Journal of Materials Engineering, Structures and Computation
Journal homepage: www.nipesjournals.org.ng

Structural Properties of Some Indigenous Timber Species in Nigeria.

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ARTICLE INFORMATION

Article history:
Received 20 May 2024
Revised 28 May 2024
Accepted 31 May 2024
Available online

Keywords:
Compressive Strength, Tensile Strength, Shear Strength, Moisture Content and Modelling.

https://doi.org/10.5281/zenodo.11479414

ISSN-1115-5825/

ABSTRACT

Indigenous timber has been in use for centuries now, but the absence of data on their structural properties has made their application technically inconclusive. In this study, samples were taken for field and laboratory tests and experiments conducted by NCP 2 (1973), BS 373 (1957), and BS 5268 (2002). The field experiments result of the ten species obtained were observed to fall within the range of 28 to 35m for height, 0.8 to 1.5m for diameter, brown and yellow for colour, 32.78N/mm2 to 68.67N/mm2 for compressive strength, 68.64N/mm2 to 98.95N/mm2 for flexural strength, 61.34N/mm2 to 166.08N/mm2 for tensile strength and 3022N to 12805N for hardness. Some species taste pleasant, unpleasant, bitter and unspecific taste. Some species were fine to coarse for texture with straight and interlocked grains. Other include moisture content of compressive strength was 10.27% to 12.77%, moisture content for tensile strength was 10.13% to 12.67%, and moisture content for flexural strength was 11.41% to 16.09%. Density for the ten species ranges from 640kg/m3 to 1060kg/m3. The study identified Lophira alata, Nauclea diderrichii, Cylicodiscus gabunesis, afzelia bipindensis, Entandrophragma cylindricum, Brachystegia nigerica, Holotelea grandis, Khaya ivorensis, Mitragyna cilliata and Terminalia superba to be structurally adequate for civil engineering construction and Furniture, and are sufficiently available in commercial quantities for required applications. In this research, engineering data of these indigenous timber have been generated for practical applications in the design and construction of structures as well as furniture fabrication.

1. Introduction

The demand for more shelter such as residential houses, government offices, market shops, warehouses, workshops and halls is growing alarmingly. A shelter is usually covered by a structural member known as the roof. The roof is conventionally constructed with concrete, steel or timber. A roof that is made of sheet nails, ceiling boards and battens among others, rests on roof trusses, which are predominantly timbers. Roof trusses of these days are mostly constructed with timber. Timbers are easily available and have a low cost of production. They are easy to cut, shape, process and assemble. Even though timbers are liable to attack by fungi or insects, which may affect their performance and appearance to a greater or lesser extent; the preponderance of many timber species and their low cost of production make them sometimes preferable to concrete or steel. Apart from roof trusses, timber is also continuously applied in housing, as mainframes and sheeting, as well as in formwork for concrete, shuttering works, railway sleepers and piles. Timber is consumed by a large range of industries. Still, the bulk of the material continues to be used in construction, either structurally (such as roof trusses or floor joists) or non-structurally (e.g. doors, windows frames, skirting board or external cladding). On a volume basis, annual consumption continues to increase and there is no reason to doubt that this trend will not be maintained in the future, especially with continual high demand for shelter. From the overview, the importance and role of timber in the engineering community and society in general is recognized. Therefore, there is a need for a wider knowledge of our indigenous timber.

2. Materials and Methods

2.1 Materials

The materials adopted for this study are woods cut from trees of Lophiraalata, Khayalvorensis, Entandrophragma-cylindricum, Nauclea-diderrichii, Cylicodiscus- gabunensis, Branchystegia, Afzelia bipindensis, Mitragyna Cilliata, Termina suporba and Holoptea grandis in green condition. These samples were obtained from Oluku forest in Benin, Edo state and Sapele, Delta state. Material selection is done through inquiry and documentation using the following details: Local names of timber species, marketable size of timber, rate of patronage, source of timber species, and price per unit length of timber species. Selected timber species were sawn to 100 x150 x 3600 mm sizes. Logs of selected timber were transported to the Timber Workshop of the Civil Engineering Department, University of Benin, Edo state for seasoning, preparation and physical testing by BS 373 of 1957, BS 5268 of 2002 and NCP of 1973 specifications.

