NIPES

Journal of Materials Engineering, Structures and Computation

Journal homepage: www.nipesjournals.org.ng

Characterization and Grading of *Monoon Longifolium* and *Albizia Lebbeck* Timber Species According to Bs 5268 (2002), En 338 (2009) and Ncp 2 (1973)

Adediji[a], O.C and Wilson[b], U.N
[ab]Department of Civil Engineering, Nigerian Defence Academy, Kaduna State.
[*]Corresponding Author: unwilson@nda.edu.ng, christianaoac@gmail.com

ARTICLE INFORMATION

Article history:
Received 28 June 2024
Revised 25 July 2024
Accepted 9 August 2024
Available online August 2024

Keywords:
Monoon longifolium, *Albizia lebbeck*, hardwood, timber grading, strength classes

https://doi.org/10.5281/zenodo.13310811

ABSTRACT

This research is aimed at establishing strength categories for two native tree species from Northern Nigeria, Monoon longifolium and Albizia lebbeck, by characterizing and grading them according to established standards (BS 5268-2, EN 338, NCP 2) in order to reduce dependency on commonly utilized timber varieties. The study encompassed laboratory experiments for evaluating their physical and strength attributes, followed by categorization into specific strength classes, based on parameters like bending stress, density, and modulus of elasticity. After characterization and grading, Monoon longifolium and Albizia lebbeck were assigned to strength classes D30 and D50 respectively, according to BS 5268-2 (2002). According to NCP 2 (1973), the timber species were assigned to strength classes N6 and N3 in the same order. The samples were also assigned to strength classes D30 and D50 respectively, according to EN 338 (2009). The results indicated that both Monoon longifolium and Albizia lebbeck qualify as a hardwood, presenting potential applications in boat construction, roofing materials, doors, windows, light construction formwork, and general construction, diversifying timber resource utilization.

1. **Introduction**

This study delves into the characterization and grading of two indigenous Northern Nigerian tree species, specifically Monoon longifolium and Albizia lebbeck. The primary objective is to establish strength classes for these timber species, a crucial step in expanding the available timber resources and potentially reducing the reliance on more commonly used and often overexploited species [1].

To achieve this, the research followed established standards such as [2,3,4], for the classification and grading of timber. These standards provide a structured framework for assessing timber

properties, particularly its strength-related attributes. By adhering to these standards, the study ensures its findings are aligned with internationally recognized guidelines [5,6,7].
These timber species were subjected to laboratory experiments to determine their physical and strength properties. Property testing is critical for evaluating various attributes such as strength, density, and modulus of elasticity [8]. Following property testing, the collected data is subject to thorough analysis. This analysis aims to derive meaningful insights into the properties of each timber sample [9,10]. These properties include bending stress, density, and modulus of elasticity, which are critical factors in assessing timber's suitability for various construction applications [11,12].
Based on the experimental results and by the standards, Monoon longifolium was categorized as a softwood, while Albizia lebbeck fell under the hardwood classification. Softwoods and hardwoods have distinct properties that make them suitable for different construction purposes [13]. Softwoods are often preferred for applications where ease of manipulation and lighter structural demands are essential, such as in boat-making, roofing materials, doors, and windows [14]. Hardwoods, on the other hand, are valued for their strength and durability, making them suitable for more demanding applications like structural components and heavy construction formwork [15].
Overall, this research contributes to the sustainable utilization of local timber resources, promotes the diversification of timber species used in construction, and aligns with the global trend towards eco-friendly and renewable building materials. By expanding the knowledge base on these lesser-known timber species and their properties, this study offers valuable insights for architects, engineers, and policymakers involved in construction and resource management in Northern Nigeria and beyond.

