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Some Physical and Mechanical Properties of African Birch (*Anogeissus Leiocarpus*) Timber

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ABSTRACT: The use of locally manufactured or waste materials in structural buildings without loss of performance is very crucial to the growth of developing countries. This report provides the results of some physical and mechanical property tests carried out on air dried African birch (*Anogeissus leiocarpus*) timber grown in Nigeria. Samples of the African birch timber were procured, naturally seasoned and their properties determined, in accordance with British Standard BS 373, for moisture content, specific gravity, and density while mechanical tests carried out are for tensile, compression and static bending. Strength values were obtained and further converted to 18% moisture contents (MC) which is the acceptable moisture content of timber to be used in Nigeria. The result of this experiment revealed that African birch timber possess a tensile strength of about 16% the strength of high yield steel and about 31% the strength of mild steel at 18% MC. Also, strength properties of African birch timber perpendicular to grain were found to be much lower than its strength properties parallel to grain.

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The use of timber as a structural material is not new, in fact dating back many centuries. As time passes, developments in the various types of timber components which are available and their use in different structural forms have occurred, new advanced timber products are now available enabling structural engineers to achieve the performance and efficiency in building forms being demanded in the 21st century (Structural Timber Association, 2014). However, due to scarcity in raw material and energy consumption, the attention is drawn again towards natural fibres and timber. Nowadays, Timber is one of the main research topics in structural engineering applications. Examples of timber species in Nigeria include bamboo, fan palm, teak wood, mahogany, apa and African birch. In this study, attention is focused on the physical and mechanical properties of local timber, particularly the timber of African birch (*Anogeissus leiocarpus*).

Anogeissus leiocarpus (African birch (English) or Marke (Hausa) or Kojoli (Fulani) or Atara (Igbo) or Ayin (Yoruba)) is an important evergreen tree of the family Combretaceae, widely distributed in Africa and is well known in African and Sudanese traditional medicine for treatment of many diseases such as toothache, diarrhea, respiratory diseases, jaundice, hepatitis, haemorrhoids, headache and as antimalarial, leprotic, laxative and anthelmintic skin diseases and infections, wounds infections, sore feet, boils, cysts, syphilitic and diabetic ulcers. It showed strong antibacterial and antifungal activity against many pathogenic microorganisms (Ikram Mohamed et al., 2015). Ahmad (2014) gave the botanical description of *Anogeissus leiocarpus* as a deciduous tree species that can grow up to 15–18 m of height and measure up to 1 m diameter. Bark greyish, scaly. Branches often dropping and slender, leaves alternate, ovate-lanceolate in shape, 2-8 cm long and 1.3-5 cm across. The leaves are acute at the apex and attenuate at the base, pubescent beneath. Inflorescence globose heads, 2 cm across, yellow. The flowers are bisexual, petals absent. Fruits are globose cone like heads. Each fruit is broadly winged, dark grey, 3cm across. It can reproduce by seeds as well as vegetative propagation.

Jimoh (2005) worked on ultimate strength design of axially loaded Ayin (*Anogeissus leiocarpus*) timber columns having the Compression parallel to grain value of 54.35 N/mm^2 for 20 x 20 x 80 mm standard specimen dimension (scaled down). Adeyemi et al. (2016) also carried out a review on African birch (Ayin) timber. From his review, it was observed that Ayin timber column compression strength parallel to grain was 28.65 N/mm^2 for varying dimensions. A value of 50.72 N/mm^2 was also observed for 25 x 25 x 100 mm using manual compression machine with unspecified speed. And the ultimate strength design of axially loaded Ayin (*Anogeissus leiocarpus*) timber columns has a compression parallel to grain value of 54.35 N/mm^2 for 20 x 20 x 80 mm standard specimen dimension. The aim of this study is to investigate the physical

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and mechanical properties of air dried African birch (*Anogeissus leiocarpus*) timber grown in Nigeria in accordance with British Standard BS 373 (methods of testing small clear specimens of timber).

MATERIALS AND METHODS

Air dried African birch (*Anogeissus leiocarpus*) timber used for this research work was purchased from two (2) different local timber markets in Ilorin metropolis namely; Ilorin sawmill (I.S) along Gari Alimi road and Alaja sawmill (A.S) along F-Division, tanke, Ilorin, Kwara state. Source of timber from Ilorin sawmill (I.S) was from Kaiama, Kwara state and the Alaja sawmill (A.S) timber was sourced from Oke Ode, Kwara state. The sliced timber boards were naturally seasoned for 28 days for the samples to attain equilibrium moisture content (EMC) before conversion for various property tests. Specimen shapes and test methods for this experiment were carried out in accordance with BS 373:1957 (Methods of testing small clear specimens of timber).

