Ethiopian Journal of Environmental Studies & Management 19(5): 563 – 574, 2026
ISSN:1998-0507 doi: https://ejesm.org/doi/v19i5.2
Submitted: June 13, 2026 Accepted: August 24, 2026

STRENGTH RESPONSE OF TEAK (*Tectona grandis* Linn. F.) GLUE-LAM BOARDS TO VARIATIONS IN ADHESIVE SPREAD RATE AND LAMINA DIMENSION

***OJO, A.R.[1] AND OJO-ADEDEJI, T.R.[2]**
[1]Forestry Research Institute of Nigeria, Ibadan, Oyo State, Nigeria
[2]Federal College of Forestry, Jericho Ibadan, Oyo State, Nigeria
*Corresponding author: djofafrica2000@yahoo.com

Abstract
The over-exploitation of the forest has left the forest with small diameter logs. Apart from having small diameter, the trees are also characterized by juvenile wood with large proportion of sapwood, therefore, there is need for laminated board to meet the need of end users. This research assesses the effect of glue quantity and laminate dimension on strength properties of glue-laminated board of Tectona grandis (teak). T. grandis planks were converted to laminate sizes of 20mm x 20mm; 20mm x 10mm; 20mm x 5mm and 20mm x 2.5mm and laminated into boards with different glue quantities (10g, 20g and 30g). Strength properties such as the Impact strength, Modulus of Rupture, Compression strength, Shear strength both parallel and perpendicular to the grain were assessed and the results were subjected to Analysis of Variance. The mean values for Impact strength ranged from 18.55±2.16 to 32.83± 2.97 for the10g adhesive, while it ranged from 20.95± 1.37 to 32.70± 0.43fir 20g and 20.05± 0.09 to 32.90±3.22 for 30g quantity of adhesive. The for Modulus of Rupture varied between 63.27±10.07N/mm^2 and 101.91±3.47N/mm^2, for the 10g adhesive 68.72 ±4.82N/mm^2 and 101.92±3.38N/mm^2 for 20g adhesive, while for 30g adhesive, it ranged from 71.05±4.43 to 103.24±5.29. Compression Strength, ranged from 24.65±2.00N/mm^2 to 48.09±5.18N/mm^2 for the 10g and 25.25 ± 1.84 to 48.73 ± 5.49 for 20g, and 26.63 ± 2.72 to 48.73±5.49. For 30g Shear Strength in parallel direction to the grain and 9.57N/mm^2 to 24.29N/mm^2 for shear strength in perpendicular direction to the grain. It was therefore concluded that quantity of glue and laminate sizes have significant effects on the strength properties of the laminate board.

Keywords: *Adhesive, Laminate, Compression strength, Modulus of Rupture, Shear strength*

Introduction
The over-exploitation of the wood species in Africa and the world forest has led to the disappearance of many and consequently threatening their survival in the forest. The popularity of these species is borne out of their favourable mechanical, durability and aesthetics properties. These favourable properties are gradually reducing or have reduced thereby leaving the forest with small diameter logs. Apart from having small diameter, the trees are also characterized by juvenile wood with large proportion of sapwood which is not as durable as the matured timber of the same species.

(Ogunsanwo *et al.,* 2007). Wood has been found to be important raw materials that contribute significantly in improving the country's economic base, industrialization and comfort of the teeming population. Solid wood being a biological material and important raw-material for various end uses in the wood industry for low raise construction, rural housing, framework and scaffolding, packaging, bullock carts and agricultural implements, is still considered indispensable and highly demanded in spite of many substitute materials like iron, steel, concrete and plastics (Kamala *et al*., 1999). These substitutes have not always been successful because of their difficulties in matching the versatility and intrinsic properties of wood as a natural engineering material.

These properties of wood have led to the perpetual interest and demand for wood and its product. In 1993, consumption of sawn wood and wood-based panels was put at 2.688 and 0.121 million m^3, respectively (FAO, 1995). The projection of wood consumption of 4.704 and 0.688 million m^3 was made for the year 2010 for sawn wood and wood-based panels, respectively (FAO, 1995). This increasing demand for wood has been reported to be commensurate with the increasing world population. Koch (1992), reported that the world population is projected to be more than double by the end of this twenty first century meaning that demand for wood and its product will rise to this level. As a result, more pressure is mounted on forest estates thereby leading to the over exploitation of the available forest resources in both the natural and plantation forest.

