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CHARACTERIZATION OF CERTAIN NIGERIAN WOOD (TIMBER) USING MODULUS OF ELASTICITY (MOE)

C. E. MOKOBIA, V. A. AKPAN and M. A. EZE

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ABSTRACT

The Moduli of Elasticity MOE of thirteen timber species obtained from a recognized saw mill in Sapele Delta State Nigeria, have been determined using the simple cantilever principle with a view to characterizing them into hard/soft wood. The values of MOE obtained range from 5.6- 15.6GPa. Of the thirteen samples investigated, seven of them representing 54% are classified as hard while the remaining 46% are soft.

KEYWORDS: Characterization, Nigerian timber species, Hard and soft wood, Modulus of Elasticity, Simple cantilever principle.

INTRODUCTION

Wood belongs to the class of composite materials in materials science and engineering (Callister, 1977). Amongst its other properties, static bending modulus of elasticity appears to be the most reliable indicator of strength especially when a more tightly controlled strength unit is desired for a specific application as is the case for small diameter logs (Ronald and Cassandra, 2000). On its part, the strength of timber specie that is its ability to resist certain stresses and strains, has been identified as one of the most important mechanical properties (Findlay, 1982). Measurement of MOE of timber species is aimed at Safety and Health in buildings amongst others (ODPM, 2003).

This engineering material is found in abundance in the South West as well as South East of Nigeria. In these places, a number of saw mills are found. Sapele in Delta State for example is acknowledged to be the home of timber.

The European test method for the determination of the MOE in bending of structural timber is outlined in the standard EN 408:1995- 'Timber Structures: test methods for determining most of the strength and stiffness properties of structural and glued timber' (Solli, 2000).Besides, Kretschmann and Green (1999) used the pulse echo stress wave technique to estimate the MOE of green timbers while Holmqvist and Bostr$\bar{o}$m (2000) had used a combination of the EN 408:1995 method (local MOE, E_L) and the global MOE,E_G proposed by Bostr$\bar{o}$m (1999). Neither of these methods appeared feasible in our circumstances due to lack of relevant equipment for meaningful investigations in Nigeria as in most developing countries. These investigators believe however that the handicap notwithstanding, some amount of work could still be done and in line with an earlier investigation carried out on foam mattresses by these same investigators (Mokobia and Akpan, 2004), a simple arrangement (figure 1) was utilized to determine MOE for certain Nigerian timber species. The values obtained were then used to characterize the species into hard or soft as the case may be.

THEORY

When a uniform beam of length l and rectangular cross-section A of thickness d and width b is depressed, the moment of inertia I is given by (Callister, 1997):

$$I = \frac{bd^3}{12} \quad [1]$$

The depression D in the beam is then given as:

$$D = \frac{FL^3}{3EI} \quad [2]$$

F=mg is the force causing the depression, E the Young's modulus of elasticity. Substituting equation [1] into equation [2], we obtain:

$$D = \frac{4mgL^3}{bEd^3} \quad [3]$$

so that the mass m causing the depression can be expressed as:

$$m = \frac{DbE}{4g}\left\{\frac{d}{L}\right\}^3 \quad [4]$$

Consequently, a plot of m against D will produce a straight line graph of slope (static slope):

$$S_{st} = \frac{\Delta m}{\Delta D} = \frac{bE}{4g}\left\{\frac{d}{L}\right\}^3 \quad [5]$$

Young's modulus of elasticity E is then determined as;

$$E = \frac{4g\Delta m}{b\Delta D}\left\{\frac{L}{d}\right\}^3 \quad [6]$$

Alternatively, we note that each applied force on the end of each timber beam causes the beam to oscillate about a mean position with a period T given by:

$$T = 2\pi\left\{\frac{d}{g}\right\}^{1/2} \quad [7]$$

✉ C. E. MOKOBIA, Department of Physics, Delta State University, Abraka, Nigeria. E-mail: mokobia_c@yahoo.com
V. A. AKPAN, Department of Physics, Delta State University, Abraka, Nigeria.
M. A. EZE, Department of Physics, Delta State University, Abraka, Nigeria.

