Determination of Young's modulus of elasticity of various timbers in delta state (Nigeria) using the cantilever method

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ABSTRACT

The cantilever method was used to determine the Young's modulus of elasticity of some timbre found in Delta state , Nigeria. The results Obtained showed that:Opepe and Afara have the highest values of Young's modulus of elasticity, While Mansonia has the lowest.Chi-square statistics revealed that these results conform to the international standard values.

INTRODUCTION

Timbre is one of the natural resources provided by God to man. It has been the basic material for construction since the existence of man. This can be attributed to its abundance, cheapness, in addition to its lightness, strength and durability. Although, timbre is becoming scarce due to it's over usage with no correspondent replacement, resulting in it becoming expensive to procure. (Michael B.B, 1986)

Therefore, a complete knowledge of its characteristics and variety are of vital importance to both the structural engineers and scientists alike, as these properties allow them to make proper choice for usage. For instance, the architect needs to know the quality of timbre with respect to is strength, lightness, etc. these will help in his choice for the proper wood which will meet his purpose. For instance, the architect will professionally recommend a light and soft wood in the building of an auditorium. This is to avoid the reflection of sound waves as excessive reverberation may be high and undesirable, for a given speech will continue to be heard by reverberation while the next sound is being sent forth.(Derucher and Heins, 1981))

Timbre is in high demand all over the world for various purposes such as buildings, furniture and domestic works.

THEORY

Young's modulus of elasticity is defined as the ratio of stress to its strain. When a uniform beam is bent, Young's modulus comes into play.(Robert and Kenneth,1947) The arrangement below, demonstrating the bending of a beam is called a cantilever.

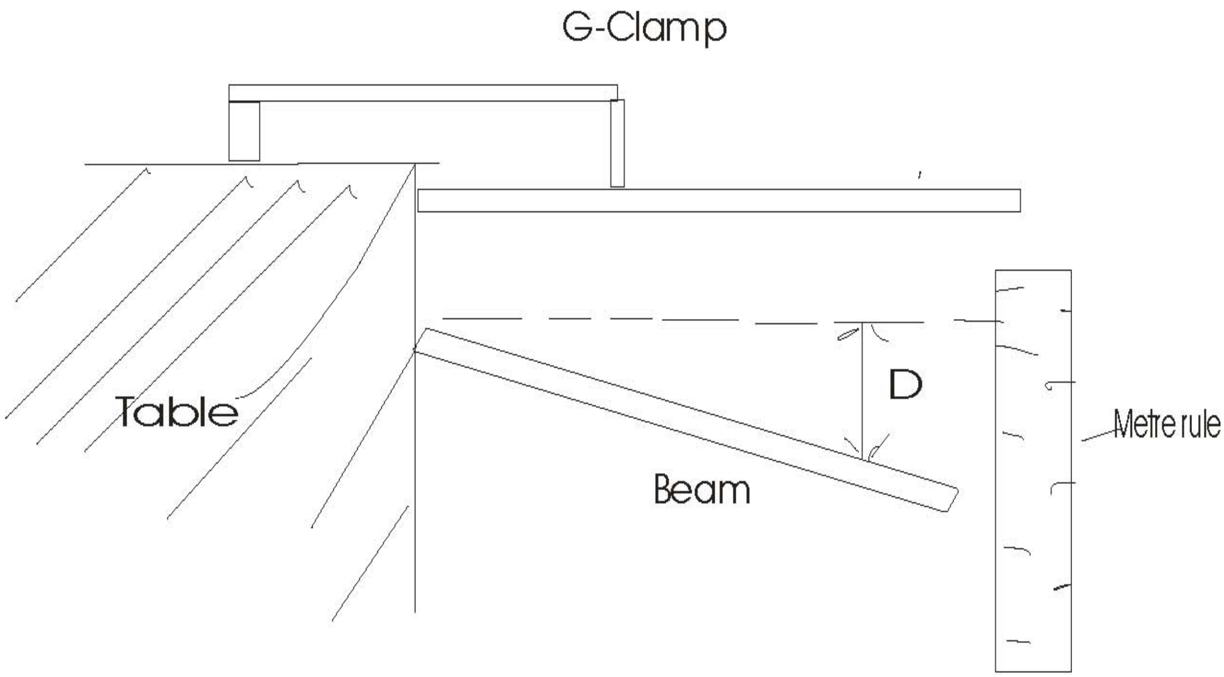


Figure 1.1 Experimental set up

For a beam of uniform rectangular cross-section with thickness d and width b

$$I = \frac{bd^3}{12} (Tyler, 1980) \quad \text{----------------------} (1)$$

Where I is the moment of inertia in $Kg.m^2$.

If the depression of the beam is due to a force, F, then this depression, D is given by (Findlay, 1982)

$$D = \frac{FL^3}{3EI} \quad \text{------------------------------} (2)$$

Where L is length of the beam and E is Young's modulus of elasticity of the beam.

For a loaded cantilever, where F = mg, equation 2 becomes

$$D = \frac{mgL^3}{3EI} \quad \text{-------------------} (3)$$

Where m and g are the mass and the acceleration due to gravity in kg and ms^{-2} respectively.