It has been reported that less than the two third of the harvested tree is finally taken away from the forest for further processing (FAO 1995). In addition, Ajayi (2001) stated that only about 50-55% of the harvested wood becomes marketable after processing in the sawmill. This indicates that large quantity of wood waste is generated during wood processing. Wood waste by definition is residues generated from wood during conversion processes, this starts from primary to secondary conversion.

Badejo and Giwa, (1995) reported that the bulk of wood wastes generated in Nigeria was estimated to be 1.72 million square meters and rose to 2.3 million square meters by the year 2010. These waste in time past has been mostly burnt by most sawmills therefore resulting to environmental pollution through the emission of poisonous gases during burning method disposal. However, research on viable option of wood waste utilization to meet future wood products need and reduce environmental pollution has brought about the development of wood composite technology for the production of value-added products (waste-to-wealth approach) where it is possible to use small diameter logs, small particle in the forms of fine, coarse and flake in the production of particleboard and medium density fiberboard particle or layered composite to produce laminated boards.

The term glue was first applied to bonding materials of nature origin while "adhesive" has been used to describe those of synthetic compositions. Today the terms are often used interchangeably, but adhesive better covers all types of materials. Feirer (1975) described an adhesive as a substance that bind two or more objects together, his description takes into consideration other wood connectors, such as; nails, cements, mucilage, paste and glue. (Forest Products

Laboratory services) "FPL' maintained that glue has a long and distinguished record for strength and durability in wood joints under service conditions, where wood remains dry. It has been observed that the glues in laminated wood products furnished sufficient original bonding strength to enable the glue member to perform as a structural unit, such strength throughout its service life. Glued-laminated board was first used as early as 1893 and since then it has been of use till date. Glue laminated board has been found to give a greater yield potentials in terms of dimensional stability, uniformity, greater desired mechanical strength, availability in larger sizes, improved stress distributing properties, appealing appearances, easy mould-ability and adaptability to engineering end use designs and has been a successful alternative to solid wood (Shukla *et al.,* 1999).

Due to these advantages, many researchers have studied the properties of glued-laminated board produced from various wood species. Therefore, it would be important that further investigation should be carried out on the production of glued-laminated board using a common and widely used tropical wood species such as Teak (*Tectona grandis).*

Teak has been recognized as the most preferred timber species in the tropics for saw log and veneer production from planted forests. It is a very durable hardwood, with rich beauty, resistant to fungi, rot and termites. For this reason, it has been the preferred choice for many uses including structural applications; this is because of its ability to resist splintering, warping and rotting. With the renowned durability and decorative values of its heartwood, teak has proved eminently suitable for multiple end uses (Bhat, 2000). Teak wood is famous in World over for its strength, durability, dimensional stability, working qualities, and the fact that it does not cause corrosion when in contact with metal (Kukachka, 1970). It rarely shakes, shrinks or warps to any appreciable extent during conversion and in this respect, it is a much safer wood for innumerable uses.

With the above uses of teak in conjunction with the prospective problems of demand for wood and conversion processes, it is important that teak should be fully utilized hence the production of laminated boards using teak wood residues. This study therefore evaluated the technical properties of glued-laminated boards of *Tectona grandis* with a view to determining the processed variables which are critical to service performance such as influence of glue quantity and effect of laminate dimension on the strength properties of glued-laminated *T. grandis*.

Materials and Method

Conversion Process

The *Tectona grandis* lumbers obtained from Forestry Research Institute of Nigeria's sawmill were converted to test specimen of standard size 20mm x 20mm x 300mm in accordance with British Standard BS 373 (1989). The processed samples were oven-dried at 105^{o}C to attain 8% moisture content prior to adhesive application and bonding processing. This was done exactly one week before testing for mechanical properties in order to prevent possible dimensional changes as a result of loss of moisture from wood.

The samples were converted into four variables (Laminate sizes) namely A (20x20mm), B (20x10mm), C (20x5mm) and D (20x2.5mm). 15 samples each were produced for all the variables to produce a total of 60 samples

Bonding Process

The wood pieces were oven-dried at 105°C to reduce the moisture content after which they were weighed on a weighing balance. The quantity of the adhesive used were as follows; 10g (QTY I), 20g (QTY II), and 30g (QTYIII). The adhesive glue was spread on the wood, paired and glue together following an arrangement of plain wood – adhesive – plain wood. Wood samples were clamp together for the period of 72 hours at a constant temperature and pressure. Surfacing treatment was carried out by the use of sandpapers to smoothen the surface of the laminates in order to aids uniform and perfect bonding between laminates

Impact Bending Test

The impact bending test was carried out using the Hatt-Turner Impact Testing Machine at the Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria, Ibadan; following British Standard BS 373 (1989). In this method, standard test specimen 20 x 20 x 300mm was supported over a span of 240mm on a support radiused 15mm, spring restricted yokes are fitted in order to arrest rebounce.

