American Journal of Engineering Science and Technology Research
Vol. 3, No. 1, September 2015, pp. 1 - 14, ISSN: 2327 - 8269 (Online)
Available online at www.ajestr.com

Research article

FLEXURAL STRENGTH OF SOLID AND GLUE-LAMINATED TIMBER BEAMS

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ABSTRACT

An investigation into the flexural strength of solid and laminated timber beams under working conditions was conducted. Six locally available species, which consist of three hardwoods and three softwoods were investigated, which were Berlina, Danta, Alstonia, Agba, Ohia, and Obeche. The dimension of the hardwoods solid beams are 100mm×100mm×900mm and softwoods solid beams are 150mm×150mm×900mm. The result showed that the density of Berlina is 0.00128g/mm^3, Danta is 0.000903g/mm^3, Alstonia is 0.00816g/mm^3, Agba is 0.000724g/mm^2, Ohia is 0.000716g/mm^3 and Obeche is 0.000568g/mm^3 and the weight for Berlina was 11.58kg, Danta was 8.13kg, Alstonia was 7.75kg, Agba was 14.67kg, Ohia was 14.5kg and Obeche was 11.5kg. Comparing it with the maximum load the species could carry, Berlina was 108kN, Danta was 85.0kN, Alstonia was 66.0kN, Agba was 50.0kN, Ohia was 103kN and Obeche was 60.0kN. Futhermore, twenty-four (24) laminated timber beams of the same dimensions were manufactured with six (6) different species, viz: Afara, Okwen, Danta, Obeche, Alstonia, Bombax. These beams were glued together using top-bond gum and allowed to dry for twenty-four hours after which they were weighed before testing. The twenty-four beams were tested to failure and the deflection reading taken from the dial-guage. Finally, a curve of deflection against the load was plotted. It can be seen that with a stress of 10.80N/mm^2, 8.50N/mm^2, 6.60N/mm^2, 2.222N/mm^2, 4.58N/mm^2 and 2.67N/mm^2 the design stress, deflection criteria cannot be ignored, after comparing result from the experiment, limiting deflection and actual deflection. A theoretical and experimental correlation of strength evaluation was established for glue solid and glue laminated beams which were formed from combining timber with glue. **Copyright © AJESTR, all rights reserved.**

KEYWORDS: Beams, Deflection, Flexural, Laminated, Solid, and Strength

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INTRODUCTION

Beams are structural members which are acted upon by external loads at right angle to the area. It is a horizontal member e.g. a long piece of timber, metal, or concrete that spans a gap and supports a floor, roof, or other structures (Encarta 2009).Wood is to be a cellular material which is composed of cellulose lignin and small quantities of other essential material (Johansson,2003). It has been put into use for a long period of time having excellent records of performance and durability. Timber is a natural material that varies; it is the variability which provides the inherent visual attraction of the material (David, 2002). It is a cellular material which is composed of other materials just like concrete, steel masonry, ceramics and plastics. Although relevant in every field of construction, timber is very rarely used (Ashley and Jones, 1986). Timber is readily available in most parts of the world in a variety of species. One of the important properties of timber is that unlike other raw materials it is renewable (Jackson,1999). Another important property is its, relatively, high strength to weight ratio making it efficient in resisting both tensile and compressive stresses and can absorb a considerable amount of energy before it fails (Wilson and Conttingham, 1952).

Furthermore, Nigeria as a nation is now spending her huge resources on importation of steel which is not necessary even in fabrication of long span trusses for sophisticated structures because timber can be used to achieve economy, strength, durability, aesthetic, and time saving (Ezeagu and Nwokoye,2009). Timber itself is an anisotropic material having different properties in different directions. As a result its stiffness and strength along the direction of the grain are considerably higher than perpendicular to the grain. Timber thus has high tensile strength (David, 2002). Flexural strength, also known as modulus of rupture or bending strength is the material's ability to resist deformation under load (Fred, 1996). The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular across section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress. Encarta (2009) Flexural rigidity is defined as the force couple required to bend a rigid structure to a unit curvature.

David (2002) defines Flexural strength of a material as the strength of the material in bending, expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength is expressed as

$$\frac{3LP}{2bd^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[1]$$

Where; P is the load applied to a sample of test length L, width b, and thickness d.