2. Materials and Methods

The process began with the procurement of tree trunks from various villages and timber sheds located within Kano State. These tree trunks originate from different tree species and serve as the raw material for the study. To prepare them for testing and analysis, a series of steps were followed:

- Initial Cutting: The tree trunks were initially cut using a motorized chain saw. This primary cutting process results in the formation of large pieces and shapes from the tree trunks.
- Marking for Identification: Before further processing, each of these large pieces was carefully marked for identification purposes. This step ensures that the pieces can be traced back to their respective sources and species, a crucial aspect of maintaining accurate records for the study.
- Transfer to Timber Workshop: Following identification marking, the large pieces were transported to a timber workshop. Here, they underwent further processing to achieve specific sizes and dimensions that align with the standards outlined in the relevant codes.
- Dimensional Specifications: The pieces were split and cut into precise sizes and dimensions as specified in the codes. For instance, dimensions such as 2cm x 2cm, 2in x 2in (by [16]), and 3cm x 3cm (in alignment with [17]) were achieved during this stage.
- Length Consideration: Additionally, the lengths of these timber pieces were determined with careful consideration of the mechanical tests that will be conducted on them [5,8,18]. Ensuring that the lengths correspond to the testing requirements is essential for accurate and meaningful test results.

Plate 1. *Monoon longifolium* (left), *Albizia lebbeck* (right)

2.1 Determination of Moisture Content and Weight Density

These 2cm x 2cm x 2cm timber samples were vital for assessing moisture content and weight density. Initially weighed, they underwent controlled drying at 103±2oC for 24 hours. Afterwards, reweighing and specific mathematical formulas were used to determine the volume (Eqn 1) moisture content (Eqn 2) and weight density (Eqn 3).

$$\text{Volume} = l \times b \times h \quad (1)$$

$$\%\ \text{moisture content} = \frac{initial\ weight - final\ weight}{final\ weight} \quad (2)$$

$$\text{Weight density} = \frac{final\ weight}{volume} \quad (3)$$

2.2 Determination of Weight Density at 12% and 18% Moisture Contents

The densities computed above were adjusted to values at 12% and 18% moisture content in accordance with [2] using Eqn 4 and Eqn 5:

$$p_{12} = p_w[1 - \frac{(1-0.5)(u-12)}{100}] \quad (4)$$

$$p_{18} = p_w[1 - \frac{(1-0.5)(u-18)}{100}] \quad (5)$$

Where is ρ_{12} = density at 12% moisture content in kg/m3, ρ_{18} = density at 18% moisture content in kg/m3, ρ_w = density at experimental moisture content, u = experimental moisture content in %.

2.3 Determination of physical and Mechanical Properties

Tests were done according to standards and as was done by [8,19,20]. The failure loads and deflections recorded were then employed to calculate critical parameters such as failure stresses, mean failure stress, and standard deviation. Subsequently, these failure loads play a crucial role in determining the characteristic strengths of the samples in various modes, including bending, compression, tension, and shear, both parallel and perpendicular to the grain [6,19,21]. These calculations are performed following the guidelines outlined in [2,3].

2.4 Mechanical Testing to BS 373:1957

2.4.1 Bending Strength Parallel to Grain (BS 373)

The test procedures used were in accordance to [16] (Figure 1).

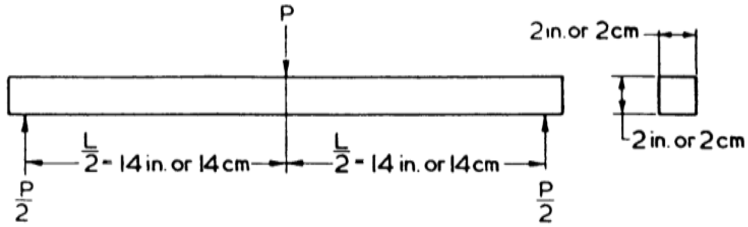

Figure 1. Three-point bending test setup [16]

Test loads were applied to the samples until failure occurred and the relationships (Equation 6 to 11) were used in determining their strength properties.