This was then subjected to a repeated blow from a weight 1.5 kg at increasing height initially from 50.8mm, and then every 25.4mm, until complete failure occurred at which point the height was recorded in meter as the height of maximum hammer drop and the Impact strength is expressed as follow:

$$IMB = \frac{mgh}{A} \quad \text{..(1)}$$

Where IMB = Impact Strength (Kj/m^2)
M= mass of harmer in kg
G=acceleration due to gravity
H=height of fall (m)
A= Cross sectional area of the specimen (m^2)

Modulus of Rupture (MOR)

The Modulus of Rupture was carried out in accordance with British Standard Method BS 373. This involves the use of standard test specimens (20mm x 20mm x 300mm) on Instron 3369 model Universal Testing Machine (UTM). The load was applied at the rate of 0.1 mm/sec with the grain parallel to the direction of loading, that is, specimens was loaded on the radial face. The bending strength of wood usually expressed as (MOR) which is the equivalent fibre stress in the extreme fibres of the specimen at the point of failure was determine from the machine. Load at failure was recorded and the corresponding PC monitored values were taken directly from the machine. And the Modulus of Rupture was determined using the equation:

$$MOR = \frac{3PL}{2bd^2} \quad \text{..(2)}$$

Where:
P = Maximum load at failure (N)
L = Span of the material between the supports (mm)
b =Width of the material (mm)
d = Thickness of the material (mm)
The unit of MOR is N/mm²

Determination of Maximum Compression Strength (MCS)

The maximum compressive strength parallel to grain was determined. Test specimens used for density determination were used for this test, that is, 20mm x 20mm x 60 mm according to BS 373, method of testing small clear specimen of timber, was prepared and used on Instron 3369 model Universal Testing Machine (UTM).

Load at failure was recorded and the corresponding PC monitored values were taken directly from the machine. The MCS// was determined by the equation:

$$MCS// = \frac{P_{max}}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where: Pmax= maximum load at failure
A=sectional area of test sample

Determination of Shear Strength

The measurement of shear strength both parallel and perpendicular to grain was carried out in Instron 3369 model Universal Testing Machine (UTM). according to BS EN 205 and TS EN 12765 The loading was carried out until a break or separation occurred on the surface of the test samples. The shear strength was calculated using the observed load (Fmax) and bonding surface area of the sample (A, mm^2) according to the following formula

$$\infty = \frac{Fmax}{A} = \frac{Fmax}{ab} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where a is the width of the glued surface (10mm) and b is the length of the glued surface (20mm)

Data Analysis

The experimental design adopted for the experiment was 3x4 Factorial in Completely Randomized Design (CRD). Analysis of variance was carried out to determine the significant effect of the factors of production on laminate's properties.

Result and Discussion

Impact Strength

The mean values of the various variables tested for impact strength ranged from 20.05± 0.09Kj/m^2 to 32.90±3.22Kj/m^2 as shown in Table 1. The highest value was recorded in glue quantity of 30grams with impact strength of 32.90±3.22Kj/m^2, the highest impact strength in glue quantity 10grams was 32.83±2.97 Kj/m^2 and in the glue quantity of 20grams, the highest impact strength was 32.70±0.43Kj/m^2. In relation to the quantity of glue applied to the various samples in accordance to the impact strength derived, in 10grams of glue, the highest value was from the laminated dimension of 20mm x 5mm with 32.83± 2.97 Kj/m^2, followed by 20mm x 10mm with 26.43±4.14Kj/m^2 and the least was from 20mm x 20mm with 18.55±2.16 Kj/m^2. In 20grams of glue, the highest impact strength was from laminated dimension of 20mm x 5mm with 32.70±0.43 Kj/m^2 followed by laminated dimensional size of 20mm x 10mm with impact strength of 26.45± 1.04Kj/m^2 and the least strength was from laminated dimension of 20mm x 20mm with 20.95± 1.37 Kj/m^2.

