LAUTECH Journal of Civil and Environmental Studies
Volume 8, Issue 1; March, 2022

DOI: 10.36108/laujoces/2202.80.0140

EN 338 Strength Characterization and Grading of Four Less-used Timber Species Grown in Nigeria for Structural Uses

[1*] Lamidi, N. A.,[2] Hassan, Q.O, [2]Ajoje, G. O. and [3] Muili, M. A.

[1, 2] Department of Wood Products Engineering, University of Ibadan, Ibadan, Nigeria.
[2] Department of Physics, University of Ibadan, Ibadan, Nigeria.
[3]Technical Support Units, Faculty of Technology, University of Ibadan, Ibadan, Nigeria.

[*] Corresponding Author E-mail: lamidinureni@yahoo.com Tel: 08059541092

Submitted on: 26/11/2021 *Accepted on: 18/03/2022*

Abstract

In Nigeria recently, less-used timber species have been introduced into the main stream of timber markets, as a relief for over-exploitation of well-known species that are going into extinction due to over-exploitation for construction purposes. This study successfully classified four timber species grown in Nigeria into different strength classes in accordance with EN338, such as Ako-(Brachystegia eurycoma), Ara-(Pterocarpus erinarceus), Obobo-(Guarea cedrata) and Epuu-(Ricinodendron heudelotii) timber species. These timbers were obtained from famous timber market in Ibadan, southwestern Nigeria. All timber specimens used for physical and mechanical tests were prepared and tested in accordance with EN 13183-1 and EN 408 for structural timber. Four- point bending test was used for determining the bending strength and modulus of elasticity of each specimen using Universal Testing Machine. Characteristic values of the bending strength, modulus of elasticity and density were determined. The average moisture content of Ako, Ara, Obobo and Epuu were 11.78, 12.71, 23 and 24 %, respectively. Timber classification was conducted after properties values adjusted to 12 % moisture content as specified by EN 384. For density, Ako had the highest of 747.26 kg/m^3 density followed by Ara and Obobo and Epuu had the lowest density of 481.71 and 477.15 kg/m^{3}and also assigned to strength classes D 50, D 24, D 18 and C 16 respectively, in accordance with EN 338.

Keywords: Less-used timber species, Well-known timbers, Density, Mechanical properties, Structural uses.

.

Introduction

Timber is a unique structural material among all materials used for civil engineering structures due to its renewability, strength/weight ratio, and efficient potentiality as environmentally friendly nature attributes (Lamidi, 2019). In design of engineering structures, cost, durability, serviceability and functionality are majorly considered (Raheem and Audu, 2013). In the past, well-known commercial timber species like Apa (*Afzelia africana*), Ekki (*Lophira alatia*), Ayan (*Prosopis africana*), Iroko (*Milica excelsa*), Ita (*Celtris accidantalus*) and Mahongany (*Khaya ivorensis*) just to mention few are used extensively for structural members in civil and construction industries. Ataguba *et al*. (2015) timber and wood-based products are used for various purposes by industries but bulk of these materials continue to be utilized in both civil and construction industries for both structural and non-structural purposes. Globally, timber structural uses include; roof trusses, floors, bridges and laminated arches. Therefore, the timber demand for above-stated applications is quit unlimited as it continues to increase rapidly in most of developing countries Nigeria inclusive. If alternative for timber materials are not sourced, it may resulting to the acute shortage of timbers as construction materials and unsustainable. This has forced some stakeholders like foresters, wood-workers, and other professionals in timber production industry look inward for available untapped potential timber species that not yet fully utilized due to lack of information on the basic properties for its selection and utilization (Bernard, 2006 and Lamidi, 2018).There are many less-used and durable timber species in the natural and plantation forests but being underutilized for minor work like shed, fence, and brace of damaged work, firewood and charcoal or otherwise left as waste (Lamidi *et al*., 2020). The utilization of some less-used or unpopular timber species as replacement for the commercially valued timber species has been a matter of debate recently, in order to prevent their extinction within the forests. However, for such unpopular timber species to gain acceptance globally, they must have physical and strength properties comparable to or better than the scarce timber species. Furthermore, durability for long-term use is essential (Raheem and Audu, 2013). These properties have been used to characterize and grade timber species to the required strength class for structural engineering applications. Lamidi *et al*. (2020) worked on characterization and grading of (*F. elastica*) and Akoko (*N. laevis*) as less-known or less-used timber species and found that both timbers have acceptable design parameters for the structural engineering applications in both civil and construction works. As a result, more research is needed to capture the much potential of such timber species grown in developing countries Nigeria inclusive, in order to sustain and manage tropical forests in Nigeria to meet the currently higher demand for timbers for this generation and future generations.