On the other hand, the use of glue-laminated timber beams popularly called glulam as building materials is now on the increase within our country, Nigeria. Glued laminated timber, also called glulam, is a type of structural timber product composed of several layers of dimensioned timber glued together(wikipedia 2009). Its size and shape is almost unlimited. Its reliability is verified by the good performance and long service life of large structural timber members. To insure continued reliability and competitive position for large glue-laminated members, the design criteria must engender confidence in the strength of glue-laminated construction. Conversely, the criteria should not produce beams that are greatly overdesigned; thereby resulting in a”waste of strength” with culminates in wastes of resources; materials and labour. The glue-laminated wood industry in the United States has built a research started in the forest products laboratory in the early 1930’s. Many of the design criteria defining strength characteristics of glue-laminated construction were developed in the 1940’s.This early research was conducted on relatively small members up to 300mm in depth with essentially no large beam being evaluated. The large timber member now being manufactured and the possibilities of even larger members have caused both producers and consumers to realize the importance of re-evaluating the design criteria of glue-laminated construction.

Many data have been obtained from flexural tests of laminated beams 300mm or less in depth, however, similar data on large beams are limited. Only a few beams over 750mm deep have been tested. The strength of three structural grade douglas-fir beams, 800mm deep, tested by the laboratory in 1966 were lower than were predicted by the then current design criteria(Nwokoye, 1966). According to Ezeagu,2009 and Somayaji,1990, based on the observed failure and strength data from large beam tests on prestressing of wood beams, and on tensile strength of structural lumber both in the laboratory and industry, it was concluded that more importance should be placed on the grading of tension lamination for glue-laminated timber members. A small part of

Bohannan's research on prestressed wood beam was directed toward evaluating the importance of tension lamination. Ezeagu,2009 found that addition of a clear straight grained tension lamination had a pronounced effect on modulus of rupture of 262.5mm deep laminated beams made of L-3 grade lumber. The addition of 37.5mm thick clear lamination representing 14 percent of the beam depth increased the modulus of rupture by 32 percent, and one 14mm thick clear lamination representing 5 percent of the beam depth increased the modulus of rupture by 23 percent. These data indicate a potential for signicant importance in flexural strength of structural glue-laminated beams by giving special attention to small portion of the beam, the outer few tension laminations.

According to the United States department of Agriculture and Forest Service, a theoretical concept was developed and experimentally evaluated permitting combination of different species of wood within the same glued-laminated beams.

Twenty large beams manufactured with visually graded Douglas-fir outer laminations and lodgepole pine inner laminations all attained desired bending strength and stiffness levels. Results indicate that substantial amounts of lower strength and stiffness lodgepole pine can be utilized in the inner laminations of Douglas-fir glued-laminated beams with little detectable effect on their bending strength and stiffness. Design criteria presented can be used to determine the extent to which such a lower strength species might be utilized and the effect on beam properties.

In selecting the species of timber for laminating, the two prime characteristics are :

i. Gluability of the species

ii. dimensional stability with changing atmospheric condition.

Many tropical hardwoods are difficult to glue because of natural oil and resins contaminating the gluing surface. Timber with large movement value such as Ekki have to be used with caution and special care taken in the orientation of laminates to reduce the risk of glue line splitting.

It is essential to control the moiture content of the timber at the time of manufacture. BSEN 386, specifies that the moisture content of the laminates should lie in the range 8% to 15% with range between the highest and lowest laminates in the laminates in the member being 4%.It is also prudent to the moisture content at manufacture as close as possible to the likely equilibrium moisture in service, particularly in heated environment to avoid glue line splitting.

RESEARCH METHODOLOGY AND FABRICATION

Six types of woods were used for the solid timber experiments. A total of thirty-six specimens were made out from the six species of woods (three of the specimens were of hardwood while three were of softwood). The hardwoods specimens were cut to the size of 100mm × 100mm × 900mm while those of the softwood were 150mm×150mm×900mm, with some variations in dimensions due to poor machine ability by the operator's, non uniformity of the wood sold and also the inconsistency of the blade used in cutting which take some millimeters from the wood.

BEAM A

Standard name – Berlina; Botanical name: Berlina (*Confuse grandifliona*) other Nigerian common names: **Yoruba:** Abaila; **Benin:** Ekpoyor; **Hausa**: Dokaruji; **Igbo:** Ubaba.
Where available: Benin, Ijebu, Akare and Calabar Area. It is one of the hardwood and it is of size 100mm × 100mm × 900mm.

BEAM B

Standard name: Danta Botanical name: *Neogradonia*
Other Nigerian common names: **Benin** – Urhuaro. Were found available: very common in high forest.
It is one of the softwoods and it is of the sizes 150mm × 150mm × 900mm.

BEAM C

Standard Name – Alstonia. Botanical Name – Alstonia (*Boone congensis*)
Other Nigerian common names: Bini – Ukpa, Tfik – Ukpo; Ijaw – Ndondo; Ibo – egbu and Yoruba – awan.

