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SUSTAINABILITY AND STRESS PROPERTIES OF SELECTED HARDWOOD TIMBER SECTION IN LAGOS, NIGERIA

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ABSTRACT
Hardwood Timber sections are usually used for structural members in various areas in construction works; hence the knowledge of wood strength properties is important. Reconnaissance survey of common hardwoods used in Lagos was made, Ikorodu area was used to gather respondent social and timber technical data with the aid of questionnaire. The physical and mechanical properties five (5) selected hardwood timbers species was carried out in accordance with BS 373 (1957); the species scientific names are *Hallea ciliata*, *Uacapa guineensis*, *Albizia zygia*, *Sacoglottis gabonensis* and *Symphonia globulifera*. Small clear specimen samples of 20 x 20 x 20 mm, 20 x 20 x 60 mm and 20 x 20 x 300 with respect to BS 373 were used to carry out the test on Shear strength, Specific gravity (SG), Moisture Content (MC), Maximum Compressive Strength parallel to grain (MCS//), Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) respectively. 35 x 35 x 750 mm specimen was used for the third point bending test. The result showed *Uacapa guineensis* having the highest MOE of 21635.1N/mm^2 with a minimum MC of 20.4%, and *Symphonia globulifera and Uacapa guineensis* having Shear strength of 7.34 and 7.33 N/mm^2 respectively.

KEYWORDS: hardwood, *hallea ciliate*, *uacapa guineensis*, modulus of elasticity, modulus of rupture.

INTRODUCTION
Wood is a very versatile raw material and is widely used in construction, especially in this nation where there is an abundance of good quality timber. Timber is the most sustainable building product available and naturally renewable, it can be used in a range of structural applications including marine works: construction of wharves, piers, cofferdams, and heavy civil works: bridges, piles, shoring, pylon, domestic housing: roofs, partitions, shuttering for precast and in situ concrete, for brick or stone construction. Timber species are in varieties; they are divided into softwood and hardwood; however hardwood is of high priority. The term softwood and hardwood does not refer to the density of the wood, but rather the type of tree that the wood comes from, hardwood comes from angiosperms (broad leaves) while softwood comes from gymnosperm (narrow leaves).

However this study is intended to evaluate the strength properties of available timber hardwoods and check if standard practices are adhered to during the process of handling. The obvious fact of important notice is that non-standard section sizes is dominant in the market while seasoning is not assured. Information from this report will be useful to users of timber for strength classification and policy makers for attention on enforcing adherence to standard practices.

Obviously the suitability of a particular hardwood timber type for any given purpose will depend upon various factors such as performance, cost, appearance, durability and availability. Commonly available hardwood local and English names are; Okilolo, Eku, Iroko, Itara, Akun, Abura, Ayunre, Omoh, Afara, Oriro, Teak, Mansonia and Mahogany Timber used for structural applications must be graded and clearly marked to show it complies with the correct standards and strength requirements laid down by building codes and regulations. (Chanakra A. 2003)

Wahab et al., (2014), reported the result of bending strength of timbers of structural and laboratory sizes and it was found that the values of the bending strength of real structural size are lower when compared to smaller sizes. However, several properties have not been estimated and some have been inadequately estimated, partly because the assessments were based on a small quantity of material and partly because there is variation in mechanical properties even in the same log of timber.

The Specific gravity of timber is found to predict the mechanical properties of wood like its strength, dimensional stability with moisture content change, ability to retain paint, fibre yield per unit volume, suitability for making particle-board and related wood composite materials and suitability as a raw material for making paper (Wani, 2013).