The NCP 2, Code is the structural timber design code that governs design and construction of timber structures or elements in Nigeria, the code is based on the permissible stress design principles, derived from the form CP112. With introduction of another permissible stress design BS 5268 Code, CP 112 was withdrawn. BS 5268 also was replaced with the Eurocode 5 after revision, which is a limit state design code that provides common design criteria and method but fulfill the specified requirements of safety, serviceability and economy. Unlike most conventional design codes of larger safety factors, which are uneconomical design of structures compared with Eurocodes 5 that uses smaller factor of safety without compromising safety integrity of the structures (Nwofor and Sule, 2017). There is the need for NCP2 revision as Nigerian Timber Design Code; so that Nigeria will be the same page with other developed countries that have adopted the said Eurocodes 5 for structural timber design. However, is becoming imperative to investigate the potentialities and properties of four less-used timber species using EN 338 approach. Therefore, it will help the designers to be acquainted with strength grades of these less-used timber species, to ensure their relevant performance criteria are met as required by standard codes. This means that the risk of under or over-design will be reduced and the suppliers can supply less-used timber species /grade together with timber of known strength/grades for better utilization thereby reducing over-exploitation or extinction of well-known timber species in Nigeria as whole.

.

Materials and Methods

Timber species used for this study were logs obtained from famous Bodija plank market in Ibadan, Oyo State, Nigeria. Five timber logs sawn into (75 mm x 150 mm x 3600 mm) commercial sizes were carefully selected and purchased and transported to Wood Processing Workshop of the Department Wood Products Engineering, University of Ibadan, Nigeria, where the selected timbers were seasoned for six months to attain equilibrium moisture condition (EMC). For bending strength and Modulus of Elasticity tests, 60 No. beams of 50 mm×50 mm×1000 mm each, that is, 15 pieces per specie, while for moisture content and density tests, a total 20 test samples each of size 50 mm x 50 mm x 50 mm were processed with circular machine and planing machine to the standard sizes in accordance with EN 408. The timber species used are Ako- (*Brachystegia eurycoma*), Ara-(*Pterocarpus erinarceus*), Obobo-(*Guarea cedrata*) and Epuu-(*Ricinodendron heudelotii*) as shown in Table 1.

Determination of Moisture Content

A total number of twenty (20) specimens of size 50 mm x 50 mm x 50 mm were randomly taken from each of air-dried timbers, weighed and thereafter specimens were oven-dried to a constant weight at 103 ± 2℃ for 24 h, reweighed (EN 408).

Table 1: Selected Structural Timber Species in Ibadan, Oyo State

Common Name	Botanical Name`	Family Name	Colour
Ako	*Brachystegia eurycoma*	*Caesalpinaceae*	Dark red
Ara	*Pterocarpus erinarceus*	*Fabaceae*	Dark brown
Obobo	*Guarea cedrata*	*Meliaceae*	Pinkish brown
Epuu	*Ricinodendron heudelotii*	*Euphorbiaceae*	Pale yellow

Moisture content used was calculated using Equation 1.

$$MC = \frac{W1-W2}{W2}\ x\ 100\% \qquad (1)$$

Where: MC is the moisture content, W1 is the initial weight of the timber before oven-dried, W2 is the final eight of the timber after oven-dried.

Determination of Density

Twenty (20) timber specimens of sizes 50 mm x 50 mm x 50 mm were randomly cut from each of species and oven- dried to a constant weight at 103 ± 2℃ for 24 h, reweighed. Density was calculated using Equation 2 in accordance with EN 384.

$$\rho = \frac{W}{V}\ (kg/m^3) \qquad (2)$$

Where: ρ is the timber density, W is the weight of the timber specimen and V is the volume of the timber specimen.

$$P_k = P_{0.05} = P - 1.65s \quad (kg/m^3) \qquad (3)$$

Where: P_k is the characteristic density, $P_{0.05}$ is the 5-percentile density, P and s are the mean and standard deviation of densities of all specimens respectively.

