RESEARCH ARTICLE OPEN ACCESS

Characterization and Strength Classification of Timber Species in Akwa Ibom State, Nigeria for Structural Engineering Applications

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ABSTRACT
In Nigeria, only few studies have characterized timber species for structural design applications. In this study, determination of the physical and mechanical properties of timber species in Akwa Ibom state in southern Nigeria was carried out using methods defined in BS EN 1193:1998, BS EN 384:2016, BS EN 408:2010 and BS 373:1957, while strength classification of the timber species was in accordance with BS EN 338:2016. Twenty-five (25) samples each of five common timber species in Akwa Ibom namely: IyipOkoyo (*Stauditiastipitata*), Owen (*Mitragyna spp.*), Mkpenek (*Uapacaguineensis*), Atarabang (*Xylopia spp.*) and Ata (*XanthoxylonSenegalensis*) were selected for the study. Results of physical properties indicated that the timber species have low susceptibility to fungal degradation and high durability but prone to dimensional change. Of the five timber species, Atarabang (*Xylopia spp.*) was the only softwood specie, suggesting that Akwa Ibom is dominated by hardwood species. Mechanical properties obtained were consistent with properties of strength class assigned to each timber specie and are useful parameters for structural engineering design process. The study further showed that the timber species have moderate to high densities and find application in general construction such as for flooring, formwork systems, cladding, joinery and paneling.

Keywords: Akwa Ibom State, Characterization, Mechanical Properties, Physical Properties, Strength Classification, Timber

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Date of Submission: 20-09-2017 Date of acceptance: 13-10-2017

I. INTRODUCTION

The use of timber as a structural material is not new. With rapid development in structural engineering occurring over the years, developments in the various types of timber components which are available and their use in different structural forms have occurred simultaneously. New advanced timber products are now available, enabling structural engineers to achieve the performance and efficiency in building forms being demanded in the present day [1].

Timber is one product amongst many designers can choose from and are promoted as environmentally viable options compared to other structural materials such as reinforced concrete and steel. As a natural and renewable building material, timber has excellent ecological attributes. It acts as a carbon sink and has low embodied energy. The energy needed to convert trees into wood and hence into structural timber is significantly lower than that required by steel and concrete. In addition, timber is unique in that it does not corrode. Corrosion, coupled with abrasion, may result in the loss of thickness in steel, or exposure of concrete reinforcement.

The many species of timber used in timber engineering can be divided into two categories: softwoods and hardwoods. Softwood is the timber of a conifer whereas hardwood is that of a deciduous tree. Softwood and hardwood are botanical terms and do not necessarily refer to the density or hardness of the wood. Though most hardwoods have a higher density than most softwoods, some softwoods can be quite hard and some hardwoods can be quite soft. The Structural Timber Association [1] reports that softwood is commonly used for timber structures as it is readily available, easily worked, of relatively low cost and its fast rate of growth gives a continuous supply from regenerated forest areas. Hardwoods are typically used for exposed structures and claddings where durability and particular aesthetic characteristics, such as colour or grain pattern, are required.

There has been resistance from modern Engineers to the use of timber, partly because of general lack of understanding of species, properties of strength and durability, and of the construction details necessary for sound design and construction. This has generated new resistance to the use of timber for permanent structures [2].

For designers, properties like strength, stiffness and density of the material are of special importance for the design of load bearing constructions. Physical properties related to moisture content, form and appearance are also crucial quality requirements [3]. This brings to fore the need to have grading procedures for timber to meet the requirements for either visual appearance or strength or both. Strength properties are essential for structural design although other properties may well come into consideration when assessing the overall performance of a component or structure [4].

In general, structural timber is assigned to a specific strength class. Several strength class systems exist on an international scale, e.g. in Europe it is the EN 338 [5] which constitutes the classification of timber based on the prescription of characteristic values for the material properties; i.e. for every timber strength class a characteristic value for every relevant material property is given. Timber that is assigned to a certain strength class is also referred to as a timber grade. As a result of grading, timber is provided to the market as a graded material [6]. The grades imply that the material properties (strength and stiffness) lie within desirable and predictable limits that can be controlled, thereby forming a criteria for timber to be used as a material for structural purpose [7].