2.2. Methods

2.2.1 Standard Methodology for Testing Timber

The method of preparing Timber Testing samples and methods of testing are based on British Standard (BS373 of 1957). Improvements on the Methods of testing small clear specimens of timber have been made over the years and a brief account of the current is given in this work.

2.2.2 Compression Strength Parallel to the Grain

One of the precautions necessary in the evaluation of this property is the need to ensure that the specimen does not buckle during loading, thereby subjecting it to bending rather than compressive stress. Therefore, it is customary to use a special cage which ensures a uniform distribution of load over the cross-section. Ten (10) specimens obtained from each of the timber markets were cut into rectangular sections of 600mm x 20mm x 20mm dimensions to determine the compressive strength. The load was applied at both ends of the test piece in such a way that the loading plates of the Universal Testing Machine (UTM) approached each other at a rate of 0.635mm/min. The test was stopped when the deformation of the specimen was observed and the applied load stopped increasing. The compressive strength is obtained by dividing the load at failure by the cross-sectional area.

$$Compressive\ strength\ (N/mm^2) = \frac{force\ at\ failure(N)}{Cross\ sectional\ area\ (mm^2)} = \frac{P}{A} \quad (1)$$

2.2.3 Compression Strength Perpendicular to the Grain

This involves crushing the wood between the steel plates. The strength is determined from the hardness of the timber since it has been established that there is a very high correlation between the two properties. Mathematical equations are available to calculate the compressive strength from the hardness values from timber at both green and 12% moisture content. To determine the compression perpendicular to grain strength, the load was applied to both ends of the test piece such that the loading plates of the Universal testing machine (UTM) approached each other at a rate of 0.635mm/min. the test was stopped when a deformation on the specimen was observed. The compressive strength perpendicular to the grain was calculated by dividing the load of failure by the cross-sectional area of the specimen.

2.2.4 Tensile Strength Parallel to the Grain.

Owing to the very high tensile strength of timber, only thin strips can be used. However, such strips would be crushed in the jaws of the testing machine. The sample size is 300mm x 20mm x 6mm loaded at a constant speed of 0.02mm/s. To determine the tensile strength of the timber, the sectioned specimens were supported with the aid of the gripping devices of the Universal testing machine (UTM) which permits the application of the tensile load without causing bending of the specimen. The tensile load was applied to the 2cm face of the ends of the test pieces by the special toothed plate grips which was forced into the wood to prevent the slippage of the specimen during the test. The load was applied to the test piece until a sudden sound was heard which broke the sample into two (2).

$$Tensile\ Strength\ (N/mm^2) = \frac{Maximum\ Load(N)}{Smallest\ Cross\ Sectional\ Area\ (\mathrm{mm}^2)} \quad (2)$$

2.2.5 Preparation of Test Specimens

Timber specimens were seasoned naturally for a few months to attain the equilibrium moisture condition (EMC) at the Wood Section of the Civil Engineering Laboratory, University of Benin, Nigeria. The natural method of seasoning was carried out in line with Aguwa (2010). The natural seasoning was done by stacking the wood so that air could circulate all over each piece. This increases their dimensional stability, weight, durability and strength. Ten (10) species were prepared for different laboratory tests which include three-point bending strength parallel to the grain, shear strength parallel to the grain, tension strength parallel to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, natural moisture content, specific gravity and density in line with BS373 (1957) Method of Testing Small clear specimen of Timber.

2.2.6 Determination of Physical and Mechanical Properties

Determination of all various physical and mechanical properties was examined using the Universal Testing Machine (UTM), Testometric Model of 300 KN capacity with a computer interface for data acquisition and analysis. Tests carried out were the three-point bending strength parallel to the grain, shear strength parallel to the grain, tension strength parallel to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, moisture content, specific gravity, cleavage and density tests.