By substituting equation 1 into 3, we have,

$$D = \frac{mgL^3}{3E\text{X}\frac{bd^3}{12}}, \quad D = \frac{12mgL^3}{3bEd^3}, \quad \therefore D = \frac{4mgL^3}{bEd^3}$$

The arrangement can then execute simple harmonic motion about it's equilibrium position with speed.

$$T = 2\pi\sqrt{\frac{D}{g}} = 2\pi\sqrt{\frac{L}{g}}$$ (Davis et al, 1955) ------------------- (5)

So that, $$T^2 = \frac{4\pi^2 D}{g}$$ -- (6)

By substituting the value of D in equation 4 into 6, we have that,

$$T^2 = \frac{16\pi mL^3}{bEd^3}$$ --- (7a)

And

$$E = \frac{16\pi^2 mL^3}{bT^2 d^3}$$ --- (7b)

From equation 7a, the graph of m against T^2 gives a straight line whose slope is given by

$$slope = \frac{bEd^3}{16\pi^2 L^3}$$ -- (8)

So that the young's modulus of elasticity from equation 7b becomes

$$E = \frac{16\pi^2 L^3}{bd^3}\text{X}slope$$ -- (9)

Alternatively, from equation 4, a graph of m against D also gives a straight line, with slope.

$$E = \frac{4gL^3}{bd^3} X slope \quad \text{---} (10)$$

The slope in equation 9 is called the dynamic slope, S_d, while that involved in equation 10 is called the static slope, S_s young's modulus of elasticity can thus be obtained using any of the equations

$$E = \frac{4gL^3}{bd^3} XSs \quad \text{And} \quad E = \frac{16\pi^2 L^3}{bd^3} XSd$$

Chi- square test was used to determine the calculated values of young's modulus of elasticity for Sapele, Opepe, and Abura in the static case because they are the only samples we can find in literature (Appendix 11) of all the samples used for this work.

MATERIALS AND METHOD

In this work, the materials used are, a retort stand, set of masses, vernier calipers, a metre rule, a G-clamp, a stop watch, optical pin and different rectangular pieces of different types of timbre (Opepe, Lagos, Mansonia, Afara and Abura woods) of lengths 0.95-1.05m,0.03-0.04m wide, and about $0.6x10^{-2}$m thick. The different types of timbre used, were kept under the same temperature condition.

The cantilever method was used in this work. A beam of known dimension was clamped at one end using a G-clamp to a table at one end and at the other end an optical pin was attached. This aided the reading of the depression of the beam each time a mass was added to the free end. A metre rule was clamped parallel to a retort stand and placed in a position, such that it can be read with the pin as an indicator.

A mass was then placed on the free end of the beam and the depression noted. This was done for five or six other readings. A further set of readings was then taken as the masses were removed one after the other to ensure that correct readings of the depression were obtained.

Again, for each added mass, simple harmonic motions were performed and the time for twenty oscillations was obtained. The period T for one complete oscillation was evaluated. A graph of (m), against depression (D) as well as graph of (m) against (T^2) were plotted and from the slopes of either of the two graphs, the young's modulus of elasticity of the particular timbre from which the beam is made was calculated. This was done for six (6) beams of different types of timbre (wood) samples the experimental set up is as shown in figure 1.1.