Physical Properties of African Birch: Physical property tests carried out on the air dried African birch timber are moisture content, specific gravity, density and water absorption.

Moisture Content: Twenty (20) samples with sizes 20 mm x 20 mm x 60 mm were collected. The moisture content of the samples were determined by weighing the test pieces at the air dried state and after they were oven dried in an oven for 48 hours at constant temperature of 105^{0}C. The moisture content was computed using Equation 1. The loss in weight expressed as a percentage of the final oven-dry weight was taken as the moisture content of the test samples.

$$\textit{Moisture Content (M.C)} = \frac{(M_1 - M_0)}{M_0} \times 100\% \quad (1)$$

Where M_1 is weight of sample at test in grams (g) and M_0 is oven-dry weight of sample in grams (g)

Specific Gravity: All test pieces before moisture content tests were weighed and their dimensions determined. The specific gravity at test was computed using Equation 2.

$$\text{Specific gravity at test } (S_1) = \frac{W_1}{V_1} = \frac{W_1}{l \times b \times h \times 16.39} \quad (2)$$

Where W_1 is weight of sample at test in grams (g), V_1 is volume of sample at test in cubic meters (cm^3), l is length in mm, b is breadth in mm and h is height in mm

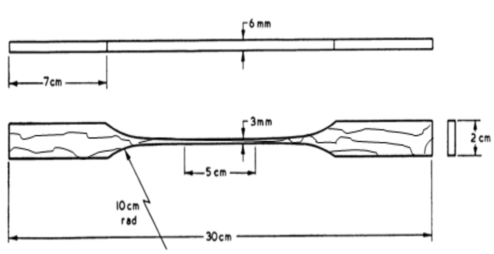
Density: The density of the African birch timber at test was computed using Equation 3.

$$\text{Density at test } (D_1) = S_1 \times 62.35 \frac{(X+100)}{100} \quad (3)$$

Where x is the percentage moisture contents and S_1 is specific gravity at test.

Mechanical Properties of African Birch: Four (4) mechanical strength tests were carried out on the air dried African birch timber. These tests are tensile stress parallel to grain, compressive stress parallel to grain, compressive stress perpendicular to grain, and static bending test. The tensile perpendicular to grain specimens was unable to be sectioned due to timber being very weak across the grain

Tensile Stress Parallel to the Grain: Twenty (20) specimens gotten from each of the timber markets were formed and dimensioned as illustrated in Figure 1 (a) 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 a tensile load without causing bending of the specimen. The tensile load was applied to the 2 cm face of the ends of the test pieces by the special toothed plate grips which were forced into the wood to prevent slippage of specimen during test. The load was applied to the test piece at a constant head speed of 1.27mm/min until a sudden sound was heard which broke the sample into two (2) as shown in Figure 1 (b).



(a) Tensile test sample geometry

(b) failure mode

Fig 1: Tensile test

Tensile strength parallel-to-grain was computed using Equation 4.

$$\textit{Tensile strength} = \frac{\textit{Force at failure } (N)}{\textit{Minimum Cross-sectional area } (mm^2)} \quad (4)$$

Compressive Stress Parallel to the Grain: Twenty (20) specimens gotten from each of the timber markets were cut into rectangular cross sections of 20 mm by 20 mm by 60 mm dimensions as illustrated in Figure 2 (a) to determine the compression strength. The load was applied to both ends of test piece in such a way that the loading plates of the universal testing machine (UTM) approached each other at a rate of 0.635 mm/min as shown in Figure 2 (b). The test was stopped when a deformation on the specimen was observed as shown in Figure 2 (c) and the applied load stopped increasing on the record chat.

(a) Compression parallel to grain sample geometry

(b) Compression stress parallel to grain test set up

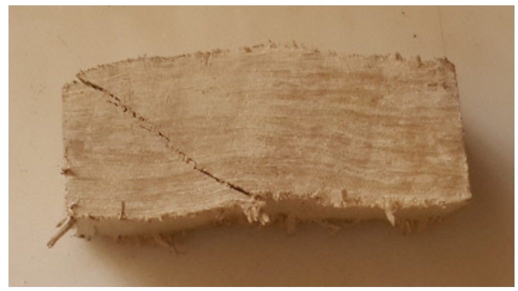

(c) failure mode

Fig 2: Compression parallel to grain test

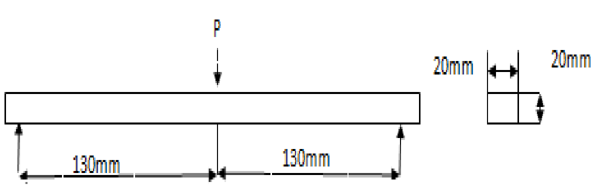
Compressive strength parallel-to-grain was calculated using Equation 5.