2.3 Timber Test

2.3.1 Cleavage Test

The cleavage sample usually 45mm x 20mm x 20mm was cut at one end to accommodate the grips, splitting force is applied at 0.4mm/s and the resistance to cleavage is expressed as force per unit width. Separate samples were employed to give values for radial and tangential clearance.

2.3.2 Bending

The usual method of supporting and loading the 300mm x 20mm x 20mm sample was such that the central loading head was radiuses and that the ends of the sample were supported turnings carried on roller bearings. The sample was prepared so that the growth ring was parallel to one edge and the sample was tested with the growth ring parallel to the direction of loading; which implied that it was loaded on the radial face. Load was applied at a speed of 0.1mms-1 or 0.1mm/s. the bending strength of the wood is usually presented as modulus of rupture (MOR) in Nmm-2 or N/mm2.

$$MOR = \frac{3PL}{2BD^2} \qquad (3)$$

Where:

P = Applied load in Newton [N],

L = Length of the Sample,

B = Breadth of the Sample,
D = Depth of the Sample

2.3.3 Hardness Test

The hardness of the wood was assessed by its resistance to the impregnation of a special hardened steel tool rounded to a diameter of 11.3mm embedded to half its diameter. A hardness test is typically performed by pressing a specifically dimensioned and loaded indenter into the surface of the timber. The hardness is determined by measuring the depth of the indenter penetration.

2.3.3 Field Examination Test

The heights and Diameters of these trees were measured at the field while Colour, Taste, Texture and Odor were examined and recorded.

2.3.4 Laboratory Test

Samples were taken from the top, middle and bottom of each wood of the ten (10) species for Moisture content, Density, Specific gravity, Compressive strength, at three (3) different grain directions, Flexural strength, at two different grain directions and hardness determination. The entire tests were carried out by NCP2 of 1973 and BS 5268 specifications. Sample size was 60mm x 20mm x 20mm was used in all the tests, except for the Flexural test, where 300mm x 20mm x 20mm was used. Regression and Variance analysis were also undertaken.

2.3.5 Moisture Content Test

In obtaining moisture content of the timber species, ten (10) specimens of size 20 x 20 x 40 mm samples. where there was a controlled temperature. This has equally minimized the chance of the sample picking up or losing moisture content, thereby introducing appreciable errors in calculating the moisture content. After the initial weighing, the samples were transferred into the drying oven. The samples were in the oven for 24 hours. The samples were reweighed for the dry weight.

$$MC = \frac{Original\ weight - Oven\ dry\ weight}{Oven\ dry\ weight} \times 100$$

$$= \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100\% \quad (4)$$

Where:

MC = Moisture Content,
m_{wet} = Original weight of sample in grams, g
m_{dry} = Oven-dry weight of sample in grams, g

2.3.7 Density Test

Ten samples of the timber species of size 20 x 20 x 20 mm were used to determine the density by BS 373 (1957). The Density (Bulk) of the samples was obtained by weighing the mass of the samples and dividing it by the measured volume of the sample. In weighing the sample, the weights of the extractives and moisture were inclusive. Density is calculated using direct measurement of length, width and thickness of the specimen using Vernier calliper using equation 5

$$P = \frac{m}{v} \tag{5}$$

Where P = Timber Density,
M = Mass of specimen,
V = Volume of specimen.