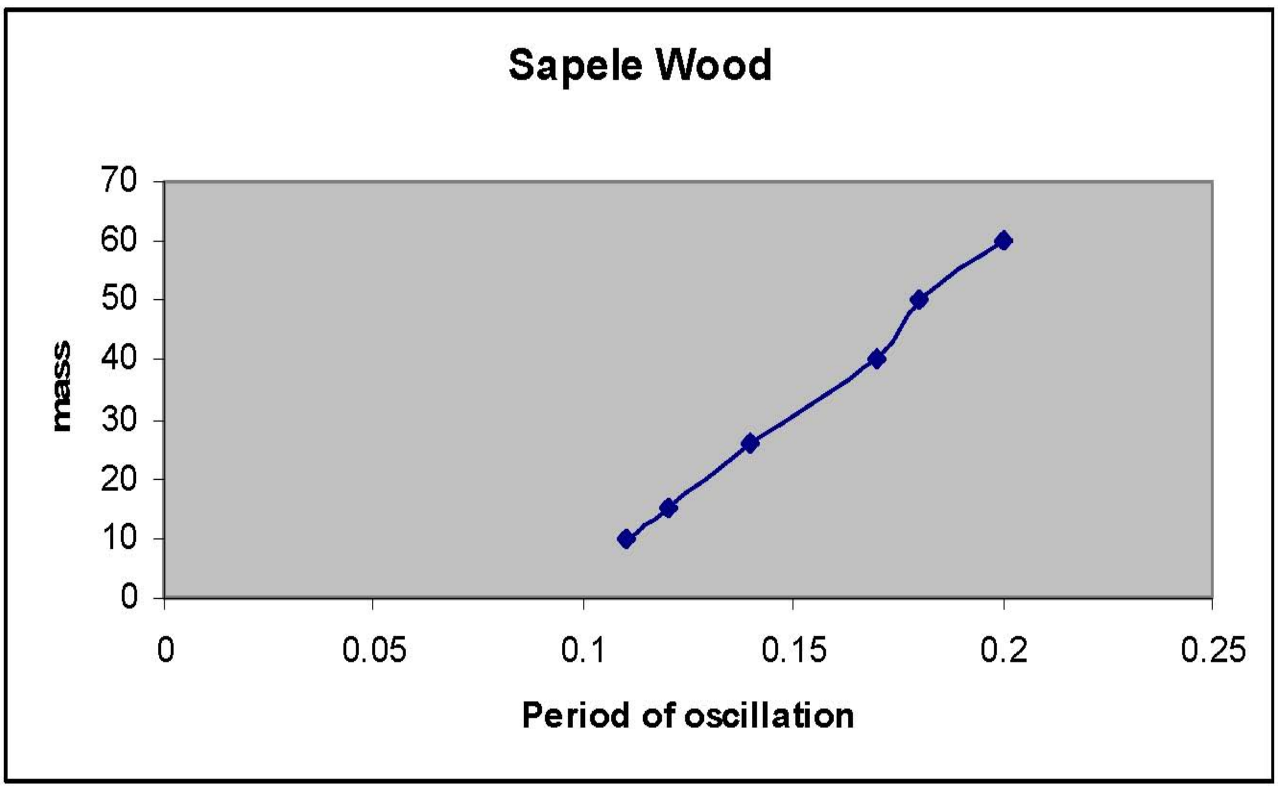
REULTS

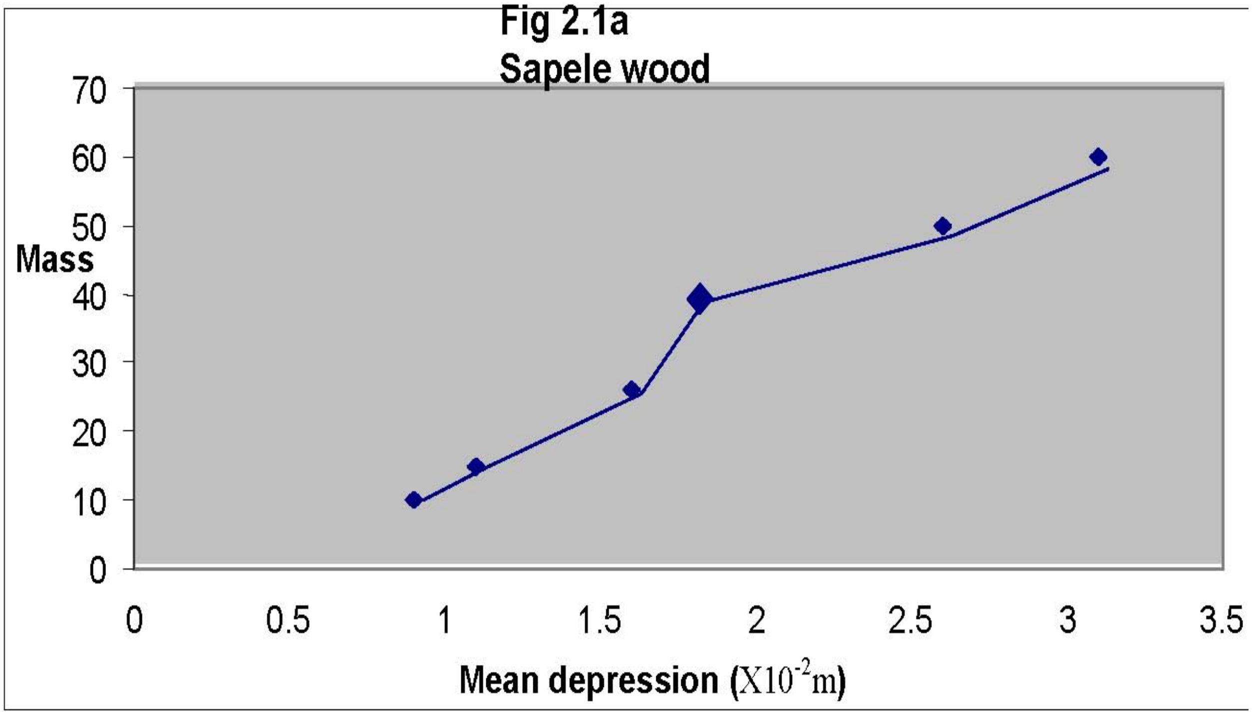
Table 2.1 (a-e), shows the readings of the mass and mean depression of beam and square of the period for the different timbre samples are presented.

Mass(kg)	mean depression($X10^{-2}$ m)	period of oscillation T^2 (sec^2)
10	0.9	0.11
20	1.1	0.12
30	1.6	0.14
40	1.8	0.17
50	2.6	0.18
60	3.1	0.20

Table 2.1

(a) Sapele wood. Length L=98$X10^{-2}$ m, Width b =3.16$X10^{-2}$ m Thickness =0.57 $X10^{-2}$ m

