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EN 338 Strength Characterization and Grading of Igba (Rhizophora Racemosa) and Adere (Syzgium Guineense) Timbers for Structural Applications

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ABSTRACT

The paper characterizes two potential timbers grown in Nigeria according to EN338 (2009) timber strength classification. The timbers namely Igba (Rhizophora racemosa) and Adere (Syzgium guineense) were obtained in Kwara state in the North-central part of Nigeria. Physical and Mechanical properties of timber species were obtained in accordance with EN 13183-1 (2002) and EN 408 (2003). Four point bending tests based on EN 408 (2003) with specimen size 50x50x1000 mm was carried out using a Universal testing machine (UTM) to determine the bending strength and Modulus of Elasticity of each timber specie. Characteristic values of Bending strength, Modulus of Rupture and Density were determined using EN 384(2004). Rhizophora racemosa and Syzgium guineense had equilibrium moisture content (EMC) of 10.59 % and 22.34 % respectively. This moisture content were adjusted to 12% using adjustment factors so as to satisfy EN338 (2009) requirements for strength grading of timber. Rhizophora racemosa and Syzgium guineense were assigned to strength class C14 and D24 respectively. The Kolmogorov Smirnov test of goodness of fit test at 95% level of significance (α = 0.05) for bending strength of the two timber species as obtained using Easyfit 5.6 software shows that the most fitted distribution model for bending strength of Rhizophora racemosa is the normal distribution, while Lognormal Distribution is the most fitted for Syzgium guineense.

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1. Introduction

With less than 4 billion hectares of forest globally which covers approximately 20% of the world's land area, timber demand increases at an annual rate of 1.7 per cent [1]. With this statistics, forestry resources are insufficient to meet the demand for timber. The scope for enlargement of forested areas is limited. This has mounted pressure on the need for commercial exploitation of natural forests unless forest reserves can be increased [2]. According to [3], timber remains a very important structural material in technological advancement and high level engineering production. Timbers grow best in temperate and moist tropical climates but do not grow in cold or very dry areas of Nigeria. Furthermore, Nigeria as a nation is now allocating urge resources on importation of steel which is not necessary even in fabrication of long span trusses for sophisticated structures because timber can be used to achieve strength, durability, aesthetic and even time conservation [4]. The demand for timber is unlimited as it continues to increase rapidly in Nigeria. Even though several research works have been done on characterization of timbers which has resulted in comprehensive information about their material properties, there is still research gap to cover many useful but unpopular timber species, most especially, those species in developing countries like Nigeria [5].

Structural timber is basically used in framing and load-bearing structures, where emphasis of selection is based on strength. Most timbers used in the building construction are softwoods. Roof truss structures, bridges and railway sleepers require hardwood species [6]. Classification of these timbers to standards then becomes of great importance because of diverse and also similar properties of some of them. When a timber is classified and graded, designers can easily use different available timbers for a purpose. The properties of large size specimens are preferred to those of small clear specimens when characterizing timbers for structural applications because of unavoidable defects such as shakes, knots other defects found in timber [7].

This paper intends to classify potential Nigerian timbers in accordance to[8] which is the limit state design. This will give an opportunity to adopt the Eurocode 5 design procedure in the Nigerian case of study. The authors conclude that the work would serve as a revision to the Nigerian timber design code so as to meet up with international standards.

2. Materials and methodology

2.1. Materials

Materials used for this work are timber specimens obtained from Kwara state in North-central part of Nigeria. This timber species are Rhizophora racemosa and Syzgium guineense as shown in Table 1:

Table 1
Timber Nomenclature.

S/N	Local Name	Botanical Name	Family
1.	Igba	Rhizophora racemosa	Rhizophoraceae
2.	Adere	Syzgium guineense	Myrtaceae

2.2. Preparing Test specimen

To carry out bending strength and Modulus of Elasticity tests, 40 No. beams of 50 mm×50 mm×1000 mm each, that is, 20 pieces per specie were carefully prepared with the aid of sawing and milling machines obtained from the wood processing unit of the department of Civil Engineering, University of Ilorin, Nigeria. For moisture content and density, a total of 30 No. slices of 50 mm×50mm×50 mm sawn after bending tests from timber beams section close to fracture were also prepared at the same unit.

