# THE USE OF NON-DESTRUCTIVE ACOUSTIC METHOD FOR MEASURING THE ELASTICITY OF BOSCIA ANGUSTIFOLIA WOOD

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***Abstract***
*This study was carried out to determine the MOE of Bosciaaugustifolia wood using non-destructive acoustic test method with the view to examining its reliability.Three trees of this specieswere obtained, and samples of* $20 \times 20 \times 300\ \mathrm{mm}^3$ *were collected for testing. The samples were stored for a month after oven dried prior to testing. Non-destructive acousticand mechanical destructive methods were used to determine the MOE. The mean values of MOE of B. augustifoliawood obtained for the acoustic method was 6908.42±752.49N/mm*$^2$*while MOE determined by the mechanical methodwas 6914.75±586.95N/mm*$^2$*. Analysis done showed no significant difference between the two methods. Therefore, the acoustic test methodused was reliable for measuring MOE of the wood, and it is thus recommended for adoption. As such, this study was able to determineMOE of wood using a non-destructive acoustic test method.*

**Keywords:** *Acoustic; B. augustifoliawood; MOE; Non-destructive; Mechanical; Prediction*

## Introduction

Elasticity of a material can better be described as the ability of that material to return to its shape and size after it has been distorted by an external force (Albert et al., 2002). As such, Halabeet al. (1997) observed that when force is applied to wood for a very short duration as with dynamic testing,the wood behaves like an elastic solid while when force is applied for longer duration as with static testing, the wood behaves like a viscous liquid. It can therefore be said that modulus of elasticity (MOE) which is also known as Young's modulus describes the stiffness of a material. Thus, a high value of MOE implies a high resistance of wood to deformation (Liang and Fu, 2007). From the afore-mentioned, no doubt MOE is an important property needed to be tested before recommending a wood for mechanical purposes. However, mechanical testing of wood samples common to wood scientist over the years has been known to be destructive, resulting to a damage and undesirable effect on the samples. Contrarily, non-destructive acoustic test methods (NDAT) does not result in damages of wood samples, and it could estimate the viscoelastic properties with high accuracy in short time (Mohammed et al. 2010).Though NDAT method is not new, it has been used by some authors such asDecneut (1970), Chiu (1991), Roebben and Biest (2002) for properties of ceramic, Kollura (2000) on concrete, Mohammedet al. (2010) on polymeric composite, and (Kaiserlik, 1978); Ross (1994); Roohnia (2005); Baradit and Niemz (2012); Hassan et al. (2013); Olaoye (2019) on wood.Also, Buccur (1996) affirms that many acoustic methods have been studied and used on standing trees, logs and wood products to measure elastic properties or to reveal defects.

Apparently, NDAT method is a powerful tool which can be adopted to test for mechanical properties of wood. Ross and Pellerin (1994); Lin and Wu (2013) also certify that it can be used to evaluate the physical and mechanical properties of wood and wood-based materials. It is expected that NDAT technique be fast and affordable (Sandoz et al. 2000; Olaoye, 2019). In order to encourage a wider adoption of NDAT method for determining MOE, Olaoye (2019) recommended that NDAT method should be used on other wood species to substantiate these findings. Therefore, there is need to substantiate the efficacy of this method on other wood species, especially with lesser used wood species. Boscia angustifolia wood is a lesser used wood species (LUWS) in Nigeria and it belongs to the family Capparaceae. Its common name in Nigeria is fula-fulfulde(Hausa) (Burkill, 1985), and Laoro (Yoruba). The objective of this study is to use non-destructive acoustic test method to measure the modulus of elasticity of B. angustifolia wood with the view of validating the reliability and efficacy of this method to determining MOE of wood species.

## Materials and Method

Three trees of Boscia angustifolia with 25 ± 2cm in diameter at breast height (DBH) were obtained from Gambari Forest Reserve. From each tree of merchantable height, bolts of 60cm in length were collected axially i.e. from top, middle and base. Along each sampling height, 10 samples each of

***(Baar et al., 2016)***

$$E = \left(\frac{2f_n}{\gamma_n \pi}\right)^2 \frac{mL^3}{I} \quad (N/mm^2) \qquad (1a)$$

Where m is the specimen weight, $f_n$ is the 1st bending natural (fundamental) frequency, n is the mode number, L is the length of the sample. $\gamma_n$ is for the first mode 2.267, and I is inertia.

$$I = \frac{(bh^3)}{12} \qquad (1b)$$

Where b is the width and h is the thickness of the specimen
Note: the experiment was conducted in an enclosed place at room temperature having ensured a total silence, and the FFT analyzer showing no sign of sound signal.