Confidence Limit

Ninety-five and Ninety-nine percent, confident limit of mean density and moisture content at natural were calculated using statistical Equation 4 and 5 for the upper and lower limits.

$$MC \pm \frac{t\alpha}{n},\ _{n-1}\frac{s}{\sqrt{n}} \qquad (4)$$

$$\rho_w \pm \frac{t\alpha}{n},\ n\text{-}1\frac{s}{\sqrt{n}} \qquad (5)$$

Density at 12%

The characteristic values of density were adjusted to the equivalent at 12% moisture contents in accordance with EN 338. Equation 6 was used for the adjustment.

$$\rho_{12} = \rho_w \qquad (6)$$

Where: ρ_{12} is the density at 12% MC, ρ_w is the density of the specimen during the bending test (kg/m^3) and u is the measured MC (%) at test.

Determination of Bending Strength

Four point static bending tests as specified by EN 408 were carried out on fifteen (15) timber specimens each (50 mm x 50 mm x 1000 mm) with the aid of a Universal Testing Machine (UTM) with a maximum capacity of 600 kN at the of Department Wood Products Engineering, University of Ibadan, Nigeria. The load was applied until failure occurs shown in Figures 1 and 2 and the failure load in respect of the individual beam was recorded. The bending strengths were determined using Equation 7.

$$f_m = \frac{a\,F_{max}}{2W} \quad (N/mm^2) \qquad (7)$$

Where: F_{max} is the maximum load applied (N), a is the distance between loading position and end supports (mm), W is the section modulus (mm^3) and f_m` is the bending strength (N/mm^2).

The strength properties of the each specimen obtained from Equation 7 were characterized in line with the requirements of EN 384 using Equation.

$$f_k = 1.12 f_{0.05} \qquad (8)$$

Where: f_k and f_{05} are the characteristic and 5th-percentile values of bending strength

Figure 1: Four Point Bending Test Setup

Figure 2: Failure Mode of Bending Specimens Test

Modulus of Elasticity

The global modulus of elasticity was determined from the values obtained at the point of failure under loading of bending tests with deflection values corresponding to the applied load from computer interface was used for calculation and the global modulus of elasticity of the individual beam was then computed from the Equation 9.

$$E_{m.g} = \frac{l^3 \Delta F}{4.7bh3\Delta w} \qquad (9)$$

Where: l is the span between the timber specimen supports (mm), ΔF is the increment in applied forces on the specimen (N), b is the width of the specimen (mm), h is the depth of the specimen (mm), and Δw is the increment in deflection (mm).

Modulus of Elasticity at 12% Moisture Content

Characteristic values of modulus of elasticity at experimental moisture content were adjusted to values at12% moisture content in conformity with EN 338 and the values were computed with Equation 10 and 11.

$$Em_{12} = \frac{E_{measured}}{1+0.0143(12-u)} \qquad (10)$$

Where: $E_{measured}$ = the modulus of elasticity at experimental moisture content, E_{m12} = Modulus of elasticity at 12% moisture content and U = experimental moisture content.

$$E= \left(\frac{\sum E1}{n}\right) 1.3\text{-}2690 \quad (11)$$

Where: n is the number of specimens, E_1 is the mean values of MOE in bending.

Reference Mechanical Properties

The characteristic values of other mechanical properties at 12% moisture content such as tension strength parallel and perpendicular to the grain, shear modulus, compressive strength parallel and perpendicular to the grain and other stiffness properties of the timbers were determined according to EN 338.

The characteristic values of tensile strength parallel to grain ($f_{t,o,k}$) and compressive strength parallel to grain($f_{c,o,k}$) were computed from the Equations 12 and 13 respectively.

$$f_{t,o,k} = 0.6 f_{m,k} \quad (12)$$

$$f_{c,o,k} = 5(f_{m,k})^{0.45} \quad (13)$$

The characteristic values of tensile strength perpendicular to grain ($f_{t, 90, k}$) and compressive strength perpendicular to grain ($f_{c, 90, k}$) were computed from the Equations 14 to 17 respectively.

$$f_{t, 90, k} = 0.4 \text{ N/mm}^2 \text{ for softwoods} \quad (14)$$

$$f_{t, 90, k} = 0.6 \text{ N/mm}^2 \text{ for hardwoods} \quad (15)$$

$$f_{c, 90, k} = 0.007 \rho k \text{ for softwoods} \quad (16)$$

$$f_{c, 90, k} = 0.015 \rho k \text{ for hardwoods} \quad (17)$$

Fractilte 5th percentile values of MOE parallel to grain ($E_{0,0.05}$) was computed from Equation 18 and 19.