Modulus of Rupture (MOR) = $\frac{3Pa}{2bd^2} N/mm^2$ (6)

Modulus of Elasticity (MOE) = $\frac{PL^3}{4\Delta bd^3} N/mm^2$ (7)

MOR at 12% MC, F_{12} = $(1 + (W - 12)$ (8)

MOR at 18% MC, $F_{18\%} = \frac{F_{12\%} \ x \ 18}{12}$ (9)

MOE at 12% MC, $E_{m12} = \frac{E_{measured}}{1+0.0143(12-u)}$ (10)

Minimum MOE, Emin = $E_{mean} \frac{2.33\sigma}{\sqrt{N}}$ (11)

2.4.2 Other Mechanical Strength Tests

The test procedures for the compressive strength parallel to grain, compressive strength perpendicular to grain, tensile strength parallel to grain and shear strength parallel to grain tests are all done in accordance to [16], and their failure loads are recorded for the calculation of their failure stresses.

2.5 Mechanical Testing to EN 408:2010

The testing procedures adhered to the standards set in [17] (Figure 2).

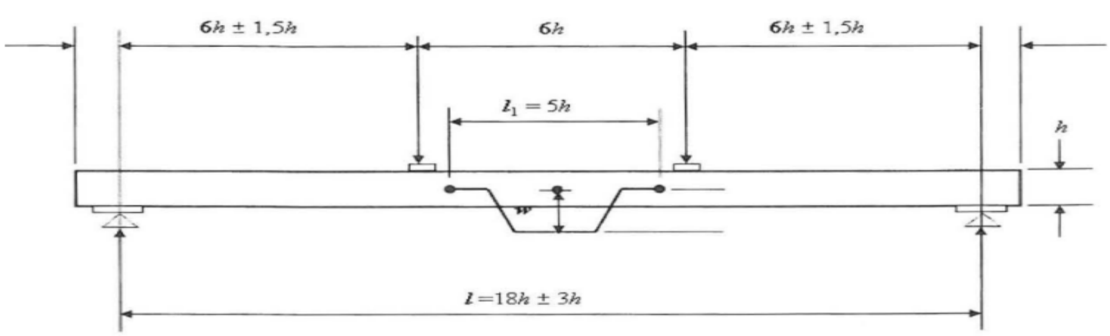

Figure 2. Four-point bending test setup [17]

Samples were subjected to increasing loads until they reached the point of failure. The subsequent analysis relied on established relationships (Equation 12 to 24) to ascertain the strength properties of these samples.

Moisture content, $MC = \frac{m_1 - m_2}{m_0} x\ 100$ (12)

Dry density, $p_d = \frac{m_0}{v}$ (13)

Bulk density, $p_b = \frac{m_1}{v}$ (14)

5th percentile value of density, $p_{05} = (\bar{p} - 1.65s)$ (15)

Characteristic density, $p_k = \frac{\sum p_{05}, n_j}{\sum n_j}$ (16)

Mean density, $p_{mean} = 1.2p_k$ (17)

12% density value, $p_{k,12\%} = p_w(1 - \frac{(1-0.5)(u-12)}{100}$ (18)

Measured bending strength value, $f_m = \frac{af_{max}}{2w}$ (19)

Characteristic bending strength value, $f_k = 1.12f_{0.5}$ (20)

12% MC value of bending strength, $f_{m,12\%} = \frac{f_{measured}}{1+0.0295(12-u)}$ (21)

MOE, $E_m = \frac{l^3(F_2 - F_1)}{4.7bh^3(w_2 - w_1)}$ (22)

mean MOE, $\bar{E} = [\frac{\sum Ei}{n}]1.3 - 2690$ (23)

12%MC of MOE, $E_{m,12\%} = \frac{E_{measured}}{1+0.0143(12-u)}$ (24)

2.5.1 Other Derived Properties to EN 408:2010

The below expressions (Equation 25 to 34) were used to determine the other strength properties of the samples according to [21]

Tensile stress stress parallel to grain

$f_{t,0,k} = 0.6f_{m,k}$ (25)

Compressive stress parallel to grain

$f_{c,0,k} = 5(f_{m,k})^{0.45}$ (26)

Compressive stress parpendicular to grain

$f_{c,0,k} = min.\begin{cases} 3.8 \\ 0.2(f_{m,k})^{0.8} \end{cases}$ (27)