2.3. Methods

2.3.1 Physical properties of timber

i) Moisture content of Timber

The timber moisture contents (MCs) were obtained in accordance with [9] and[10]. The MC for each timber was obtained by first measuring its initial mass before drying using an electronic weighing balance. The test samples were then oven dried at a temperature of 103 ± 2^0c. The specimens were dried until the final weight of oven-dried timber is constant after two successive weighing. The initial and oven dry mass of each specimen sample were recorded and the MC was then obtained from equation 1:

$$\mathrm{MC} = \frac{\mathrm{m1-m2}}{\mathrm{m2}} \text{ x } 100\% \tag{1}$$

where m1, m2 and MC are the initial mass, oven dry mass and moisture content of test specimen respectively. The mean Moisture content was then obtained by finding the mean value of MC for the 15 specimens of each wood specie.

ii) Density

The density of timber equals its mass per unit volume at a specified value of MC. Density of samples was obtained in accordance with[10] using equation 2 with its characteristic values determined in accordance with [11] using equation 3.

$$\text{Density} = \rho = \frac{\mathrm{Mass\ (m1)}}{\mathrm{Volume}}\ \mathrm{g/cm^3} \tag{2}$$

$$\rho_\kappa = \rho_{05} = (\ \rho - 1.65s\ ) \tag{3}$$

where ρ_κ is the characteristic density, ρ_{05} is the 5-percentile density, ρ and s are the mean and the standard deviation of densities of all specimen (in kg/m3), respectively.

2.3.2. Mechanical properties of timbers

Mechanical strength properties of timbers are affected by variation in moisture content lower than the fibre saturated point (FSP). Generally, many of the strength properties of timber increases as wood are dried. Above FSP, a change in moisture content does not affect most of the mechanical properties of timber[12].

i) Bending Strength

This was carried out in accordance with BS 408:2003 for structural timber. The strength tests were carried out with the aid of a Universal Testing Machine (UTM) with a maximum load capacity of 300KN at the Agricultural Engineering laboratory of the university of Ilorin. The UTM has a square shaped loading head. The Modulus of rupture was computed from equation 4.

$$\mathbf{f_m} = \frac{\mathbf{a\,F_{max}}}{\mathbf{2W}} \tag{4}$$

Where "a" is the distance between loading position and the nearest support (mm), F_{max} represents the maximum load (N), "W" represents the section modulus (mm^3) and f_m represents the bending strength (N/mm^2).

According to [13], the characteristic value of strength properties obtained from the measured MC were computed from equation 5 derived from EN 384(2004):

$$f_k = 1.12 f_{05} \tag{5}$$

Where f_k and f_{05} are the characteristic value and 5th- percentile value of bending strength, respectively. Figure 2 and 3 shows the 4-point bending test setup and its failure mode respectively.

Fig. 2. 4-Point Bending test Setup.

Fig. 3. Failure Mode of 4-point Bending Test.

ii) Modulus of Elasticity

The Local modulus of Elasticity (MOE) was derived from the 4-point bending test as prescribed in EN408(2003). The rate of movement of the loading head was adjusted not to be greater than 9mm/min giving a strain rate of 0.15/s. The guage length for the test is five (5) times more than the depth of the section (250 mm). The local MOE was then computed using the following equation:

$$\mathbf{E_{m,l}} = \frac{\mathbf{a l_1^2 (F_2 - F_1)}}{\mathbf{16 I\ (w_2 - w_1)}} \tag{6}$$

Where $E_{m,l}$ is the local MOE in bending, a is the distance between inner point loads and supports (mm), l_1 is the gauge length (250mm)

$(F_2 - F_1)$ is increment in load (Newton) on the regression line with a correlation coefficient of 0.99 and $(w_2 - w_1)$ is increment in deformation (mm) corresponding to $(F_2 - F_1)$.