$$Compressive\ strength = \frac{Force\ at\ failure\ (N)}{Cross\text{-}sectional\ area\ (mm^2)} \quad (5)$$

Compressive Stress Perpendicular to the Grain: Twenty (20) specimens gotten from each of the timber markets were cut into rectangular cross sections of 20 mm by 20 mm by 60 mm dimensions as shown for compressive strength parallel-to-grain in Figure 2 (a) to determine the compression perpendicular to grain strength. The load was applied to both ends of test piece in such a way that the loading plates of the universal testing machine (UTM) approached each other at a rate of 0.635 mm/min. The test was stopped when a deformation on the specimen was observed.

The Compressive strength perpendicular to grain was calculated by dividing the load to failure by the cross-sectional area of the specimen as shown in Equation 5.

Static Bending Test: Twenty (20) specimens gotten from each of the timber markets were cut into rectangular cross sections of 20 mm by 20 mm by 300 mm dimensions as illustrated in Figure 3 (a) to determine the static bending test. The static bending test was carried out using the central loading method. The distance between the points of support of the test piece was 260 mm, that is, 130 mm between the point of application of load and the nearest support. The loading head of the universal testing machine (UTM) moved at a constant speed of 6.6 mm/min. Deflection of the specimen during tests were derived from the chart recorded. Failure mode of specimen is shown in Figure 3 (b).



(a) Bending strength test arrangement (Central loading)


(b) Static bending failure mode

Fig 3: Static bending

The static bending strength (flexural strength or Modulus of Rupture (MOR) was calculated using Equation 6.

$$\text{Bending strength or MOR} = \frac{3Fa}{bd^2}\ (N/mm^2) \qquad (6)$$

F = Maximum Load applied,

a = distance between load and the nearest support

b = width of cross-section,

d = depth of cross-section.

Adjustment of moisture content values of the samples to their 12% and 18% equivalents

All strength values were adjusted to their 12% equivalent moisture content using Equation 7 and then these results were further converted to their equivalent moisture content of 18% which is the acceptable moisture content of timber to be used in Nigeria using Equation 7.

$$F_{12} = F_w(1+\alpha\,(W-12)) \qquad (7)$$

Converting to 18% Moisture content using Equation 8

$$F_{18} = F_w(1+\alpha\,(W-18) \qquad (8)$$

Where,
α = the correction factor for moisture content as shown in (Table 1)

W = Moisture content at the time of test. Moisture content at test (10.1%)

F_w = is the strength value at the time of test.

F_{12}= the strength value at 12% moisture content

F_{18}= the strength value at 18% moisture content

Table 1: Correction factor for moisture content

State of stress	α-values	Reference
Modulus of Elasticity (MOE)	0.02	Zziwa *et al.* (2010)
Tensile	0.05	Zziwa *et al.* (2010)
Modulus of Rupture (MOR)	0.04	Aguwa (2016)
Compression	0.05	Aguwa (2016)

RESULTS AND DISCUSSION

Moisture Content of Timber: Moisture content (%) value for the African birch timber was computed using Equation 1. The average moisture content value at test was 10.1%, which falls below the fibre saturation point (FSP). The FSP is usually between 25-30% moisture Content (Nabade, 2012).

Specific Gravity of Timber: The average specific gravity of African birch timber at test was 1.046. The specific gravity could be influenced by different factors such as age, location and also genetic inherited in the tree of African birch. According to Panshin and de Zeeuw (1980), environmental factors affect the growth of the trees in particular site. Timber would sink in water due to its specific gravity less than 4^0C.

Density of Timber: The density of the African birch timber was calculated using Equation 3. The average density of the African birch timber at test was obtained as 1150 kg/cm^3. As stated in BS 5268 (Structural use of timber), the density range from 610 to 1150 kg/m^3 belongs to strength class of D30–D70 (hardwood). This shows that the African birch timber is a hardwood since the values obtained are greater than 640 kg/m^3. Also, according to Findlay (1975), African birch timber is classified as very heavy wood.

