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# DENSITY EVALUATION OF RAW AND LAMINATED *Bambusa vulgaris* Schrad. WITH A VIEW TO ASSESS ITS STRUCTURAL APPLICATION POTENTIALS

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ABSTRACT

The suitability of bamboo for construction and structural composite products is demonstrated by its physical properties in which density is one. Thus, in order to satisfactorily use bamboo as a raw material for construction and composite products, the density must be studied. The study therefore evaluated and compared the density of raw and laminated *Bambusa vulgaris*. *B. vulgaris* culms were harvested and sectioned into four parts: Base, Middle 1 (immediate portion after the base), Middle 2 (portion after middle 1), and Top for raw bamboo and another set processed into different laminate thickness of 4mm, 6mm, 8mm and 10mm. the density of the two categories were then evaluated using standard procedure. Data were analysed using descriptive statistics and ANOVA at $a_{0.05}$. The average density of raw specimen of *B. vulgaris* was 616.84±98.42 kg/m$^3$. The result ranges from, 637.06±44.98 kg/m$^3$, 619.61±67.29 kg/m$^3$, 615.44±70.31 kg/m$^3$and 595.26±74.80 kg/m$^3$ for base, Middle 1, Middle 2 and top, respectively. The Density for laminated *B. vulgaris* was 650.57±57.97 kg/m$^3$. The mean values varied accordingly with the laminate thickness. Density values decreased linearly from laminate thickness of 4mm to 10mm with 687.86±68.20 kg/m$^3$ for laminate thickness of 4mm; 659.81±42.64 kg/m$^3$ for laminate thickness of 6mm; 636.37±41.40 kg/m$^3$ for laminate thickness of 8mm and for laminate thickness of 10mm is 618.24±55.04 kg/m$^3$. Statistically, there was no significant difference among the sampling height for the raw bamboo but there was significant difference among the laminate thickness of laminated bamboo. There no significant difference among the two variables, that is, raw and laminated bamboo. It is therefore concluded that *Bambusa vulgaris* is a medium density wood and is suitable for structural application that the tropical timber species can be used for.

**Keywords**: Bamboo, density, suitability, *Bambusa vulgaris* and laminate

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## INTRODUCTION

As in wood, the mechanical properties and structural application of bamboo are density dependent. Therefore, higher density denotes larger amount of cell wall obtainable to resist external forces. It serves as a measure for the mechanical properties such as bending and represents the simplest and the best indicator of wood quality (Kubler, 1980).

Increasing density results in corresponding increases in all strength properties except for axial tension (Dinwoodie, 1989). Density is defined as the amount of wood substance per unit volume, Panshin and de Zeeuw, (1980); Dinwoodie, (1981); Desch, (1988), explained that density of wood is a function of the cell wall thickness and also depends on the level of cell wall growth. Chafe, (1991) reported that high cellulose content in wood is a good indication of high density and low lignin content.

Properties of bamboo change because of an extensive variety of genera, families and species. Besides, important bamboo properties which are density dependent include: Tensile and compressive strength, Shrinkage, Resistibility and Elasticity. Bamboo strength varies along with culm height, Bamboo has an enormous elasticity which makes it a good building material which is environmental friendly for areas with earthquake. Also, bamboo has a comparatively low weight and can be transported easily and utilized (Klaus, 2002).

High density is associated with thick fibre walls and a higher proportion of fibres. These are the very qualities which contribute to strength and in the absence of any other data about the properties of a particular species, density is used as a guide to its utilization (Shrivastava, 1997).

Tsoumis (1991) pointed out that density is the best and simplest index of the strength of a clear wood, with increasing density, strength also increases. This is because density is a measure of the amount of cell wall materials contained in a given volume of wood.

The use of bamboo can be grouped into the following aspects: Construction, Furniture production, Paper making, Textile, Pharmaceutical usage and Household-items in which the suitability for the first two are density dependent. In the constructional aspect, bamboo is used as a building material for decoration and as a structural member of a house. Bamboo has been utilized by the local general public for housings years back, being used as poles, purlins, trusses, rafter, mats, flooring, ceiling, roof, wall, window and door frames, foot bridges and fence posts. They are in addition used in modern-day as scaffolds to support slabs during construction. Bamboo production is now common to the world and has been developed in China, India, Vietnam and Thailand and many other places where bamboo mat boards are manufactured. With studies observed, in Asian countries, bamboo can be a valuable sustainable natural resource (Naxium, 2001). Bamboo has been utilized in furniture production and pulp and paper making, as a fuel (charcoal, oil, gas produced through pyrolysis), and the fibres are used for textile making, and other ranges of products like chopsticks and table wears, also for medicinal health care products (Xaing, 2010). Bamboo has been chosen to be used as a raw material in construction due to its environmental friendly attributes and ready availability (Yu *et al.*, 2011).