$$E_{0, 0.05} = 0.67 E_{0,mean} \text{ for softwoods} \quad (18)$$

$$E_{0, 0.05} = 0.84 E_{0,mean} \text{ for hardwoods} \quad (19)$$

The characteristic values of mean modulus of elasticity perpendicular to grain ($E_{90\ mean}$) for the timbers were computed from Equations 20 and 21.

$$E_{90, mean} = E_{0, mean} / 30 \text{ for softwoods} \quad (20)$$

$$E_{90, mean} = E_{0, mean} / 15 \text{ for hardwoods} \quad (21)$$

The characteristic values of mean shear modulus (G_{mean}) for the timbers were computed from Equations 22.

$$G_{mean} = E_{0, mean} / 16 \quad (22)$$

The characteristic mean density (ρ_{mean}) of each timber was computed from Equations 23

$$\rho_{Mean} = 1.2 \times \rho k \quad (23)$$

Shear strength $f_{v,k}$ would be taken from Table 1 of EN 338 as specified by the code. Equations 14 to 21, which differentiate softwood from hardwood, would be dependent on the characteristic density range of the timber investigated in accordance with EN 338.

Results and Discussion

Physical Properties of the Less-used Timber Species

Moisture Content

The average moisture contents of Ako, Ara, Obobo and Epuu were 9.31, 9.74, 7.20 and 15.33 %, respectively with corresponding coefficient of variation 32.2, 41.1, 42.6 and 37.0 as presented in Table 2, This result is satisfactory; since it is not higher the maximum recommended moisture content of 20 % for air-dried timber specimens and the decay of these timbers at such moisture content is greatly reduced (Lamide *et al*., 2020). Hussin and Al-Bared (2014) also emphasized that moisture content of timber is one of the most important properties that influences the durability against the fungi and fungi and the result showed that there is a small variation in moisture content values among specimens of all species. This indicates that the data is more consistent.

Table 2: Average Results of Moisture Content for Timber Species

Timber	Min	Max	Mean	Std. Dev.	C. V	Confidence Limit 95%	Confidence Limit 99%
Ako	5.56	14.29	9.31	3.01	32.20	$8.89 \leq X \leq 9.73$	$8.76 \leq X \leq 9.86$
Ara	6.67	18.18	9.74	4.01	41.10	$9.18 \leq X \leq 10.30$	$8.99 \leq X \leq 10.47$
Obobo	4.76	13.33	7.20	3.07	42.60	$6.70 \leq X \leq 7.74$	$6.43 \leq X \leq 8.01$
Epuu	6.25	22.22	15.33	5.68	37.00	$14.53 \leq X \leq 16.12$	$14.28 \leq X \leq 16.37$

Density

Density is the main factor of determining the timber strength according to (Raja-Hussin and Al-Bared 2014). In this work, the mean values of density (ρ) for Ako, Ara, Obobo and Epuu were 747.26, 515.27, 477.15 and 481.71 kg/m^3 respectively with the corresponding values of standard deviation of 32.89, 31.09, 52.84 and 49.47 Table 3. Similarly, the species coefficients of variation were given in the same order as 4.4, 6.03, 11.07, and 10.27.The results revealed that the average coefficient of variations of mean density for timbers tested was 8% which describes better variability of timber density required for structural materials in domestic buildings (FWPA, 2014).

Table 3: Average Results of Density for Timber Species

Timber	Min	Max	Mean	Std. Dev.	C. V	Confidence Limit 95%	Confidence Limit 99%
Ako	686.60	800.91	747.26	32.89	4.40	$742.66 \leq X \leq 751.87$	$741.21 \leq X \leq 753.31$
Ara	481.93	572.58	515.27	31.09	6.03	$510.91 \leq X \leq 519.62$	$509.55 \leq X \leq 520.99$
Obobo	386.49	585.14	477.15	52.84	11.07	$466.80 \leq X \leq 487.51$	$463.54 \leq X \leq 490.76$
Epuu	421.36	558.02	481.71	49.47	10.27	$474.79 \leq X \leq 488.64$	$472.61 \leq X \leq 490.82$

Mechanical properties of the less-used Timber Species

Bending Strength

Table 4 presented the results of the average bending strength of selected four less-used timber species. It can be observed that the value obtained for Ako timber species was greater than Ara, Obobo and Epuu, that is 59.05 N/mm^2 which corresponds with standard deviation of 3.77 N/mm^2 and coefficients of variation of 6.38 %, then Ara followed by Obobo and the least strength value of 23.86 N/mm^2 correspond to Epuu with Standard deviation of 4.72 N/mm^2 and COV of 19.78 %. These coefficients of variation indicate how large the standard deviation is in relation to the mean of the species (FWPA, 2014).