Defining limits of material properties for timber cannot be achieved in the same way as for manufactured structural materials such as steel, concrete, plastics and wood fibre board where a certain material quality is obtained by changing the composition of the raw materials or by changing some of the environmental conditions such as temperature and pressure. For timber, the only realistic way of obtaining quality within desired limits is by grading [7].

Knowledge of the properties of timber and its grading will assist in making the most suitable selection of the material for a particular use. These properties vary depending on the species and growth conditions of the Timber as well as on the method of processing of the timber [6, 8].

According to [6], the variability in the properties of timber presents two main concerns. First, large number of carefully sampled timber specimens are needed to properly determine the timber properties. Secondly, the determination of the timber properties and its subsequent grading has to be tied to a defined population, covering at least the species and the growth area. Unfortunately, this means that timber cannot readily be graded for use in construction unless the testing work to support the grading has been carried out.

Characterization and grading of timber species for structural engineering applications have been very limited in Nigeria. The few studies carried out have been on trees predominantly found in Western and Northern part of the country [9 – 13] where the trees and likely its characteristics are expected to be different from those in the South of Nigeria because each of these regions are located in different forest (vegetation) zones in Nigeria. Akwa Ibom is in the South-South of Nigeria and the grading of forest trees in this region will give an indication of the characteristics and strength of tress found in Southern Nigeria.

This study therefore focuses on the determination of properties and strength classification of selected local timbers in Akwa Ibom state of Nigeria by carrying out relevant tests on sampled timber species, and how these can be employed by the designer, specifier, engineer and contractor concerned with timber design and construction.

II. MATERIALS AND METHODS

Timber strength grading according to BS EN 338:2016 is based on three key grade determining properties: strength, stiffness and density [5]. The physical properties (moisture content and density) and mechanical properties (strength properties and stiffness properties) of the timber specimens were determined in the laboratory and machine grading of the timber species carried out. The properties are determined in accordance with BS EN 1193:1998, BS EN 384:2016, BS EN 408:2010 and BS 373:1957, while grading of the timber is in accordance with BS EN 338:2016 [5, 14 – 17]. These standards were adopted because design in Nigeria are generally to the British standards. BS EN 338:2016 lists a set of strength classes for softwoods and another for hardwoods representing two grades or class, C and D respectively [5].

Five species of timber in Akwa Ibom state, southern Nigeria, were sampled, tested and graded. 25 samples were tested for each timber specie. These were selected as they were found to be the mostly used for structural applications in Akwa Ibom state, Nigeria from survey of the timber market in Akwa Ibom State by the authors. Table 1 shows the common (local) names and scientific names of the timber species as well as their classification into softwood and hardwood based on the physical appearance of the trees such as shape of the leaves and nature of tree branch and trunk.

2.1 Physical Properties

2.1.1 Moisture Content

In determining moisture content for structural timber, a full cross section, free from knots and resin pockets was utilized. The moisture content was determined in accordance with BS EN 408:2010, BS EN 13183-1:2002 and BS 373:1957, on a section taken from the test piece by weighing and then drying the sample in anoven at a temperature of 103 ± 2 °C (217 ± 4 °F)until the weight is constant. The moisture content (MC) of the test piece is the loss in weight expressed as a percentage of thefinal oven-dry weight.

$$MC = \frac{W_1 - W_0}{W_0} \times 100 \quad (1)$$

Where W_1 = Weight of sample at test and W_0 = Oven-dry weight of sample

While the moisture content of the timber specie provided an indication of its durability, it was also required for adjusting strength and stiffness properties of timber to an equivalent moisture content of 12% on which the grading of timber according to BS EN 338:2016 is based. The moisture content of timber can affect the strength and stiffness properties and generally, timber strength increases with decreasing moisture content values.