Were available: common in damp high forest. It is one of the hardwoods; it is of the size 100mm × 100mm × 900mm.

BEAM D

Standard Name – Agba. Botanical Name – *Gossweilerodendron balsomiferun*
Other Nigerian common names: Bini – emonga, Ijaw – tokiroetan; Igbo – achiaro.
Were available: restricted to wet, Midwest and east central states. It is one of the softwood; it is of the size 150mm × 150mm × 900mm.

BEAM E

Standard Name – Celtis Ohia. Botanical Name – Celtis *Zenkeri midbraedil*
Other Nigerian common names: Bini – Ohia ohiunaleya, Ibo – akpulu and Yoruba – ita.
Were available: very common in high forest. It is one of the softwood; it is of the size 150mm × 150mm × 900mm.

BEAM F

Standard Name – Obeche. Botanical Name – *Triptocholum sclexylon*
Other Nigerian common names: Ibo – Okpobo, Yoruba – Arere.
Were available: Abundant in high forest. It is one of the softwood; it is of the size 150mm × 150mm × 900mm.

THE BEAM SPECIMEN

Fig 1; The beams used for these experiments were referenced as shown below. A list of their places of abundance within Nigeria, their vernacular names, and botanical names has also been made.

FLEXURAL STRENGTH TEST

A universal testing machine and a Dial gauge were used in this experiment. Compression was done along the length of the specimen with the given running parallel to the length of the timber piece.

The testing machine was equipped with special bearing plates in order to obtain a uniform stress distribution over the cross section of the specimen. As the load was applied, readings were taken from the dial gauge of the universal testing machine at different levels of loading. With the help of a constructed piece of metal that was use to clip the timber, the deflection was measured as the beam sag.

The maximum compression strength parallel to the grain was obtained by dividing the maximum compressive load (which was off when the dial started returning to the zero position) by the cross-sectional area of the specimen.

$$C_u = \frac{P_c}{A_c} \qquad (2)$$

Where C_u is the ultimate compression stress (N/mm^2)

P_C is the maximum compression load (N)
A_C is the cross sectional stress (mm^2)

Fig 2; The diagram of the universal testing machine when the testing is carried out.

A total of twenty-four beams were evaluated with the glue lamination, twelve of the beams were fabricated from hardwood of different species of Danta, Afara(Berlinia confusa), Okwen(Brachstgia spp) and the other half were fabricated from softwood of different species of Astonia, Bombax(buonopozense) and Obeche.All twenty-four(24) beams were of the same size of 150mm wide ,150mm deep and 900mm long and contain five 0.2mm thick laminations. Beams were manufactured using lumber grade conbinations.The lumber are numbered for identification such as Okwen (OK1,OK2,OK3,OK4), Alstonia(AS1,AS2,AS3,AS4), Afara (AF1,AF2,AF3,AF4), Obeche (OB1,OB2,OB3,OB4), Bombax (BO1,BO2,BO3,BO4), Danta (DAN1,DAN2,DAN3,DAN4). All beams were laminated parallel to the grain, that is, horizontal lamination.

FABRICATION OF BEAMS

The lumbers of the timber species gotten from the wood shelve, fig 3, were plane and seasoned to arrive at the moisture content specified by the code of practice (BS 386) which is about 8%-15%. The beams were laminated horizontally. The glue was applied to the face of the lumber on both surfaces except for the outer one which have the glue applied only to one face only. The lumber were brought together and clamped to enable the lumbers stick together for a period of 24 hour as in fig 4. The clamp was untied after 24 hours and the beams were planed to make all the side equal as in fig 5.

Fig 3; Specimen stack together in wood shelve

Fig 4; Clamping wood together after applying glue

Fig 5; Planning beams after lamination

The method of loading is shown schematically in fig 6, with a general overall view of 900mm beam during test. The test was carried out using the universal testing machine at the Mechanical Strength of Material Laboratory, Faculty of Engineering, University of Benin. Before the test, all 24 beams were weighed to get each weight of the beam as shown in Table 1.

Fig 6; Universal testing machine and specimen

Each of the beam were supported 200mm at the two end faces such that 500mm is the clear space between the supports. A bracket is fixed at the centre of beam which is also the point where the load is applied. The bracket has an extension which touches the dial guage clamped to a retort stand. So, as the load is increasing, the beam begin to deflect the deflect reading is then read from the dial guage until a final stop in the dial guage. That is, when the beam has failed.