2.3.8 Specific Gravity Test

A test block (wood) of 40mm x 20mm x 10mm was used for the test. A beaker of water was placed on a weighing balance and was counterbalanced by weights, and then the test block was completely immersed in the water. Weights were added to restore equilibrium. Then the specific gravity was computed as the ratio of weight of the dry test block in grams to the weight in grams added to restore equilibrium.

$$W_g = \frac{w_{d(1+m)}}{100} \tag{6}$$

Where:

W_g = Green weight of wood (kg)
M= Moisture content (percent)
W_d = Oven-dry weight of wood

2.3.9 Compressive Strength Test

The Compressive machine in the structures Laboratory was used for the test. The test sample size is 60mm x 20mm x 20mm. The maximum strength was obtained area of the sample. Place the specimen in the compressive testing machine. Following this, apply load parallel to the grains. The specimen should be free from defects. Gradually increase the load. Then note down the load at which the timber breaks. Finally, the compressive strength is calculated.

$$Compressive\ strength\ (N/mm^2) = \frac{Crushing\ Load\ (N)}{Cross\ Sectional\ Area\ (mm^2)} = \frac{P}{A} \tag{7}$$

2.3.10 Hardness Test

The Compressive machine was also used for this test. A 12mm Diameter Rod was forced to penetrate the sample to a minimum depth of 6mm. the amount of force in Newton recorded at the penetration depth of 6mm was the hardness of the sample.

2.3.11 Flexural Strength Test

Flexural strength is a method used to measure the mechanical behaviour of unified bending loads. It is used to define the structural integrity of materials being tested. The flexural machine in the

Structures Laboratory was used for this test which determines the flexural properties of the timber species. Examples of the properties are the modulus of rupture and the modulus of elasticity in flexure in line with BS 373:1957 (Method of Testing Small Clear samples of Timber). The sample size for the test is 300mm x 20mm x 20mm and the loading rate was 0.2mm/s-1 as specified by the British Standard.

For a rectangular sample under a load in a three-point bending setup

$$Bending\,Stress\;(N/mm^2) = \frac{3PL}{2bh^2} \quad (8)$$

Where:

P = Maximum load in Newton (N)
L = Distance between supports in millimeter (mm)
B = Breadth/width of the Sample in millimeter (mm)
D = Depth/ thickness of the Sample in millimeter (mm)

2.4 Linear Regression

Linear regression is an approach for modelling the relationship between scalar dependent variable, Y and one or more independent variables X (Wikipedia, 2016). When the independent variable is more than one, it is called a multiple linear regression. Linear regression analysis is commonly used for prediction and forecasting, a casual analysis. Linear Regression analysis is governed by the equation:

Y = a +bX (9)

Where
X = Independent Varaiable
Y = Dependent Variable
a = Intercept

b = Slope of the line

2. 5 Correlation coefficient, R

Correlation can be defined as a link between two or more sets of data. Correlation is divided into two types namely:

1. Positive Correlation (This occurs when values increase together)
2. Negative Correlation (This occurs when one value decreases as the other increases).

Correlation Coefficient R is used to show how strong is between two variables. There are several types of correlation coefficients but the most commonly used one is Pearson's correlation coefficient for linear regression.

Pearson's Correlation Coefficient is a linear coefficient that returns a value between +1 and -1. A -1 means there is a strong negative correlation and +1 means there is a strong positive correlation.

Pearson's Correlation Coefficient R, is expressed as:

$$R = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where:
n = number of pairs of scores
∑xy = sum of the products of paired scores
∑x = sum of x scores
∑y = sum of y scores

(10)

$\sum x^2$ =sum of squared x scored
$\sum y^2$ = sum of the squared y scores

2.6 Hypothesis

Ho: There is a linear relationship between compressive Strength and Nominal Density for each of the ten (10) Specimens.

H1: There is no linear relationship between compressive Strength and Nominal Density for each of the ten (10) Specimens.

Decision Rule:

The null hypothesis (H0) would be rejected if the p-value is less than 0.05 at a 5% level of significance otherwise, there would be no strong evidence to reject the null hypothesis for each of the specimens.