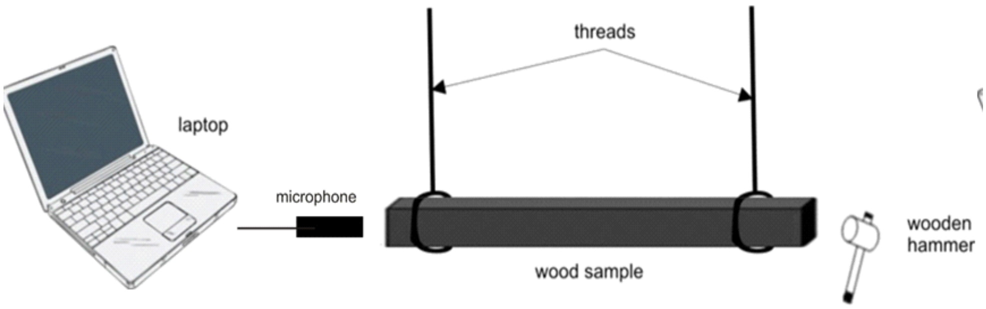


**Fig. 1: The set-up of longitudinal free vibration test**

**Mechanical Measurement of MOE Using a universal Testing Machine (UTM)**
The same wood samples that were used to determine MOE from the NDAT method were taken to the department of forest product development and utilization, Forestry Research Institute of Nigeria (FRIN), Nigeria for testing using the UTM. The samples were tested at a cost. The process involves the destruction of the samples. However, necessary variables were obtained and equation 2 was used to calculate the modulus of elasticity of the wood samples

$$MOE = \frac{PL^3}{4\Delta bd^3}(N/mm^2) \qquad (2)$$

Descriptive statistic and analysis of variance (ANOVA) was used to analyze the data obtained, while post-hoc test were also used where necessary.

**Results and Discussion**
Table 1 showed the mean summary of the different methods used to determine the MOE ofB angustifolia wood. For NDAT method, the middle wood had the highest mean value (8247.77 ± 1383.37N/mm$^2$) and top wood had the lowest mean value (4531.55 ± 314.32N/mm$^2$), while the total mean value of MOE for the NDAT method was (6908.42±752.49N/mm$^2$). On the other hand, the total mean MOE for UTM method was 6914.75±586.95N/mm$^2$ with the base wood having the highest mean (8545.23 ± 647.65N/mm$^2$) and top wood representing the lowest value with 5290.86 ± 510.60N/mm$^2$.

In addition, separate analysis done on axial and radial position of both methods in Table 2 indicates a significant difference of 0.052 and 0.046 for NDAT and UTM methods respectively in the axial position only, while radial position shows no significant differencesfor each methods. Similarly, ANOVA done for the two methods shows no significant difference (P–value = 0.994).

Furthermore, Post-hoc analysis done for NDAT method shows MOE of top wood was significantly different from both middle wood and base wood with P–value of 0.029 and 0.039 respectively. Contrarily, MOE of top wood was not significantly different from middle wood but was significantly different with base wood (P–value = 0.155 and 0.017 respectively), and middle wood was not significantly different from base wood (P–value = 0.151) for UTM method.

The total mean MOE obtained from UTM method was greater than that of NDAT method. Thedifferencebetween this values is very small thus implying it may be significantly the same. These values thus compared favourably with the findings of Adebawoet al. (2019) who reported a MOE value of 6291.44 N/mm$^2$ for the same species.

The insignificant difference obtained between the MOE of the two methods adopted in this study was high, having a P-value very close to 1. The closer a P-value to 1, the more insignificant are the sources of variation to each other. Therefore, it can be said convincingly that MOE obtained in this study for both NDAT and UTM methods are strongly the same, and it should be assumed as the same. Notwithstanding, P-value (0.17) recorded by Olaoyeet al. (2019) between these methods when testing for MOE of G.arborea was lower than what was obtained in this study. A suspected reason for this variation may be due to difference in number of sample size, or other precautionary measures. Nevertheless, a non-significant difference in the two studies was found.