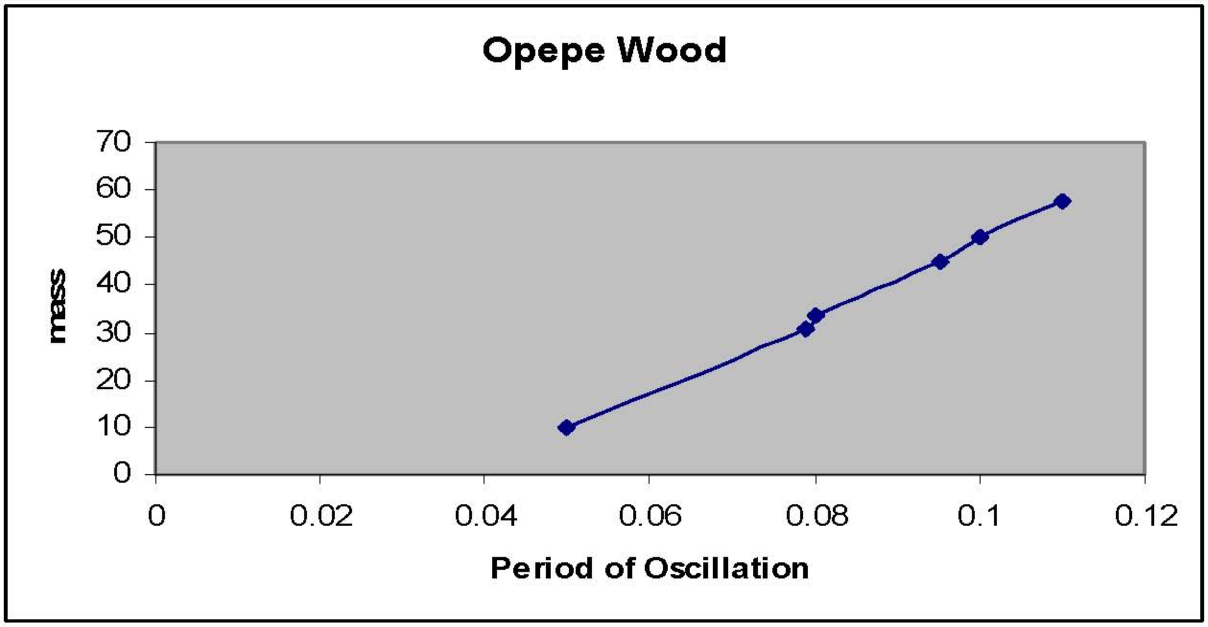


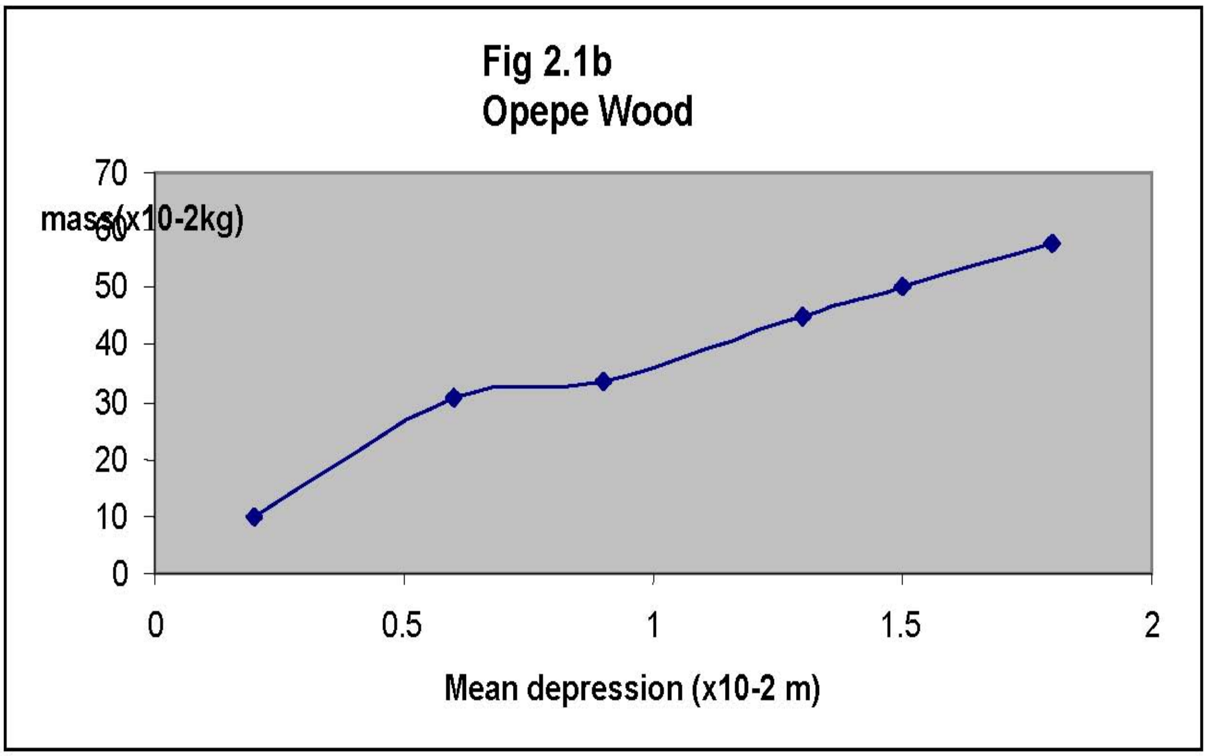


Mass(kg)	mean depression($X10^{-2}$ m)	period of oscillation T^2(sec^2)
10	0.2	0.05
20	0.6	0.08
30	0.9	0.08
40	1.3	0.09
50	1.5	0.10
60	1.8	0.11

Table 2.1

(b) Opepe wood. Length L=98$X10^{-2}$m, Width b =3.2$X10^{-2}$m Thickness =0.53$X10^{-2}$m

