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STRENGTH PROPERTIES OF THERMAL TREATED GLUE LAM OF BAMBOO *BAMBUSA VULGARIS* (SCHRAD. Ex J.C.WENDL)

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ABSTRACT
This study was therefore conducted to assess the influence of thermal modification on, gluability and strength of bamboo. 50 culms were harvested in New-Bussa, Niger State. Production of *Bambusa vulgaris* strips was carried out in the Department of Forest Resources Management, using a Circular saw; samples were thermal treated by steaming at 121^{0}C for 2hours, 4hours, 6hrs, and 8hours respectively. They were air dried for 2 weeks and laminated using top bond glue. Selected strength properties namely; Impact bending, Tensile Strength, Compressive strength, Shear Strength parallel to glue line and Shear strength perpendicular to Glue line were conducted and the result analysed using ANOVA and regression analysis. Results showed that impact strength ranged from 22.97 ± 0.06 (mm) to 30.00 ±1.00 (mm). The mean tensile strength ranged from 28.67N/mm^2 to 36.57N/mm^2. Compression strength parallel ranged from 42.33 ± 0.31 N/mm^2 to 49.37 ± 0.72 N/mm^2. The mean values for shear strength parallel to glue line ranged from 0.22N/mm^2 to 0.32N/mm^2. While that perpendicular to glue line ranged from 0.99N/mm^2 to 1.15N/mm^2. Analysis of variance showed significant variation among strength values for thermal treated glue-lam at varying Temperature. Thermal treatment significantly improved gluability of bamboo. Both the main factors, which are the heat time and pressing time considered in the processing of the bamboo laminate samples, are significantly different at 0.05% level of probability. The effect of interaction between the two factors also shows a significant influence at 5% level of probability. Based on the result from this research work the strength of bamboo glue-lam is significantly affected by period of exposure to thermal treatment, also gluability of *Bambusa vulgaris* laminates are affected by pressure time.

KEYWORD: Strength properties, Thermal modification, glue laminate, gluability

INTRODUCTION
Physical and mechanical properties of several bamboo species have been studied extensively, bamboo is a hollow tube, sometimes with thin walls and consequently it is more difficult to join bamboo than pieces of wood. Bamboo does not contain the same chemical extractives as wood, and can therefore be glued very well [Jassen, 1995]. Bamboo's diameters, thickness and intermodal length have a macroscopically graded structure while the fibre distribution exhibits a microscopically granted architecture, which lead to favourable properties of bamboo (Amada et al., 1997).
Bamboo has been globally recognized as an ecologically friendly substitute to the commonly used timber, The rate of over exploitation of various economic trees in the world is yielding to a bleak future of various tree plants of significant important .With the continued rapid development of the global economy and constant increase in population, the overall demand for wood and wood based product, will likely continue to increase in the future. This according to FAO, (1997) will be in order of 20% by 2010. However, bamboo's strength, lightness combined with extraordinary hardness, ranges in size, abundance, easy propagation and short gestation period make it suitable for various construction purposes. The role of bamboo in conserving soil and protecting watersheds is also substantial in Africa. (Ongugo et al., 2000) Compared with wood, bamboo has many advantages; greater strength, more tenacity, strong rigidity, treatability, and has better physical-mechanical performance, bamboo's static bending, rigidity and strength of extension can be up to twice that of other hardwood flooring. Folding strength and surface degree of bamboo flooring is greater than that of other hardwood flooringBamboo is the fastest growing plant on earth; it has been measured surging skyward as fast as 121cm (47.6inches) in a 24-hour period. (David, 2003) unlike trees, all bamboo species grow to full height and girth in a single growing season of 3-4 months, Recently, there has been a great shift towards the usage of glue-lam bamboo for various furniture and other construction purposes. Although, bamboo is said to be a non durable products, the scope of use has continued to expand. There is really no limit to the uses of laminated bamboo, it can be used for Chairs and other form of Furniture materials, domestics utensils in fact it can be used just like laminated wood, with the advantage that bamboo laminates are much lighter in weight. The fact that bamboo is not yet fully utilized in modern structures generally in all over the world, due largely to lack of validation based on the theory of mechanics, material science, structural design and testing. (Xiao, 2009) however, modern usages of different solid materials obviously necessitate for the determination of the various strength properties of diverse solids material so as to determine the appropriate specification for different design and construction usage of such materials for various products, such materials as metals and wood which had really helped in precise specification of