Characteristic values of MOE which also the mean modulus of elasticity based on measured moisture content is then calculated from the equation as given in EN 384:2004

$$\mathbf{E_{mean}} = \left(\frac{\sum \mathbf{E_i}}{\mathbf{n}}\right)\mathbf{1.3 - 2690} \tag{7}$$

where E_i is the ith value of MOE, n is the number of samples and E_{mean} is the mean value of MOE in bending. Figure 4 shows the local modulus of Elasticity setup in Bending.

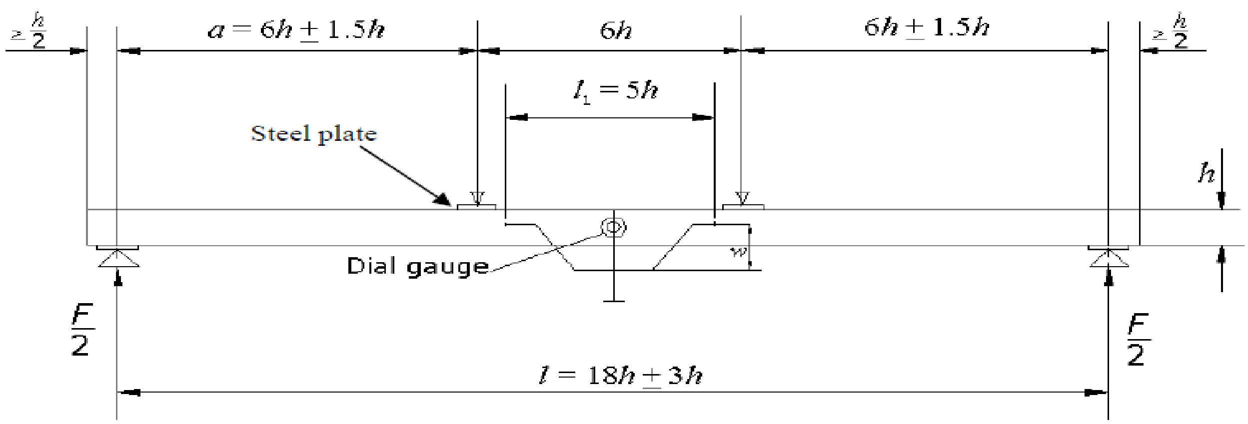

Fig. 4. Setup to measure local modulus of Elasticity in Bending [7].

3. Adjusting values to 12% moisture content (mc) equivalent

Strength class values according to EN 338:2009 for structural timbers are obtained from timbers at about 12% MC, which is used as reference moisture content. Thus the strength characteristics of timber were adjusted to 12% moisture content using equation 8. These results are then converted to their equivalent moisture content of 18% by interpolation which is the acceptable moisture content of timber to be used in Northern Nigeria using equation 8.

$$F_{12} = F_w(1 + \alpha(W - 12) \tag{8}$$

Where;

F_{12} = ultimate strength at 12% moisture content,

W = moisture content at the time of test,

F_w = ultimate strength at the moisture content at the time of test,

α = adjustment factor for moisture content, equivalent to the percentage (%) change in strength values for 1% change in moisture content. This is contained in Table 2

Table 2
Adjustment factor for Wood state of stress.

State of stress	α (for all wood specie)	**Reference**
Modulus of Elasticity (E_m , $E_{c,0}$)	0.02	[11]
Bending Strength	0.04	[14]
Density	-0.005	[15]

4. Other mechanical properties

Characteristic values of other mechanical properties at 12% MC such as tensile strength parallel to grain, tensile strength perpendicular to grain, shear modulus, compressive strength parallel to grain, compressive strength perpendicular to grain and other stiffness properties of the timbers were determined using the following equations from Annex A of EN338(2009).