Also the a study into the effect of the specific gravity on several mechanical properties of some world woods shows the logarithmic regression of the specific gravity versus the particular mechanical property for each data collected shows a 95% confidence level as determined by correlation analysis and covariance analysis revealed significant differences in specific gravity – mechanical property relationships for soft and hardwood from different geographical location for non conclusive trends. (Armstrong et al., 1984)

Antwi et al., (2014)**,** studied the strength and some physical properties of *Allanblackia Parviflora* for Furniture Production in Ghana, and reports that almost all the strength tests conducted showed a consistent trend, the heartwood portion of each division was slightly stronger in terms of resistance to failure than its corresponding sapwood portion. Comparing the strength of *Allanblackia parviflora* to an existing classification (grade), strength is 'medium' in *Allanblackia parviflora* and this could be related to one of the trees variety in Nigeria known locally as (Orogbo-erin) i.e *Allanblackia floribunda.* (Forestry Research Institute of Nigeria, FRIN 1980)

Ogunsanwo and Akinlade (2011), researched into the effects of age sampling position on wood property variations in Nigeria grown *Gmelina arborea*, and discovered that the MOR, MOE and MCS// generally decrease from the base to top of timber logs, for all age classes except in the medium age class of 28 year old trees, where variation in MOE was inconsistent and all the properties studied increased from inner wood to outer wood sections.

An assessment of the environmental characteristics of timber and wood products from a user's perspective should consider.

- The procurement of the raw materials including forest management practices.
- The amount of energy used to extract and process timber into finished building components.
- The imports of timber throughout use-phase including imports and benefits on greenhouse erosions', energy efficiency and air quality.
- The fate of the products, its recyclability, reliability and biodegradability.
- The social sustainability of the supply chain and actions within it. (Ecospecifier, 2014)

Sustainability considerations of about timbers in Indonesia market was critically evaluated based on the policy reform of the HPH system as a means to achieve sustainable forest management generally, with priorities in three objectives. First, they have sought to increase the government's capacity to enforce the technical aspect of sustainable concession management practice, such efforts have largely been oriented towards designing more effective mechanisms for monitoring concessionaires' harvesting practices to ensure that they adhere to the selective cutting guidelines stipulated in the HPH contract. Secondly, forest economists have advocated a sharp increase in the government's timber royalties and fees to halt the flow of resources rent that is, revenue above a 'normal' rate of return-to concession holders. From a fiscal perspective, they maintain that the government's failure to fully capture timber rents implies the loss of funds that might otherwise be used by the state for formal budgetary allocations.

Thirdly, policy analysts have long called on the Indonesian government to lift the prohibitive restrictions on log exports that it has maintained since the early 1980s. They emphasize that these restrictions have led concession holders to sell virtually all of the products to Indonesia's wood-processing industries at prices that are well below international market rates. Under-pricing of this sort is believed to promote inefficiency both at the point of log harvesting and during processing operations. Taken together, these three sets of prescriptions – selective cutting, full rent capture and market-based efficiency, represent the essential pillars of what can be called the 'sustainable logging' paradigm, which can be reviewed to ensure sustainability. (Barr, C. 2002)

METHODS AND PROCEDURES

STUDY AREA

Ikorodu environment is the study area as a representation of Lagos area with the samples of timber species a replicate of what is available during a state wide survey. All the three main sawmills in Ikorodu were visited for investigation. This area is precisely along Shagamu Expressway and Ijebu-ode Expressway, located on co-ordinates 0734588 Northing and 0557280 Easting**.**

RECONNAISSANCE SURVEY

A reconnaissance survey was carried out to various timber selling points in Lagos environs to gather information on available hardwood timbers commonly used. Ikorodu being a major access way for timber log entry into Lagos, three (3) sawmills (Itamaga, Okegbegun and Odoguyan- Flower bustop sawmill) were later identified as source information area for the samples of timber and other social parameters. Lots of hardwood species were discovered, out of which five most utilized were chosen for the research study; they are *Hallea ciliata* (Abura), *Uacapa guineensis* (Akun), *Albizia zygia* (Ayunre), *Sacoglottis gabonensis* (Itara) and

Symphonia globulifera (Okilolo). The survey also gathered some information about the available hardwood timber sizes, colours, standard length, physical defects, cost, availability and usages. (Forestry Research Institute of Nigeria, 1980)

Two hundred Questionnaires were administered saw mill machinist, merchant and timber craftsmen in these environments; in order to get factual information which includes:

- Sources of timber in the market and Seasoning methods
- Types of timber used for form work and furniture work
- The major natural defects of hardwood
- Standard sizing of timber section
- Factors that enhances the durability of the hardwood timber in use
- Rate of accidents during the processing

Selection of Species

Five (5) numbers species of hardwood were selected, three (3) samples were taken for each species were chosen in accordance with the BS 373, 1957.

