Relationship between Fibre Characteristics and Physico-Mechanical Properties of A*ningeria robusta* (A.CHEV) Wood

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Abstract— Aningeria robusta wood is fast becoming popular in Nigeria, due to its excellent performance in structural applications especially in roofing, and in recent times, door frames and furniture. Thus, consideration must be given to its mechanical properties, and fibres in wood is known for providing mechanical support for the wood. Notwithstanding, mechanical failure of wood in service still occurs. To limit such failures assessment is needed to be done on some parameters associated to quality of wood. This study thus assess the relationship between fibre characteristics and physico-mechanical properties of Aningeria robusta wood. Three trees of Aningeria robusta were obtained wood samples of 20x20x300mm were collected to determine modulus of elasticity and modulus of rupture (mechanical property), 20X20X20mm for fibre characteristics, and 20x20x60mm for wood density and moisture content. The mean fibre length, fibre diameter, lumen, cell wall thickness (CWT), 1.55mm, 11.71μm, 8.78μm, 1.46μm, while the mean moisture content, density, modulus of rupture (MOR) and modulus of elasticity (MOE) were 55.54%, 429.34kg/m³, 123.91N/mm², 5876.89N/mm² respectively. There existed a negatively significant correlation between fibre length and MOR, and well as CWT and moisture content. This existing relationship implies that the shorter the fibre length, the more the MOR. It can therefore be concluded that existing relationship between fibre characteristics and physico-mechanical properties taken cognisance of where mechanical failure of wood is to be limited.
Keywords— A.robusta wood, fibre, mechanical, physical, relationship.

I. INTRODUCTION

The wood of *Aningeria robusta* is fast becoming popular due to its excellent performance in structural applications especially in roofing, and in recent times, door frames and furniture. *Aningeria robusta* belongs to the family Sapotaceae, a hardwood. It is referred to as 'agengre' in Cote d'Ivoire, 'landosan' in Nigeria and 'osan' in Uganda (TRADA 1979 cited in Ajala and Ogunsanwo, 2011), 'mukali' in Angola, 'mukangu' in Kenya (Chudnoff 1980 cited in Ajala and Ogunsanwo, 2011) and 'asafonia' in Ghana (Okai 2003).

Wood fibre are usually a thread like cellulosic elements that are extracted from trees and used to make materials including paper, paperboard, tissue, cardboard etc. However, its main function in a tree is to provide mechanical support. Sizes of fibre cell wall range from thin-walled to thick-walled fibre depending on the wood species.

Physical properties are the quantitative characteristics of wood and its behavior to external influences other than applied forces. Density and moisture content are some of the relevant physical properties of wood that are relevant to wood structural performance. Familiarity with physical properties is important because they can significantly influence the performance and strength of wood used in structural applications (Winandy, 1994). Mechanical properties are the characteristics of a material in response to externally applied forces. They include elastic properties such as modulus of elasticity, which relate the resistance of a material to deformation under an applied stress to the ability of the material to regain its original dimensions when the stress is removed, and modulus of rupture, which measures wood strength before rupture when load is applied. Mechanical property values are given in terms of stress (force per unit area) and strain (deformation resulting from the applied stress.

Also, Samuel 2004 stated that mechanical properties of wood are its fitness and ability to resist applied or external forces. This means that mechanical properties

determines to a large extent the use of wood for structural and building purposes.

There has been records of wood failure when in use, and these failures may be attributed to poor mechanical factors. Samuel 2004 reported that a buckling and bending failure will occur where the fibre walls of a wood show gradations of thickness i.e. transition from the thin-walled cells of the early wood to the thick-walled cells of the late wood is gradual. Also that moisture in wood decreases the stiffness of the fibre walls and enlarges the region of failure. It can therefore be stated that the manner of failure depends partly upon the anatomical structure and partly upon the degree of humidity of the wood, such that the fibres (tracheids in conifers) act as hollow tubes bound closely together, and can buckle or bend when force is applied.

Therefore, to limit the failure of wood in service, it is imperative to assess the wood quality parameters. This involves the consideration of anatomical such as fibre characteristics, physical and mechanical properties of wood. Thus, the objective of this study is to investigate the relationship between fibre characteristics and physico-mechanical properties of *Aningeria robusta* (A.chev) wood.

II. MATERIALS AND METHOD

Three trees of *Aningeria robusta* with at least 25cm DBH were obtained from Onigambari Forest Reserve. From each tree, bolts were collected at the base, middle and top portion, and the wood samples was processed using circular machine and planning machine to a dimension of 20x20x300mm for modulus of elasticity and modulus of rupture (mechanical property), 20X20X20mm for fibre characteristics, 20x20x60mm for wood density and moisture content according to ASTM, 1991.