In the highest quantity of glue of 30grams, the highest impact strength value recorded was from laminated dimension of 20mm x 5mm with 32.90±3.22 Kj/m^2, followed by laminated dimension of 20mm x 10mm with 30.03±1.58 Kj/m^2 and the least impact strength value was from laminated dimension of 20mm x 20mm with 20.05± 0.09Kj/m^2. This observation shows that as the quantity of the glue applied increases, the impact strength of the samples increases in laminated dimensions of 20mm x 10mm and 20mm x 2.5mm, while laminated dimension of 20mm x 5mm shows un-proportionate in the impact strength values. Adejoba (2008), obtained 11.04 Kj/m^2 for the IMB of *Ficus mucuso.* In his findings, he opined that the IMB was the same at any dimension of the wood of *Ficus mucuso*. This variation pattern in IMB may be attributed to the fact that wood is a natural material and the tree is subject to many constantly changing influences, hence wood properties vary considerably. (Green *et al*, 1999).

Table 1: The mean values of strength properties of laminated boards produced with *Tectonia grandis* (teak)

Laminated Variables		**Strength Properties**				
Glue Quantity	**Laminate Dimension**	**Impact test (KJ/m^2)**	**Modulus of rupture (N/mm^2)**	**Compression strength (N/mm^2)**	**Shear strength // (N/mm^2)**	**Shear strength ⊥ (N/mm^2)**
10 grams	20mmx20mm	18.55±2.16	101.91±3.47	48.09±5.18	24.05±0.95	24.29±1.04
	20mmx10mm	26.43± 4.14	97.53±5.47	47.30±0.48	22.44±0.62	22.50±0.54
	20mm x 5mm	32.83± 2.97	75.78± .80	47.19±0.24	20.59±0.72	20.31±0.90
	20mmx2.5mm	18.90±3.20	63.27±10.07	24.65±2.00	10.12±0.15	9.57±0.70
20grams	20mmx 20mm	20.95± 1.37	101.92 ± 3.38	48.73 ± 5.49	24.07±0.96	24.29±1.04
	20mmx 10mm	26.45± 1.04	98.36 ± 3.58	47.85 ± 0.81	22.74±0.90	23.00±0.74
	20mm x 5mm	32.70± 0.43	79.67 ± 7.25	47.56 ± 0.31	20.25±0.65	20.63±0.85
	20mmx2.5mm	22.60± 2.01	68.72 ±4.82	25.25 ± 1.84	10.40±1.63	10.11±0.44
30grams	20mmx 20mm	20.05± 0.09	103.24±5.29	48.73±5.49	24.07±0.96	24.2 ± 1.04
	20mmx 10mm	30.03±1.58	101.58±1.95	47.88± 0.32	22.94±1.71	23.63±1.25
	20mm x 5mm	32.90±3.22	82.89±9.14	47.68 ± 0.36	20.55±0.67	20.81±0.69
	20mmx2.5mm	25.85± 2.13	71.05±4.43	26.63 ± 2.72	10.47±0.67	10.44±1.61

The result of ANOVA (table 2) showed that, there were significant differences in the factor A (glue quantity) and B (laminate sizes), while the effect of interaction between the two factors was not significantly different at 0.05 level of probability. This implies that both factors had significant effect on the impact strength values assessed.

Modulus of Rupture (MOR)

The average values of various variables assessed for Modulus of rupture ranged from 63.27±10.00N/mm^2 to 103.24±5.29N/mm^2 as shown in Table 1. The highest modulus of rupture value for the laminated samples was recorded in glue quantity of 30grams with 103.24±5.29N/mm^2, in 20grams with 101.92±3.38N/mm^2 and in10grams with 101.91±3.47N/mm^2. In relation to the quantity of glue applied to the samples and the modulus of rupture derived, in 10grams of glue applied, the highest value was from laminated dimension 20mm x20mm with 101.91±3.47, Followed by 20mmx10mm with 97.53±5.47N/mm^2, followed by 20mm x 5mm with 75.78±±0.80N/mm^2 and the least modulus of rupture was from laminated dimension of 20mm x 2.5mm with 63.27±10.07N/mm^2. In 20grams of glue applied, the highest strength was from laminated dimension of 20mm x 20mm with 101.58±3.38N/mm^2 followed by laminated dimension of 20mm x 10mm with 98.36±3.58N/mm^2 and the least modulus of rupture was from laminated dimension of 20mm x 2.5mm with 68.72±4.82N/mm^2. In the highest quantity of glue applied (30grams), the highest modulus of rupture value recorded was from laminated dimension of 20mm x 20mm with103.24±5.29. Followed by 20 x10mm with101.58±1.95N/mm^2, followed by laminated dimension of 20mm x 5mm with 82.89±9.14N/mm^2 and the least modulus of rupture value was from laminated dimension of 20mm x 2.5mm with 71.05±4.43N/mm^2 respectively. It was observed that as the quantity of glue applied and laminate size assessed increases, the modulus of rupture of the samples also increases