According to RMRDC, (2004), bamboo is widely distributed in Nigeria. However, RMRDC, (2004) indicates that bamboo is widely distributed in the south and middle belt regions of the country. In reference to this report the states in which the bamboo is not less than 10% of their natural vegetation are: Ogun, Oyo, Osun, Ondo, Edo, Delta, Rivers, Akwa-Ibom, Cross-River, Abia, Ebonyi, Enugu, Anambra and Imo states. While states like, Ekiti, Bayelsa, Lagos, Kogi, Kwara, Benue, and Nassarawa have not less than 6.0–9.0% of their natural vegetation occupied by bamboo. Compartment of bamboo clumps is found in Niger, Taraba, Plateau and Abuja, in these states however the availability of bamboo is short of about 3.0–5.9% of natural vegetation. In Adamawa, Bauchi, Borno, Gombe Kano, Kaduna, Katsina, Kebbi, Sokoto, Jigawa, Yobe and Zamfara states, they have less than 3% of their natural vegetation dominated by bamboo

*B. vulgaris* species are found in temperate, tropical and subtropical regions. They have culms which are not straight, and the internodes are often curved. These species are of two varieties, namely: *B. vulgaris* ‘vittata’ having yellow culms and *B. vulgaris* ‘wamin’, having green culms. The culm diameter is between 50-100mm with a height of 20000mm. This species has a culm-wall thickness of about 15mm with an internode length ranging from 250-350mm (Akinlabi *et al.*, 2017).The suitability of *B. vulgaris* for structural composite products and applications are dependent upon its physical properties such as density. It is there imperative to assess the density of raw bamboo (Clear specimen) and Bamboo laminated board to make comparison between the two with a view to establish its suitability for structural composite and application

## MATERIALS AND METHODS

The bamboo culms used for this study were harvested from bamboo stand at Forestry Research Institute of Nigeria (FRIN), Ibadan. Defect free culms of above seven (7) years old were harvested from the stand. Forestry Research Institute of Nigeria, Ibadan is between latitude 7$^{o}$N and 7.2$^{o}$N and longitude 26$^{o}$E and 27$^{o}$E.

The species of bamboo used for this study is *Bambusa vulgaris* (Variety. Wamin), a bamboo species endemic to Southern Nigeria. For the raw bamboo specimen, Sections in between the nodes of the bamboo culms were cut to produce the test samples and no preservative treatment was applied to them. Samples were classified into base, Middle 1 (immediate portion after the base), Middle 2 (portion after middle 1) and top (Fig. 1). To determine the density of raw bamboo, ISO 22157-1 (2004) standard with a little modification in sample size was followed and test sample size of 25 mm x 20 mm x original wall thickness of sample was used. Samples were oven-dried at 105°C to a constant weight and the weight was recorded. Volume was computed by multiplying length, width and wall thickness which were measured using digital Caliper.

For the determination of density for laminated bamboo, Laminate thickness sizes-4mm, 6mm, 8mm and 10mm were produced and test samples of dimension 20 x 20 x 60mm were produced from the different sizes of laminates. The test samples were oven-dried to a constant weight at 105$^{o}$C. Density gradient was thus determined as given below in accordance with ASTM D 2395, 1983 for both raw and laminated bamboo

$$D = \frac{M}{V}(kg/m^3) \text{ ...........................................................(1)}$$

Where: D=Density

M = Weight of the wood

V = Volume of wood

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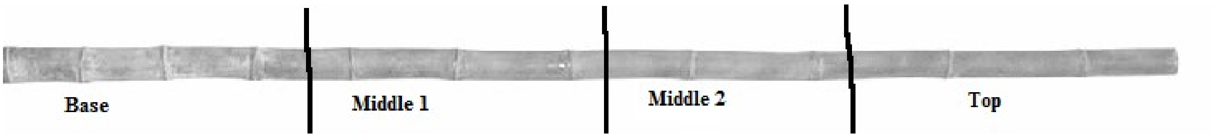


**Figure 1: Schematic diagram of sample selection for clear bamboo specimen**

## EXPERIMENTAL DESIGN AND DATA ANALYSIS

The experimental design adopted for Laminated bamboo study was a Completely Randomized Design (CRD) with the laminate thickness as the treatments and replicated sixteen times resulting into 64 test samples. The treatment (Laminate thickness) is as follows: 4mm, 6mm, 8mm and 10mm. also, the same experimental design was also adopted for raw bamboo specimen with sampling height as the treatment and was replicated 45 times resulting in 180 test samples. The treatment (sampling height) is as follows: Base, Middle 1 (immediate portion after the base), Middle 2 (portion after middle 1), and Top. Thereafter, Laminate irrespective of thickness and raw bamboo specimen irrespective of sampling height were considered as a single experiment and CRD was also adopted to test for significant difference between laminated and unlaminated (raw specimen) bamboo. Analysis of variance (ANOVA) was carried out to determine the significant effects of sources of variation in the experiment.