Compressive stress perpendicular to grain

$f_{c,90,k} = 0.007p_k\ for\ softwoods$ (28)

$f_{c,90,k} = 0.015p_k\ for\ hardwoods$ (29)

Modulus of elasticity parallel to grain

$E_{0.05} = 0.67E_{0,mean} for\ softwoods$ (30)

$E_{0.05} = 0.84E_{0,mean} for\ hardwoods$ (31)

Mean modulus of elasticity perpendicular to grain

$E_{90,mean} = \frac{E_{0,mean}}{30} for\ softwoods$ (32)

$E_{90,mean} = \frac{E_{0,mean}}{15} for\ hardwoods$ (33)

Mean shear modulus

$G_{mean} = \frac{E_{0,mean}}{16}$ (34)

2.6 Basic and Grade Stresses

Basic stresses for bending, tensile, compressive, shear parallel to the grain, compressive stress perpendicular to the grain, are calculated from failure stresses. Eqn 35 was used for the computation. Various grade stresses at 80%, 63%, 50% and 40% values respectively were also be calculated [9,22,23].

$$f_b = \frac{f_m - k_p \sigma}{k_r} \tag{35}$$

Where f_b = basic stress, mean failure stress at 12% moisture content, σ = standard deviation of failure stress, k_r = reduction factor and k_p = modification factor = 2.33, K_r for bending, tension and shear parallel to the grain = 2.25. K_r for compression parallel to the grain = 1.4 while K_r for compression perpendicular to the grain = 1.2 [18,24,25].

3. Result and discussion

3.1 Moisture Contents and Weight Densities of Samples

The value of percentage moisture contents of the samples is shown in Table 1, which also shows the weight density of samples (g/cm^3), 12% and 18% weight density values.

Table 1. Moisture Contents and Weight Densities of Samples

	Monoon longifolium	*Albizia lebbeck*
Volume (cm^3)	8	8
Initial Weight (g)	5.6	6.6
Final Weight (g)	4.5	6.0
Moisture Content (%)	24.6	10.0
Weight Density (g/cm^3)	0.50	0.68
ρ_{12} (g/cm^3)	0.47	0.68
ρ_{18} (g/cm^3)	0.49	0.70

The *Monoon longifolium* has the higher average amount of moisture (24.6%) and the lesser density value (0.5 g/cm^3), while *Albizia lebbeck* has the lesser amount of moisture content (10%), and also denser (0.68 g/cm^3).

3.2 Testing Results to BS 373

3.2.1 Test Results of Samples

The *Albizia lebbeck* had a higher level of resistance to the applied bending load (31.48 N/mm^2), compressive stress parallel (30.58 N/mm^2), compressive stress perpendicular (3.73 N/mm^2), tensile stress (16.67 N/mm^2) and shear stress (6.06 N/mm^2). A summary of this can be seen in Table 2.

Table 2. Obtained Values of Stresses of Samples

	Monoon longifolium	*Albizia lebbeck*
Failure load (kN)	10.0	12.6
Area (mm^2)	400	400
Bending stress (N/mm^2)	24.94	31.48
Maximum Deflection(mm)	8	10
MOR (N/mm^2)	261.83	330.50
MOE (N/mm^2)	52600.77	53116.76
$F_{12\%}$ (N/mm^2)	1584.82	72.14
$F_{18\%}$ (N/mm^2)	2377.23	108.21

E_{m12} (N/mm^2)	64197.04	51672.66
E_{min} (N/mm^2)	13833.13	17600.84
Compressive stress (N/mm^2)	18.42	30.58
Compressive perpendicular (N/mm^2)	3.73	4.19
Tensile stress (N/mm^2)	16.60	16.67
Shear stress (N/mm^2)	4.13	6.06

3.2.2 Basic Stresses of Samples and Grading to BS 5268

Table 8 of the BS 5268 is used for characterization. *Monoon longifolium* is classified as a softwood while *Albizia lebbeck* is classified as a hardwood. Table 7 (moisture content below 18%) of NCP 2 is used to characterize *Albizia lebbeck*, while Table 6 (moisture content above 18%) was used to characterize *Monoon longifolium.* A summary of this can be seen in Table 3.