FPRL (1966) recorded a mean value of 83.3N/mm^{2,} for *Milicia excelsa*, 76.3 N/mm^2 for *Mitragyna* sp. 95.5N/mm^2 for *Khaya senegalensis*, and 39.9N/mm^2 for *Antiaris africana*. Ayarkwa, (1997) and Asafu-Adjaye, *et al,* (2013) obtained 65N/mm^2 for *Borassus. aethiopum* from Ghana. While Ojo *et al.* (2012) obtained 59.20N/mm^2 for the same species in a derived savannah zone in Nigeria. The value obtained in this study compares well with most of species already used for structural applications. From this, it will be observed that MOR decreased as the laminate sizes decrease. Ogunsanwo (2000), emphasized that such increase of MOR might be due to variations in some morphological parameters such as fibre length, wall thickness and fibre diameter.

The result of ANOVA (table 2) showed that, there was significant difference in the factor B only while the other factors such as the glue quantity and interaction between the two factors were not significantly different at 0.05 level of probability. This revealed that laminate dimension significantly influenced the modulus of rupture of the samples assessed while the quantity of glue does not have significant influence on the modulus of rupture assessed.

Compression Strength

The mean values of the various variables assessed for compression strength ranged from 24.65±1.84 to 48.73 ± 5.49 as shown in Table 1. The compression strength values for laminated samples produced with 30grams of glue quantity ranged from 26.63±2.72 N/mm^2

to 48.73±5.49 N/mm^2, in this glue quantity, dimensional size of 20mm x 20mm had the highest compression strength value with 48.73±5.49N/mm^2, followed by dimensional size of 20mm x 10mm with 47.88± 0.32N/mm^2, dimensional size of 20mm x 5mm followed with 47.68±0.36N/mm^2 and the least compression strength value was from dimensional size of 20mm x 2.5mm with 26.63±2.72N/mm^2. In 20grams of glue application for the production of the laminated boards, compression strength value ranged from 25.25±1.84 N/mm^2 to 48.73±5.49N/mm^2, dimensional size of 20mm x 20mm had the best compression strength value with 48.73±5.49N/mm^2, followed by dimensional size of 20mm x 10mm with 47.85±0.48 N/mm^2, dimensional size 20mm x 5mm followed with 47.56±0.24N/mm^2 and the least compression strength value was from dimensional size of 20mm x 2.5mm with 25.25±1.84N/mm^2. In 10grams of glue application, compression strength value ranged from 24.65N/mm^2 to 48.09N/mm^2, dimensional size of 20mm x 20mm had the highest compression strength value with 48.09 N/mm^2, followed by dimensional size of 20mm x 10mm with compression strength value of 47.30N/mm^2, dimensional size of 20mm x 5mm had the compression strength value of 47.19N/mm^2 and the least compression strength value of 24.65N/mm^2 was from dimensional size of 20mm x 2.5mm.

Akira (1978), reported 16N/mm^2 for *B. aethiopum* sampled in Ghana, Guinea, Sudan and Kenya while, Ayarkwa (1997) reported 58N/mm^2 and Asafu-Adjaye (2013), reported 35.10N/mm^2 for *B. aethiopum* from Ghana. The difference could have been caused by ages, laminate sizes and type of adhesives used. Lausberg *et al.* (1995), were of the opinion that genetic factors and growing conditions could cause such variation. FPRL (1966), recorded 16.94N/mm^2 for *Hildergadia barteri*, 30.45N/mm^2 for *A. africana* and 34.44N/mm^2 for *Daniellia oliveri*. This indicates that value obtained from the present study is in the same range with those from primary species that are already popular in structural applications.