2.1.2 Timber Density

The specimens used were same as those for the moisture content test in accordance with BS EN 408:2010. The mass of each specimen was recorded from a simple scale balance, while the volume was calculated based on direct measurement of length, width and thickness of the required specimen using a Vernier calliper. The density of each specimen was then calculated by substituting in the expression:

$$\rho = {}^{M}/_{V} \quad (2)$$

Where ρ is the timber density, M is the mass of the specimen and V is the volume of the specimen.

Table 1: Selected Timber Species in Akwa Ibom State, Nigeria

S/N	Common (Local) Name	Scientific Name	Type of Wood	Source used for Scientific Naming and Classification into Hardwood and Softwood
1	IyipOkoyo	*Stauditiastipitata*	Hardwood	[18 – 22]
2	Owen	*Mitragyna spp.*	Hardwood	
3	Mkpenek	*Uapacaguineensis*	Hardwood	
4	Atarabang	*Xylopia spp.*	Softwood	
5	Ata	*XanthoxylonSenegalensis*	Hardwood	

2.2 Mechanical Properties

The mechanical properties were obtained from tests of small pieces of wood termed clear specimens free from characteristics such as knots, cross grain, checks, and splits. These properties were determined in accordance with BS EN 408:2010, BS EN 1193:1998 and BS 373:1957.

2.2.1 Compressive Strength Parallel to Grain

This represents the maximum stress sustained by a compression parallel-to-grain specimen having a ratio of length to least dimension of less than 11. This was determined from specimens prepared to sizes of 50 x 50 x 200mm each. Each specimen was placed on the testing machine with its length parallel to the direction of the load. Care was taken to ensure that the specimen is placed in such a way that the load will be truly centric load. The load was then applied until failure occurred, the load at failure being the maximum compressive load (F_{max}). The compressive strength parallel to the grain was obtained by dividing the maximum compressive load by the cross-sectional area of the specimen (A). The ultimate compressive strength was calculated from Equation (3).

$$f_{c,0} = \frac{F_{max}}{A} \quad (3)$$

2.2.2 Compressive Strength Perpendicular to Grain

This represents the stress at the limit of proportionality and was obtained with the same type of specimen and procedure as for the compressive strength parallel to grain only that in this case, the specimens were placed on the testing machine with its length perpendicular to the direction of the applied load. The compressive strength perpendicular ($f_{c,90}$) to the grain was obtained from equation (4).

$$f_{c,90} = \frac{F_{c,max,90}}{bl} \quad (4)$$

Where $F_{c,max,90}$is the maximum compressive load perpendicular to grain ($F_{c,max,90}$), b is the specimen width in mm and l is the specimen length in mm.

2.2.3 Tensile Strength

Only the tensile strength parallel to grain of the timber species were determined. This is because the tensile strength perpendicular to grain is considered to be constant (0.6N/mm^2 for Hardwood and 0.4N/mm^2 for softwood) for the purpose of grading [5]. The tensile strength parallel to grain represents the maximum tensile stress sustained in direction parallel to grain and was determined using a specimen with nominal size of 20 x 6 x 300mm. Each specimen was placed in the testing machine with its length parallel to the direction of the load. The specimen is gripped at the ends between two jaws. The loading was applied to the 20 x 6mm face of the ends of the test specimen at a constant rate of 0.05mm/sec. The load was increased until failure occurred. The ultimate tensile strength is given by Equation (5).

$$f_{t,o} = \frac{F_{max}}{A} \qquad (5)$$

Where $f_{t,o}$ is tensile strength parallel to the grain, in N/mm^2, F_{max} is maximum load, in N and A is cross-sectional area in mm^2.

2.2.4 Determination of Stiffness Properties

The stiffness properties determined were Modulus of Elasticity (MOE) and the Modulus of Rupture (MOR) or bending strength of the timber species. MOE contributes to determination of the grade of the timber species whereas according to [9], the MOR is a property in which commonly adopted equations for design of timber beams are based.