DENSITY TEST

The specimens were weighed and with their dimensions the volumes of the specimens were obtained.

Density (ρ) = $^{M}/_{V}$
V = The volume of the specimen (mm^3)
M = The mass of the specimen (g)

RESULTS

Table 1: The Observed Weights of the Timber Specimens

Beams	Units	W 1	W 2	W 3	W 4	W 5	W 6	Average Weight
Berlina (BeamA)	Kg	11.50	11.00	12.00	11.50	12.00	11.50	11.50
	N	112.82	107.91	117.72	112.82	117.72	112.82	113.64
Danta (BeamB)	Kg	8.00	8.00	8.50	8.50	8.00	7.80	8.13
	N	78.48	78.48	83.39	83.39	78.48	76.79	79.79
Alstonia (BeamC)	Kg	7.50	8.00	7.00	8.00	8.00	8.00	7.75
	N	73.58	78.48	68.67	78.48	78.48	78.48	76.03
Agba (BeamD)	Kg	14.00	15.00	14.00	15.50	15.50	14.00	14.67
	N	137.34	147.15	137.34	152.06	152.06	137.34	143.88
Ohia (BeamE)	Kg	14.00	15.00	15.00	14.00	15.00	14.00	14.50
	N	137.34	147.15	147.15	137.34	147.15	137.34	142.25
Obeche (BeamF)	Kg	11.00	11.50	12.00	11.50	11.00	12.00	11.50
	N	107.91	112.82	117.72	112.82	107.91	117.72	112.82

Table 2; Weights of the Glue-laminated Beam with different Species

Species	Sample1 wt in kg	Sample2 wt in kg	Sample3 wt in kg	Sample4 wt in kg
Afara	6.825	7	6.604	6.64
Alstonia	7.08	7.2	7.957	7.7
Obeche	7.002	6.992	6.924	6.285
Bombax	7.896	8.482	8.8	9.424
Okwen	15.903	16.527	16.901	15.847
Danta	13.235	14.9	15.472	16.289

Table 3: Averaged Experimental Deflections of the Solid Beams with different species.

Load (KN)	Average Deflections of the Beams (mm)					
	Berlina (BeamA)	Danta (BeamB)	Alstonia (BeamC)	Agba (BeamD)	Ohia (BeamE)	Obeche (BeamF)
0.1	0.009	-	-	0.05	-	-
0.5	-	0.005	-	-	-	0.005
1.0	0.20	0.08	0.05	0.10	0.005	-
4.0	-	0.60	0.86	1.03	0.42	0.31
5.0	-	1.22	-	1.51	0.82	0.61
7.0	0.56	1.62	-	2.53	0.97	0.88
10.0	0.90	1.78	1.42	3.05	1.12	1.19
12.0	1.00	1.83	1.79	-	1.25	1.42
15.0	1.17	2.00	2.23	3.77	1.56	1.81
18.0	1.26	2.06	2.44	3.94	2.25	2.33
20.0	1.34	2.32	2.61	4.13	2.58	2.63
22.0	1.51	2.48	3.21	4.54	2.63	2.78
25.0	1.80	2.61	3.93	4.70	2.85	2.91
27.0	1.90	2.87	4.18	5.05	3.16	3.53
30.0	2.01	3.13	4.73	5.18	3.43	4.03
35.0	2.10	3.46	4.96	5.50	3.63	4.79
40.0	2.54	4.02	5.09	6.13	3.83	5.49
42.0	2.70	4.25	5.30	6.38	-	-
45.0	3.00	4.77	5.60	6.28	4.05	6.10
50.0	3.45	-	-	7.04	4.44	6.36
55.0	3.73	5.93	6.03	-	4.68	6.65
60.0	3.90	6.13	-	-	4.83	6.90
65.0	4.21	6.79	6.75	-	5.13	-
70.0	4.54	7.42	-	-	5.41	-
75.0	5.07	8.05	-	-	5.58	-
80.0	5.35	8.55	-	-	6.86	-
85.0	5.65	10.51	-	-	-	-
90.0	6.10	-	-	-	7.65	-
95.0	6.86	-	-	-	8.26	-
100.0	7.15	-	-	-	8.79	-
103.0	7.44	-	-	-	10.34	-
106.0	7.95	-	-	-	-	-
108.0	8.42	-	-	-	-	-

The following analytical graphs can be deduced from the results obtained showing the structural behaviour of the timber under experimental and actual working load