3 Analyses and Results

3.1 Field experiments for each specimen

Table 1. Summary of Field Test Results

SPECIES	HEIGHT	DIAMETER	COLOUR	TASTE	TEXTURE	GRAIN
Lopira alata	34	1.5	Brown	No specific taste	Coarse	Interlocked
Khaya ivorensis	35	1.4	Reddish-brown	Bitter	Coarse	Interlocked
Entandropragma cylindricum	30	1.0	Reddish-brown	Pleasant	Fine	Straight
Nauclea diderrichii	35	1.2	Yellowish-brown	No specific taste	Coarse	Interlocked
Terminalia superba	35	1.3	Pale yellow	No specific taste	Even	Straight
Brachystegia nigerica	28	1.0	Brown	No specific taste	Coarse	Interlocked
Afzelia bipindensis	32	1.4	Reddish-brown	Pleasant	Coarse	Straight
Mitragyna cilliata	30	1.1	Pinkish-brown	Unpleasant	Fine	Straight
Cylicodiscus gabunesis	30	1.2	Yellowish-brown	No specific taste	Even	Interlocked
Holoptelea grandis	32	0.8	Yellowish-white	Unpleasant	Even	Straight

Table 1 presents the field test results of the ten species. The primary consideration of timber is its strength property. It is usual to specify that it should be straight grain from a practical point of view, colour is of importance because it may enhance or detract from the decorative value of timber. Mahogany of light brown to deep red and Bush mansonia of light brown with red tinge are notable instances in which the use of timber has to some extent been determined by its colour. It can be observed that Terminalia superba, Mitragyna cilliata and Holoptelea grandis are pale yellow and pinkish brown, the remaining species are barely of the same colour as mahogany. Many timbers darken with age, and others fade. Mahogany fades under strong sunlight but darkens in moderate light. This shows that except for Terminalia superba, Mitragyna cilliata, and Holoptelea grandis, the other species are liable to change colour as they attain more age in life. Many timbers have a characteristic odour

which is apparent when they are in fairly fresh condition, but usually disappears as the wood dries out. The most outstanding example is the characteristic resinous odour of the pines and the pleasant odour and mahogany. The taste of wood is closely related to the odour, both properties influence the utilization of timber. Except for Khaya ivorensis which has a bitter taste, the remaining species are pleasant, unpleasant, and have no specific taste. The odour indicates that it could be used for timber construction as revealed in Dinwoodie work of 1995. From Table 8.89, it can also be seen that all the species are either straight-grained or interlocked-grained which also indicates the strength properties.

Table 2. Summary Strength of Timber

SPECIE BOTANICAL NAME	OTHER NAMES	STRENGTH GROUP	DURABILITY	WORKING QUALITIES
Lophira Alata	Ekki	N_1	Very durable	Excellent
Khaya Ivorensis	Lagos mahogany	N_5	Moderately durable	Good
Entandrophragma cylindricum	Sapele mahogany	N_3	Durable	Good
Nauclea Diderrichii	Opepe	N_1	Very durable	Excellent
Terminalia Superba	Afara	N_5	Non-durable	Good
Brachystegia Nigerica	Okwen	N_3	Moderately durable	Good
Afzelia Bipindensis	Apa	N_2	Very durable	Excellent
Mitragyna Cilliata	Abura	N_4	Non-durable	Good
Cylicodiscus Gabunesis	Okan	N_1	Very durable	Excellent
Holoptelea Grandis	Ayo,kekele	N_3	Moderately durable	Good

Table 2 shows the strength group of the specimen, durability and working qualities. From the results it indicated that the ten specimens have them from strength from N_1 and N_7. Lophira alata, Nauclea diderrichii, Cyclicodiscus gabunesis falls in N_1 and Afzelia bipindensis N_2, which happens to be very durable to decay and excellent in qualities. Brachystegia nigerica N_3, Holoptelea grandis N_3, and Khaya ivorensis N_5 are moderately durable and good quality. Mitragyna cilliata N_4 and Terminalia superba N_5 are non-durable and also good in quality. Generally, the ten species are good qualities of timber but with different strength group.