2.2.4.1 Modulus of Elasticity (MOE) in Bending

The MOE measures the stiffness of a timber specie and was determined from small clear specimens of nominal size 20 x 6 x 500mm. The three-point loading method was used with the specimen supported over a span of 360mm. The deflection of the specimen at mid length was measured from the dial gauge mounted at the mid-point. The modulus of elasticity (E_m) was calculated Equation (6).

$$E_m = \frac{\Delta P l^3}{4\Delta\delta b d^3} \qquad (6)$$

Where ΔP is the increment of load below the limit of proportionality in N, l is the bending span in mm, Δl is the increment of deflection corresponding the load in mm, b is the width of the specimen in mm and d is the depth of the specimen in mm.

2.2.4.2 Modulus of Rupture (MOR) / Bending Strength

The MOR or bending strength indicates the maximum load carrying capacity of a timber member in bending and is proportional to maximum moment allowed by the specimen. Specimens with nominal size of 50 x 50 x 200mm was used for the determination of the MOR. The three-point loading method was used. The specimen was positioned with the growth rings parallel to the direction of loading. The load was applied at a rate of speed of 0.1mm/sec until failure occurred and the MOR was estimated using Equation (7).

$$f_m = \frac{3P_{max} l}{2bd^2} \qquad (7)$$

Where Pmax is the maximum applied load in N, l is the bending span in mm, b is the width of the specimen in mm and d is the depth of the specimen in mm.

2.3 Allocation of Strength Class

BS EN 338:2016 defines a total of 26 strength classes: 12 for softwoods – C14, C16, C18, C20, C22, C24, C27, C30, C35, C40, C45 and C50; and 14 for hardwoods – D18, D24, D27, D30, D35, D40, D45, D50, D55, D60, D65, D70, D75 and D80. The letters C and D refer to coniferous species (C classes) or deciduous species (D classes), and the number in each strength class refers to its characteristic bending strength in N/mm^2 units; for example, C40 timber is softwood with a characteristic bending strength of 40 N/mm^2. In allocating the timber species to a strength class based on BS EN 338:2016, only the mean value of MOE ($E_{m,0,mean}$), characteristic value of bending strength ($f_{m,k}$) and characteristic density (p_k) value of the timber species are required. The mean value of MOE is obtained directly from Equation 6 and taking the mean of values for all 25 samples tested for each timber specie. Characteristic values of all properties are obtained using the general equation given by Equation 8. Equation 8 is based on a confidence limit of 95% same as used in [13]. The values obtained are compared with the respective minimum for each strength class given in BS EN 338:2016 in determining the class of the five timber species.

$$f_k = f_{mean} - 1.65SD \qquad (8)$$

Where f_k is characteristic value, f_{mean} is mean value from test and SD is standard deviation of values obtained from samples tested for a particular timber specie and is defined as the product of the Coefficient of Variation (CoV) and the mean value.

For each particular class of timber specie, BS EN 338:2016 gives the characteristic compressive strength parallel to grain ($f_{c,0,k}$), characteristic compressive strength perpendicular to grain ($f_{c,90,k}$) and characteristic tensile strength parallel to grain ($f_{t,0,k}$). These values were then compared with those obtained directly from tests to validate the strength classification and further characterize the timber species.

Because moisture makes up part of the weight of timber and as such affect the other properties of timber, these other properties are adjusted to a reference moisture content of 12% used as a standard for strength classification and to enable comparison of results of different timber species from different locations.

In calculating the characteristic values and in strength class allocation, the mean values are first adjusted to the reference moisture content of 12%. From the moisture content results, samples not tested at the reference moisture content but having a mean moisture content in the range 8% to 18% Service Class 1 and Service Class 2 are adjusted by the method described in BS EN 384:2016 and presented in Table 2. Design strengths given in BS EN 338:2016 are only suitable for grading timber species in Service Classes 1 and 2.