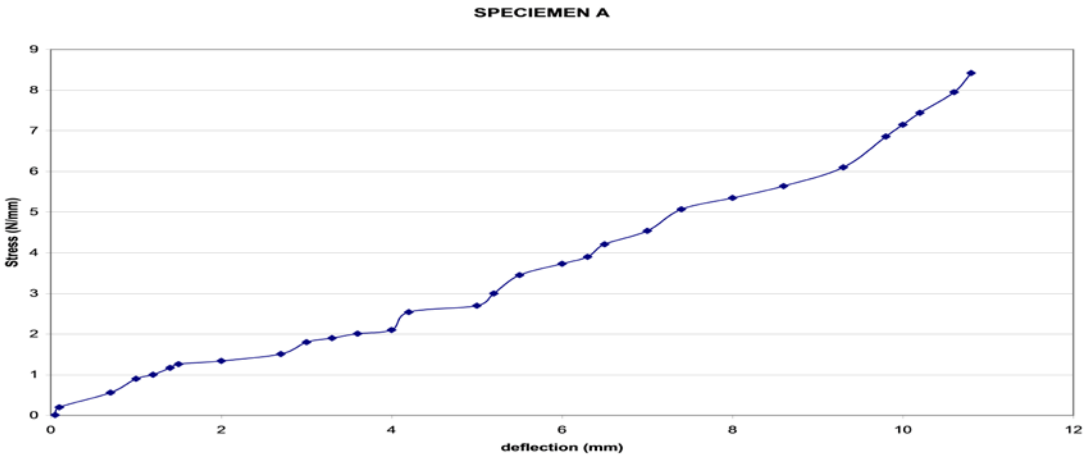

Figure 7; Stress/Deflection graph for Solid Beam A (Berlina)

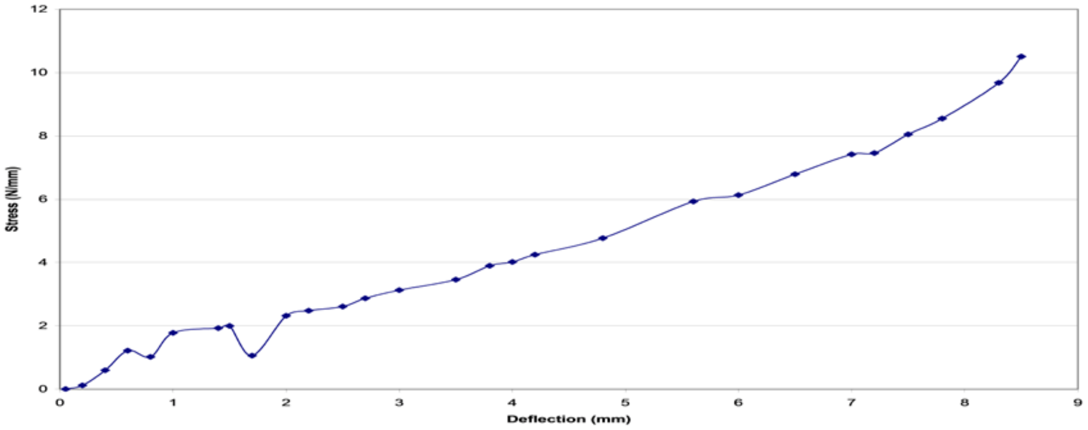

Figure 8; Stress/Deflection graph for Solid Beam B (Danta)

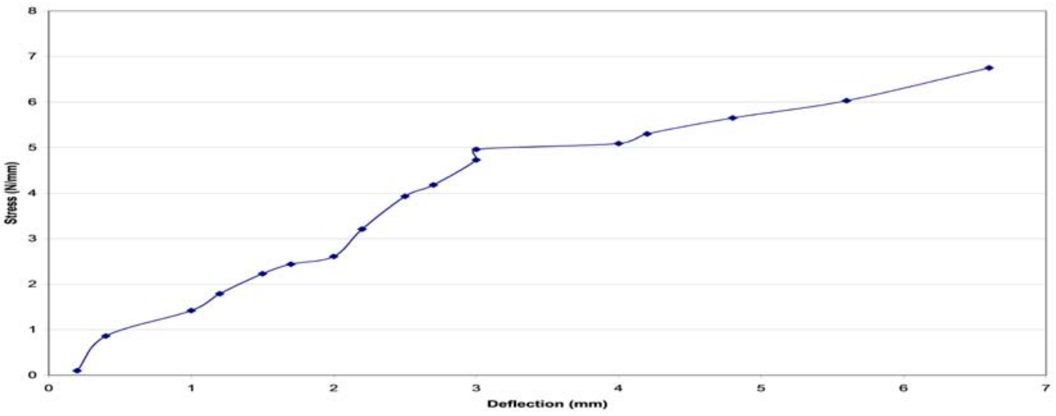

Figure 9; Stress/Deflection graph for Solid Beam C (Alstonia)