The characteristic values of tensile strength parallel to grain ($f_{t,0,k}$) and compressive strength parallel to grain($f_{c,0,k}$) are computed from the equations 9 and 10 respectively:

$$f_{t,0,k} = 0.6\ f_{m,k} \tag{9}$$

$$f_{c,0,k} = 5\ (f_{m,k})^{0.45} \tag{10}$$

The characteristic values of tensile strength perpendicular to grain ($f_{t,90,k}$) and compressive strength perpendicular to grain($f_{c,90,k}$) are computed from equations 11-14:

$$f_{t,90,k} = 0.4\ \text{N/mm}^2 \text{ for softwoods} \tag{11}$$

$$f_{t,90,k} = 0.6\ \text{N/mm}^2 \text{ for hardwoods} \tag{12}$$

$$f_{c,90,k} = 0.007\ \rho_K \text{ for softwoods} \tag{13}$$

$$f_{c,90,k} = 0.015\ \rho_K \text{ for hardwoods} \tag{14}$$

Fractile 5^{th} percentile values of MOE parallel to grain ($E_{0,0.05}$) was computed from equations 15 and 16:

$$E_{0,0.05} = 0.67\ E0\text{,mean for softwoods} \tag{15}$$

$$E_{0.0.05} = 0.84\ E0\text{,mean for hardwoods} \tag{16}$$

The characteristic values of mean MOE perpendicular to grain ($E_{90,mean}$) for the timbers were computed from the equations 17 and 18:

$$E_{90,mean} = E_{0,mean} /30 \text{ for softwoods} \tag{17}$$

$$E_{90,mean} = E_{0,mean} /15 \text{ for hardwoods} \tag{18}$$

The characteristic values of mean shear modulus (G_{mean}) were computed from equation 19:

$$G_{mean} = E_{0,mean} /16 \tag{19}$$

The characteristic mean density mean density (ρ_{mean}) is computed from equation 20:

$$\rho_{mean} =1.2 \text{ x } \rho_k \tag{20}$$

Shear strength $f_{t,0,k}$, was taken from Table 1 of EN 338 (2009) as specified by the code.

Equations 10 to 20 $E_{0,mean}$ is the mean MOE parallel to grain, ρ_k is the characteristic density while $f_{m,k}$ is the characteristic bending strength all which are used to derive the other mechanical properties. Shear strength $f_{v,k}$ would be taken from Table 1 of EN338 as put forward by the code. Equations 12-19 which differentiates softwood from hardwood would be dependent on the characteristic density range of the timber in accordance with EN338.

5. Result and discussion

Table 3 shows the results obtained for the MC of the two (2) timber specie. Syzgium guineense (Adere) had a higher moisture content (MC) of 22.34 % as compared to Rhizophora racemosa (Igba) with MC of 10.59 %. The standard deviation and coefficient of variance for Adere are 3.20 % and 14.31 while that of Igba are 1.12 % and 10.56 respectively. Moisture content values in general of the two species were below fiber saturation point (FSP) which usually between 25-30 % as recorded in[3].

Table 3
Summary of Moisture content result.

Timber specie	Mean Moisture content (%)	Standard Deviation (%)	Coefficient of variation	95% Confidence Interval (UCL and LCL)	99% Confidence Interval (UCL and LCL)
Rhizophora racemosa (Igba)	10.59	1.12	10.56	$9.8958 \leq x \leq 11.2842$	$9.6777 \leq x \leq 11.5023$
Syzgium guineense (Adere)	22.34	3.20	14.31	$20.3567 \leq x \leq 24.3233$	$19.7334 \leq x \leq 24.9466$

Table 4 presents the adjusted 12% characteristic density of the timbers to be used for timber classification in accordance with EN338.

Table 4
Mean and Characteristic density of Timbers.

Timber Type	Mean Density $\boldsymbol{\rho}$ (Kg/m^3)	Standard Deviation (Kg/m^3)	Characteristic Density $\boldsymbol{\rho_k}$ (Kg/m^3)	12% MC Density $\boldsymbol{\rho_{k,12\%}}$(Kg/m^3)
Rhizophora racemosa (Igba)	433	43.755	360	363
Syzgium guineense (Adere)	713	63.249	608	577

Mechanical Properties of Rhizophora racemosa

Table 5 shows the mean modulus of rupture (MOR) at failure and local modulus of elasticity (MOE) of Rhizophora racemosa (Igba) timber speice. The 95% and 99% confidence limits for the mean MOR and local MOE of these timbers are also shown in the table and they are satisfactory, since most of determined values from test are within the ranges.

Table 5
Bending Strength for Rhizophora racemosa Timber.