Table 2: Adjustment of Mean values of Properties of the Timber Species to the Reference Moisture Content of 12% (Source: [5])

Property	**Method of Adjustment**
Density	$\rho = \frac{\rho_{test}}{\{1 + 0.005(u - u_{ref})\}}$
Bending and Tension Strength	No adjustment
Compression parallel to grain strength	$f_{c,0} = \frac{f_{c,0,test}}{\{1 + 0.03(u - u_{ref})\}}$
Modulus of elasticity	$E_0 = \frac{E_{0,test}}{\{1 + 0.01(u - u_{ref})\}}$

In Table 2, u = moisture content at testing and u_{ref} = reference moisture content (12%).

III. RESULTS AND DISCUSSION

Results of characterization of the Timber species as well as their strength grading are presented and discussed in the following sub sections.

3.1 Characterization of the Timber Species

Table 3 shows the physical properties (Moisture Content and Density) of the different timber species. The results show that Moisture content of timber species in Akwa Ibom considerably vary with a range of about 6.93%. While Ata (XanthoxylonSenegalensis) and Owen (Mitragyna spp.) timber species have the lowest moisture content with values of 7.36% and 8.33% respectively, Mkpenek (Uapacaguineensis) and Atarabang (Xylopia spp.) gave the highest moisture content with almost equal moisture characteristics having moisture content values of 14.13% and 14.29% respectively. From the results of the moisture test and according to BS EN 1995-1-1, all timber species tested are either Service Class 1 timbers (moisture content < 12%) or Service Class 2 timbers (moisture content < 20%) and as such can be graded using characteristic strengths specified in BS EN 338:2016 [5].

The moisture content values of all the timber species tested were within intermediate levels (8% to 20%) and at such moisture content levels, the timber species will expand on heating, but then will shrink to a smaller volume than it was initially before heating due to loss of moisture while still being heated. Therefore, the result of prolonged heating on all the five timber species will be a negative dimensional change even in the longitudinal (grain) direction where dimensional change due to change in moisture content is usually very minimal [23]. Dimensional change (shrinking and swelling) in the timber species could also occur due to changes in moisture content when exposed to the environment from repeated wetting and drying, typical of the environmental conditions of Akwa Ibom State, Nigeria.

The result of mean density is in tandem with the classification of the timber species into hardwood and softwood given in Table 1 following values set in BS EN 338:2016 with the hardwood species all having density values greater than 520 kg/m^3 (maximum value of density for softwood) while the only softwood specie i.e. Atarabang (Xylopia spp.) having a mean density value of 352 kg/m^3. The results show that IyipOkoyo (*Stauditiastipitata*) has the highest density of the hardwood species with a mean density of 720 kg/m^3 and is expected to have the highest stiffness since stiffness generally increases with density and also will not dent easily when depressed compared to the other timber species [23]. From Table 3, the average coefficient of variation (CoV) in mean density for all timber species tested was 10%, which is suitable for describing variability of density within common domestic timber species [23].

Table 3: Physical Properties (Moisture Content and Density) of Timber Species

S/N	Timber Specie	Moisture Content	Mean Density (kg/m³)	CoV of Mean Density	Mean Density Adjusted to Reference Moisture Content of 12% (kg/m³)
1	Iyipokoyo (*Stauditiastipitata*)	12.50%	720	0.10	718
2	Owen (*Mitragyna spp.*)	8.33%	560	0.10	570
3	Mkpenek (*Uapacaguineensis*)	14.13%	653	0.11	646
4	Atarabang (*Xylopia spp.*)	14.29%	356	0.09	352
5	Ata (*XanthoxylonSenegalensis*)	7.36%	573	0.10	587

Mechanical properties of the timber species are presented in Table 4. The values shown in Table 4 have been adjusted to the reference moisture content of 12% for classification and grading purpose. The results show that IyipOkoyo (*Stauditiastipitata*) possesses the highest values of Compressive Strength Parallel to Grain, Tensile Strength Parallel to Grain, Modulus of Rupture (Bending Strength) and Modulus of Elasticity in Bending. This was followed by Mkpenek (Uapacaguineensis), Ata (XanthoxylonSenegalensis), Owen (Mitragyna spp.) and Atarabang (Xylopia spp.). For Compressive Strength Perpendicular to Grain, Mkpenek (Uapacaguineensis) had the highest strength value of 10.36 N/mm^2 closely followed by IyipOkoyo (*Stauditiastipitata*) with a value of 9.78 N/mm^2 with Atarabang (Xylopia spp.) again giving the least value as was with the other properties. These results further validates the classification of the timber species into hardwood and softwood in Table 1, with the hardwood species having higher strength and stiffness properties than the softwood specie. The coefficient of variation (CoV) obtained from the timber properties tested are comparable with corresponding average values specified by [23] and therefore acceptable.