Modulus of Elasticity

As presented in Table 4, the average values of modulus of elasticity for tested less-used timber species were 15871.51, 8412.84, 7187.47 and 7334.07 N/mm^2 with the corresponding coefficients of variations of 6.66, 11.88, 23.64 and 21.65 for the Ako, Ara, Obobo and Epuu timbers respectively. However, the highest COV was recorded for Obobo followed by Epuu and Ako has the least but still within range variability of 20-40 % specified for structural timber properties (FWPA, 2014). It can be concluded that the resistance of Ako timber specie to failure in bending parallel to grain was higher than counterpart timber species.

Table 4: Bending Strength and Modulus of Elasticity Test Results

Timber	Bending strength (N/mm^2)			Modulus of Elasticity (N/mm^2)		
	Mean Value	S D	COV	Mean Value	SD	COV
Ako	59.05	3.77	6.38	15871.51	1057.04	6.66
Ara	32.40	3.83	11.82	8589.85	1020.47	11.88
Obobo	28.11	6.05	21.52	7187.4	1699.12	23.64
Epuu	23.86	4.72	19.78	7334.07	1587.83	21.65

Characteristic Properties

Results of the characteristic properties indicate that Ako had the highest values of density, bending strength and modulus of elasticity of 702.14kg/m^3,59.05 N/mm^2, and15871.15 N/mm^2 N/ followed by Ara and Obobo while Epuu timber recorded the least density of 392.43 kg/m^{3}and bending strength of 27.17 respectively.

Table 5: Characteristic Strength Values of Timber Properties to 12% Moisture Content

Timber	Density $\boldsymbol{\rho}_{k12}$ (kg/m^3)	Bending strength $f_{m,k12}$ (N/mm^2)	Modulus of Elasticity $E_{0,mean}$ (N/mm^2)
Ako	702.14	65.26	15947.81
Ara	469.21	35.88	9620.63
Obobo	399.29	30.73	6584.38
Epuu	392.43	27.17	9344.72

Strength Classification

According to EN 338, the strength class may be assigned to timber specie, if the characteristic values of bending strength and density equal or exceed the values for that strength class given in Table 1 of EN 338 and its characteristic mean modulus of elasticity in bending equals or exceeds 95% of the value given for that strength class. Based on similar criteria, Ako, Ara, Obobo and Epuu timber species were assigned to strength classes D 50, D 24, D 18 and C 16, respectively due to their material properties such as characteristic bending strength, density and mean modulus of elasticity parallel to grain as specified by the code. Table 6 shows the strength classification according to EN 338.

Table 6: Derived Mechanical Properties of the Timber

	Timber species			
Other mechanical properties	Ako	Ara	Obobo	Epuu
Tensile Parallel $f_{t,o,k}$ (N/mm^2)	39.2	21.5	18.4	16.3
Tensile Perpendicular $f_{t,90,k}$ (N/mm^2)	0.6	0.6	0.4	0.6
Compressive Parallel $f_{c\,o,k}$ (N/mm^2)	32.8	25.0	23.4	22.1
Compressive Perpendicular $f_{c\,90,k}$ (N/mm^2)	10.5	7.4	2.8	5.9
Shear Strength $F_{v,k}$ (N/mm^2)	4.5	4.0	3.2	3.4
5% MOE Parallel $E_{0,\,0.05}$ (k N/mm^2)	13.4	8.1	4.4	7.8
Mean MOE Perpendicular $E_{90,\,mean}$ (k N/mm^2)	1.1	0.6	0.2	0.6
Mean Shear Modulus G_{mean} (k N/mm^2)	1.0	0.6	0.4	0.6
Mean Density $\boldsymbol{\rho}_{mean}$ (kg/m^3)	843	563	479	471
Strength Classes	D 50	D 24	D 18	C 16