Tension Parallel to Grain: Tensile strength parallel to grain results of African birch timber are presented in Table 2. Tensile strength value for African birch at 12% moisture content was gotten as 115.91 N/mm^2. This value is higher than 74.71 N/mm^2 for Ayan (Adeyemi, 2016) and 69.61 N/mm^2 reported for Apa according to Adefemi (2015). This result shows that African birch timber is stronger than Ayan and Apa. Also, African birch timber possessed a tensile strength of about 28% the strength of high yield steel and about 51% the strength of mild steel at test (10.1% MC).

Compressive Test Parallel to Grain: Compressive strength parallel to grain results of African birch timber are presented in Table 2. African birch timber average compressive strain of 8.203% is greater than that of concrete which is 0.35%. This shows that African birch timber is less brittle than concrete. African birch timber possessed a compressive strength of about 12% the strength of high yield steel and about 23% the strength of mild steel at test (10.1% MC).

Compressive Test Perpendicular to Grain: Compressive strength perpendicular to grain results of African birch timber are presented in Table 2. African birch average compressive strength perpendicular to grain of 25.64 N/mm^2 is about 45% of its average compressive strength parallel to grain of 57.15 N/mm^2. This is results indicates that African birch timber is weak when perpendicular to grain.

Table 2: Tensile and Compressive strength test result for timber

Statistical Parameter	Stress (σ) at Yield (N/mm^2)	Strain (ε) at Yield (%)	Youngs Modulus (N/mm^2)	Energy to Yield (N.m)
		Tensile Strength		
Minimum	99.677	3.424	3441.77	1.901
Maximum	153.978	4.353	4729.769	3.832
Mean	128.084	4.022	4087.654	2.969
S.D	25.606	0.389	592.374	0.894
C. of V.	20.051	10.96	15.333	29.832
		Compressive Strength Parallel To Grain		
Minimum	52.316	5.646	1270.351	26.114
Maximum	62.577	13.326	1838.906	101.525
Mean	57.148	8.203	1587.100	53.204
S.D	5.043	3.070	227.085	29.163
C. of V.	6.997	32.719	13.727	47.445
		Compressive Strength Perpendicular To Grain		
Minimum	22.163	11.794	366.452	42.246
Maximum	30.614	25.041	796.378	118.976
Mean	25.639	16.866	524.953	70.722
S.D	3.275	5.294	182.188	30.622
C. of V.	12.782	30.118	34.698	42.140

Static Bending Test: Static bending strength results of African birch timber are presented in Table 3. The mean flexural strength (MOR) at peak was 111.121 N/mm^2. The average flexural strength at yield is about 98% of the average flexural strength at peak. Strain at yield of African birch timber indicates that African birch timber is liable to break (brittle) at air dried state.

Table 3: Static bending strength test result for timber

Statistical Parameter	Bending Strength (MOR) at Yield (N/mm^2)	Strain (ε) at Yield (%)	Deflection at yield (mm)	Bending Modulus (MOE) (N/mm^2)	Energy to Yield (N.m)
Minimum	80.504	1.045	5.884	9348.360	4.932
Maximum	129.210	2.360	13.293	11636.536	20.942
Mean	108.966	1.815	10.223	10516.491	13.651
S.D	19.479	0.508	2.863	882.807	6.196
C. of V.	19.549	28.057	28.057	11.129	45.038

Characteristic Strength of African Birch Timber At 12% And 18% Moisture Content: African birch timber mechanical property results at 10.1% moisture content (MC) were further converted to 12% and 18% moisture content. Table 4 presents the characteristic strength of African birch timber at 12% and 18% moisture content. African birch timber possess a tensile strength of about 16% the strength of high yield steel and about 31% the strength of mild steel at 18% MC.

Table 4: Characteristic strength of African birch timber at 12% and 18% moisture content

Mechanical Property	Tensile stress at yield (N/mm^2)	Compressive stress parallel to grain at Yield	Compressive stress perpendicular to grain at Yield (N/mm^2)	Static bending strength at Yield (MOR) (N/mm^2)	Bending Modulus (MOE) (N/mm^2)
Strength at 10.1% MC (N/mm^2)	128.08	57.15	25.64	108.97	10516.49
Strength at 12% MC (N/mm^2)	115.91	51.82	23.20	100.69	10116.86
Strength at 18% MC (N/mm^2)	77.49	46.94	15.51	74.54	9065.21

*Conclusion***:** Strength properties of African birch timber perpendicular to grain were found to be much lower than its strength properties when parallel to grain. African birch timber belongs to strength class of D30 – D70 as stated in BS 5268 (Structural use of timber) which indicates that African birch timber is a hardwood and can be used for structural applications. Also, African birch timber can be classified as very heavy wood.

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