In other vein, there was a intersperse variation in values of MOE axially for the NDAT method, while a decrease in MOE values was recorded axially (base to top) such as similar to Adebawoet al. (2019) for B.angustifolia wood for the UTM method. Yang et al.(2003), Hassan et al. (2013), and Zhou et al. (2013) all confirmed the reliability of NDAT method for testing wood properties of decayed wood, timber and logs respectively. However, axial variation observed in this study for UTM method thus questions the reliability of the Non-destructive acoustic test method for determining MOE along and across a wood species.

**Table 1: Mean summary of Modulus of Elasticity of Boscia Angustifolia wood from Nondestructive Acoustic Method and UTM Method**

| Axial Position | Radial Position | MOE (N/mm$^2$) (NDAT) | MOE (N/mm$^2$) (UTM) |
|---|---|---|---|
| TOP | CORE | 4462.36 | 4484.69 |
| | MIDDLE | 4025.04 | 5151.08 |
| | OUTER | 5107.26 | 6236.82 |
| **Mean** | | 4531.55 ± 314.32 | **5290.86 ± 510.60** |
| MIDDLE | CORE | 10228.37 | 8388.39 |
| | MIDDLE | 8931.74 | 7048.51 |
| | OUTER | 5583.19 | 5287.60 |
| **Mean** | | **8247.77 ± 1383.37** | **6908.17 ± 867.87** |
| BASE | CORE | 7083.51 | 8714.44 |
| | MIDDLE | 7374.50 | 7348.49 |
| | OUTER | 9379.80 | 9572.77 |
| **Mean** | | **7945.93 ± 721.84** | **8545.23 ± 647.65** |
| **Total Mean** | | **6908.42±752.49** | **6914.75±586.95** |

Mean ± Standard Error

**Table 2: ANOVA for Axial and Radial Position of MOE Tested Using NDAT and UTM**

| *Source of Variation* | *SS* | *df* | *MS* | *P-value* |
|---|---|---|---|---|
| NDAT | | | | |
| Axial Position | 25559334 | 2 | 12779667 | 0.052 |
| Error | 15209619 | 6 | 2534937 | |
| Total | 40768953 | 8 | | |
| Radial Position | 347019 | 2 | 173509.5 | 0.982 |
| Error | 29242338 | 3 | 9747446 | |
| Total | 29589357 | 5 | | |
| UTM method | | | | |
| Axial Position | 15886592 | 2 | 7943296 | 0.046 |
| Error | 8917950 | 6 | 1486325 | |
| Total | 24804542 | 8 | | |
| Radial Position | 755495.6 | 2 | 377747.8 | 0.911 |
| Error | 24049046 | 6 | 4008174 | |
| Total | 24804542 | 8 | | |

Table 3: ANOVA for the different methods used (NDAT and UTM)

| *Source of Variation* | *SS* | *df* | *MS* | *P-value* |
|---|---|---|---|---|
| MOE Methods | 180.7122 | 1 | 180.7122 | 0.994 |
| Error | 65573495 | 16 | 4098343 | |
| Total | 65573676 | 17 | | |

Table 4: Post-hoc analysis of MOE for NDAT and UTM method showing Significant P-values within the Axial Position

| **Axial Position** | | **P-Value (NDAT)** | **P-Value (UTM)** |
|---|---|---|---|
| **Top** | Middle | 0.155 | 0.155 |
| | Base | 0.017 | 0.017 |
| **Middle** | Top | 0.155 | 0.155 |
| | Base | 0.151 | 0.151 |
| **Base** | Top | 0.017 | 0.017 |
| | Middle | 0.151 | 0.151 |

**Conclusion**

This study successfully determined modulus of elasticity of B.angustifolia wood using a non-destructive acoustic test method and with the universal testing machine. There was no significant difference in the values of MOE obtained from the two methods, and as such validating the reliability of using NDAT for measuring MOE of wood species. However, this research couldn't ascertain the suitability of NDAT method to test for variation in MOE along and across the radial position of B.angustifolia wood.

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