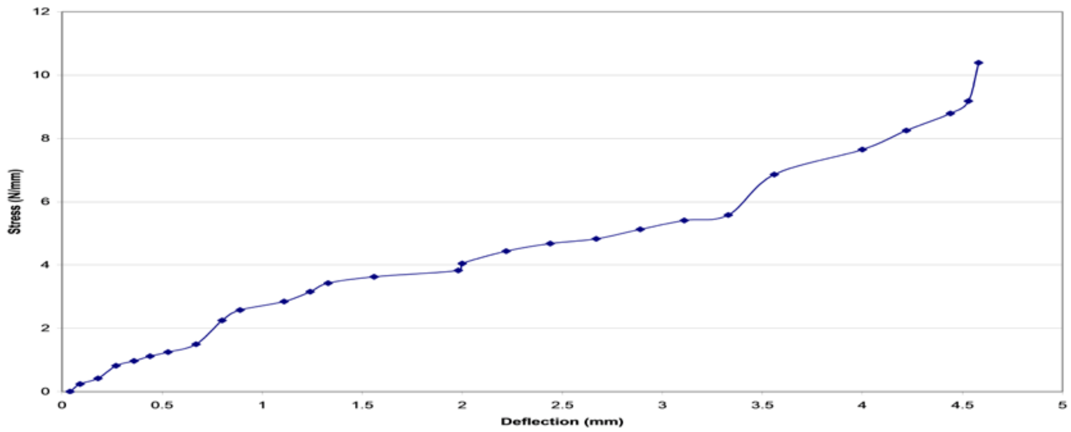

Figure 10; Stress/Deflection graph for Solid Beam D (Agba)

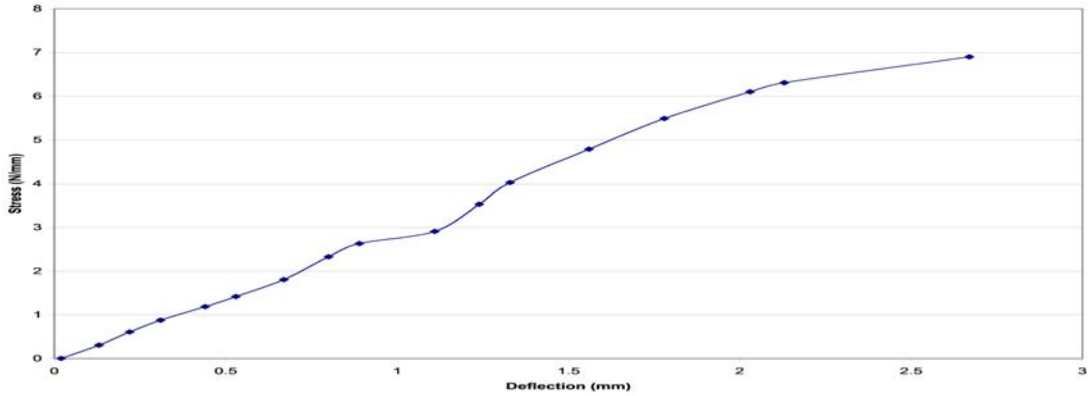

Figure 11; Stress/Deflection graph for Solid Beam E (Ohia)