Generally,

$$T^2 = 4\pi^2 \left\{ \frac{d}{g} \right\} \quad [8]'$$

When equation [4] is substituted into [8], we obtain:

$$T^2 = \frac{16\pi^2 M}{bE} \left[\frac{L}{d} \right]^3 \quad [9]$$

so that the mass M causing the oscillation is given by:

$$M = bE \left[\frac{T}{4\pi} \right]^2 \left\{ \frac{d}{L} \right\}^3 \quad [10]$$

so that a graph of M against T^2 is a straight line of slope S_d given by:

$$S_d = \frac{\Delta M}{\Delta T^2} = \frac{bE}{16\pi^2} \left\{ \frac{d}{L} \right\}^3 \quad [11]$$

and the modulus of elasticity MOE is then:

$$E = \frac{16\pi^2}{b} \left\{ \frac{L}{d} \right\}^3 \frac{\Delta M}{\Delta T^2} \quad [12]$$

EXPERIMENTAL

Thirteen timber species obtained from a recognized saw mill in Sapele Delta State Nigeria, sawn at source into beams of varying dimensions (Table 1) and stored in the Physical Sciences Laboratory of the Delta State University for a period of one month at same temperature and environmental conditions were used.

Table 1: Identification and dimensions of the timbe samples

Sample identity	Sample Specie	Length ($\times 10^{-2}$m)	Width ($\times 10^{-2}$m)	Thickness ($\times 10^{-2}$m)
S1	Sapele	98.0	3.16	0.57
S2.	Orcan	97.7	3.20	0.59
S3.	Walnut	102.5	3.47	0.55
S4.	Ubelo	97.5	3.14	0.50
S5.	Opepe	98.0	3.70	0.53
S6.	Etoh	97.8	3.60	0.60
S7.	Con	103.0	3.52	0.50
S8.	Lagos	102.6	3.54	0.59
S9.	Mansonia	102.5	3.65	0.55
S10.	Acordia	96.0	3.00	0.64
S11.	Afara	104.3	3.50	0.55
S12.	Gwaria	103.0	3.50	0.50
S13.	Abura	103.4	3.34	0.57

The cantilever principle (figure 1) was used. The sample beams were one at a time clamped at one end to a rigid support. Known weights ranging from $(9.80 - 58.80) \times 10^{-1}$ N were then applied to the free ends. The depression D_{is} for each of the samples for varying applied loads was noted. Each measurement was made five times and the mean depression $\overline{D_{is}}$ recorded. A graph of the mass M producing depression against depression D was then plotted. The slope of the said plot was then used to calculate the modulus of elasticity, E using equation [6] above.