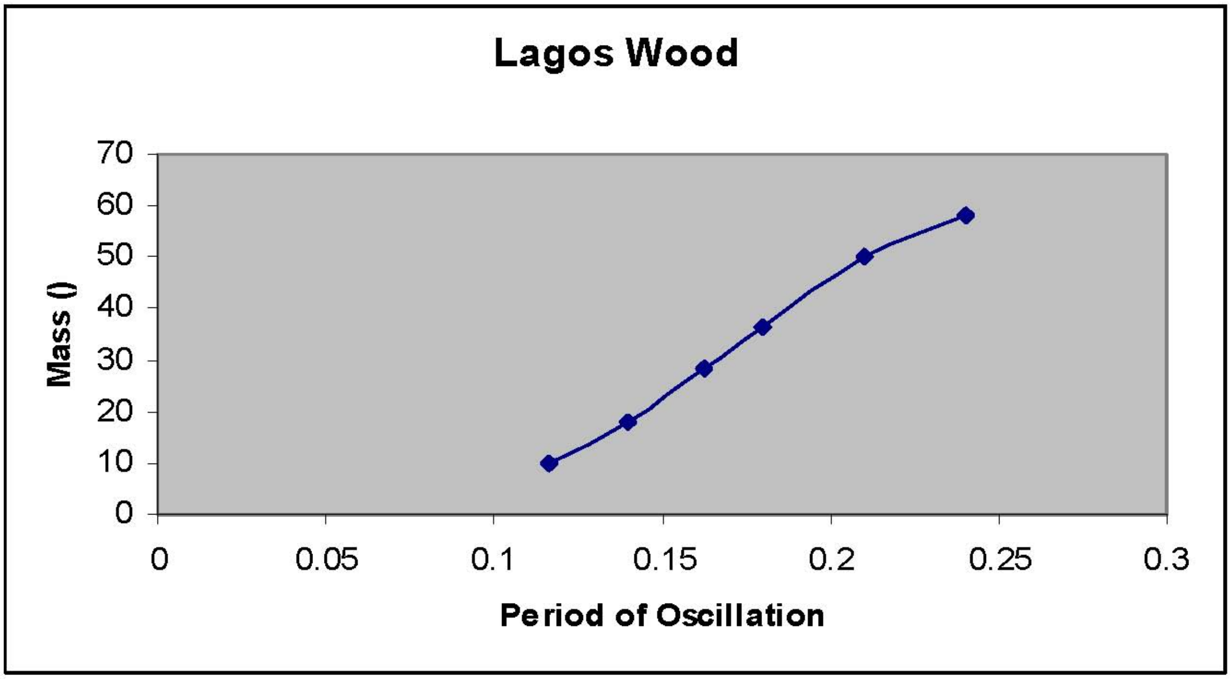


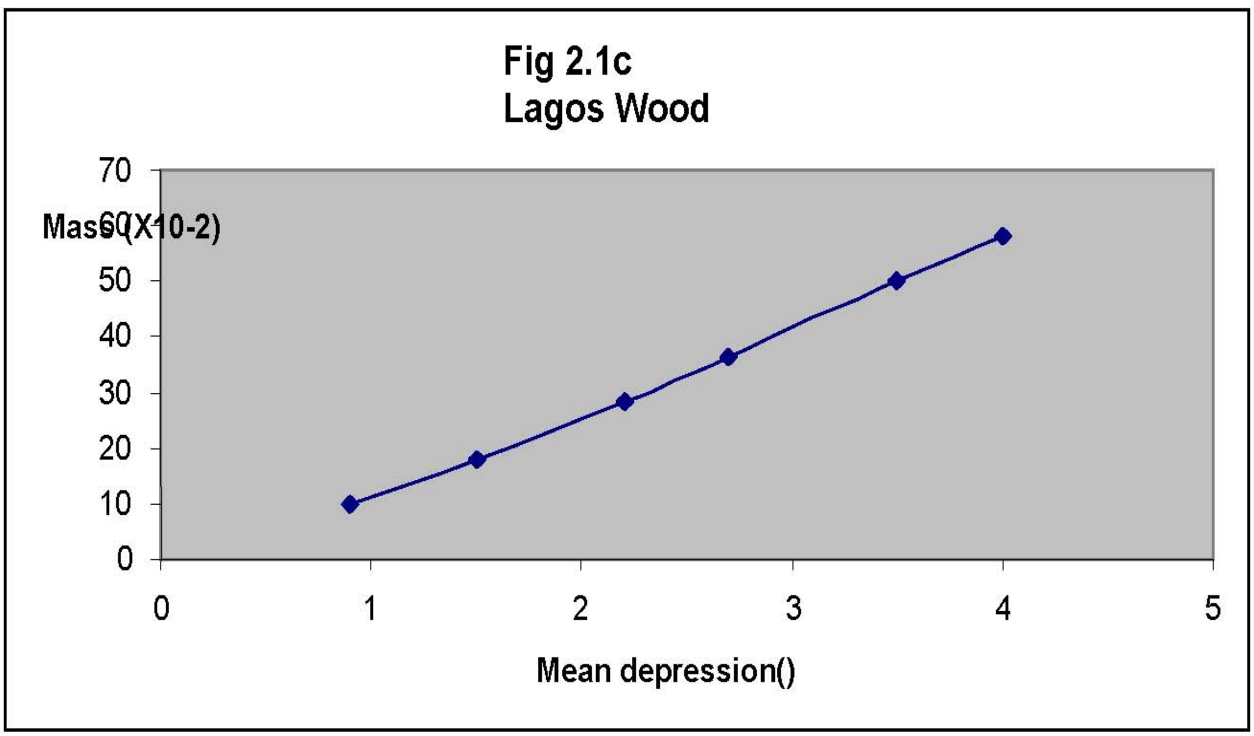


Mass(kg)	mean depression($X10^{-2}$ m)	period of oscillation $T^2(sec^2)$
10	0.9	0.12
20	1.5	0.14
30	2.2	0.17
40	2.7	0.18
50	3.5	0.21
60	4.0	0.24