High Strength in compression parallel to the grain is required of timber used as columns, posts, and as notched timbers. It is worth noting that, the variation in strength properties found among different sections of the same wood species influences the selection of a section for a particular use. Cell wall thickness could have contributed to this because Panshin and de Zeeuw (1980), noted that it controls mechanical properties especially MCS//.

The Compression strength Parallel to the Grain have been classified according to Farmer, (1972), as very low, low, medium, high, and very high when the strength values are under 20N/mm^2, ranging from 20-35N/mm^2, 35-55N/mm^2, 55-85N/mm^2 and over 85N/mm^2 respectively. This classification consequently rates the laminated products as high. The result of compression strength in relation to the quantity of glue applied to the samples showed that as the quantity of the adhesive increases, the compression strength of the samples increases, while the laminated dimensional size is proportionate to the compression strength value recorded, this is illustrated in Figure 3

The result of ANOVA (table 2) showed that, there were significant difference in factor B only (laminated size), while factor A (glue quantity) and interaction between the two factors were not significantly different at 0.05 level of probability. This revealed that there was no significant effect between the glue quantity and two factors interaction between laminate size and glue quantity assessed. Laminated sizes of the board were found to significantly influence the compression strength of the samples irrespective of the glue quantity used.

Shear Strength Parallel (//) and Perpendicular (┴) to Grain

The mean values of shear strength in parallel direction conducted on the variables were presented in Table 1. The shear strength in parallel direction values of the laminated samples ranged from 10.12 ± 1.17N/mm^2 to 24.07 ± 0.95N/mm^2. laminated samples of dimensional size of 20mm x 20mm x 20mm had the highest shear strength in parallel direction for both variables of laminate size and glue quantity respectively. The shear strength in parallel direction values for laminated samples produced with 30grams of glue quantity ranged from 10.47N/mm^2 to 24.07 N/mm^2, dimensional size of 20mm x 20mm had the highest shear strength (//) value with 24.07 N/mm^2, followed by dimensional size of 20mm x 10mm with 22.94N/mm^2, dimensional size of 20mm x 5mm followed with 20.55N/mm^2 and the least shear strength in (//) value was from dimensional size of 20mm x 2.5mm with 10.47N/mm^2. In 20grams of glue application for the production of the laminated boards, shear strength in (//) value ranged from 10.40 N/mm^2 to 24.07N/mm^2, dimensional size of 20mm x 20mm had the highest shear strength in (//) value with 24.07N/mm^2, followed by dimensional size of 20mm x 10mm with 22.74 N/mm^2, dimensional size 20mm x 5mm followed with 20.25N/mm^2 and the least shear strength in (//) value was from dimensional size of 20mm x 2.5mm with 10.40N/mm^2. In 10 grams of glue application, shear strength in (//) value ranged from 10.12N/mm^2 to 24.05N/mm^2, dimensional size of 20mm x 20mm had the highest shear strength in (//) value with 24.05 N/mm^2, followed by dimensional size of 20mm x 10mm with shear strength in (//) value of 22.44N/mm^2, dimensional size of 20mm x 5mm had the shear strength in (//) value of 20.59N/mm^2 and the least shear strength in (//) value of 10.12N/mm^2 was from dimensional size of 20mm x 2.5mm.

The result of shear strength in (//) in relation to the quantity of glue applied to the samples showed as the quantity of the glue applied increases, the shear strength of the samples increases, while the laminated dimensional size is proportionate to the shear strength in (//) value recorded. The analysis of variance presented in (Table 2) showed that there were significant differences between the groups of variables assessed. The various dimensional sizes had effect on the shear strength along the glued joint assessed on the variables.

The mean values of shear stress in perpendicular direction conducted on the variables were presented in Table 1. The shear strength in (┴) direction values of the laminated samples ranged from 9.57 ± 1.17N/mm^2 to 24.29 ± 0.95N/mm^2. laminated samples of dimensional size of 20mm x 20mm x 20mm had the highest shear strength in (┴) direction for both variables of laminate size and glue quantity respectively. The shear strength in (┴) direction values for laminated samples produced with 30grams of glue quantity ranged from 10.44N/mm^2 to 24.29 N/mm^2, dimensional size of 20mm x 20mm had the highest shear strength in (┴) value with 24.29 N/mm^2, followed by dimensional size of 20mm x 10mm with 23.63N/mm^2, dimensional size of 20mm x 5mm followed with 20.81N/mm^2 and the least shear strength in (┴) value was from dimensional size of 20mm x 2.5mm with