Rhizophora racemosa	MOR(N/mm^2)	Local MOE (N/mm^2)
Minimum	12.685	7186.66
Maximum	28.526	19088.50
Mean	21.574	11186.26
Standard deviation	5.660	4901.30
Coefficient of Variation	26.240%	43.815%
99% Confidence limit	$18.066 \leq x \leq 25.082$	$8148.46 \leq x \leq 14224.06$
95% Confidence limit	$16.964 \leq x \leq 26.184$	$7193.912 \leq x \leq 15178.61$

Mechanical Properties of Syzgium guineense

Table 6 shows the mean modulus of rupture (MOR) at failure and local modulus of elasticity (MOE) of Syzgium guineense timber specie. The 95% and 99% confidence limits for the mean modulus of rupture and local modulus of elasticity of these timbers are also shown in the table and they are satisfactory, since most of determined values from test are within the ranges.

Table 6
Bending Strength of Syzgium guineense Timber.

Syzgium guineense	MOR (N/mm^2)	Local MOE (N/mm^2)
Minimum	16.178	7186.66
Maximum	50.408	15679.8
Mean	36.394	9553.96
Standard deviation	12.301	3649.091
Coefficient of Variation	33.799%	38.194%
99% Confidence limit	$26.37424 \leq x \leq 46.4138$	$6581.597 \leq x \leq 12526.322$
95% Confidence limit	$28.7699 \leq x \leq 44.0181$	$7292.2715 \leq x \leq 11815.6485$

Adjusted characteristic density, bending strength and modulus of elasticity values of material properties for the timber species to 12% MC is given in Table 7. Rhizophora racemosa (11.517k N/mm^2) and Syzgium guineense (11.74 k N/mm^2) had lower MOE when compared with white Afara (13.32kN/mm^2) in [16] but higher than Macrocarpa bequaertii (8.169 kN/mm^2) in[15]. When comparing the bending of Rhizophora racemosa (14.0 N/mm^2) and Syzgium guineense (25.47 N/mm^2) with other known specie, they were lower than Nauclea diderrichii (54.45 N/mm^2) in[15].

Table 7
Adjusted Characteristic value of Material properties to 12% MC.

Timber Type	Density $\rho_{k,12\%}$ (Kg/m^3)	Bending Strength $f_{m,k12\%}$ (N/mm^2)	Modulus of Elasticity $E_{0,mean}$ (N/mm^2)
Igba Rhizophora racemosa	363	14.0	11517.91
Adere Syzgium guineense	577	25.47	11742.34

Table 8 presents the results of the other derived mechanical properties of timber species as computed from equation 10-21.

Table 8
Derived Mechanical properties of the Timbers.

Timber Specie Other (Mechanical Properties)	Tension Parallel $f_{t,0,k}$ (N/mm^2)	Tension Perpendicular $f_{t,90,k}$ (N/mm^2)	Compression Parallel $f_{c,0,k}$ (N/mm^2)	Compression Perpendicular $f_{c,90,k}$ (N/mm^2)	Shear Strength $f_{v,k}$ (N/mm^2)	5% MOE, Parallel $E_{0,0.05}$ (KN/mm^2)	Mean MOE, Perpendicular $E_{90,mean}$ (KN/mm^2)	Mean Shear Modulus G_{mean} (KN/mm^2)	Mean Density ρ_{mean} (Kg/m^3)
Rhizophora racemosa	8.4	0.4	16.39	2.5	4.0	7.72	0.384	0.719	436
Syzgium guineense	15.0	0.6	21.28	8.6	4.0	9.86	0.783	0.734	692

From the results, the Nigerian timbers were allocated a strength class. This assignment was based on EN338 which states that a solid timber can be assigned to a strength class if the characteristic values of bending strength and density of timber equals or exceed the values of strength class given in Table 1 of EN338, and the characteristic mean MOE of timber in bending equals or exceeds 95% of the value given for that strength class. Based on this, Rhizophora racemosa belongs to strength class C14 due to its minimum characteristic bending strength of 14.0 N/mm^2, characteristic density of 363 kg/m^3 and minimum mean MOE parallel to grain of 11.52KN/mm^2. The characteristic density, bending strength and mean MOE of strength class C14 as provided in EN338 are 14 N/mm^2, 7 KN/mm^2 and 290 kg/m^3 respectively. Based on similar criteria, Syzgium guineense timber specie is assigned to strength class D24.