different materials for different purpose. The rural communities harvest bamboo products indiscriminately in their land for sale to the urban dwellers. Although, Bamboo and Rattan exploitation and utilization have yielded direct and immediate micro level benefits to economically disadvantages of rural people in Nigeria (Olufemi, 2003). The importance of Bamboo cannot be overemphasized, as it had gained both International and Local recognition in term of its uses. The usage of bamboo is not exceptional in Nigeria, According to Ogunjimi, et al., (2009) *Bambusa vulgaris* has significant Social economic impact on the lives of the people living in rural area in Nigeria. The lives of the people in rural area revolve around the use of *Bambusa vulgaris* for one purpose or the other, such as medicine, shelter, and fishing and host of others. The bamboo plants support an International trade, which amounts to over US$2billon per year. International trade, however, form only a part of bamboo usage, with domestic use estimated to account for at least80 percent of the total, Bamboo is thus a major world commodity. (Bystriakova, 2004). Notwithstanding, more intensive and meaningful manipulation of bamboo in term of structures and designs are essential to be able to fit-in the more into global usage. To use bamboo effectively in building industry also means to reduce the use of timber this, in turn, will help the world lifting the burden on the environment due to excessive logging, especially of the diminishing tropical forests. With this aim, bamboo scientists and engineers are striving to generate deeper knowledge on bamboo and better technology of manufacturing bamboo composite beams.

Bamboo lamination is the modern methods of making bamboo durable to structural applications. However, gluability of bamboo depends on several factors amongst which are chemical components. Presence of high level of glucose in bamboo had been attributed to low level of adhesion with several adhesive agents. According to Li, (2004) Pre-treatment of wood and other lignocellulosic materials with heat will reduce sugar content of wood and can therefore enhance wood adhesion. This study is therefore embarked upon to thermal modify bamboo strips with a view to assessing its gluability. The perception and evaluation of non-wood forest products is changing due to alarming rates of deforestation and decreased timber yields (Kigomo, 2007) Interest in bamboo has increased as several studies have been done to evaluate bamboo's physical and mechanical properties and its utilization potential as an alternative to wood resources [lee et al., 1994, Ahmad 2000, Shupe et al., 2002). Utilization of bamboo strips in laminated form is seen to have great potential to supplement timber, hence reducing dependency on some timber species for furniture in the future (Zheng, 2009).

Heat treatment has been used for various wood products to improve their dimensional stability and durability against biodeterioration (Kamdem et al, 2002, Militz, 2002). Heat treatment does not involve toxic chemical and is environmentally friendly. Different types of heat treatment process have been investigated and it was found that process conditions, such as wet or dry application and type of chemicals or oils and their temperatures were major parameters influencing overall properties of the treated products (Rapp and Sailer, 2000; Syrjänen and Kangas, 2000). Recently, interest have been shown to apply heat treatment to non-wood products such as bamboo (Leithoff and Peek, 2001 and Razak et al., 2004a). This process usually involves with dipping in hot diesel for a few hours prior to air drying (Razak et al., 2004b). Heat treatment can also be applied to bamboo using different materials such as various types of oils, water and hot air.

METHODOLOGY

The Bamboo samples for the research work were collected from Ibi in New-Bussa, Niger State Ibi has a total land mass of 5,340.82km^2 of Latitude 9^{0}40'N and 10^{0}30'N and Longitude 3^{0}30'E and 5^{0}5'E (Aremu et al., 2002)

Methods of data collection

Sample Selection and Harvesting

The samples were collected from the site; bamboos of the same sizes, i.e. 35-40cm in diameter and height of 300cm-450cm, of good grades with no appearance of defects were harvested. Total numbers of 10 bamboo culms per stand were harvested in 5 stands to give a total of 50 culms.

Conversion process

Processed and dried bamboo stem were air dried to attain 85% moisture content prior application of the adhesive chemicals. The adhesive chemicals were prepared and applied through the process of spreading method to the planed surface of the bamboo. The mat laying was left for 5 minutes in order to allow proper penetration of the adhesives before the introduction of pressure with hydraulic press machine. The samples were converted into standard dimensional sizes of 20 mm x 20 mm x 300 mm, 20 mm x 20 mm x 60mm and 20 mm x 20 mm x 20mm respectively for strength test in accordance with British Standard D 373.