The moisture content test was carried out to check for the presence of moisture within the wood for each strength test sample. Table 3 shows the results of compressive strength test, Entandrophragma cylindricum had the highest amount of moisture content (12.77%) which Khaya ivorensis had the lowest Moisture content (10.27%). A low moisture content value is required in wood as it enhances increases in durability. The likely reason for high water content is as a result of improper storage of improper seasoning. This puts the wood at a high risk of insect infestation and fungi attack.

The volume of the samples was uniform in cross section and the length for the compressive test samples. Hence, the difference in samples was strictly dependent on their weighs.

From Table 3 showing compression strength test results, specimen with the highest average nominal density was lophira alata (1.06g/cm^3) while terminalia superba had the lowest nominal density (0.41g/cm^3).

Compressive Strength is the ability of a material to withstand axial load. From table 3.3 the sample with the highest compressive was lophira alata was (68.67N/mm^2) While the lowest was Khaya ivorensis (32.78N/mm^2). This shows that lophira alata can be used in the construction of heavy duty structures such as railway line.

Table 3. Compressive Strength, Nominal Density and Moisture Content of Each Specimen

Species	**Average Compressive Strength (N/mm^2)**	**Nominal Density (g/cm^3)**	**Moisture Content (%)**
LophiraAlata	68.67	1.06	11.31
Khaya Ivorensis	39.3	0.48	10.27
EntandrophragmCylindricum	45.91	0.65	12.77
NaucleaDiderrichii	50.53	0.83	11.21
Terminalia Superba	33.18	0.41	10.94
BrachystegiaNigerica	45.7	0.62	10.94
AfzeliaBipindensis	43.68	0.76	11.76
MitragynaCilliata	42.03	0.53	12.34
CylicodiscusGabunesis	49.69	0.85	10.6
Holoptelea Grandis	32.78	0.64	10.54

Table 4. Flexural Strength, Nominal Density and Moisture Content for Each Specimen

Timber Specimen	**Nominal Density (g/cm^3)**	**Average Flexural Strength (N/mm^2)**	**Moisture Content (%)**
LophiraAlata	1.06	98.95	16.09
Khaya Ivorensis	0.48	80.29	11.72
EntandrophragmCylindricum	0.61	81.25	12.61
NaucleaDiderrichii	1.02	96.53	12.17

Terminalia Superba	0.41	68.64	12.27
BrachystegiaNigerica	0.62	84.65	11.53
AfzeliaBipindensis	0.80	98.58	12.81
MitragynaCilliata	0.55	83.95	13.46
CylicodiscusGabunesis	0.95	95.64	11.41
Holoptelea Grandis	0.65	72.68	11.83

The moisture content test was carried out to check for the presence of moisture within the wood for each strength test sample. Table 4 shows the results of flexural strength with the highest value being Lophira alata (16.09%) and cyclicodiscus gabunensis had the lowest moisture content (11.41%). A low moisture content value is required in wood as it enhances increases in durability. The likely reason for high water content is as a result of improper storage of improper seasoning. This puts the wood at a high risk of insect infestation and fungi attack. The volume of the samples was uniform in cross section and the length for the compressive and flexural test samples respectively. Hence, the difference in samples was strictly dependent on their weight. From Table **4** specimen with the highest average nominal density was Lophira alata (1.06g/cm3) and Terminalia superba had the lowest nominal density (0.41g/cm3).
The flexural test was used to determine the bending properties. From Table 3.4, the sample with the highest compressive was lophira alata (98.95N/mm2) While the lowest was Holoptelea grandis (72.68N/mm2). This shows that lophira alata can be used in the construction of heavy-duty structures such as railway lines and has a severe blunting effect on cutters and tools.
The flexural strength can be related to the density of the material and hence, the high density of Lophira alata goes in hand with high flexural strength**.**

Table 5. Tensile Strength, Tensile Strength and Moisture Content for Each Specimen