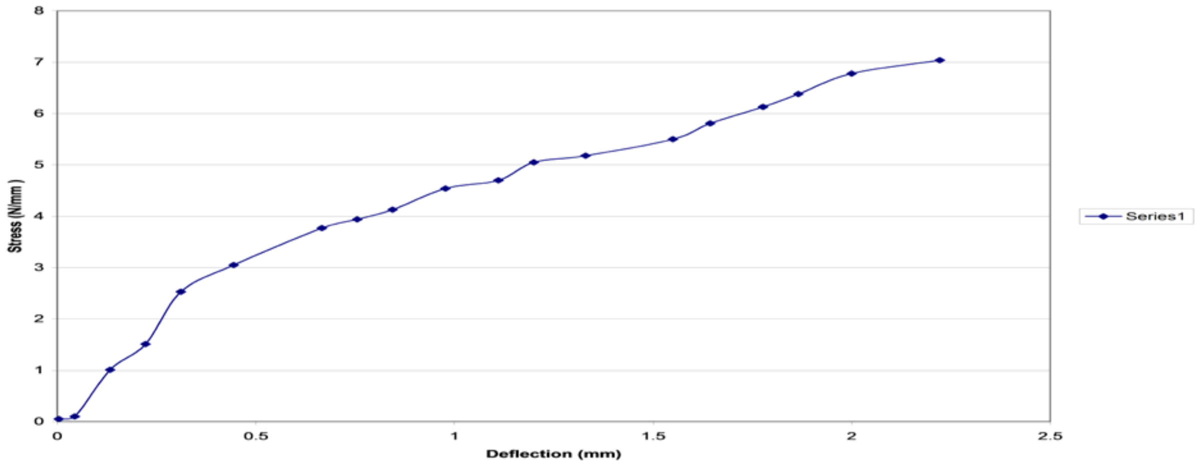

Figure 12; Stress/Deflection graph for Solid Beam F (Obeche)

Table 4; Comparison between Theoretical, Experimental, and Limiting Deflections of the Solid Beams.

SPECIMEN	ACTUAL/THEORETICAL DEFLECTION (mm) $= \frac{PL^3}{48EI}$	LIMITING DEFLECTION (mm) [AS1170(1) 1989]		EXPERIMENTAL DEFLECTION (mm)
		Long Term	Short Term	
Specimen A (Berlina)	0.920	20.00	15.00	8.42
Specimen B (Danta)	0.612	20.00	15.00	10.51
Specimen C (Alstonia)	0.792	20.00	15.00	9.75
Specimen D (Agba)	3.040	20.00	15.00	7.34
Specimen E (Ohia)	5.200	20.00	15.00	10.35
Specimen F (Obeche)	4.340	20.00	15.00	6.90

Table 5: Loads and Average dial guage result of Glue-laminated Beams

LOAD (KN)	Alstonia (mm)	Okwen (mm)	Obeche (mm)	Danta (mm)	Afara (mm)	Bombax (mm)
1	0.2	0.625	0.2	-	0.75	-
2	1.2	-	0.65	0.75	1.4	0.3
3	-	0.4	0	1.05	1.9	0.6
4	2.15	1.95	2.45	2.2	0.95	0.5
5	1.95	0.8	-	2.2	3.05	1.6
6	1.4	-	4.7	1.4	1.6	1.05
7	2.55	2.1	-	2.6	1.85	-
8	1.75	-	5.5	3.45	4.7	5.25
9	4.7	-	-	-	-	-
10	2.15	3.65	7.6	5.2	5.75	3.85
11	-	-	-	-	2.8	2.35
12	2.75	3.05	2.85	6.475	-	-
13	-	-	-	-	3.2	2.9
14	3.15	3.45	-	-	-	-
15	6.2	1.8	9.05	4.8	9.15	8.45
16	2.075	5.75	-	-	-	-
17	-	-	-	-	9.45	-
18	12.1	4.05	6.3	3.45	4.2	11.25
19	-	-	3.45	5.6	0	-
20	7.8	6.4	7.55	-	10.65	9.05
21	-	-	3.55	-	-	-
22	5.15	7.275	8.55	3.95	-	4.55
23	-	-	3.95	-	-	-
24	-	7.8	-	4.4	6.75	4.9
25	-	-	-	6.1	5.2	-
26	-	5.05	-	4.9	6.9	5.4
27	-	-	-	-	-	-
28	-	9.1	4.6	5.45	13.1	-
29	-	-	-	-	-	-

30	-	9.85	18	6.95	6.6	-
31	-	-	-	-	-	-
32	-	6.6	5.45	-	-	-
33	-	4	-	5.6	6.95	-
34	-	6.95	6.2	7.05	-	-
35	-	4.9	-	6.4	7.55	-
36	-	7.45	-	7.6	-	-
37	-	-	-	-	-	-
38	-	5.2	-	6.65	-	-
39	-	-	-	-	-	-
40	-	14.1	-	7.95	8.6	-
41	-	-	-	-	-	-
42	-	7.95	-	7.4	-	-
43	-	7.35	-	8.6	8.975	-
44	-	-	-	-	-	-
45	-	15.9	-	-	-	-
46	-	-	-	-	-	-
47	-	-	-	-	-	-
48	-	-	-	7.9	-	-

DISCUSSION

Weights and Densities of Specimens

The weights of the specimens varied significantly. From table 1, the weights of the hardwoods were more than those of the softwoods when compared. Whereas the volume of the hardwood is 9,000,000mm^3 and that of the softwood is 20,250,000mm^3. This shows that the volumes of the softwoods used were more than two times the volumes of the hardwoods used in the experiments. The fact that density is the ratio of mass to volume makes it obvious, consequent upon these observations that hardwoods are generally denser than softwoods.