6. Distribution fitting and tests of goodness of fit

Kolmogorov-Smirnov (K-S) Goodness-of-Fit Test is adopted in this paper and implemented using the Easyfit 5.6 software. The test was carried out based on density and bending strength values of timber species at 95% level of significance ($\alpha = 0.05$). This was in order to access if each data set comes from a population with a specific distribution. Three distribution models were considered namely Normal, Lognormal and Gumbel distribution. The results are presented in Tables 9 and 10 for density and bending strength respectively.

The critical value of 0.29408 for the timber species was obtained from the easyfit software for Kolmogorov Smirnov test at $\alpha = 0.05$. This critical value is greater than the K-S statistics of the normal, lognormal and gumbel distribution of the timber species thus making the density value hypothesis for three tested distribution models acceptable. This shows all the three distribution models can be used to model the density of each of the specie. However, based on the P-value ranking of the three fitted distribution model, it can be deduced that Gumbel distribution is most suitable for Rhizophora racemosa while the Normal distribution is best used for Syzgium guineense. The P-Value, in Table 9 is calculated based on the test statistics, and denotes the theoretical value of the significance levels in the sense that the null hypothesis (Ho) will be accepted for all values of α less than the P-Value.

Table 9
K-S Goodness of Fit Tests on Density Test Results at $\alpha = 0.05$.

Timber Specie	Distribution	Statistics	P-Value	Rank	Reject Hypothesis
Igba (Rhizophora racemosa)	Normal	0.22781	0.21481	3	No
	Lognormal	0.20677	0.31468	2	No
	Gumbel	0.20244	0.33864	1	No
Adere (Syzgium guineense)	Normal	0.18151	0.4708	1	No
	Lognormal	0.1965	0.37349	2	No
	Gumbel	0.25042	0.13642	3	No

The Kolmogorov Smirnov test of goodness of fit test at $\alpha = 0.05$, for bending strength of the two timber species is shown in Table 10. The critical value of 0.29408 as obtained from the analysis is higher than the corresponding K-S statistics of the normal, lognormal, and gumbel distribution. Thus, three distribution models can therefore be used to model the bending strength of timber. It is observed that the most fitted distribution model based on its P-value ranking for bending strength of Rhizophora racemosa is the normal distribution, while Lognormal Distribution is the most fitted for Syzgium guineense

Table 10
K-S Goodness of Fit Tests on Bending Strength Test at $\alpha = 0.05$.

Timber Specie	Distribution	Statistics	P-Value	Rank	Reject Hypothesis
Igba (Rhizophora racemosa)	Normal	0.20246	0.33854	1	No
	Lognormal	0.23388	0.19099	2	No
	Gumbel	0.26047	0.1099	3	No
Adere (Syzgium guineense)	Normal	0.20414	0.32912	2	No
	Lognormal	0.20217	0.3402	1	No
	Gumbel	0.2293	0.20876	3	No

7. Skewness and excess kurtosis

Skewness is the extent and direction of skew which connotes the deviation from horizontal symmetry and kurtosis tells you how tall and sharp the central peak is, relative to a standard distribution curve. A reference standard for skewness and Kurtosis is Normal distribution, which has excess kurtosis of 0 and kurtosis of 3. This connotes that excess kurtosis is simply equals to kurtosis minus 3.[17]

Figure 5 and Figure 6 are histograms for the distribution of density data and plots for the probability density functions (pdf) of the fitted theoretical distribution models (gumbel distribution, normal distribution and lognormal distribution) for the timber species.