Table 3. Basic Stresses of Samples and Grading of Samples

	Monoon longifolium	*Albizia lebbeck*
Bending Strength $f_{bb, par}$	10.56	13.33
Compression parallel $f_{bc, par}$	10.77	19.54
Compression perpendicular $f_{bc, per}$	3.00	3.37
Tension parallel fbt, par	6.77	6.82
Shear parallel $f_{bv, par}$	1.59	2.30
MOE_{mean}	52600.77	53116.76
E_{min}	13833.13	17600.84
Density (ρ_w)	0.50	0.68
Final Grading, BS	C30	D50
Final Grading NCP	N6	N3

3.2.3 Grade Stresses of Samples to BS 5268 and NCP 2

The grade stresses of the samples at 80%, 63%, 50% and 40% are also calculated and are summarized in Table 4.

Table 4. Grade Stresses of Samples (N/mm2)

	Monoon longifolium	*Albizia lebbeck*
Bending Strength	10.56	13.33
80%	8.448	10.664
63%	6.6528	8.3979
50%	5.28	6.665
40%	4.224	5.332
Compression parallel	10.77	19.54
80%	8.616	15.632
63%	6.7851	12.3102
50%	5.385	9.77
40%	4.308	7.816
Compression perpendicular	3	3.37
80%	2.4	2.696

63%	1.89	2.1231
50%	1.5	1.685
40%	1.2	1.348
Tension parallel	6.77	6.82
80%	5.416	5.456
63%	4.2651	4.2966
50%	3.385	3.41
40%	2.708	2.728
Shear parallel	1.59	2.3
80%	1.272	1.84
63%	1.0017	1.449
50%	0.795	1.15
40%	0.636	0.92

3.3 Testing Results to EN 408:2010.

3.3.1 Density Test Result

The wet and dry densities of the samples are determined by measuring their volume and weight before they enter the oven and after being removed following 24 hours of exposure to a constant temperature of 105°C, respectively. The values obtained and those of the fifth percentile density, mean density and density at 12% moisture contents calculated are also shown in Table 5.

Table 5. Density Test Result of Test Samples

	Monoon longifolium	*Albizia lebbeck*
Volume (cm^3)	8	8
Initial Weight (g)	5.0	6.0
Final Weight (g)	4.0	5.4
Moisture Content (%)	24.6	10.0
Characteristic dry density, ρ_k (kg/m^3)	504.23	677.53
Wet Density ρ_b	628.43	745.59
ρ_{05}	503.63	676.93
ρ_{mean}	604.35	812.32
$\rho_{k,12\%}$	534.48	718.18

3.3.2 Four-Point Bending Test Result

The four-point bending test results for the specimens are highlighted in Table 6. From the results of the four-point loading test, various values related to bending strength are evaluated. These include bending strength values, fifth percentile strength values, characteristic values of bending strength properties, and values corresponding to a 12% moisture content for the bending strength.

Table 6. Four-Point Bending Test Results of Samples

	Mangifera indica	*Terminalia catappa*
Failure load f_{max} (kN)	8.7	10.5
$f_m = \frac{af_{max}}{2w} (N)$	31.42	38.00

$f_{0.5}$	30.65	37.20
Characteristic values of bending strength properties f_k	34.32	41.66
$f_{m,12\%}$	33.58	40.29
$F_{12} = F_w\ (1 + \alpha(W - 12)$	34.16	40.93

3.3.3 Modulus of Elasticity (MOE) Test Result

The MOE values of the samples are obtained concurrently from the four-point loading test and are summarized on Table 7. The 12% moisture content MOE is also estimated for the samples.