3.2 Allocation of Strength Class

Table 5 shows the strength classification of the different timber species based on the grade determining properties (i.e. characteristic density, characteristic bending strength and mean modulus of elasticity parallel to grain). The characteristic values are calculated from the mean and CoV values in Table 4. The results further confirm the hardwood (D – class) and softwood (C- class) classification in Table 1 that was based on physical appearance of the timber species. For all timber species, the characteristic density, characteristic bending strength and mean modulus of elasticity parallel to grain were either greater than or approximately equal to corresponding values specified by BS EN 338:2016 for the strength class assigned. This satisfies the requirements of clause 6.2.4.10 of BS EN 14081-2-2010 [24] where it is required that characteristic values of the grade determining properties for the assigned grades be equal or exceed the values required for the grade.

Table 6 compares other characteristic values (compressive and tensile strength) of the timber species obtained directly from test with those specified in BS EN 338:2016 for the grades assigned to each timber specie. The results show that values of test are greater than corresponding values specified, which further validates the strength allocation. The values take no direct account of material factors of safety which are usually applied as part of the process for structural timber design.

Table 4: Mechanical Properties of Timber Species Adjusted to the Reference Moisture Content of 12%

Timber Specie	**Iyip Okoyo (*Stauditiastipitata*)**		**Owen (*Mitragyna spp.*)**		**Mkpenek (*Uapacaguineensis*)**		**Atarabang (*Xylopia spp.*)**		**Ata (*XanthoxylonSenegalensis*)**	
Property	**Mean**	**CoV**	**Mean**	**CoV**	**Mean**	**CoV**	**Mean**	**CoV**	**Mean**	**CoV**
Compressive Strength Parallel to Grain (N/mm^2)	40.13	0.15	24.32	0.12	33.68	0.14	21.01	0.13	27.96	0.14
Compressive Strength Perpendicular to Grain (N/mm^2)	9.78	0.21	8.51	0.20	10.36	0.22	3.77	0.22	8.54	0.23

Tensile Strength Parallel to Grain (N/mm^2)	53.84	0.24	19.06	0.23	36.62	0.24	13.28	0.25	24.18	0.25
Modulus of Rupture (Bending Strength) (N/mm^2)	87.38	0.29	36.55	0.31	64.91	0.28	28.20	0.30	49.40	0.31
Modulus of Elasticity in Bending (kN/mm^2)	13.71	0.19	9.47	0.21	11.95	0.19	7.32	0.18	10.20	0.20

Table 5: Strength Classification of Timber Species according to BS EN 338:2016

S/N	**Timber Specie**	**Characteristic Density, ρ_k (kg/m^3)**	**Characteristic Bending Strength, $f_{m,k}$(N/mm^2)**	**Mean Modulus of Elasticity Parallel to Grain, $E_{m,0,mean}$ (kN/mm^2)**	**Strength Classification based on BS EN 338:2016**
1	Iyip Okoyo (*Stauditiastipitata*)	598	45.8	13.71	D45
2	Owen (*Mitragyna spp.*)	475	17.90	9.47	D18
3	Mkpenek (*Uapacaguineensis*)	538	34.88	11.95	D35
4	Atarabang (*Xylopia spp.*)	300	14.24	7.32	C14
5	Ata (*XanthoxylonSenegalensis*)	489	24.15	10.20	D24

Table 6: Comparison of test values of characteristic strength of different classes of timber species with corresponding values specified in BS EN 338:2016