Table 2.1

(c) Lagos wood. Length L=102X10^{-2}m, Width b =3.54X10^{-2}m Thickness =0.59X10^{-2}m

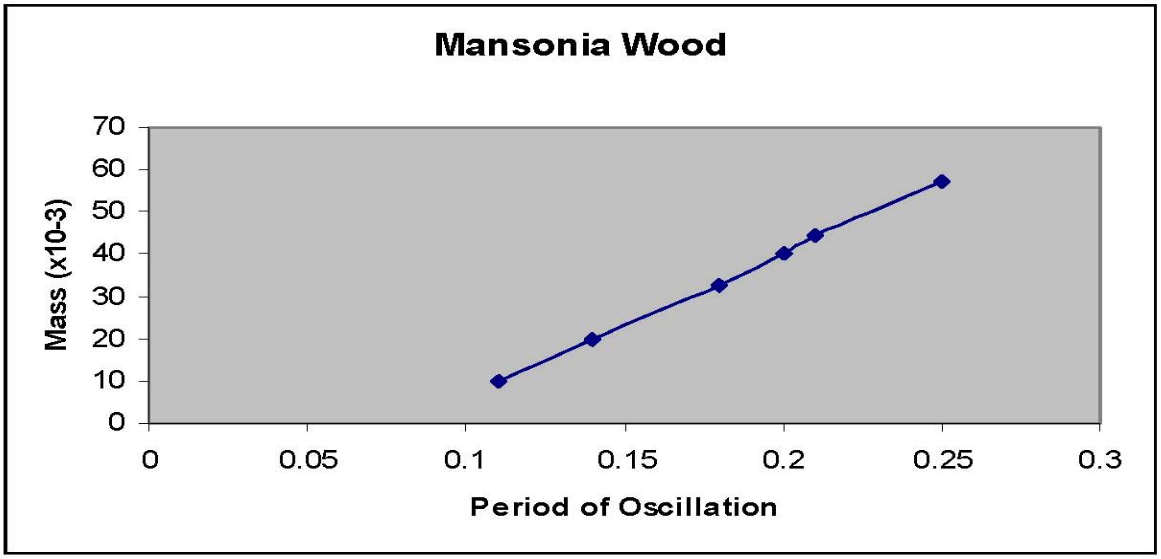


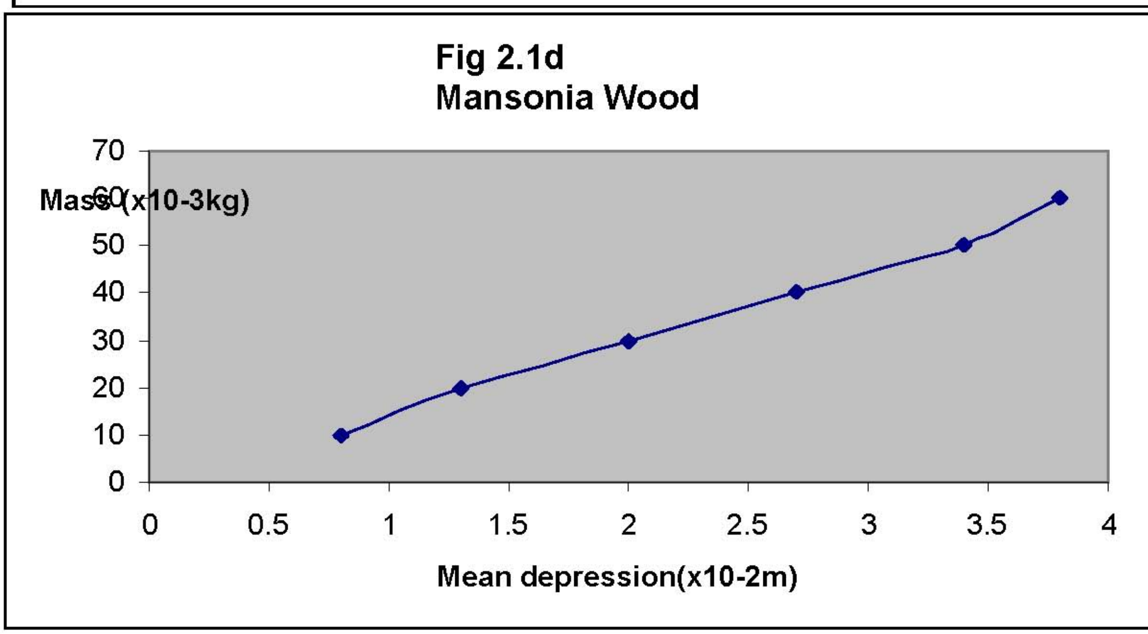


Mass(kg)	mean depression($X10^{-2}$ m)	period of oscillation T^2(sec^2)
10	0.8	0.11
20	1.3	0.14
30	2.0	0.18
40	2.7	0.20
50	3.4	0.21
60	3.8	0.25