Table 7. MOE Test Results of Samples (N/mm^2)

	Monoon longifolium	*Albizia lebbeck*
$E_m = \dfrac{l^3(F_2 - F_1)}{4.7bh^3(w_2 - w_1)}$	17915.5	22960.5
$\bar{E} = [\dfrac{\sum Ei}{n}]1.3 - 2690$	20600.10	27158.63
$E_{m,12\%}$	21864.36	22331.39

3.3.4 Derived Mechanical Properties of the Samples and Final Grading of Samples

Comparing the results of the characteristic stresses of the samples with Table 8 of the EN 338:2003. *Monoon longifolium* fall under soft woods while *Albizia lebbeck* fall under hardwood. This is shown in Table 8.

Table 8. MOE Test Results of Samples and Grading of Samples (N/mm^2)

	Monoon longifolium	*Albizia lebbeck*
Bending parallel $f_{m,k}$	28.51	40.92
Tension parallel $f_{t,0,k}$	17.10	24.55
Compression parallel $f_{c,0,k}$	22.58	26.57
Shear parallel $f_{v,k}$	2.92	3.80
Compression perpendicular $f_{c,90,k}$	7.56	10.16
Tension perpendicular $f_{t,90,k}$	0.60	0.60
5% MOE Parallel $E_{0.05}$	15.05	19.29
MOE mean perpendicular $E_{90\ mean}$	1.19	1.53
Mean shear modulus G_{mean}	1.12	1.44
Mean density	604.35	812.32
Final Grading	C35	D50

4.0 Conclusion

The study conducted laboratory experiments on *Monoon longifolium* and *Albizia lebbeck*, following BS 373 (1957) and EN 384 (2004) standards. It established their physical and mechanical properties, successfully characterizing and grading them. According to BS and NCP standards, their densities were 500kg/m^3 and 610kg/m^3 for *Monoon longifolium* and *Albizia lebbeck*, respectively. The basic bending stress values were 10.56N/mm^2 and 13.33N/mm^2, with 80% grade bending stresses of 8.45N/mm^2 and 10.66N/mm^2 for the same species, respectively.

In accordance with EN standards, characteristic densities were 504.23kg/m^3 and 677.53kg/m^3, for *Monoon longifolium* and *Albizia lebbeck*. Basic bending stress values obtained were 28.5N/mm^2, and 40.92N/mm^2 in the same order.

Following characterization and grading, *Monoon longifolium* and *Albizia lebbeck* were assigned strength classes C30, and D50, respectively, according to BS 5268-2 (2002). Based on NCP 2 (1973), these timber species fell into strength classes N6 and N3, respectively. Lastly, according to EN 338 (2009), the samples were assigned strength classes C35 and D50, respectively.

References

[1] Ede, A., Olomu, O., Akpabot, A., & Oyebisi, S. (2021). Review of recently characterized Nigeria timber species for structural applications. IOP Conference Series: Materials Science and Engineering,

[2] BS 5268 (2002). Structural use of timber - Part 2: Code of practice for permissible stress design, materials and workmanship. British Standard Institute. 2(1), 1–184.

[3] EN338 (2009) “Structural Timber: Strength Classes,” European Committee for Standardisation, CEN, Brussels, Belgium.

[4] NCP2. Nigerian Standard Code of Practice: The use of timber for costruction. Lagos, Nigeria: Standard Organisation of Nigeria, Federal Ministry of Industries, (1973)

[5] Ozelton, E. C., & Baird, J. A. (2008). Timber designers' manual. John Wiley & Sons.

[6] Idris, A., and Muhammad, N. A., (2013). Development of EN338 (2009) Strength Classes for Some Common Nigerian Timber Species Using Three Point Bending Test. 338(5), 193–197.

[7] Wilson, U., Adedeji, A., Alomaja, J., Sani, J., Babatunde, O., & Abubakar, P. (2021). Comparative reliability assessment of a solid, box and I-section Nigerian-grown African birch (Anogeissus leiocarpus) timber column. International Wood Products Journal, 12(1), 40-50.