Laminate Production Method

The culms in the experiment were obtained by taking out the first segment at about 60 cm in length from the bottom. The remaining culms (only the bottom and middle parts) measuring about 2m in length were crossed cut into segments.

Production of the *Bambusa vulgaris* strips was carried out in the Department of Forest Resources Management, University of Ibadan. The Culms sections of 2m were cut again into 1m to 1.5m in order to have straight pieces. Each piece was split in the axial direction into proper number of slices; the slices are dried, and were immersed in Sodium pentachlorophenate Solution to protect it against biodegradation. Each slice was machined by cutting off the inner and outer faces to form Bambusa strips with thickness of 0.5cm. Top bond glue of 10g was applied on each side surface of the bamboo strip using a metal spatula. (Sulastiningsil et al., 2009), was applied on bamboo strips then stacked to form Bambusa laminates of 2cm thickness dimension .Hence; each laminate was pressed in hydraulic press at 75 Pascal (constant) for Three (3) different pressing times (period). Such as, 1hour, 2hours, 3hours

Thermal treatment

Strips of 30cm x 2 cm x 0.5cm cm were produced. Strips were dried at indoor conditions until moisture content value range between 75 to 80%. Thermal treatment was conducted at Biotechnology department in Forestry Research Institute of Nigeria, Ibadan in an autoclave. Strips were subjected to temperature of 121 ± 2^0c (Constant) at different period interval; 2hrs, 4hrs, 6hrs and 8hrs.

Testing of Laminated Bamboo

Tensile bending

Tensile bending properties was used to test according to British Standard for testing Smaller clear specimens of timber (BS375:1957) Using Universal Testing Machine Tensiometer. The dimension of the Central loading specimen 20mm width(W) x 20mm depth(D) x300mm length (L) and the distance between the point of support of the test piece (L) is 280mm. Standard Load head was controlled at the constant Speed of 0.26in/mm.

Compression Parallel to Grain –ASTM D143-52 of 1997

The specimens' dimensions were 20mm by 20mm in section and 60mm in length. A continuously compression load with load rate of 0.6mm/min was applied.
Processed bamboo samples for compression test

Shear Strength Parallel to Grain ASTM D143-52 of 1997

Shear parallel to grain was performed base on the dimension of the specimen. The load was applied continuously throughout the test at the rate of 0.6mm/min. Ultimate shear stress was calculated.

Shear Strength Perpendicular to Grain ASTM D143-52 of 1997

Shear parallel to grain was performed based on the dimension of the specimen. The load was applied continuously throughout the test at the rate of 0.6mm/min. Ultimate shear stress was calculated.

Impact bending strength

The impact bending test was carried out using Hatt-Turner impact testing machine available at the Department of Forest Products Development and Utilization, FRIN, Ibadan; dimensional standard test specimen of 20 mm x 20 mm x 300 mm was adopted in accordance with BS D373 1989. 3 replicated samples of each bamboo glued laminated was supported over a span of 240 mm on a support radius 15 mm spring restricted yokes which were fitted in order to arrest rebounce. This specimen was subjected to a repeated blow from a weigh 1.5kg at increasing height from 50.8mm and continues increasing every 50.8mm until complete failure occurred. At the point of final failure, the height at which failure occurred was recorded in meter as the height of maximum hammer drop (Dinwoodie, 1989).

DATA ANALYSIS

Experimental Design

The study was focused on the experimental study of 2 factors; (4) heating period (hr) levels (3) Pressing time (hr). The laminated bamboo was experimented under these factors to find mechanical properties; tensile strength, compression strength, impact bending test, shears in both parallel and perpendicular direction. Each experiment was run for 3 replicates with a total test sample for each of the mechanical tests conducted.

Analysis of Variance (ANOVA)

One-way Analysis of variance (1-way ANOVA) and multiple regression was conducted to investigate and model the relationship between response variable tensile strength and 2 independent variables i.e. heating period (hr) and pressing time(hr) respectively. Completely randomized design (CRD) with 3 replications was adopted as the experimental design while the treatment design adopted and was laid in 3 x 4 Factorial resulting in 12 treatment combinations.