Table 2.1

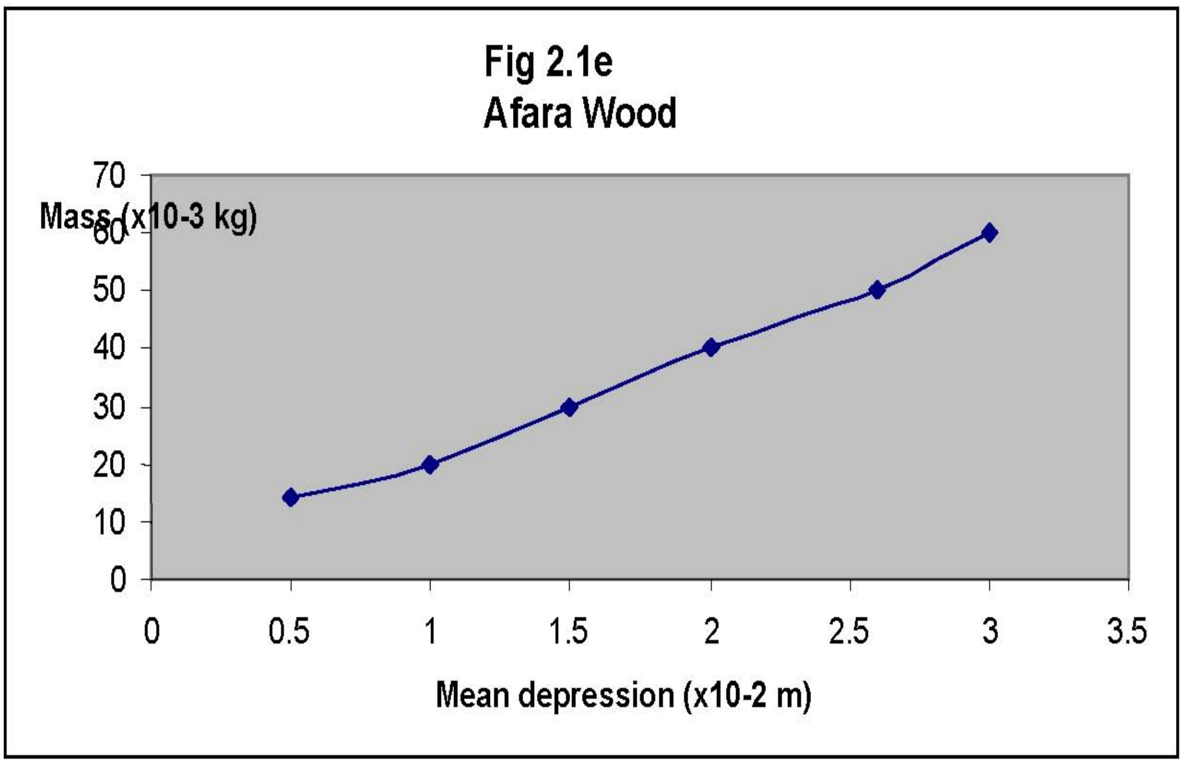
(d) Mansonia wood. Length $L=102X10^{-2}$ m, Width $b=3.54X10^{-2}$ m Thickness $=0.59X10^{-2}$ m





Mass(kg)	mean depression($X10^{-2}$ m)	period of oscillation T^2(sec^2)
10	0.5	0.08
20	1.0	0.09
30	1.5	0.11
40	2.0	0.13
50	2.6	0.15
60	3.0	0.17

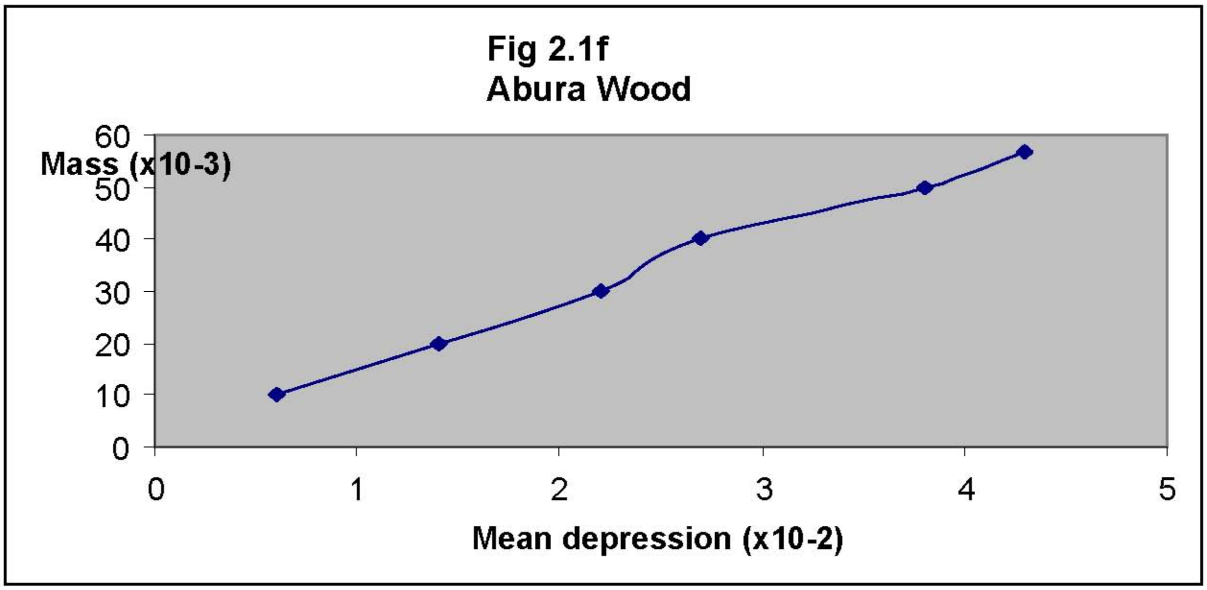
(e) Afara wood. Length L=104X10^{-2}m, Width b =3.5X10^{-2}m Thickness =0.55X10^{-2}m