[8] Wilson, U., Bakori, A., Oriola, F. O., Odeyemi, S., Adeyemi, F., Zayyanu, A., & Rahmon, R. (2023). Characterisation of The Nigerian-Grown Eucalyptus Camaldulensis Timber Specie According to En 338 (2009) And Ncp 2 (1973). Lautech Journal of Engineering And Technology, 17(1), 18-24. Retrieved From Http://Laujet.Com/Index.Php/Laujet/Article/View/548

[9] Jimoh, A., & Ibitolu, B. (2018). Characterisation and grading of three selected timber species grown in Kwara State Nigeria according to EN 338 (2009) for structural use. Nigerian Journal of Technology, 37(2), 322-329.

[10] Adeyemi, F. O., Jimoh, A. A., & Wilson, U. N. (2016). A review of mechanical strength properties of some selected timbers in Nigeria. The International Journal of Science and Technology, 4(2), 9.

[11] Rahmon, R., Jimoh, A., Babatunde, O., & Tazou, O. (2017). Strength Characterization and Grading of Eku (Brachystegia eurycoma) Timber grown in Kwara State, Nigeria in accordance to BS 5268.

[12] Adediji, O. C., Wilson, U. N., Mohammed, I. S. (2023). Characterization of Three Selected Timber Species According to BS 5268 (2002), EN 338 (2009) & NCP 2 (1973). Journal of Science and Technology Research 5(4) 2023pp. 40-50 ISSN-2682-5821

[13] Krajnc, L., Farrelly, N., & Harte, A. M. (2019). The influence of crown and stem characteristics on timber quality in softwoods. Forest Ecology and Management, 435, 8-17.

[14] Sholadoye, I. O., & Abubakar, I. I. (2020). Determination of Strength Classes of Selected Nigerian Timbers in Accordance with EN338 (2009). FUOYE Journal of Engineering and Technology, 5(1).

[15] Aguwa, J. (2012). Reliability assessment of the Nigerian apa (afzelia bipindensis) timber bridge beam subjected to bending and deflection under the ultimate limit state of loading. International Journal of Engineering and Technology, 2(6), 1076-1088.

[16] BS 373 (1957). Method of Testing Small Clear Specimens of Timber. British Standard Institute, London.
[17] EN 408 (2010).Timber structures, test methods-solid timber and glued laminated timber-determination of some physical and mechanical properties", TSE, Ankara.
[18] Aguwa, J., Chukwu, P., & Auta, S. M. (2015). Aguwa, J. Characterization and Grading of South Eastern Nigeria grown Irvingia gabonensis Timber in Accordance with BS 5268.
[19] Jimoh, A., & Aina, S. (2017). Characterisation and Grading of two selected timber species grown in Kwara State Nigeria. Nigerian Journal of Technology, 36(4), 1002-1009.
[20] Wilson, U. N., Mohammad, Y. N., Mohammed, I. S., & Adeyemi, F. O. (2021). Characterisation and grading of four selected timber species grown in Nigeria in accordance with Bs 5268. Nigerian Journal of Technology, 40(4), 576-583.
[21] EN 384 (2010). Structural timber-Determination of characteristic values of mechanical properties and density.British Standard Institution, London.
[22] Fatolu, A. S. (2017). Characterization and grading of some selected Nigerian Timber species grown in Kwara state, Nigeria for Structural uses. University of Ilorin, Ilorin, Nigeria.
[23] Obinnaosuji, S., and Inerhunwa, I. (2017). Characterization and Strength Classification of Timber Species in Akwa Ibom State, Nigeria for Structural Engineering Applications. Journal of Engineering Research and Application. 7(103), 2248–962201. https://doi.org/10.9790/9622-0710030109
[24] Wilson, U. N., Adedeji, A. A., Afolayan, J. O., Mohammed, I. S., Sani, J. E., Alomaja, J. A., & Yoro, K. O. Reliability-Based Investigation on the Compressive Strength of Commonly Used Nigerian Timber Species.
[25] Abubakar, P., Iorkar, A., Adedeji, A. A., Aguwa, J. I., & Wilson, U. N. (2020). Structural reliability-based assessment of Nigerian Anogeissus schimperi timber bridge beam in shear and bearing forces. Nigerian Journal of Technology, 39(4), 1011-1020.