Timber Specie	**Iyip Okoyo (*Stauditiastipitata*)**		**Owen (*Mitragyna spp.*)**		**Mkpenek (*Uapacaguineensis*)**		**Atarabang (*Xylopia spp.*)**		**Ata (*XanthoxylonSenegalensis*)**	
Strength Class	**D45**		**D18**		**D35**		**C14**		**D24**	
Property	**Based on Test**	**Based on BS EN 338**	**Based on Test**	**Based on BS EN 338**	**Based on Test**	**Based on BS EN 338**	**Based on Test**	**Based on BS EN 338**	**Based on Test**	**Based on BS EN 338**
Compressive Strength Parallel to Grain (N/mm^2)	30.2	29.0	19.5	18.0	25.9	25.0	16.5	16.0	21.5	21.0
Compressive Strength Perpendicular to Grain (N/mm^2)	6.4	5.8	5.7	4.0	6.6	5.4	2.4	2.0	5.3	4.9
Tensile Strength Parallel to Grain (N/mm^2)	28.1	27.0	11.8	11.0	22.1	21.0	7.8	7.2	14.2	14.0

IV. CONCLUSION AND RECOMMENDATIONS

This paper have characterized and graded five timber species in Akwa Ibom State, Nigeria based on BS EN 338:2016. Results of moisture content showed that the timber species have intermediate levels of moisture indicating low susceptibility to fungal degradation and high durability but prone to dimensional change when exposed to prolong heating and seasonal variations typical in Akwa Ibom State, Nigeria where there are two seasons, wet and dry. During the wet (rainy) season, the timber species will absorb moisture and swell (positive dimensional change), while during the dry season, the timber species loses moisture and shrinks (negative dimensional change). The amount of dimensional change will depend on the surface area of the timber exposed to the environment. The durability and environmental resistance of the timber species can be further improved by application of thermal and chemical treatments before use especially in roof timbers, flat roof joist, tiling battens, soleplates above damp proof course (DPC) levels and external wall studs.

Four of the five timber species were hardwood with Atarabang**(*Xylopia spp.*)** being the only softwood specie, indicating that timber species in Akwa Ibom State are predominantly hardwood species with moderate to high densities. But this need to be confirmed in further studies by extensive sampling and testing of timber species in Akwa Ibom State and the entire southern Nigeria. The physical and mechanical properties obtained met the requirements for the grade assigned to each specie, therefore other properties not tested such as shear strength and mean shear modulus can be obtained directly from BS EN 338:2016 corresponding to the strength class assigned to each timber specie in this research.

The test results together are useful for indicating suitability of the different timber species in Akwa-Ibom State for different structural applications and design to relevant codes such as Eurocode 5 (BS EN 1995-1-1:2004). Overall, IyipOkoyo (*Stauditiastipitata*) showed better performance in terms of bending, compressive and tensile capacities and as such best suited for structural engineering applications among all species tested, whereas Atarabang (Xylopia spp.) had the least resistance. With the lowest density, Atarabang (Xylopia spp.) will be particularly suitable in lightweight applications where high strength is not a major requirement such as in formwork systems. With moderate to high density values, all five timber species are not suitable for heavy construction such as bridges but can be utilized for general construction such in building frames, flooring, interior and exterior joinery, paneling, claddings, mouldings and boat building.

Due to the high strength to weight ratio of the timber species tested when compared with other conventional structural materials such as steel and concrete, the timber species become an effective structural material in structural systems where self weight constitutes a large share of the load to be carried. But more research still needs to be done in the areas of use where fire resistance, lateral stability in high rise buildings and resistance in harsh environmental conditions are required and where presently, timber is not the material of choice due to its inherent properties which have been determined in this work.

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Sylvester ObinnaOsuji. "Characterization and Strength Classification of Timber Species in Akwa Ibom State, Nigeria for Structural Engineering Applications." International Journal of Engineering Research and Applications (IJERA) , vol. 7, no. 10, 2017, pp. 01–09.