Timber Specimen	Average Tensile Strength (N/mm^2)	Moisture Content (%)
LophiraAlata	166.08	12.67
Khaya Ivorensis	82.85	10.93
EntandrophragmCylindricum	88.35	11.23
NaucleaDiderrichii	84.3	11.68
Terminalia Superba	61.34	12.17
BrachystegiaNigerica	77.29	11.54
AfzeliaBipindensis	130.45	12
MitragynaCilliata	73.63	11.15
CylicodiscusGabunesis	120.37	10.13
Holoptelea Grandis	71.47	11.24

The moisture content test was carried out to check for the presence of moisture within the wood for each strength test sample. Table 5 shows the results of the tensile strength test, Lophira alata had the highest amount of moisture content (12.67%) and Holoptelea grandis had the lowest Moisture content (10.13%). A low moisture content value is required in wood as it enhances increases in durability. The Mitragyna cilliata N4 and Terminalia superba N5 are non-durable and also good in quality. Generally, the ten species are good qualities of timber but with different strength groups. The likely reason for high water content is as a result of improper storage of improper seasoning. This puts the wood at a high risk of insect infestation and fungi attack.

This shows the ability of a material to withstand axial load. From the table, the sample with the highest tensile strength was Lophira alata with the highest tensile strength (166.08N/mm2) while the lowest terminalia superba had the lowest tensile strength (61.34N/mm2).

Table 6. Correlation Coefficient, R, for Each Test and their Specimen

Timber Specimen	**Compressive Strength Vs Nominal Density**	**Flexural Strength Vs Nominal Density**	**Flexural Strength Vs Compressive Strength**	**Tensile Strength Vs Compressive Strength**	**Cleavage Vs Shear Strength**	**Compressive Strength Vs Moisture Content**	**Flexural Strength Vs Moisture Content**	**Tensile Strength Vs Moisture Content**
Lophira Alata	0.98	0.86	0.96	0.80	0.98	0.97	0.86	0.94
Khaya Ivorensis	0.87	0.96	0.98	0.95	0.94	1.00	0.99	0.86
EntandrophragmCylindricum	0.90	0.87	0.99	0.94	0.94	0.77	0.97	0.99
Nauclea Diderrichii	0.90	1.00	0.91	0.62	0.91	0.89	0.90	0.78
Terminalia Superba	0.90	0.82	0.92	0.88	0.92	0.96	0.95	0.98
Brachystegia Nigerica	0.91	0.97	1.00	0.99	0.78	0.94	0.98	0.93
Afzelia Bipindensis	0.87	0.99	0.89	0.73	0.79	0.98	0.98	0.94
Mitragyna Cilliata	0.85	0.93	0.98	0.98	0.99	0.82	0.98	0.69
Cylicodiscus Gabunesis	0.96	0.76	0.93	0.78	0.93	0.95	0.93	0.83
Holoptelea Grandis	0.95	0.98	0.69	0.98	0.86	0.99	0.99	0.80

These show the links between two or more sets of data. All correlation coefficient values obtained were greater than +0.50 which signifies a strong positive relationship as stated in Table 6. From Table 6, the following results were obtained:
Regarding compressive strength against nominal density graphs of each specimen, Lophira Alata had the highest correlation coefficient value (0.98) while Mitragyna Cilliata had the lowest value (0.85). The flexural strength against nominal density graphs of each specimen, Nauclea Diderrichii had the highest correlation coefficient value (1.00) while Cylicodiscus Gabunesis had the lowest value (0.76). The flexural strength against compressive strength graphs of each specimen, Brachystegia Nigerica had the highest correlation coefficient value (1.00) while Holoptelea Grandis had the lowest value (0.69). Tensile strength against compressive strength graphs of each specimen, Brachystegia Nigerica had the highest correlation coefficient value (0.99) while Nauclea Diderrichii had the lowest value (0.62). Cleavage against shear strength graphs of each specimen, Mitragyna Cilliata had the highest value (0.99) while Brachystegia Nigerica had the lowest value (0.78). Compressive strength against moisture content graphs of each specimen, Khaya Ivorensis had the highest value (1.00) while Entandrophragma Cylindricum had the lowest value (0.77). Flexural strength against moisture Content graphs of each specimen, Khaya Ivoensis and Holoptelea Grandis had the highest values (0.99) while Lophira Alata had the lowest value (0.86).