## RESULT AND DISCUSSION

The average density of raw specimen of *Bambussa vulgaris* was 616.84±98.42 kg/m$^3$. The result ranges from 595.26±74.80 kg/m$^3$, 615.44±70.31 kg/m$^3$, 619.61±67.29 kg/m$^3$ and 637.06±44.98 kg/m$^3$ for Top, Middle 1, Middle 2 and base, respectively (Table 1). It was observed that the density of *B. vulgaris* decreases from the base to the top (Fig. 2), this is in line with the trend found by several studies Satter *et al*. (1991 and 1994) which indicated an increase of relative density from bottom to the top

Ahmad, (2000) obtained the density of *Dendrocalamus strictus* commonly recognized as Calcutta bamboo to be 643 kg/m$^3$, he stated that density of base was 636 kg/m$^3$, while middle 1, middle 2 and top which he labeled to be Location 1 (base), 2, 3 and 4, respectively were 640 kg/m$^3$, 651 kg/m$^3$ and 644 kg/m$^3$, respectively. According to him, the relative density increased from location 1 to location 3, but location 4 was slightly lower.

Chew *et al*. (1992) gives the density of *B. vulgaris* from china at 630 kg/m$^3$, he claimed that it is relatively light compared to other bamboo in the area. The density of some bamboo species are listed according to Ahmad (2000) as follows: *Bambusa arundinacea* 790 kg/m$^3$, *Bambusa longispiculata* 910 kg/m$^3$, *Bambusa vulgaris* 790 kg/m$^3$ *Dendrocalamus giganteus* 730 kg/m$^3$, *Bambusa arundinacea* 649 kg/m$^3$. The variations observed in density of different bamboo species are the results of genetic design, as well as the affect of the climate and soil condition. Color, grain pattern and texture (Ahmad, 2000)

Ojo *et al*. (2014) obtained the density of *Borassus aethiopum* to be 685.29 Kg/m$^3$. They opined that the density decreases from the base to the top of the palm which is also monocot like bamboo, higher density denotes larger amount of cell wall available to resist external forces. It serves as a measure for the mechanical properties such as bending and represents the simplest and the best indicator of wood quality (Kubler, 1980).

Statistically, there is no significant difference in the density of the culm along the sampling height (Table 2). In other words, there is no significant variability of the material in terms of mass of dry woody substance per volume along the culm. From a manufacturing point of view, the selection of *B. vulgaris* for utilization in composite materials on the basis of its density would not be affected by the location along the culm.

**Table 1: Mean table for Laminate thickness and Sampling Height**

| Laminate thickness | Mean | Sampling height | Mean |
|---|---|---|---|
| 4mm | 687.86$^a$±68.20 | Top | 595.26$^a$±74.80 |
| 6mm | 659.81$^{ab}$±42.64 | Middle 1 | 615.44$^a$±70.31 |
| 8mm | 636.37$^{bc}$±41.40 | Middle 2 | 619.61$^a$±67.29 |
| 10mm | 618.24$^c$±55.04 | Base | 637.06$^a$±44.98 |
| Total | 650.57±57.97 | Total | 616.84±98.42 |