10.44N/mm^2. In 20grams of glue application for the production of the laminated boards, shear strength in (⊥) value ranged from 10.11 N/mm^2 to 24.29N/mm^2, dimensional size of 20mm x 20mm had the highest shear strength in (⊥) value with 24.29N/mm^2, followed by dimensional size of 20mm x 10mm with 23.00 N/mm^2, dimensional size 20mm x 5mm followed with 20.63N/mm^2 and the least shear strength in (⊥) value was from dimensional size of 20mm x 2.5mm with 10.11N/mm^2. In 10 grams of glue application, shear strength in (⊥) value ranged from 9.57N/mm^2 to 24.29N/mm^2, dimensional size of 20mm x 20mm had the highest shear strength in (⊥) value with 24.29 N/mm^2, followed by dimensional size of 20mm x 10mm with shear strength in (⊥) value of 22.50N/mm^2, dimensional size of 20mm x 5mm had the shear strength in (⊥) value of 20.31N/mm^2 and the least shear strength in (⊥) value of 9.57N/mm^2 was from dimensional size of 20mm x 2.5mm.

The result of shear strength in (⊥) in relation to the quantity of glue applied to the samples shows that as the quantity of the adhesive increases, the shear strength in (⊥) for the sample increases, while the laminated dimensional size is proportionate to the shear strength in (⊥) value recorded. Analysis of variance presented in (Table 2), showed that there were significant differences between the groups of variables assessed. The various dimensional sizes had effect on the shear strength assessed on the variables.

In this study, the decreases in shear strength depending on the quantity of adhesives used were relatively similar (Table 1). Sernek *et al*. (2007) reported a decrease in shear strength of 13% for spruce bonded with PF and UF. In another study Sernek *et al.* (2008) reported that shear strength was 6.28N/mm^2 for untreated spruce bonded with MUF and 4.86 N/mm^2 for heat treated spruce, a decrease of 23%. But these results are not directly comparable, properly because of variation in quantity of glue and method used and especially due to the different wood species used in these studies.

Table 2: result of the analysis of variance conducted on the laminated boards

Sources of variation	**df**	**Ftab**	**Fcal-value**				
			Impact test	**MOR**	**Comp. strength**	**Shear strength//**	**Shear strength⊥**
Factor A (Glue qty)	2	3.27	6.26*	2.35ns	0.015ns	0.20ns	0.64ns
Factor B (Lam size)	3	2.87	66.26*	94.82*	175.14*	490.35*	546.88*
Interaction (AxB)	6	2.37	1.94ns	0.57ns	0.20ns	0.12ns	0.62ns
Error	36						
Total	47						

*=significant at 0.05level of probability
ns=not significant at 0.05 level of probability

Conclusion

The result obtained in this study showed that dimensional size of glu-lam produced had effect on the strength properties of the tested samples. This is because strength properties assessed reduced proportionately to the dimensional sizes used. Laminated samples of dimensional size 20mm x 10mm had the highest strength values followed by dimensional size 20mm x 5mm and the lowest strength value was from laminated sample of dimensional size 20mm x 2.5mm. Hence, as laminate size increases, the strength properties also increases and performance of such laminated boards in service becomes better. Also from the study, glue quantity had influence on the strength properties of samples tested. This was obvious in the impact strength. The highest glue quantity (30g) applied showed the highest strength followed by glue quantity 20grams and the least strength was found in glue quantity 10 grams. Therefore, the more the glue applied to samples, the higher the strength displayed and better performance achieved.

It is recommended that further studies be carried out on the effect of other types of glue in different quantities on the strength of glue- laminated boards of *Tectona grandis* so as to give better understanding and clarity on how glue can improve the strength of laminated boards of *T. grandis* due to its versatility. There is need to also investigate properties such as the physical properties in order to determine how suitable glue-laminated board could assist in serving as alternative to solid wood.

References

Adejoba, O.R. (2008). Evaluation of *Ficus mucuso* (Welw. Ex Ficalho) Wood Properties and Their Variations. Unpublished Ph.D. Thesis, Dept. of Agriculture and Environmental Engineering, University of Ibadan, 197pp

Ajayi, B. (2001). Wood waste management of forest industries. *Journal of Tropical Forest Resources,* 17(2): 91-102.

Akira, T. (1978). Compilation of Data on the Mechanical Properties of Foreign woods. No 7, Part III (Africa). January, 1978. A monograph published by Matsue: Shimane University.

