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IMPACT OF THE NODAL AND INTERNODAL SECTIONS ON THE STRENGTH PROPERTIES OF BAMBOO

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ABSTRACT

The structural use of bamboo as a material of construction demands for the deeper study of the mechanical properties of the culm as regards its nodal and internodal sections. Most literatures have concentrated majorly on the use of bamboo as reinforcement in low modulus concrete with little or no regard on the other factors that affect its structural performance. This study therefore investigates the influence of nodal and internodal sections on the strength properties of bamboo.

The results indicate that the average compressive stress was 59.4 N/mm^2 for the internodal section and 66.09 N/mm^2 for the nodal section. The average flexural stresses were 35.78 N/mm^2 and 46.44 N/mm^2 respectively for the internodal and nodal sections. The average modulus of elasticity was between 2.68 and 8.22 x 10^4 N/mm^2 for the nodal section. It is concluded that the strength of bamboo culm is a function of the nodal and internodal sections and that nodal section has higher strength when compared with the internodal section.

INTRODUCTION

Bamboo is a replenisable material and is indigenous to many tropical countries. It has not been well exploited for major structural and engineering applications except in some few areas where it is used as roof trusses. floor members and as columns. It is predominantly used in the urban areas as prop for formwork and as a scaffolding during plastering work on construction sites. etc.

The dearth of research results on Nigerian bamboo is striking and investigation on the use of bamboo in Nigeria has revealed that Nigeria grow three major varieties namely Bambusa vulgaris. Dendrocalamus and Oxyten antheria. Bambusa vulgaris

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however has the most extensive distribution and is available mostly in the southern states including Oyo. Osun. Ogun. Ondo. Lagos. Ekiti. Edo and Delta States as well as Enugu. Abia. Anambra. Imo and Ebonyi States. Olateju (1993) reported that Oxytenantheria is commonest in the northern part of the country and is found at the fringes of the forests and swamps.

LITERATURE REVIEW

Published works on the structural use of bamboo was not available until 1914 and to a greater detail in 1950 (Olateju. 1993).Zhou (1981) carried out a comprehensive test on the influence of age on green (wet) and dry conditions of bamboo and concluded that there is an increase in strength properties up to 6 years for tensile and compressive strength and up to 8 years for bending strength with a decrease in all strength properties in older culms. Omojola and Omoyosi (3) reported that bamboo and Sapele wood's ultimate stress is nearly the same and usually about the same as that of concrete. It was further reported that failure occurred more readily in tension than in compression tests and that the mode of failure was a repeated one splitting longitudinally.

Janssen (4.5) formulated design standard for determining the allowable stress for bamboos by arriving at the ratio between the density of dry and wet bamboo and the compressive. flexural and shearing strengths as shown in Table 1. Mehta. etal (6) (1951) investigated the water absorption and volume change of bamboo. Mentizinger and Plourde (1966) also carried out tension and bond test on untreated. varnish treated and sealer treated bamboo.

Table 1: **The Ratio between the Density (kg/m³) and the Allowable Stress (N/mm²) of Bamboo**

	Compression (No Buckling)	Bending	Stress
Dry Bamboo	0.013	0.020	0.003
Green Bamboo	0.011	0.015	

Source: Janssen. J. J. A. (1988)

In Nigeria. the most widely available specie of bamboo of structural values is the *Bambusa vulgaris* and little research efforts have been geared towards its standardization as an engineering material. Lucas and Ogedengbe (8) (1987) studied the shrinkage characteristics of bamboo and came to conclusion that bamboo culms shrink mainly in the radia direction and that there was no measurable shrinkage in the longitudinal direction. Nwa (9) (1978) explored the use of bamboo as a drainage material and found that it could be used effectively as field drainage. Olateju (1993) investigated the characteristics and technology of *Bambusa vulgaris* reinforced terracrete slabs by determining their physical and structural capabilities. He then concluded that *Bambusa vulgaris* is a viable substitute for light flexural applications in affordable housing component development and that bamboo splints performed better as reinforcement than when the whole culm is used. Fagbenle (10) (1990) also investigated tapering and the strenght properties of bamboo and concluded that bamboo tapers from the bottom to the top. Moreover. the strenght decreases with increasing height.

Standardization of the application of bamboo as an engineering material is however achievable only when design details and methods of fabricating components are evolved. This calls for more indepth study of the influence of some physical conditions on the variation of strength along the length of the culm. This study therefore attempts to investigate the influence of nodal and internodal conditions on the compressive and flexural strength of bamboo culm.

Protimeter timbermini is a battery operated hand instrument used for the approximate determination of moisture content percentage of wood/concrete blockwall. A red light (indicator) makes from zero to the required moisture percentage level up to 28 percent.