Furthermore, comparing the average weights of the specimens; specimen A is 113.64N, specimen B is 79.79N, specimen C is 76.03N, specimen D is 143.88N, specimen E is 142.25N, and specimen F is 112.82N. Specimens A, B, and C are hardwoods, while specimen D, E, and F are softwoods. Comparing their volumes to their weights, it can be concluded that the hardwood has an evidently higher Weight/Volume ratio than the softwood.

Load Resistance

From Table 3 and Figures 7 to 12, it is observed that there is a variation in the resistance of the woods to the external loads. At rupture, the loads on the beams were found to be 50KN for Agba, 60KN for Obeche, 65KN for Alstonia, 85KN for Danta, 103KN for Ohia, and 108KN for Berlina. This result shows that Berlina, though a softwood, has the highest resistance to axial loads. This also suggests that a wood may be classified as hardwood but it does not necessitate it being better in load resistance than every other softwood.

Deflection of Solid Beams

Table 3 is the result of the experimental deflection. The table displays the deflections of the beams at every given load. At every given load, Agba deflects higher than all the other woods whereas Berlina had the least deflection at every load level. The deflections of Alstonia and Obeche are comparably close at every load level. The result also shows that there is a relationship between deflection and load resistance of the beams. This explains why the Agba failed at the least compressive load of 50KN. Obeche and Alstonia failed at 60KN and 65KN respectively, which are relatively close as their deflections at all loadings are close as well. Berlina with the least deflection resisted the highest compressive force of 108KN.

Table 4 reveals an important issue. All the calculated deflections were far below the experimental deflections. This shows that it is essential that every wood to be adopted for timber design and construction should be investigated for its deflection under the estimated design load. Besides, all the beams tested were good in deflection. The reason for this opinion is because all the experimental deflections were below the limiting value of deflection for long and short term timber construction as specified by AS1170 V0l 1, 1989.

Deflection of the Glue-laminated Beams; Table 5 shows that the glue laminated Danta has the highest load resistant characteristics. Danta being a softwood with such a high load resistance futher justifies that the softness or hardness of wood is not a measure of strength but rather a mere distinction of physical qualities. The figures 14 pictorially displays the irregular deflection pattern of the glue-laminmated beams. Instead of achieving an increase in deflection for a corresponding increase in load it surprisingly displays a zig-zag graph which suggests that for a particular point load on a gluelam one may not expect a lesser deflection than from a bigger load. This calls for more care in the handling of beams made with such materials. The jaggared curve may be as a result of few reasons which may include the progressive splitting of the extreme tension fibres.

Improvement of Flexural Strength with Glue-lamination.

The results show that the solid beams have better flexural strengths than the glue laminated beams. This inference was drawn from the Alstonia, Obeche, and Danta species of the beams which were used for both the solid beam and gluelam experiments. The flexural strengths of all the beams reduced very significantly. Alstonia reduced by 66%, Obeche by 43%, and Danta by 37%. The high percentage reduction in load resistance may be due to inconsistencies in the glued areas.

CONCLUSION; Consequent upon the results discussed above, it was concluded that timber is an elastic material. The fact that they depicted deflections that are within the safe limits, the six timber species tested in this study have been judged to be good as structural members for structures with loads less than the maximum compressive forces they carried. Testing of timber specimens is also eminent and pertinent as it was observed that theoretically calculated deflections were far less than the observed experimental deflections. It was also evident that solid timbers are more durable than glue-laminated timbers based on their flexural strength characteristics. Both timber lumbers were found to be good for construction with structural timber.

RECOMMENDATIONS

Based on the results obtained in the study, the following recommendations were made.

- Appropriate transfer of technology through training in utilization skills for diversification of production obtainable from timber, research on suitable cutting technique of timber should be taken serious.
- There is need for ecological studies aimed at monitoring, evaluating and redirecting the need for intensive cultivation of selected timber species in different timber reserved forests.
- Importation of timber into Nigeria should be strictly dissuaded, to encourage locally produced timber woods for construction purposes both as structural members and other uses such as scaffolding etc..
- Gluable materials should be used for the gluelam production.
- The timber used for gluelam must be well seasoned to eight (8) percent to fifteen (15) percent, specified by the BSEN 386 British standard code of practice to avoid cupping or twist.
- Knots if present in timber lumber, should be well distributed along the beam.
- Further studies is recommended in order to investigate the strength characteristics of other timber species and also the effect of modulus of rupture on deflections in timber, and the authenticity as well as the actual cause of the jaggared load/deflection curve of the glue-laminated beams.

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