Table 1: Scientific/vernacular names of species tested and their colours

S/N	Vernacular names	Scientific names	Colours
1.	Abura	Hallea ciliate	brownish
2.	Akun	Uacapa guineensis	brownish
3.	Ayunre	Albizia zygia	yellowish
4.	Itara/Atala	Sacoglottis gabonensis	Creamy
5.	Okilolo/Aba	Symphonia globulifera	Whitish

Source: Vernacular names of Nigeria planks, Forestry Research Institute of Nigeria (1980)

Thorough investigation was done to ensure that the hardwood timbers are properly identified with their respective local names, because of their popular use for comparison to be made on their properties.

SAMPLING TECHNIQUE AND TESTING

After the purchase of the species which are free of excessive knots and some other physical defects such as cracks, splits, decay as well as insect attack, three (3) cut to size section were taken at random, timbers were taken for test to compare with an acceptable limit in accordance with BS 5268: part 5 (1989). The timber log sized 50 x 150 x 3600mm were taken to the wood workshop machines in order to cut the woods to sample sizes. Physical and Mechanical parameters of timber sections were determined with the appropriate sizes in accordance with BS 5268: part 2 (2002). The physical parameter determined is the moisture content and the specific gravity. Timber section samples was obtained at top (sample 1), middle (sample 2) and bottom (sample 3) for all the specimens for the determination of some mechanical properties i.e. nine samples were tested per specie. Samples of 35 x 35 x 750mm were prepared for the third point bending stress test, the Shear strength parameters from the 20 x 20 x 20mm samples, Compressive strength on 20 x 20 x 60mm, while Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were carried out on the 20 x 20 x 300mm samples.

The samples were tested at the in the Timber Mechanics Unit, Forestry Research Institute of Nigeria (FRIN) situated at Jericho, Ibadan, Oyo state using the Hounse field Tensometer machine, except for the third point bending test carried with a Magnus frame at the Structures laboratory of the Civil engineering department, Lagos State Polytechnic, Ikorodu.

Specific Gravity (SG)

The Specific gravity indicates the amount of actual wood substances present in a unit volume of wood, the wood specimens were subjected to a gravimetric procedure in which specimen were completely saturated with water by boiling. Each cube was then removed from the water blotted to remove excess water and weighed. They were oven-dried to a constant weight at 103°C. Specific gravity was determined using the procedure developed by (Smith 1954) as seen in equations 1 and 2, using the formula. (Ogunsanwo and Akinlade, 2011)

$$G = \frac{1}{ws - wo/wo + 1/153} \qquad (1)$$

Where; G = Specific gravity
W_s = Saturated weight of wood
W_o = Oven dry weight of wood

153 = constant developed by (Stam, 1929) as the actual weight of wood substance.
And also the procedure developed by Panshin and Dezeeuw (1980) as;

G = Oven dry ÷ Displaced water weight

$$= \frac{wo\ \%}{w_w} \qquad (2)$$

Where; G = Specific gravity
Wo = Oven dry weight of wood
Ww = weight of water displaced.

Moisture Content

Moisture content was taken as a percentage of the water in the timber after being oven dried to a constant weight. It is certainly, well known that the moisture content in timber has a tremendous effect on the strength of timber pieces. Within the range of 20-25% maximum moisture content the strength of timber does not alter, but as timber dries its strength increases. Modulus of Rupture is the determinant of the deformation of the timber. The exact moisture content below which there is an increase of strength is known as the "fibre saturation point" and it is not the same for every species.