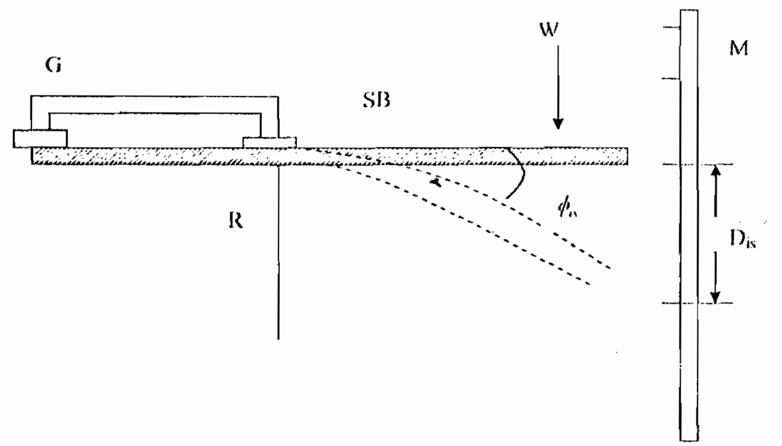


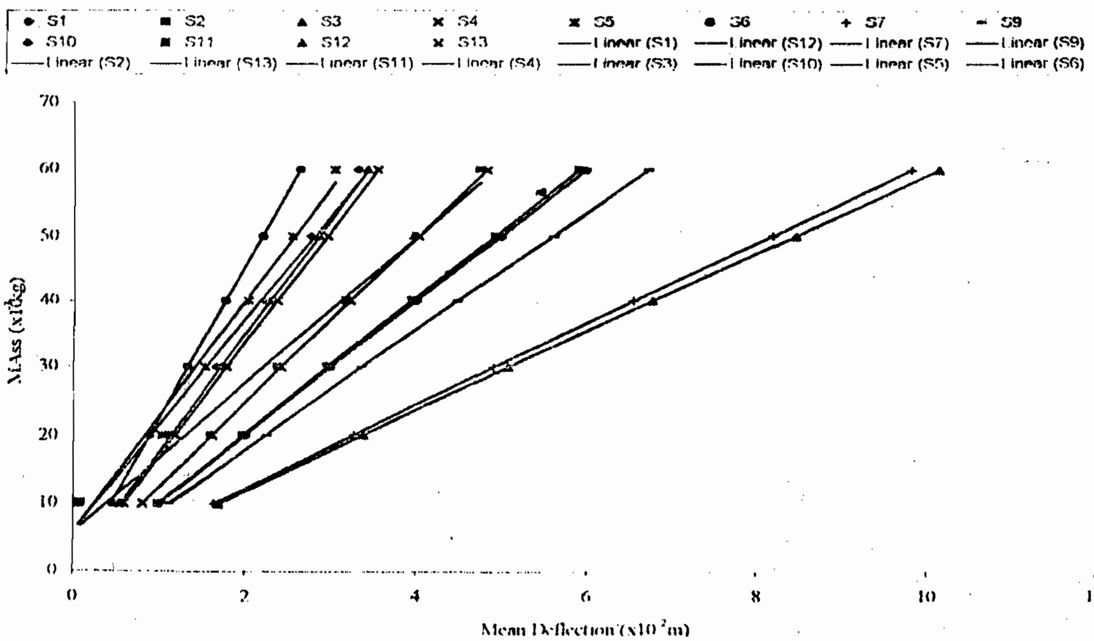
Fig. 1: Experimental setup for the determination of static modulus of elasticity

SB ⇒ Sample beam, G ⇒ Clamp, W ⇒ Applied weight.

ϕ_{is} ⇒ Angular depression, D_{is} ⇒ Linear depression, M ⇒ Metre scale.