2.1 Determination of Fibre Characteristics

For the fibre dimensions determination, small slivers were obtained each at the different sampling height. The slivers were placed in an equal volume (1:1) of 30% hydrogen peroxide and 10% glacial acetic acid, boiled until soft and bleached white (ASTM D 1413-61 2007). The slivers were then washed, placed in 30 mL-test tubes with 20 mL-distilled water and shaken vigorously to separate the fibre bundles into individual fibre. The macerated fibre suspension was carefully aligned on a slide using a rubber teat. The resulting image on Rheichert visopan microscope screen was measured for fibre length, diameter, lumen width and cell wall thickness was calculated with relevant formular.

2.2 Determination of Wood Density

The 20x20x60mm wood samples collected were oven dried to a constant weight at 103°C ± 2 for 24 hours and the weight afterward was recorded. The volume of samples at green weight was recorded and the following formula was adopted for the calculation of wood density.

$$D = \frac{m}{v} (kg/m^3) \qquad (1)$$

D = Density
m = oven-dried mass
v = green volume

2.3 Determination of Moisture Content

The samples were weighed when wet (original weight), it was then dried to a constant weight at 103°c ± 2 in an oven for 24 hours, after which it was re-weighed. The loss of weight of the wood samples on drying to a constant weight was noted. Calculation of the loss in weight as a percentage of the samples weight after drying was done by using the formula below

$$MC = \frac{ww - ow}{ow} \times 100 \qquad (2)$$

MC = Moisture Content
ww = wet weight
ow = oven dry weight

2.4 Determination of Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

This involved the use of standard test specimen (20 x 20 x 300mm), in a universal testing machine. The test sample was prepared in such a way that growth rings will be made parallel to one edge. Load was applied at the rate of 0.2mm/sec, with the growth rings parallel to the direction of loading, that is, specimen was loaded on the radial face. From the graph generated by the universal testing machine, the peak and breaking force were recorded; hence MOR and MOE was calculated as thus;

$$MOR = \frac{3PL}{2bd^2} (N/mm^2)$$

(3)

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

(4)

Where:

P = load in Newton (N)

L = span / length (mm)

B = width (mm)

D = depth (mm)

Δ = the displacement at beam centre at proportional load

III.   RESULTS AND DISCUSSION

Table 1 shows the axial variation in fibre characteristics of *A.robusta* wood. Mean for Fibre length, fibre diameter, lumen diameter and cell wall thickness were 1.55mm, 11.71μm, 8.78μm, 1.46μm respectively. Meanwhile, Table 2 shows the selected physical and mechanical properties tested for the wood sample, while Table 3 shows the correlation analysis between these properties.

Anon, (1984) stated that a mean fibre length of 1.6mm and above are classified as long fibre. Therefore, fibre length of *A.robusta* was considered short. As reported by Kpikpi (1992), some Nigerian hardwood species also had value within this value. Although the fibre length of A.robusta was short, yet it compared favourably with some Nigerian wood species. Meanwhile, the observed fibre diameter for *A.robusta* was lower to other selected wood species considered with it for comparism. Ogunleye *et al.,* (2017) recorded 41.5μm for *Ricinodendron heudelotii* wood, 30.67μm was recorded for *G. arborea* (Roger *et al.,* 2007) while 36.09 and 34.25μm for *R. racemosa* and *R. harrisonii*, respectively (Emerhi 2012), and 20.3μm for *T. scleroxylon* (Ogunsanwo 2000). Similarly, lumen diameter and cell wall thickness of *A.robusta* wood had values which compared lower to the selected wood species afore-mentioned.

Wood density obtained in this study was similar to Chudnoff (1980) (400–480kg/m³), Ajala and Ogunsanwo (2011) (430 kg/m3) for *A. robusta* but slightly lower to Arowosoge *et al.,* (2008) (510kg/m³), and Okai (2003) (500 kg/m³) for the same species. Age and location could have contributed to these differences (Arowosoge *et al.,* 2008). Furthermore, the mean MOE value obtained in the course of this study is slightly lower (5876.89N/mm2) to what was obtained by Ajala and Ogunsanwo (2011); a reason for this may be an effect of wood maturity, and/or inconsideration of radial pattern.

Existing relationship between fibre characteristics and selected physico-mechanical properties revealed that fibre length had a negatively significant correlation with wood density and MOR alone. Similarly, cell wall thickness had a negatively significant correlation with moisture contents only. This implies that the shorter the fibre length of *A.robusta* wood, the more its wood density and MOR. Also that, a thinner cell wall will means more moisture content.