Modulus of Elasticity (MOE)
The Modulus of elasticity (MOE) was calculated from the values obtained at the point of failure recorded during test for (MOR). This provided for the calculations of deflection which was used to estimate the modulus of elasticity (MOE) using equation 3 below.

$$\mathrm{MOE} = \frac{Pl^3}{4\Delta bd^3} \qquad (3)$$

Where P is load in Newton (N)
L is span in (mm)
b is width in (mm)
d is depth in (mm)
Δ is the deflection at beam center at proportional limit

Modulus of Rupture (MOR)
The bending strength of wood is usually expressed as MOR, which is the equivalent fibre stress in the extreme fibers' of the specimen at the point of failure was then calculated using the expression in equation 4;

$$MOR = \frac{3PL}{2bd^2} \qquad (4)$$

Maximum Shear Strength
The shear strength was computed using sample size 20 x 20x 20 mm with the formula in equation 5 below.

$$\frac{P}{bd} \text{ N/mm}^2 \qquad (5)$$

Where bd is cross sectional area (A)

Maximum Compressive Strength Parallel to Grain (MCS //)
Wood samples were loaded at the rate of 0.01mm/sec, and the corresponding forces at the point of failure were taken directly. This was divided by the cross sectional area of the test specimen to obtain value for maximum compressive strength parallel to grain. The formula in equation 6, below was used to compute the maximum compression strength parallel to grain, using standard size of 20 x 20 x 60 mm. (Ogunsanwo and Akinlade, 2011)

$$\frac{P}{bd} \text{ N/mm}^2 \qquad (6)$$

Third Point Bending Test
The Third point bending test was carried out using 35 x 35 x 750mm. Load was applied at the middle of the plank. The flexural stress (N/mm^2) is simply computed using maximum applied load (N), divided by the cross-sectional are b-width and d-depth (mm) of the specimen.

RESULTS

The use of these samples is receiving attention among the plank users in the market. Notable among the wood species gathered from the questionnaires shows that *Uacapa guineensis, Symphonia globulifera and Milicia excelsa* (Iroko) has the highest rating for usage in the construction of roof members of buildings which are structural elements; while furniture makers prefer others in the order of *Mansonia altissima (Mansonia), Gmelina arborea* (Melaina) and *Khaya grandifoliola* (African Mahogany) with *Hallea ciliat*a as the fifth on the preference list. (The Wood Database, 2014)

Ceiba pentandra (Araba) softwood is the commonly used timber for formwork. Social data were extracted from the respondents and displayed in Table 2.

Table 2: Respondents data

Parameters	Category	Frequency	Percentages
Gender	Male	126	63
	Female	74	37
Age Class	18 – 28	40	20
	29 - 40	88	44
	41 - 49	47	23.5
	50 and Above	25	12.5
Marital Status	Married	145	72.5
	Single	55	27.5
Education	No formal Education	14	7
	Primary	25	12.5
	Secondary	114	57
	NCE/ND/Technical	27	13
	College Graduates	20	10

The data in Table 2, shows that the timber trade is male dominated in Lagos, Nigeria, with over 60%. The most active age of those in the trade ranges from 29 to 40 years with 44% and 41 to 49 with 23.5%. The level of education shows the majority falling on and below the secondary school corresponding to the West African School leaving Certificate with 57% finishing the secondary school mostly with deficiency in their subject below the credit passes; while we still have 7% without any formal education in this computerized age.

Table 3: Respondents types

Parameters	Category	Frequency	Percentages
Professional bias	Timber Merchants	110	55
	Timber Accessories Merchants	36	18
	Timber Machinist	30	15
	Carpenters/Furniture makers	12	6
	Timber transporters	12	6
Years of Experience in Timber Trade	1 -10	87	43.5
	11-20	71	35.5
	21-30	25	12.5
	31and above	17	8.5

The information in Table 3 is to investigate the respondent types and thus giving the credibility of the collected data, from the right sources or the concerned stakeholders of the trade. 55% of the respondents are timbers merchants who have to learn during their course of apprenticeship and practice as a merchant the names, identification, age range of timber supplied, fresh or seasoned timber, sources from other states, e.t.c; with percentage of those with 11 to 20years and above in the trade around 56.5%.