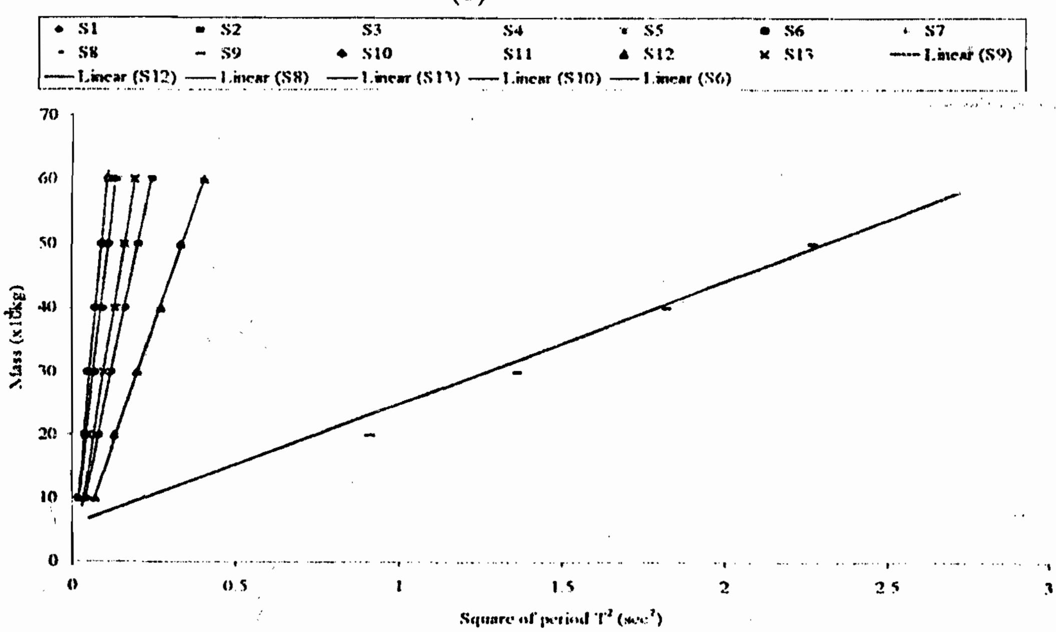
R ⇒ Rigid support

(a)



The curve for sample S8 is masked by that of sample S2.

(b)



The curves [illegible] not shown are masked by some of the shown curves.

Fig. 2: Plot of a) mass M against depression D and b) M against T^2

An alternative method was also employed. In this case, the period of oscillation T of the beam about a mean position for each loaded mass was determined using equations [7-9]. Graphs of M against T^2 were also plotted for the various timber samples the slopes of which were used to calculate the respective modulii of elasticity using equations [11-12].All experiments were carried out at the laboratory temperature.

The values of MOE determined separately using these two approaches were then tested statistically using t test statistics which is given by the relationship (Wolkowitz et al, 1988):

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}} \qquad [13]$$

Table 2: Deflection D of the timber species for varying masses M

Specie	D ($\times 10^{-2}$m)/ [T^2 sec^2]					
Mass, M	10($\times 10^{-3}$Kg)	20($\times 10^{-3}$Kg)	30($\times 10^{-3}$Kg)	40($\times 10^{-3}$Kg)	50($\times 10^{-3}$Kg)	60($\times 10^{-3}$Kg)
Sapele	1.0 [0.04]	2.0 [0.08]	3.0 [0.12]	4.0 [0.16]	5.0 [0.20]	6.0 [0.24]
Orcan	0.99 [0.04]	1.97 [0.08]	2.96 [0.12]	3.95 [0.16]	4.93 [0.20]	5.92 [0.24]
Walnut	0.54 [0.02]	1.14 [0.05]	1.71 [0.07]	2.29 [0.09]	2.86 [0.11]	3.43 [0.14]
Ubelo	0.59 [0.02]	1.18 [0.05]	1.78 [0.07]	2.37 [0.10]	2.96 [0.11]	3.55 [0.14]
Opepe	0.05 [0.02]	1.02 [0.04]	1.52 [0.06]	2.03 [0.08]	2.54 [0.10]	3.05 [0.12]
Etoh	0.44 [0.02]	0.88 [0.04]	1.32 [0.05]	1.76 [0.07]	2.20 [0.09]	2.64 [0.11]
Con	1.64 [0.07]	3.28 [0.13]	4.92 [0.20]	6.56 [0.27]	8.20[0.33]	9.84 [0.40]
Lagos	1.01 [0.04]	2.02 [0.08]	3.03 [0.12]	4.04 [0.16]	5.05 [0.20]	6.06 [0.24]
Mansonia	1.12 [0.05]	2.25 [0.91]	3.37 [1.36]	4.49 [1.82]	5.62 [2.27]	6.74 [2.72]
Acordia	0.06 [0.02]	1.10 [0.04]	1.66 [0.07]	2.21 [0.09]	2.76 [0.11]	3.32 [0.13]
Afara	0.08 [0.03]	1.59 [0.07]	2.38 [0.10]	3.18 [0.13]	3.97 [0.16]	4.76 [0.19]
Gwaria	1.70 [0.07]	3.39 [0.13]	5.09 [0.20]	6.78 [0.27]	8.48 [0.33]	10.17 [0.40]
Abura	0.81 [0.03]	1.61 [0.07]	2.42 [0.10]	3.23 [0.13]	4.03 [0.16]	4.84 [0.19]