Mass(kg)	mean depression($X10^{-2}$ m)	period of oscillation T^2(sec^2)
10	0.6	0.12
20	1.4	0.15
30	2.2	0.20
40	2.7	0.25
50	3.8	0.30
60	4.3	0.33

Table 2.1

(f) Abura wood. Length L=$103.4X10^{-2}$m, Width b =$3.34X10^{-2}$m Thickness =$0.57X10^{-2}$m



DATA ANALYSIS

The figures 2.1 (a-f) represents the graph plots,

from fig 2.1 a (static slope) = $\frac{\Delta m}{\Delta D}$

$$= \frac{(30-10)x10^{-3}}{(1.6-0.6)x10^{-2}} = \frac{30x10^{-3}}{1x10^{-2}} = 2kgm^{-1}$$

So that from equation 10, the young's modulus for this type of timbre is

$$E = \frac{4gL^3}{bd^3} x \frac{\Delta m}{\Delta D} = \frac{4x9.8x(0.98)^3}{0.0316x(5.7x10^{-3})^3} x2 = \frac{73.7744}{5.852x10^{-9}}$$

$$\therefore E = 1.26x10^{10} Nm^{-2}$$

From fig 2.1 b (static slope) = $\frac{\Delta m}{\Delta D}$

$$= \frac{(50-20)x10^{-3}}{(1.5-0.6)x10^{-2}} = \frac{30x10^{-3}}{0.9x10^{-2}} = 3.3kgm^{-1}$$

So that from equation 10, the young's modulus for this type of timbre is

$$E = \frac{4gL^3}{bd^3} x \frac{\Delta m}{\Delta D} = \frac{4x9.8x(0.98)^3}{0.032x(5.3x10^{-3})^3} x3.3 = \frac{121.728}{4.7641x10^{-9}}$$

$$\therefore E = 2.56x10^{10}\,Nm^{-2}$$

From fig 2.1 c (static slope) = $\frac{\Delta m}{\Delta D}$

$$= \frac{(40-16)x10^{-3}}{(2.7-1.5)x10^{-2}} = \frac{24x10^{-3}}{1.2x10^{-2}} = 2kgm^{-1}$$

So that from equation 10, the young's modulus for this type of timbre is

$$E = \frac{4gL^3}{bd^3} x \frac{\Delta m}{\Delta D} = \frac{4x9.8x(1.02)^3}{0.0354x(0.0058)^3} x2 = \frac{4x9.8x1.06}{0.0354x2.05x10^{-7}} x2$$

$$\therefore E = 1.19x10^{10}\,Nm^{-2}$$

From fig 2.1 d (static slope) = $\frac{\Delta m}{\Delta D}$

$$= \frac{(30-10)x10^{-3}}{(2.0-0.8)x10^{-2}} = \frac{20x10^{-3}}{1.2x10^{-2}} = 1.6kgm^{-1}$$

So that from equation 10, the young's modulus for this type of timbre is

$$E = \frac{4gL^3}{bd^3} x \frac{\Delta m}{\Delta D} = \frac{4x9.8x(1.025)^3}{0.0365x(0.0055)^3} x1.6 = \frac{4x9.8x1.077}{0.0365x1.6x10^{-7}} x1.6$$

$$\therefore E = 1.13x10^{10}\,Nm^{-2}$$

From fig 2.1 e (static slope) = $\frac{\Delta m}{\Delta D}$

$$= \frac{(50-30)x10^{-3}}{(2.6-1.5)x10^{-2}} = \frac{20x10^{-3}}{1.1x10^{-2}} = 1.8kgm^{-1}$$

So that from equation 10, the young's modulus for this type of timbre is

$$E = \frac{4gL^3}{bd^3} x \frac{\Delta m}{\Delta D} = \frac{4x9.8x(1.043)^3}{0.035x(0.0055)^3} x1.8 = \frac{80.059}{50x10^{-9}}$$

$$\therefore E = 1.60x10^{10}\, Nm^{-2}$$

The summary of the determined values of young's modulus for the considered timbre samples is given in the table below:

sample	Young's modulus for static test (x10^9 N/m^2)
Sapele wood	12.6
Opepe wood	25.6
Lagos wood	11.9
Mansonia wood	11.3
Afara wood	16.0

DISCUSSION OF RESULTS AND CONCLUSION

Considering the static case, the results indicates that Opepe and Afara have the highest values Of young's modulus, ie (25.6) x x10^9 N/m^2 and (16.0) x10^9 N/m^2 respectively while Mansonia has the lowest value of (11.3) x10^9 N/m^2.

The calculated values for Sapele is 12.6 x 10^9 N/m^2 while the mean value for all grades of Sapele timbre in literature is 9.3 x 10^9 N/m^2. Also the obtained value of Opepe is 25.6 x10^9 N/m^2 while the available value in literature is 13.8 x10^9 N/m^2.thus from here it can be deduced that the values obtained for these two timbre samples seam to their corresponding values found in literature.

The conformity or otherwise of other timbre samples used in this work, besides Opepe and Sapele, with standards found in literature could not be tested. Names for these species were not found in the British standards institute material from where the standards were obtained. (Tyler,1980). It could be possible that these are not known in the international timbre market.The results obtained for Opepe and Sapele is considered suitable for inferring these other ones since they were all kept under the same condition and underwent the same stresses.

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