Conclusion

Epuu-(Ricinodendron heudelotii) is coniferous specie (softwood) because its characteristic density fall within softwood rang of 290-460 kg/m^3 while *Ako-(Brachystegia eurycoma), Ara-(Pterocarpus erinarceus)* and *Obobo-(Guarea cedrata)* are deciduous species (hardwood), their characteristic densities fall within the range of 470-900kg/m^3 as specified by EN338. Furthermore, the timber species were assigned to strength class based on the European structural timber strength classification. Ako, Ara, Obobo and Epuu were assigned to strength classes D 50, D 24, D 18 and C 16, respectively. Wood users (Engineers, builders, wood technologists, and carpenters) can utilize the documentation above for those less-used timber species in replacement of highly demanded commercially valuable species such as Apa, Ayan, Ekki, Iroko, Mahogany, Obeche, Oro and Teak whose properties are well known. These recommendations were drawn from the research:

i. Ako, Ara and Obobo species are recommended load bearing structures that required higher stress such as beams, columns, roof trusses and floors.
ii. Epuu timber specie is suitable for furniture frames, plywood boards, formworks and packing cases.
iii. Revision of NCP2 (1973) in order to update to new timber design methodology approach is also recommended.

References

ASTM (2000). Standard Methods of Testing Small Clear Specimens of timber. ASTM, D193.West Conshocken, PA. Reapproved.

Ataguba, C., Enwelu, C., Aderibigbe, W. and Okiwe, E. (2015). Comparative Study of Some Mechanical Properties of Gmelina Arborea, Parkia Biglobosa and Prosopis Africana Timbers for Structural Use, International Journal of Technical Research and Applications, 3(3): 320-324.

Bernard, E. (2006). Development of Kiln-dying and within Tree Variability in the Physical Properties of Two Lesser - Known Timber Species in Ghana, Published M.Sc Thesis, Wood Science and Technology Department, Kwanme Nkrumati University of Science and Technology Ghana.

EN 338 (2009). Structural Timber-Strength Classes. European Committee for Standardization. Austrian Standards Institute Heinestra 38, 1020 Wien.

EN 384 (2004). Timber Structures; Structural timber Determination of characteristic values of mechanical properties and density. 2004, Comité Européen de Normalisation,Brussels, Belgium.

EN 408 (2003) “Timber structures – Structural timber and Glued-laminated timber: Determination of some physical and mechanical properties, “European Committee for Standardization, CEN, and Brussels, Belgium.

EN 408 (2004). European Standard: Timber structures -Structural Timber –Determination of Some Physical and Mechanical Properties. 2004, Comité Européen de Normalisation, Brussels, Belgium.

EN338 (2009) “Structural Timber: Strength Classes,” European Committee for Standardization, CEN, Brussels, Belgium.

EN384 (2004) “Structural timber: Determination of characteristic values of mechanical properties and density,” European Committee for Standardization, CEN, Brussels, Belgium. .

Forest and Wood Products Australia (FWPA) Limited, Supplier and product management spreadsheet for timber due diligence, FWPA, 2014.

Jimoh, A. A and Aina, S. T. (2017). Characterization and Grading of two selected timber species grown in Kwara State Nigeria. Nigerian Journal of Technology (NIJOTECH). Vol. 36, No. 4, Pp. 1002 – 1009. ISSN: 2467-8821.

Lamidi, N. A (2019). Preliminary Evaluation of Strength Properties of Mango Wood (*Magnifea indica*) as Alternative Materials for Furniture Making in Nigeria, Unpublished B.Sc. Thesis, submitted to the Department Technical Education, Ekiti State University Nigeria.

Lamidi, N. A, Muili, M. A, Akinyemi, O. O and Ajao, O. Q. (2020). Characterization and Grading of Two selected Less- Known Timber Species for Structural Applications in Nigeria. U.I Journal of Civil Engineering and Technology, Vol.2 (1): 16-27.

Raheem, A. A and Audu, M. T. (2013). Tensile Strength Characteristics of Fan palm under various Exposure Conditions. Proceeding of the Second International Conference on Engineering and Technology Research, Ladoke Akintola University of Technology, Ogbomosho, Oyo State, Nigeria. March 26th -28, 2013, ISBN: 978-2902-58-6 Vol. 2. Pp. 182-187.

T. A. Raja-Hussin and Al-Bared, A. A. M. (2014). Structural Performance of Kempas Subjected to Bending. International Conference of Engineering, Information Technology and Science. IOI Hostel and Golf Resort, Bandar Sunway, Malaysia, 4-5 December 2011. G

T. C. Nwofor and Sule, S. (2017). Optimization of Steel Reinforced Concrete Column using Eurocode 2 and BS 8110-97. International Journal of Civil Engineering, Vol. 4 (7): PP. 21-28. ISSN: 2348-8352.