[ ] = values of T^2

Table 3: Slopes of the plots and the determined values of E for varying timber species

Sample identity	Slope (Kgm^{-1}/sec^{-2})		MOE (GPa)	
	M vs. D	M vs. T^2	M vs. D	M vs. T^2
S1.	1.00	0.25	6.3	6.4
S2.	1.01	0.25	5.6	5.6
S3.	1.75	0.43	14.0	14.0
S4.	1.69	0.42	15.6	15.9
S5.	1.71	0.50	13.3	15.6
S6.	2.27	0.56	10.7	10.7
S7.	0.61	0.15	5.9	5.9
S8.	0.99	0.25	5.7	5.9
S9.	0.89	0.02	6.2	5.4
S10.	1.58	0.45	7.0	7.9
S11.	1.24	0.32	8.4	9.7
S12.	0.59	0.15	5.8	6.0
S13.	1.24	0.32	8.7	9.0

The slopes of the curves not shown were determined from their trendline equations

$\overline{X}_1$ *and* $\overline{X}_2$ represent the means of the measured MOEs of numbers N_1 and N_2 and variance s_1^2 and s_2^2 respectively.

The timber samples were then classified into hard and soft wood by comparing their MOE values with relevant standards available in the literature – 'Room temperature modulus of elasticity values for various engineering materials' (Callister, 1977).

RESULTS AND DISCUSSIONS

The mean deflection D of each sample as well as the square of the period of oscillation T^2 of each timber beam are presented in Table 2 while figures 2 (a and b) represent the plots of mass M against D and M against T^2 respectively. The slopes of each of the plots as well as the calculated values of MOE for each timber specie are presented in Table 3.

At the 95% confidence level for a degree of freedom of 22, t value obtained in the test is less than t = 2.07 in the t-able. This implies that the separate values determined using both methods (deflection as well as the oscillation) are not statistically different. It follows that in the absence of any standards for comparison, the values of MOE obtained in this work are internally not only consistent but also reliable.

The subsequent characterization of these Nigerian

Table 4: Characterization of certain Nigerian timber species using MOE values

Sample identity	Identification	Mean MOE (GPa)	Observation*	Characterization
S1	Sapele	6.35	5.5< 6.35 <13.7	soft
S2.	Orcan	5.60	5.5< 5.60<13.7	soft
S3.	Walnut	14.0	7.0:-14.0 < 15.7	hard
S4.	Ubelo	15.75	7.0>15.75 ≈ 15.7	hard
S5.	Opepe	14.45	7.0>14.45 <15.7	hard
S6.	Etoh	10.7	7.0>14.0 ≤ 15.7	hard
S7.	Con	5.90	5.5<5.90<13.7	soft
S8.	Lagos	5.80	5.5<5.80<13.7	soft
S9.	Mansonia	5.80	5.5< 5.80<13.7	soft
S10.	Acordia	7.45	7.0< 7.45<15.7	hard
S11.	Afara	9.05	7.0< 9.05 <15.7	hard
S12.	Gwaria	5.90	5.5 <5.90<13.7	soft
S13.	Abura	8.85	7.0 < 8.85 < 15.7	hard

* The standards used are obtained from Properties of Selected Engineering Materials available in the literature (Callister, 1997)

timber species is given in Table 4. The data in the Table indicate that 54% of the samples investigated are hardwood while the remaining 46% are softwood. A linear correlation coefficient of virtually equal unity obtained for both plots of M against D and M against T^2 also gives credence to the consistency of the values obtained in this work.

It is also observed that simple as the experimental set up used in this investigation is, the order of magnitude (Giga) of the MOE values obtained for these Nigerian timber species is in agreement with those of other values determined elsewhere for other timber species by other investigators using different experimental set ups (Callister, 1977, Holmqvist and Boströ m, 2000).

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