**Mean with the same alphabet in the column are not significantly different from one another**

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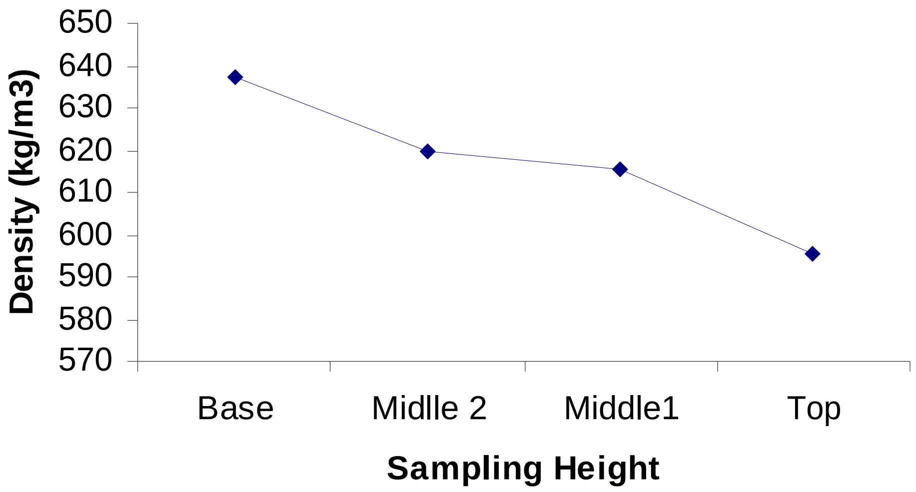


**Figure 2: Density in relation to Sampling Height**

**Table 2: ANOVA for Sampling Height**

| Sources of variation | df | SS | MS | F-value | P-value |
|---|---|---|---|---|---|
| SH | 3 | 39767 | 13256 | 1.238ns | 0.297308 |
| Error | 176 | 1883874 | 10704 | | |
| Total | 179 | 1923642 | | | |

ns= not significant at 0.05 level of probability

The Density for laminated bamboo was 650.57±57.97 kg/m$^3$. The mean values varied accordingly with the laminate thickness. Density values decreased linearly from laminate thickness of 4mm to 10mm with 687.86±68.20 kg/m$^3$ for laminate thickness of 4mm, 696.89kg/m3 for Laminate thickness of 6mm, 659.81±42.64 kg/m$^3$ for laminate thickness of 8mm, 636.37±41.40 kg/m$^3$ and for laminate thickness of 10mm 618.24±55.04 kg/m$^3$ (Table 1). It was observed that Laminate thickness 4mm has the highest density and 10mm has the lowest density (Figure 3). The variation observed can be attributed to the number of laminate that formed each of the test samples which is higher in 4mm thickness.

However from the analysis of variance carried out, there is significant difference in the density between laminate thickness of the culm (Table 3). In other words, there is significant variability of the material in terms of mass of dry woody substance per volume in each of the laminate thickness from the culm. From a manufacturing point of view, the selection of laminate thickness for utilization in composite materials on the basis of its density would be affected by the cell wall thickness along the culm. Ahmad (2000) opined that Density is the major factor that influences the mechanical properties, and it is closely related to the proportion of vascular bundles. Density is an important factor because it affects the material behavior, especially the physical and mechanical properties. In the wood-based composite material, density of the species is a strong factor that affects board properties.

There was no significant difference between the two variables, that is, Raw bamboo and laminated bamboo. The comparison of *B. vulgaris* density with other well known tropical timber species are given in table 4.

**Table 3: ANOVA for Laminate thickness**

| Source variation | df | SS | MS | F-value | P-value |
|---|---|---|---|---|---|
| **Thickness** | 3 | 43557 | 14519 | 5.178* | 0.003006 |
| **Error** | 60 | 168228 | 2804 | | |
| **Total** | 63 | 211785 | | | |