RESULTS

Impact Testing Strength

Tensile Strength

The mean values of tensile strength observed from the bamboo glued laminated samples ranged from 28.67N/mm^2 to 36.57N/mm^2

Shear Strength in parallel direction

The values for shear strength in parallel direction of bamboo glued laminated samples ranged from 0.22N/mm^2 to 0.32N/mm^2 respectively. In heating time, the shear strength reduces as the heating time increases while the pressing time within each heating time increases as the pressing time increased.

Shear Strength in perpendicular direction

The values for shear strength in perpendicular direction of bamboo glued laminated samples ranged from 0.99N/mm^2 to 1.15N/mm^2 respectively.

Compression Strength

The average values of the factors tested for compression testing strength ranged from 42.33 ± 0.31 (N/mm2) to 49.37 ± 0.72(N/mm2)

TABLE 1: The result of analysis of variance conducted on impact strength test of Bamboo glued laminated samples

SV	Df	SS	MS	F-Cal	Sig	F-tab
Heat time	3	436.700	145.567	347.276	0.000	3.01
Pressing period	2	79.711	39.855	95.082	0.000	3.40
Heat time * press period	6	68.165	11.361	27.103	0.000	2.51
Error	24	10.060	0.419			
Total	35	594.636				

P≤0.05 mean significantly different at 5% level of probability

TABLE 2: The result of analysis of variance conducted on tensile strength of Bamboo-glued laminated samples

SV	Df	SS	MS	F-Cal	Sig	F-tab
Heat time	3	158.647	52.882	199.556	0.000	3.01
Pressing period	2	8.772	4.386	16.550	0.000	3.40
Heat time * press period	6	61.702	10.284	38.806	0.000	2.51
Error	24	6.360	0.265			
Total	35	235.480				

P≤0.05 mean significantly different at 5% level of probability

TABLE 3: the result of analysis of variance conducted on compression strength values of bamboo glued laminated samples

SV	df	SS	MS	F-Cal	Sig	F-tab
Heat time	3	133.225	44.408	257.855	0.000	3.01
Pressing period	2	14.287	7.143	41.477	0.000	3.40
Heat time * press period	6	25.342	4.224	24.525	0.000	2.51
Error	24	4.133	0.172			
Total	35	176.988				

P≤0.05 mean significantly different at 5% level of probability

TABLE 4: the result of analysis of variance conducted on shear strength in parallel direction of bamboo glued laminated samples

SV	df	SS	MS	F-Cal	Sig	F-tab
Heat time	3	0.013	0.004	47.531	0.000	3.01
Pressing period	2	0.006	0.003	33.031	0.000	3.40
Heat time * press period	6	0.005	0.001	9.906	0.000	2.51
Error	24	0.002	8.89E-005			
Total	35	0.026				

P≤0.05 mean significantly different at 5% level of probability

TABLE 5: the result of analysis of variance conducted on shear strength in perpendicular direction of bamboo glued laminated samples

SV	df	SS	MS	F-Cal	Sig	F-tab
Heat time	3	0 .036	0.012	31.863	0.000	3.01
Pressing period	2	0.006	0.003	7.301	0.003	3.40
Heat time * press period	6	0.021	0.003	9.135	0.000	2.51
Error	24	0.009	0.000			
Total	35	0.026				

P≤0.05 mean significantly different at 5% level of probability

DISCUSSION

In the result of analysis of variance conducted on the strength properties assessed shows that there are significant differences in the factors considered in the production of bamboo glue laminate samples. Both the main factors, i.e. heat time and pressing time considered in the processing of the bamboo laminate samples, are significantly different at 0.05% level of probability.