The timber sources are mostly from the western states (Ogun, Ondo, Oyo, Osun and Ekiti), some from the east (Edo, Delta, Bayelsa) and the middle belt (Kogi State) of Nigeria. Information and findings shows that the timbers are not seasoned either using the kiln or the air by deliberate staking, but they get to lose their moisture with the period of process of felling, log-cutting, sizing, transporting and storage pending sales in the market under sheds while the tropical hot weather assist the moisture maintained in the timber sections.

Table 4: Timber handling data

Parameters	Category	Frequency	Percentages
Transport means from other State into Ikorodu	Lorry/ Truck Mini-Van	195 5	97.5 2.5
Transport means from Ikorodu inward Lagos metropolis	Lorry/ Truck Mini-Van	113 87	56.5 43.5
Reason for non-standards in size	Affordability/ Market price forces Machinist error	186 14	93 7
Factors for durability	Maturity/Seasoning of timber Exposure/Colour/Surface treatment	170 30	85 15
Intervention Support for Seasoning plant	Government Intervention Private sector investment Low interest Bank loan Technical Education/Enlightenment	77 33 52 38	38.5 16.5 26 19

Table 4 displays the handling data of timber sections; movement of timber into Ikorodu an access point into Lagos is mostly (97.5%) by Lorries/Trucks, while further distribution into the metropolis has the mini-van been more patronised with 43.5% as against 2.5% usage from outside the state mainly due to the low capacity of haulage.

Timber sections were found to be of varying sizes below the standard specifications 25 x 300mm, 50 x 300mm, 50 x 50mm, 50 x 75mm, 50 x 100mm, 75 x 100mm and 50 x 150mm all to length of 3600 mm. The major reason of the finding for smaller section is due to the economic status of the end users, with 93% with low capacity to afford the cost of the full timber standard section size. Of course when a customer is offered to pay less for a timber section, it is preferred with believe that the section will be adequate for its purpose without any checks on the stress capability. It was observed through the questionnaires administered that most customers prefer to buy the hardwood timber species at the non-standard prices not considering the inadequacy in the sections.

It is generally accepted that the age and seasoning adequacy are the main factors affecting durability of timber sections with 85% of the respondents in agreement. The need to improve on the current practices of timber handling made the respondents to agitate for financial and technical support, in order to be able to have better sections for the end users from control on the age of timber logs taken from the forest to proper seasoning plants request by 38.5% of the respondent.

Availability issues of hardwood timbers from the questionnaire administered shows that the logs are readily available in the dry season, while it is scarce in the rainy season due poor access roads to most areas where the timbers are sourced.

Table 5: Rate of accident during timber processing

Per month	Frequency	Percentage
0-4	93	46.5%
5-8	54	27%
9-12	30	15%
13-15	23	11.5%

The rate of accident during timber processing is as shown in table 5 above. It is gathered that the rate of accident during timber processing is quite significant with 46.5% for up to 4 per month, though timber machinist are always given proper orientation as to focus on their job before commencement of work for the day. As there is no emergency life saving unit at sawmill, but only having the first aid box.

Table 6: Major structural defects in hardwood

S/N	Types of Defect	Rate of occurrences	Percentage (%)
1	Knots	70	35%
2	Decay	30	15%
3	Lateral crack	20	10%
4	Insect attack	40	20%
5	Age related defect	10	5%
6	Accident fracture/shrinkage	5	2.5%
7	Moisture content/poor seasoning	25	12.5%
	Total	200	100%

The major structural defects in hardwood are discussed in Table 6 above. It was gathered from the questionnaires distributed that the defect with high occurrence on timber log is the knots defect. The knots occur where a branch has grown out of the trunk. A lot of knots mean the timber is difficult to work on and is weakened.