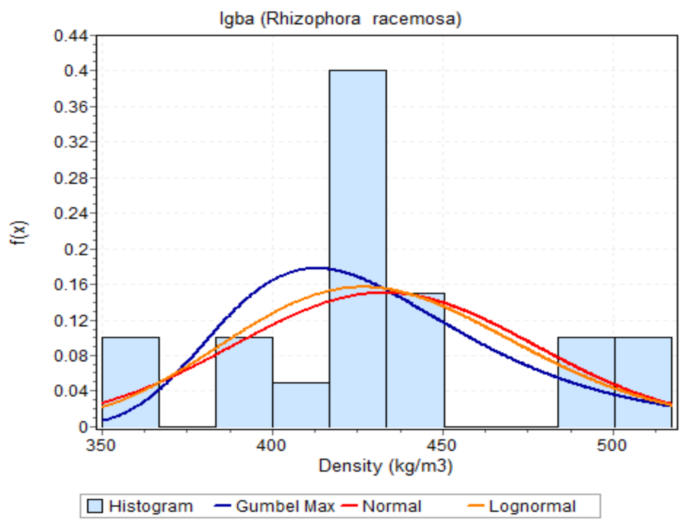

Fig. 5. Probability Density Function Plots for Density of Rhizopora racemosa.

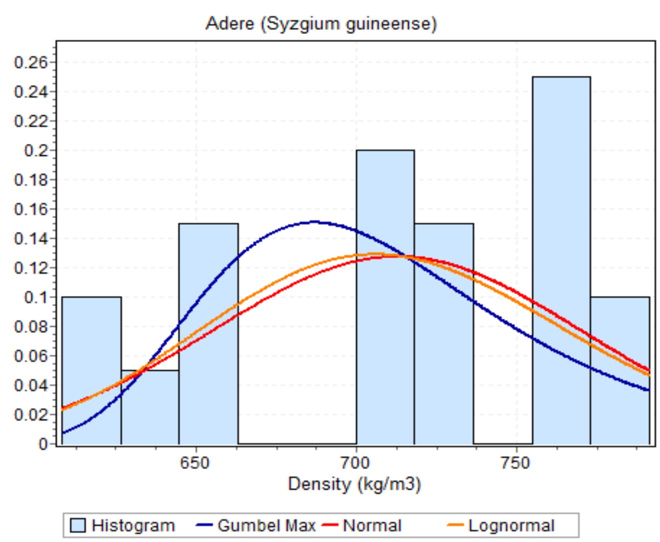

Fig. 6. Probability Density Function Plots for Density of Syzium guineense.

Figure 7 and Figure 8 are histograms for the distribution of bending strength data and plots of the probability density functions (pdf) of the fitted theoretical distribution models (gumbel distribution, normal distribution and lognormal distribution) for the timber species.

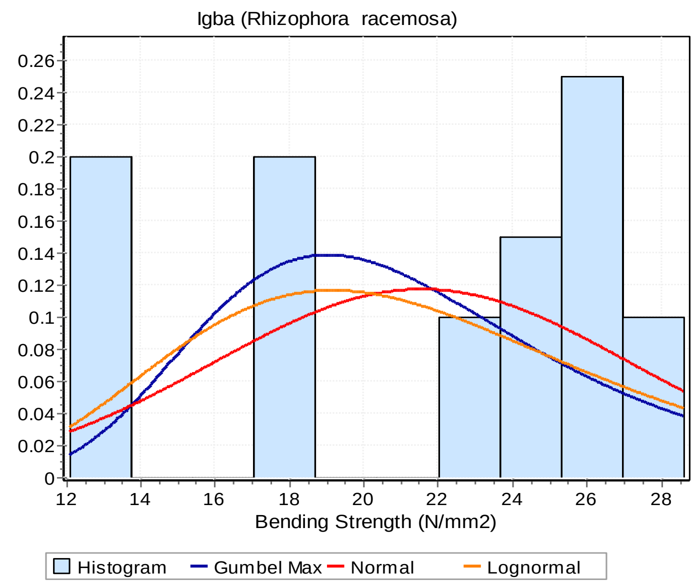

Fig. 7. Probability Density Function Plots for bending strength of Rhizopora racemosa.