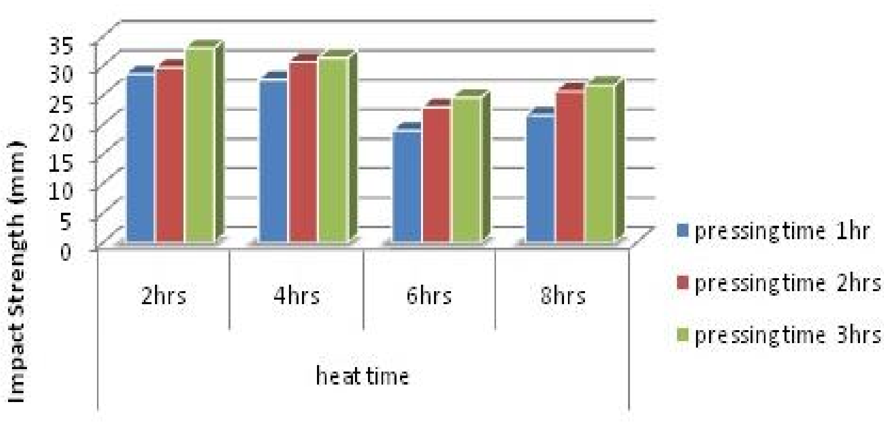

FIGURE 1: Effect of heat and pressing time on impact strength conducted on bamboo glue laminate

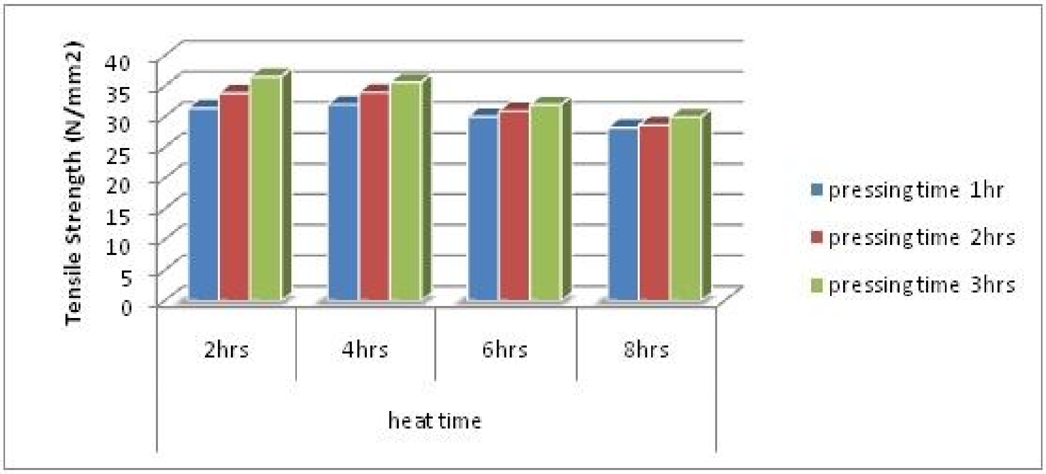

FIGURE 2: Effect of heat and pressing time on tensile strength conducted on bamboo glue laminate

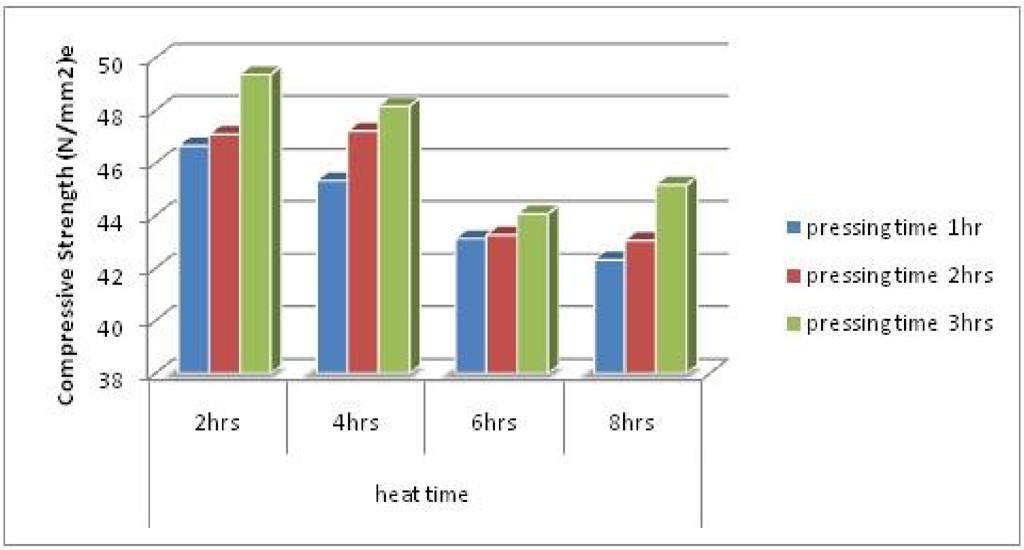

FIGURE 3: Effect of heat and pressing time on compression strength conducted on bamboo glue laminate