Table 7: Average Physical and Mechanical Properties

Species	Max. Shear (K N)	Specific Gravity	Max. Compression Strength // N/mm^2	Modulus of Rupture N/mm^2	Modulus of Elasticity N/mm^2	Moisture Content (%)	Strength Class
Hallea ciliate	6.52	1.98	45.44	87.5	11,897.31	55.4	D 40
Uacapa guineensis	7.33	3.03	50.0	152.5	21,635.1	20.4	D 70
Albizia zygia	6.15	1.77	65	52.50	8,438.96	66.5	D 30
Sacoglottis gabonensis	5.84	1.65	40.56	78.75	12,538.18	72.8	D 40
Symphonia globulifera	7.34	2.23	40.81	113.75	16,154.77	51.8	D 50

Specific Gravity (SG)

Uacapa guineensis is the heaviest with mean specific gravity of 3.03 as shown in Table 7 above, while *Sacoglottis gabonensis* has the smallest weight of all with specific gravity of 1.65.

Moisture Content

Samples timber from *Uacapa guineensis* shows average moisture content with the least value of 20.4 which effect could be seen in the higher values of the mechanical strength properties such as MOR, MOE and MCS//.

Modulus of Elasticity (MOE)

The mean MOE of the samples of ranges from 8438.96N/mm^2 to 21635.10N/mm^2 for all timbers, with *Albizia zygia* and *Uacapa guineensis* having the minimum and maximum displayed values respectively.

Modulus of Rupture (MOR)

The mean Modulus of Rupture (MOR) of the samples ranges from 52.5N/mm^2 to 152.5N/mm^2 for all timber section tested, *Albizia zygia* having the smallest value as seen in the values of MOE.

Maximum Shear Strength

The mean maximum shear strength was found for *Symphonia globulifera* with a value of 7.34N/mm^2 followed up with *Uacapa guineensis with* 7.33N/mm^2 .

Maximum Compressive Strength Parallel to Grain (MCS //)

Albizia zygia gave the highest value of 65.0N/mm^2 despite its low MOE and MOR values.

Third Point Bending Stress Test

The results of the third point bending are as shown in Table 8, *Symphonia globulifera* has an average stress of 143.7N/mm^2 being the highest, while *Sacoglottis gabonensis* with smallest value of specific gravity and maximum compression shear correlates with value of bending stress value.

PHYSICAL AND MECHANICAL PROPERTIES

Table 8 :Third Point Bending Test for Sample Two

S N	Scientific names of hardwood species	Average Stress (N/mm^2)
1	Hallea ciliate	138
2	Uacapa guineensis	134.7
3	Albizia zygia	140
4	Sacoglottis gabonensis	123.7
5	Symphonia globulifera	143.7

CONCLUSION

The strength characteristics of timber section remain stable for values of moisture content between 20 - 25%, but as timber dries, its strength increases for high moisture content to a lower value.

This assertion was verified in the result from Table 7 above, a low moisture content of 20.4% was observed for *Uacapa guineensis*, though with the highest value of specific gravity of 3.03 corresponding to the highest value of MOE of 21,635.1N/mm^2.

No proper seasoning was reported for timber logs processed into sectional sizes, and non-standard sizes have the day at sawmills, due to the economic situation and ignorance of the users of timber for structural purposes. The rate of accident (up to 4 per month) was also alarming despite the fact that no enforcement is in place for first aids provisions and non existence of emergency units.

Factors found to influences strength are moisture content and specific gravity from the data of standard tests of clear specimen of timber. Generally strength decreases from bottom to top, but however, the results from the test for all species were found to be in order with their respective strength classes with respect to their mechanical properties when compared with the British standards BS 5268: part 2

(2002). The average strength properties becomes more relevant when a timber section is used as a joist beam, rafter, strut or ties in a roof section acting as a whole structural member, either from the butt, middle or top of a tree log converted for use.

Since significant reduction in moisture content would leads to increment in strength characteristics, the use of kiln seasoning is included in the process, it would create another series of jobs to further alleviate poverty in the community, increase gross domestic product (GDP) by increase in exportation of seasoned timber and finished furniture works and decrease in its importation and would satisfy the agitations for government and/or private intervention in the provision of seasoning plants and educating the merchants. Information's on the age of timbers available in the market are not reliable, except regulations are enforced to control the felling age of timbers by forestry government agency.

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