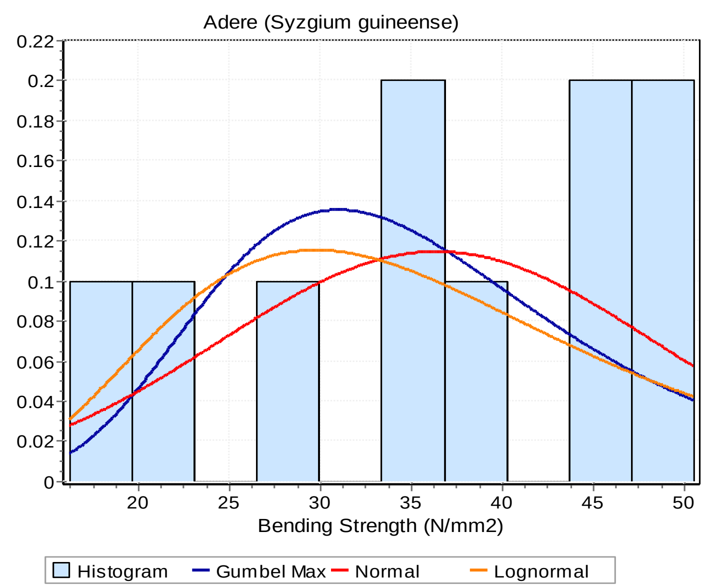

Fig. 8. Probability Density Function Plots for bending strength of Syzium guineense.

Table 11 presents values of the skewness and excess kurtosis for the bending strength and density of the two timber species. Deductions from the values presented shows that Syzgium guineense is negatively skewed for both density and bending strength values while Rhizophora racemosa has its density skewed to the right with positive value of +0.38284 and bending strength negatively skewed with skewness of -0.51478.

Table 11
Skeweness and Excess Kurtosis for Density and Bending Strength.

Timber Properties	Density		Bending Strength	
Timber Specie (Density)	Skewness	Excess Kurtosis	Skewness	Excess Kurtosis
Adere (Syzgium guineense)	-0.43424	-1.0402	-0.40519	-1.1672
Igba (Rhizophora racemosa)	0.38284	0.25306	-0.51478	-1.2358

The probability density function plots for bending strength of Syzgium guineense and Rhizophora racemosa have a broad sharp (platykurtic), with excess kurtosis of -1.1672 and -1.2358 respectively while for density values, Rhizophora racemosa has a central peak value (leptokurtic) of +0.25306.

Table 12 shows equations relating Physical and Mechanical properties of timber species. This would help to predict the strength values of mechanical properties once a particular physical property parameter has been determined and vice-versa.

Table 12
Equations relating Mechanical and Physical properties of timber species.

Relationship	Timber Type	
	Igba(Rhizophora racemosa)	Adere (Syzgium guineense)
Moisture Content and Bending Strength	$Y_{m/c} = 0.002X_b + 10.548$	$Y_{m/c} = 0.0188X_b + 21.656$
Density and Bending strength	$Y_{m/c} = -1.9664X_b + 475.1$	$Y_{m/c} = -2.258X_b + 794.9$
Moisture Content and Modulus of Elasticity	$Y_{m/c} = 4/10000X_b + 10.1$	$Y_{m/c} = -0.0002X_b + 23.93$
Density and Modulus of Elasticity	$Y_{m/c} = 0.0029X_b + 400.44$	$Y_{m/c} = 0.0188X_b + 21.656$

8. Conclusion

Rhizophora racemosa is coniferous specie(softwood) because its characteristic density fall with the softwood density range of 290-460 kg/m^3 Adere is deciduous specie(hardwood) because its characteristic density fall with the hardwood density range of 475-900 kg/m^3 as classified in EN338.Furthermore, the timbers was assigned to appropriate strength classes based on the European structural timber strength classification systems (EN338, 2009). Rhizophora racemosa (Igba) and Syzgium guineense (Adere) were assigned to strength class C14 and D24. The assignment was deduced from the reference material properties (modulus of elasticity, bending strength and density) of the species. Based on the results, Rhizophora racemosa is recommended for low-bearing purposes and furnitures while Syzgium guineense can be used for load bearing structures.

Lack of adequate strength classification on lesser-used species in Nigeria has led to high demand and use of few species such as Ayin, Mahogany, Obeche and Teak and Milicia whose properties are well known. Therefore more research should be channeled on classification of less-used timber specie.

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