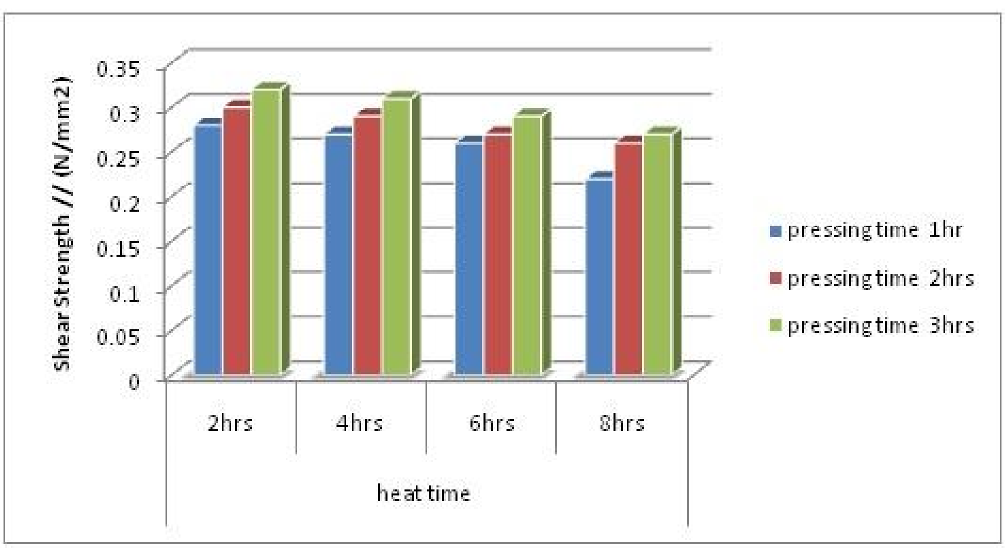

FIGURE 4: Effect of heat and pressing time of shear strength in parallel direction conducted on bamboo glue laminate

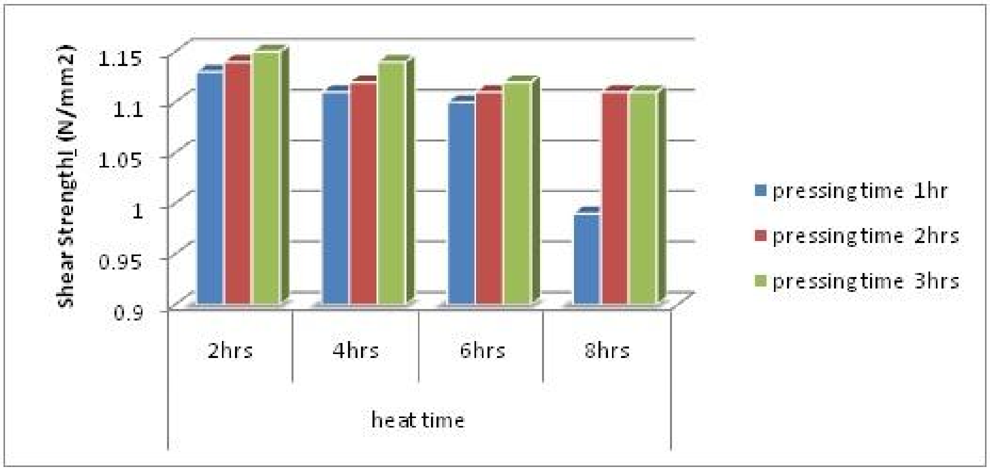

FIGURE 5: Effect of heat and pressing time of shear strength in parallel direction conducted on bamboo glue laminate