MATERIALS AND METHODS

The primary material employed in this work was *Bambusa vulgaris* culm and this was due to its wide availability. For the benefit of obtaining a uniform and consistent result. the culms were procured from the same locality in a bush directly behind the main Bus Stop of Obafemi Awolowo University. Ile-Ife. Nigeria

In choosing samples for this work. selection was made of only those samples with straight. fairly uniform and reasonable lengths.A total of thirty-two (32) fresh samples were cut at 600 mm above the ground level with the aid of a matchet. The side branches and other bud-out growths were then carefully trimmed and transported to the Faculty of Environmental Design and Management Laboratory of the University for processing. Twenty eight culm lengths were finally selected for the experimental work and were divided into two groups (A and D) of 14 culm length each. Group A relates to where compressive test specimen were to be taken while group D corresponds to flexural test specimen. Each group was then divided into two sections of seven culm lengths per section. The sections denotes the nodal and internodal investigations using ambient temperature as the only mode of seasoning. The term "internodal" here means without nodes occuring while the "nodal" means with nodes occuring at the mid point. Twenty 300 mm long compressive test specimens were selected from the culm lengths in group A while ten 600 mm long flexural test specimen were selected from each culm length in group D. A total of 40 specimens were tested in each group of the compressive test while 20 specimens were tested in each group of the flexural test. All the specimens were taken serially from the bottom of each culm length to the top. The specimens for the compressive test were numbered A_{Nij} and A_{Iij} while the flexural test specimens were numbered D_{Nij} and D_{Iij} where N and I denote the nodal and internodal sections respectively. .i is the serial number of culm length in a particular section (.i = 1. 2. 3.). j is the position of the specimen along a culm length (.J = 1. 2. 3. ... 20).

The external and internal diameters of each fresh specimen were measured with vernier callipers after which they were weighed and their moisture content determined. The specimens were then left to dry under room temperature inside the laboratory for a total period of four months after which they were weighed again and the final moisture content determined.

The compression specimens were carefully subjected to compression load one after the other using the 1000 KN ELE compression machine which was switched on at the mains and at the switch on point. the black pointer on the scale then carried along with it the red pointer at the point the specimen began to experience compressive stress. Immediately the materials failed. the black pointer moved back to the zero point leaving the red pointer to be read off.

The flexural test was performed using Avery Universal Testing Machine. In this case. two strong planks were used as loading platforms. The base platform which is longer and the upper platform had sizes 55 x 12 x 1.2 cm and 25 x 12 x 1.5 cm respectively. Two steel supports were fixed into the base platform and close to each of the ends. Similar steel loading was fixed to the upper platform for one point loading. The 600 mm long bamboo specimen were placed on the base platform one after the other. The upper platform was then fixed invertedly in position in such a way that each load point touched the bamboo specimen when the testing machine was switched on

RESULTS AND DISCUSSION

The results of the compressive test indicated a decrease in the ultimate compressive load from the bottom to the tip of the culm for both the nodal andinternodal sections. The result further showed a corresponding decrease in the compressive stress from the buttom of the culm to the tip. The compressive stress for the internodal section ranged from 57.01 N/mm^2 to 68.94 N/mm^2 and an average value of 59.41 N/mm^2 while the compressive stress for the nodal section ranged from 57.01 N/mm^2 to 75.46 N/mm^2 and an average value of 66.09 N/mm^2. The modulus of elasticity in compression was calculated by dividing the product of the load at failure and the gauge length by the product of the cross-sectional area and the axial shortening (E = PL/r). The modulus of rupture was obtained by using the equation

$$MOR = \frac{Pl}{bd^2} \quad \text{where}$$

P = ultimate load (kN)
l = span (mm)
b = d = external mean diameter (Case and Chilver 1971)

Tables 2 and 3 show the variation of the structural properties with height above ground for the internodal and nodal sections respectively The results also show higher values of both the modulus of elasticity (2.38-4.37) x 10^4 N/mm^2 and modulus of rupture (6.22-9.99) x 10^4 N/mm^2 for the nodal sections when compared with the internodal sections (2.20-3.38) x 10^4 N/mm^2 for modulus of eleasticity and (5.01-8.22) x 10^4 N/mm^2 for modulus of rupture. The lower modulus of elasticity and modulus of rupture for the internodal section could be traced to lower failure load and higher axial shortening than the nodal section. The density of the culms also showed a corresponding decrease from the bottom to the tip with the nodal sections having higher values when compared with the internodal section. the average density for the internodal section was 1.098.69 kg/m^3 and 1.161.18 kg/m^3 for the nodal section. Statistical t-tests were performed at 5% level of significance to determine whether the means of the moisture content on one hand and the means of the density on the other hand had significant difference in the two sections (nodal and internodal) considered. The results indicatethat there were significant differences in the means of the moisture content and density of the internodal section when compared with the nodal section.

