cm² to 636 kgf/cm² in teak with 20 years in Venezuela, slightly lower than found for the age of 17 years for this search. These values were also similar to those reported for teak wood to 17 years in Costa Rica with hardness of 593 kg/cm² (CASTRO, 2000). However, Flórez (2012) found a mean value of 475 kg/cm², as well as already Posch *et al.* (2004) determined Brinell hardness of 575 kgf / cm² in teak at age 34´s, and found values lower than those obtained in this study. Although the wood present high ages the test type (Brinell hardness) might have influenced the results of hardness resistance to the wood.

Santana *et al.* (2001) determined the hardness of four clones of rubber tree (Hevea brasiliensis) in order to indicate the most appropriate uses for the corresponding timber, which in no case exceeded the value of 53.7 MP (547.58 kgf/cm2) provided in wood air dried. The authors concluded that the study wood should not be employed except for light buildings, decorative objects and packaging.

Figure 2 shows the linear regression between Janka hardness and ages (A), Janka hardness and apparent specific gravity (B), obtaining a good R^2 ratio of 0.69 and 0,57respectivelly confirming close correlation between the two variables.

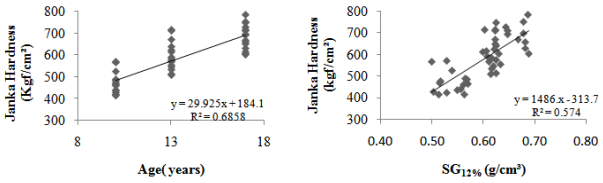

Fig. 2: Relationship of the Janka hardness with the age of trees and Janka hardness with apparent specific gravity.

In figure 2, we can observe a similar trend found with specific gravity increasing with age, showing species has the potential to increase the property. It draws much attention, justifying the need for further study to identify the moment of stabilization of the resistance of the wood to the Janka hardness and probably other properties with increasing age of planted species and fast growth.

As with increasing of the age influences the specific gravity, the lignification implies that the cell wall is tougher, with higher number of crosslinks (Abreu *et al.*, 2003). For this reason, it is possible to relate hardness with specific gravity. Figure 2 shows the linear regression between these two properties, obtaining a R^2 ratio of 0.57, confirming the relationship between the two variables.

The wood studied, although probably not include a mature wood set, indicating that the wood has not reached its maximum potential for technological use. For studies by other means Bhat, Priya and Rugmini (2001) with juvenile teak in India determined the similarities between the mechanical properties of juvenile wood (20 - 25 years old) and adult (50- 60).

According Koch (1972); Evans (2000); Dias and Lahr (2004) the specific gravity influences the mechanical properties significantly, being linearly related to most of them. Kollmann (1959); Haselein *et al.*, (2002) complement that, the wood's resistance depends on the specific gravity, and however, it is difficult to quantify this dependence, in view of the simultaneous influence of other factors.

These results are consistent with the statements that the mechanical properties are linearly related to the specific gravity. It also adds that there is a close relationship between the specific gravity and mechanical properties, and any factor that results in the change of the first factors will take effect in others.

In general, the teak wood has great potential for presenting a high dimensional stability and strong natural resistance to wood-destroying agents (Bellon, 2014). Further, it has specific gravity and Janka hardness comparable to other species already used, and are within the minimum requirements set by the standard NBR 15799:2010.

Conclusion:

The age showed an increasing trend in specific gravity and Janka hardness.

The specific gravity and Janka hardness properties showed good degree of correlation.

The wood of teak presented the resistance results of janka hardness and specific gravity close to species traditionally used in the market for higher production of various household products, including floor.

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