*= significant at 0.05 level of probability

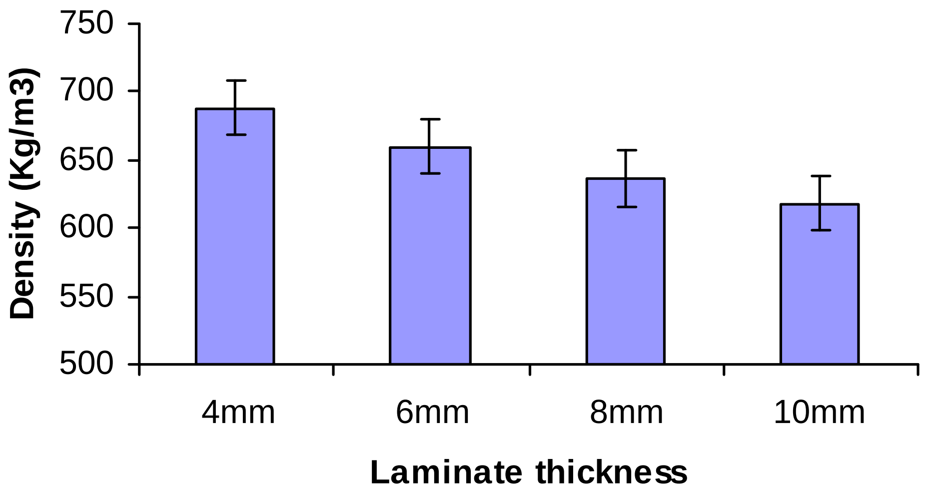


**Figure 3: Density in relation to Laminate thickness**

**Table 4: Comparison of Density of some tropical timber species with raw and laminated *Bambusa vulgaris***

| Botanical names | Common names | Density (Kg/m$^3$) |
|---|---|---|
| *Mitragyna spp* | Abura | 545 |
| *Terminalia ivorensis* | Afara (black) | 545 |
| *Terminalia superba* | Afara (white) | 497 |
| *Afromosia elata* | Afromosia (elata) | 737 |
| *Afromosia laxifloral* | | 913 |
| *Gosswellerodendron balsamiferum* | Agba | 513 |
| *Albizia zygia* | Ayunre-weere | 641 |
| *Albizia spp* | albizia | 625 |
| *Alstonia boonei* | (awun) alstonia | 400 |
| *Anogeissus leiocarpos* | Odan | 913 |

| | | |
|---|---|---|
| *Antiaris africana* | Antiaris | 433 |
| *Afzelia africana* | Apa (ita) | 720 |
| *Distemonathus bonthmianus* | Ayan | 673 |
| *Burkea africana* | Burkea, apasa | 1041 |
| *Berlinia spp* | Berlinia | 672 |
| *Canarium schweinforthii* | Cananium | 496 |
| *Celtis zenkari* | Ekugbi, Celtis | 784 |
| *Ceiba pentandra* | Ceiba | 352 |
| *Piptadeniastrum africanum* | Cotton wood | 689 |
| *Daniella ogea* | Daniella ogea | 560 |
| *Nesogordonia papaverifera* | Danta | 801 |
| *Isoberlinia doka* | Doka | 752 |
| *Diospyros mespilformis* | Ebony | 1009 |
| *Lophira alata* | Ekki | 1073 |
| *Ricinodendron neudelotii* | Erinmado | 208 |
| *Erythropleum spp* | Erun | 784 |
| *Entandrophragma angolense* | Isebo gedunohor | 560 |
| *Guarea cedrata* | Guarea (black) | 624 |
| *Guarea thompsonii* | Guarea (scented) | 544 |
| *Gmelina arborea* | Gmelina | 496 |
| *Pycnanthos angolensis* | Ilomba | 512 |
| *Milicia excelsia* | Iroko | 656 |
| *Lannea acida* | Lannea (acida) | 464 |
| *Lannea egregla* | Lannea | 448 |
| *Khaya grandifoliola* | Mahogany (Africana) | 496 |

| | | |
|---|---|---|
| *Khaya ivorensis* | Mahogany (lagos) | 496 |
| *Khaya senegalensis* | Mahogany (dry zone) | 768 |
| *Mansonia altissima* | Ofun mansonia | 640 |
| *Tryplochiton scleroxylon* | Obeche | 368 |
| *Scottellia coriacea* | Odoko | 656 |
| *Daniella ogea* | Ogea (iya) | 512 |
| *Cylicodiscus gabumensis* | okan | 929 |
| *Brachystegia spp* | okwen, (Eku) | 548 |
| *Nauclea diderrichii* | opepe | 752 |
| *Parinari congensis* | parinari | 752 |
| *Pterygota macrocarpa* | pterygota | 688 |
| *Entandrophragma cylindricum* | sapele wood | 784 |
| *Sterculia rhinopetala* | sterculia (brown) | 672 |
| *Sterculia oblonga* | sterculia (yellow) | 801 |
| *Strombosia grandifolia* | strombosia (Itako-pupa) | 831 |
| *Tectona grandis* | teak | 640 |
| *Entandrophragma utile* | utile | 640 |
| *Lovoa trichilioides* | walnut | 544 |
| **Bambusa vulgaris (Raw)* | Bamboo | 616.84 |
| **Bambusa vulgaris (Laminated)* | Bamboo | 650.57 |

**Source: Forestry Research institute of Nigeria (FRIN, 2010)**

***current work**

## CONCLUSION

The density of raw bamboo along the length of the culm and laminated bamboo with different laminate thickness have been analyzed. Density of the entire culm was determined not to significantly change along the length but density changes as a result of different laminate thickness. From a practical point of view, this is a desirable factor because more bamboo woody material can be recovered for products.

Density of laminated bamboo varies consistently and significantly among the different laminate thickness from 4mm to 10mm thickness, this gives an indication of the tendency of obtaining material of better quality with low laminate thickness. Both raw and laminated *Bambusa vulgaris* can be regarded as a medium density wood, from the foregoing, *B. vulgaris* is suitable for structural application and structural composite

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