Asafu-Adjaye, O.A., Frimpong, M.K. and Darkwa, N.A. (2013). Assessment of the effects of density on the mechanical properties variations of *Borassus aethiopum.* Scholars Research Library Archives of Applied Science Research, 2013, 5 (6): 6-19. Available online at www.scholarsresearchlibrary.com

Ayarkwa, J. (1997). Potential for the Utilization of *Borassus aethiopum* (Fun Palm) in construction in Ghana. Forest Research Institute of Ghana. WOOD: January – March 1997. pp 15-18

Badejo, S.O.O. and S.A. Giwa. (1995). Dimensional Stability of Cement Bonded Boards Manufactured with Coffee Chaff*, Journal of the Korean Wood Science and Technology* 34(5): 52-58.

Bhat, K.M. (2000). Timber quality of teak from managed plantation of the tropics. *Bios et forets des Tropiques,* 263(1): 6-16.

British Standards (BS) 373, (1957). Method of Testing Small Clear Specimens of Timber. British Standard Institute, London. pp 32

BS EN 205 (1991). *Test Methods for Wood Adhesives for Non-structural Applications-Determination of Tensile Shear Strength of Lap Joints*. British Standards Institution.

F.A.O. (1995). Forestry: Statistics today for tomorrow, Rome, 52p

Farmer, R.H. (1972). Handbook of Hardwood. Second Edition. Her Majesty’s Stationary Office London 2, 49-50pp

Fierer J.L. (1975). Wood material and process chase, A bennet publishing company inc. Pp-592.

Forest Product Research Laboratory (FPRL), (1966). Federal Department of Forestry Research, Ibadan. Federal Ministry of Information, Lagos. No. 10 p. 8.

Green, D.W., Winandy, J.E. and Krestchmann, D.E. (1999). Mechanical Properties of wood. Wood handbook. Wood as an engineering material. Madison, WI USDA Forest service. Forest Products laboratory, 1999, general technical report FPL; GTR-113: pp 1-45

Kamala, B.S., Rao, R.V. and Sharma, S.N. (1999). performance test of solid wood, *European Journal of Wood and Wood Products,* 57(2): 114-116.

Koch, F.A. (1992). Population census (internet article)

Kukachka, B.F. (1970). Properties of imported tropical woods. Res. Pap. FPL-125.

Lausberg, M.J. Cown, F., MacConchie D.J. and Skipmith, J.H. (1995). Variation in some Wood Properties of *Pseudotsuga menziensii.* Provenancies grown in New Zealand". *New Zealand Journal o*f *Forestry Scienc*e 25(2): 133- 146

Ogunsanwo, O.Y. (2000). Characterization of Wood Properties of Plantation grown Obeche (*Triplochiton sceleroxylon.* K. Schum) in Omo Forest Reserve. Ogun State, Nigeria, *Ph.D Thesis in the Department of Forest Resources Management. University of Ibadan. pp 253.*

Ogunsanwo, O.Y., Terziev, N. and Elowson, T. (2007). Evaluaion of Physical and Mechanical Properties of two lesser known Hardwoods from Nigeria. *Journal of Tropical Forest Resources,* 23(1): 28-36

Ojo, A.R., Ogunsanwo, O.Y. and Areghan, S.E (2012). Assessment of some Strength Properties of *Borassus aethiopum* (Mart) Wood from South-Western Nigeria. *Journal of Sustainable Environmental Management (JSEM),* 4: 102-109

Panshin, A.J. and de Zeeuw. C. (1980). Textbook of Wood Technology. 4th Edition MacGraw-Hill Book Company. Pp722

Sernek, M., Humar, H., Kumer, M. and Pohleven, F. (2007). "Bonding of thermally modified spruce with PF and UF adhesives," In: Proceedings of the 5th COST E34 International Workshop. Bled-Slovenia, pp. 31-39.

Sernek, M., Kamke, F.A. and Glasser, W.G. (2008). Comparative analysis of bonding performance of wood adhesives. *Wood Science and Technology,* 42(3): 195–206.

Shukla, S.R., Rao, R.V. and Sharma, S.K. (1999). Evaluation of strength properties of Glue-laminated boards, *European Journal of Wood and Wood Products*, 57(4): 267-270.

TS EN 12765 (2004). "Classification of thermosetting wood adhesives for non-structural applications," Turkish Standards Institution.