The effect of interaction between the two factors also shows significant influence at 5% level of probability. This implies that, if strength is to be well impacted in processing and production of bamboo glue laminate panel, there is needs to consider the heating and pressing time more importantly. The strength properties start from impact testing, compression, tensile, shear in parallel and in perpendicular direction were all influenced by the main factors. The relationship in the effect of the main factors to the strength properties were illustrated in Figures 1,2,3,4 and 5 respectively. These figures showed the increases in the heating and pressing time of all the strength properties in such that as the heating time increases, the strength values decreased accordingly. While in the pressing time, as the pressing time increases, the strength values increased. These observations in this study correlate with the previous findings of other studies on bamboo laminate. (Roziela Hanim *et al*., 2010) revealed the poor shear strength and bamboo failure reflection to the glue bond quality of the laminated bamboo, while (Zaidon *et al.,* 2000) reported shear strength being affected by grain orientation. As reported by other researchers, shear strength and strength properties of bamboo laminates reduces by heat treatment. The reason for the loss of strength may have been due to the presence of oil in the cells. Presence of oil may reduce the wetting of the surface, thus reducing the absorption of adhesive by the surface. This effect may eventually reduce the adhesion to the surface (Roziela Hanim *et al*., 2010). The adhesive used if water borne resins would affect the curing process, even the polymerisation, the process will lose water used in the solvent. Polymerisation process evolves too much water in the bond lines and this will retards the reaction. Insufficient water prior to polymerisation reduces the mobility of the resin and limiting heat transfer, controls of both the open and close assembly times are important in controlling the penetration and water content in the bond line (Rowell, 2005). Furthermore, follow up test was conducted on the variable factors to determine the level at which the factors significantly differed from each other. According to table 6, the subscript letter with the mean values in the strength properties shows that the best outstanding strength performance in the bamboo-glue laminate was the bamboo panel produced at heating time of 2 hours, followed by 4 hours and 6 hours. This implies that if heating treatment is to be considered in the production of bamboo panel, heat time of 2 hrs should be best considered for better strength performances. Meanwhile, the pressing time also shows significant influence in the strength properties of bamboo-glue laminate panel, the pressing time of 3 hours had the best outstanding performance in time of pressing than the other pressing times. Table 6 above shows the mean values of the data after analysed with DMRT, the subscript alphabetical letters shows the different between the values in relation to their strength performances.

TABLE 6: The result of Duncan Multiple Range Test conducted for both heat and pressing time on bamboo glue laminate samples

Factors		Strength properties				
		Impact	Compression	Tensile	Shear (//)	Shear (┴)
Heat time	2hrs	30.42^{a}	47.71^{a}	33.98^{a}	0.30^{a}	1.14^{a}
	4hrs	29.89^{b}	46.91^{b}	33.91^{b}	0.29^{b}	1.12^{b}
	6hrs	24.66^{c}	43.52^{c}	31.01^{c}	0.27^{c}	1.11^{b}
	8hrs	22.19^{c}	43.49^{c}	28.98^{c}	0.25^{d}	1.06^{c}
Pressing time	1hr	25.13^{c}	44.69^{c}	31.35^{c}	0.26^{c}	1.09^{b}
	2hrs	26.49^{b}	45.31^{b}	31.99^{b}	0.28^{b}	1.12^{a}
	3hrs	28.74^{a}	46.23^{a}	32.56^{a}	0.30^{a}	1.12^{a}

CONCLUSION

Glue-laminated bamboo structures have served as alternatives to choice timber species which are currently being over-exploited. Thermal treatment of laminate members will enhance service life as well as gluability of bamboo. Investigation into the heat and pressing treatment of bamboo glue laminate revealed that the effect of interaction between the two factors also shows significant influence at 5% level of probability. It is important to exploit the versatility of bamboo in middling and top-grade building construction, architecture decorating, and other major applications. Its high valued utilization not only promotes the economic development in bamboo areas where people are in low-income, but also saves forest resources to protect our ecological environment as a wood substitute. *Bambusa vulgaris* is a promising non-timber forest product in Nigeria, due to its outstanding strength properties values, hence, assuring its ability to stand a better alternative in terms of wood dependency in Nigeria.

RECOMMENDATION

It is hereby recommended to Federal Government of Nigeria and all Allied research Institutes that the Inventory of bamboo in terms of location, quantity and quality be further assessed, also, research and development in the establishment and management of the *Bambusa vulgaris* species in the natural forests and in plantations should be well considered.

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