This relationship is tenable because shorter fibres could mean larger percentage of fibre, which in turn equate to higher MOR. Uetimane and Ali (2011) supports this tendency in their work which showed a significant positive relationship in fibre length and MOR for sapwood. One of the parameters that determines high density is the amount of mass of a substance. Then, higher fibre percentage may also be responsible for higher density. Thus, supporting the relationship observed in this study. However, Emmanuel (2014) recorded no significant correlation between any of the fibre characteristics and physico-mechanical properties of selected wood species but recorded a significant difference among wood species sample. The resulting no significant correlation could have been caused by a significant difference in wood species samples tested. Thus, this study suggests that determining correlation of wood properties of more than one species should be done independently, as a significant difference among species may alter correlation analysis.

Table.1: Axial variation in fibre characteristics of Aningeria robusta wood

Sampling Height		TREE	FL(mm)	FD(μm)	LD(μm)	CWT(μm)
TOP		1	1.73±0.06	11.83±0.22	10.13±0.29	0.85±0.07
		2	1.37±0.03	10.67±0.37	8.16±0.49	1.26±0.08
		3	1.51±0.03	11.48±0.24	10.45±0.25	0.52±0.05
	MEAN		**1.54±0.10**	**11.33±0.34**	**9.58±0.71**	**0.88±0.21**
MIDDLE		1	2.04±0.49	12.21±0.41	8.43±0.52	1.89±0.12
		2	1.34±0.03	10.99±0.33	6.67±0.40	2.16±0.26
		3	1.52±0.05	12.43±0.58	9.60±0.61	1.42±0.28
	MEAN		**1.63±0.21**	**11.88±0.45**	**8.23±0.85**	**1.82±0.22**

BASE	1	1.44±0.16	12.64±0.63	9.12±0.62	1.76±0.02
	2	1.44±0.09	11.41±0.46	8.00±0.31	1.71±0.17
	3	1.54±0.06	11.73±0.31	8.59±0.30	1.57±0.13
MEAN		**1.47±0.03**	**11.93±0.37**	**8.57±0.32**	**1.68±0.06**
P. MEAN		**1.55±0.07**	**11.71±0.21**	**8.78±0.38**	**1.46±0.17**

FL – Fibre Length   FD – Fibre Diameter   LD – Lumen Diameter

CWT – Cell Wall Thickness   P. mean – Pooled mean

Table.2: Mean values of physico-mechanical properties determined for A. robusta

	TREE 1	TREE 2	TREE 3	MEAN
MC (%)				
TOP	58.02	62.65	65.12	**61.93±2.08**
MIDDLE	38.79	48.44	57.65	**48.29±5.44**
BASE	65.88	48.49	54.77	**56.38±5.08**
MEAN	**54.23±8.04**	**53.19±4.72**	**59.18±3.08**	**55.54±2.98**
WOOD DENSITY (kg/m^3)				
TOP	380.42	407.5	434.50	**407.47±15.61**
MIDDLE	361.67	517.67	452.92	**444.08±45.24**
BASE	412.25	515.25	381.92	**436.472±40.35**
MEAN	**384.77±14.76**	**480.14±36.32**	**423.11±21.2**	**429.34±18.91**
MOR (N/mm^2)				
TOP	122.1	129.51	129.56	**127.06±2.47**
MIDDLE	95.04	116.33	145	**118.79±14.47**
BASE	116.73	136.87	124.08	**125.893±5.88**
MEAN	**111.29±8.27**	**127.57±6.0**	**132.88±6.26**	**123.91±4.74**
MOE (N/mm^2)				
TOP	5807.8	6435.92	6609.44	**6284.39±243.50**
MIDDLE	5754.87	5576.14	5660.49	**5663.83±51.62**
BASE	6862.52	3176.22	7008.62	**5682.45±1253.82**
MEAN	**6141.73±360.71**	**5062.76±975.37**	**6426.18±399.81**	**5876.89±382.82**

*MOR = Modulus of rupture, **MOE = modulus of elasticity

Table.3: Pearson correlation analysis between fibre characteristics and physico-mechanical properties

	Wood density	Moisture content	MOR	MOE
Fibre length	-0.66*	-0.54	-0.63*	0.03
Fibre diameter	-0.36	0.01	-0.16	0.17
Lumen width	-0.50	0.55	0.29	0.36
CWT***	0.30	-0.62*	-0.48	-0.29

IV. CONCLUSION AND RECOMMENDATION

This study was successful in establishing the relationship that existed between fibre characteristics and physico-mechanical properties of *A.robusta* wood, and as such this existing relationship should be taken into consideration where mechanical failure of wood is intended to be limited.

Thus, recommending more studies into the relationship of other anatomical and physico-mechanical properties that wasn't considered in the scope of this study.

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