Table 2: Density, Compressive Stress, Modulus of Elasticity and Modulus of Rupture for Internodal Section of Bamboo

Heigh above ground (mm)	Density (kg/m^3)	Compressive stress (N/mm^2)	Modulus of elasticity x 10^4 (N/mm^2)	Modulus of Rupture x 10^4 (N/mm^2)
600	1.195.24	68.94	3.38	8.22
900	1.194.11	68.72	3.29	7.98
1200	1.191.07	68.57	3.21	7.94
1500	1.189.04	68.44	3.05	7.88
1800	1.188.17	67.77	2.99	7.86
2100	1.184.25	67.32	2.90	7.77
2400	1.175.42	66.45	2.84	7.76
2700	1.168.92	65.15	2.83	7.43
3000	1.152.44	64.19	2.81	6.44
3300	1.144.48	62.18	2.25	6.42
3600	1.111.22	61.97	2.69	6.17
3900	1.108.47	61.33	2.65	5.88
4200	1.105.65	59.35	2.61	5.44
4500	1.103.64	58.17	2.60	5.35
4800	1.101.55	54.15	2.57	5.24
5100	1.080.24	53.14	2.53	5.15
5400	985 11	50.25	2.44	5.08
5700	972.43	44.23	2.41	5.04
6000	822.73	42.23	2.32	5.04
6300	799 59	35 84	2.20	5.01
X	1.098 69	59.41	2.75	6.45

Table 3: Density, Compressive Stress, Modulus of Elasticity and Modulus of Rupture for Nodal Section of Bamboo

Heigh above (mm)	Density (kg/m^3)	Compressive stress (N/mm^2)	Modulus of elasticity x 10^4 (N/mm^2)	Modulus of Rupture x 10^4 (N/mm^2)
600	1.242.38	75.46	4.37	9.99
900	1.240.11	74.43	4.13	9.84
1200	1.212.45	72.17	3.96	9.80
1500	1.201.14	71.05	3.85	9.52
1800	1.199.08	70.09	3.77	9.26
2100	1.191.19	69.99	3.64	9.01
2400	1.189.05	69.25	3.44	8.87
2700	1.184.44	67.99	3.31	8.64
3000	1.175.47	67.93	3.27	8.33
3300	1.169.18	67.15	3.19	8.25
3600	1.160.18	67.00	3.08	8.21
3900	1.155.53	65.81	2.99	8.07
4200	1.147.77	64.17	2.92	8.01
4500	1.141.46	62.18	2.77	7.96
4800	1.138.85	62.08	2.71	7.81
5100	1.134.23	61.16	2.66	7.75
5400	1.121.28	60.88	2.65	7.56
5700	1.119.29	58.15	2.43	7.14
6000	1.111.44	57.86	2.41	6.45
6300	989.07	57.01	2.38	6.22
X	1.161.18	66.09	3.20	8.33

For the flexural test. all the specimens did not pass through significant deflection before splitting failure started at the point of application of the load and spread to the two ends. The failure load appeared to be a function of the cross-sectional area of the specimen under test. As shown in Table 4. the corresponding average bending stress were 35.78 N/mm^2 for the internodal section and 46.44 N/mm^2 for the nodal section.

Table 4: Average Flexural Stress and Modulus of Elasticity for Nodal and Internodal Sections of Bamboo

Section	Flexural stress (N/mm^2)	Modulus of Elasticity x 10^4 (N/mm^2)
Nodal	46.44	3.18
nternodal	35.78	2.68

For a simply supported beam with concentrated load at the mid-point. the modulus of elasticity. E is given by the equation $E = PL^3/48\,dI$

where:

P is the failure load

L is the gauge length

d is the deflection. and

I is the second moment of area.

The computation of the result showed that the average modulus of elasticity in bending for the internodal section was 2.68×10^4 N/mm^2 and it was 3.18×10^4 N/mm^2 for the nodal section. The differences in the strength of the internodal section and nodal section of bamboo culm may be attributed to the presence of the node occuring at the middle for the nodal specimen. The results showed negative slopes in this regard. The results are congruent to the literatures credited to Lucas and Ogedengbe (1987). Omojola and Omoyosi (1976) and Liese (1986).

CONCLUSION

The research has shown the following:

(i) The density and load carrying capacity of bamboo decreases along the length of the culm from the bottom to the tip.

(ii) The density and the load carrying capacity of the nodal section of bamboo culm is higher than that of the internodal section.

(iii) The nodal section has a higher average compressive stress. modulus of elasticity and modulus of rupture than the internodal section of bamboo culm.

(iv) The compressive stress. modulus of elasticity and modulus of rupture of bamboo culm decrease from the bottom (above the ground) to the tip.

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