Tensile Strength against moisture content graphs of each specimen, EntandrophragmaCylindricum had the highest value (0.99) while Mitragyna Cilliata had the lowest value (0.69).

Table 7. Shear Strength and Cleavage

Timber Specimen	Shear Strength (N/mm^2)	Cleavage (N/mm)
LophiraAlata	21.9	24.1
Khaya Ivorensis	12.6	20.65
EntandrophragmCylindricum	15.85	15.63
NaucleaDiderrichii	14.51	19.45
Terminalia Superba	13.35	12
BrachystegiaNigerica	12.46	15.14
AfzeliaBipindensis	14.03	19.66
MitragynaCilliata	13.35	9.29
CylicodiscusGabunesis	14.21	15.51
Holoptelea Grandis	15.86	14.91

Table 8. Experimental Results of Hardness Test (N)

Species	1	2	3	Average
LophiraAlata	12805	12810	12800	12805
Khaya Ivorensis	3305	3318	3310	3311
EntandrophragmaCylindricum	6272	6280	6275	6276
NaucleaDiderrichii	7280	7300	7287	7289
Terminalia Superba	3020	3025	3022	3022
BrachystegiaNigerica	5406	5410	5405	5407
AfzeliaBipindensis	8200	8203	8205	8202
MitragynaCilliata	3670	3680	3675	3675
CylicodiscusGabunesis	10320	10335	10332	10329
Holotelea Grandis	5952	5922	5952	5952

The hardness test of timber results from Table 8 shows Lophira alata was the hardest and strongest among the ten species with an average value of (12805N); Cylicodiscus gabunesis to be (10329N), Afzelia bipindensis (8200N) and Nauclea diderrichii (7280N). which indicates its resistant to damage from wear and tear and will also last longer. Mitragyna cilliata (3675N); Khaya ivorensis (3311N) and Terminalia superba (3022N) are also classified under hardwood though, are likely to deteriorate with time. Timber used for flooring is usually between 6000N and 12000N up to 16000N.

4. Conclusion

The structural properties of the ten Indigenous species obtained from Oluku forest in Edo state and Sapele, Delta State have been explored and the following are the conclusions derived from the investigation:

The moisture content and density of wood have an effect on the compressive, tensile and flexural strength of timber, with the timber having the highest strength. From the analyses, the Lophira alata has the highest strength (72.40N/mm2), high tensile strength (179.81N/mm2) and Cylicodiscus gabunesis with the high flexural strength (123.75N/mm2).

From the research carried out, timber is adequate in tension and compression. Hence it should be considered as a substitute for building materials. There was a strong relationship between timber strength and selected physical properties of timber carried out in the experiment from the correlation coefficient values. Also, there was a strong relationship between tensile and flexural strength properties with compressive strength.

Based on NCP 2(1973), the ten species were successfully characterized and graded according to their corresponding strength classes: Lophira alata, N1; Khaya ivorensis, N5; Entandrophragma cylindricum, N3; Naucle diderrichii, N1; Terminalia superba, N5; Brachystegia nigerica, N3;Afzelia bipindensis, N2; Holoptelea grandis, N3;Mitragyna Cilliata, N4; Cylicodiscus gabunesis, N1.

The data obtained from this research will provide some relevant design data for structural analyses of indigenous timber species and the species are generally adequate for different construction works e.g. carpentry and joinery as well as civil engineering construction such as transmission poles, railway sleepers etc.

There should be a decade of evaluation of indigenous timber species to maintain structural adequacy. Also, there is a need for further studies on other strength properties such as fatigue, rolling shear and impact bending.
Consequently, the use of preservatives should be encouraged to protect the wood from decay, insects, and fungi, extending its lifespan. It also helps prevent warping, cracking, shrinkage and splitting of the wood as well as increases fire resistance.

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