Supported by tetfund

A STUDY OF SOME MECHANICAL PROPERTIES OF *Tectona grandis*

D. A. Adetan, K. A. Oladejo* and A. T. Okunade
Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria
*Corresponding author: wolesteady@yahoo.com

Received: November 21, 2018 **Accepted:** July 09, 2019

Abstract: This study examined some mechanical properties of seasoned and unseasoned teak using wood samples from the core of 25-30 years old freshly fallen teak tree. This was with a view to establishing the effect of various seasoning methods on these engineering properties of the teak wood. Three seasoning methods were studied; these are oven-seasoning, air-oven-seasoning and air seasoning methods. All the seasoned specimens were monitored during the seasoning process until the *equilibrium moisture content* (EMC) was between 12-15%. The seasoned and unseasoned specimens were subjected to compression, flexural and hardness tests and each test was replicated three times. Another set of specimens was subjected to fatigue test at three stress levels: 60, 70, and 80% ultimate strength. The data obtained were subjected to appropriate statistical and graphical analyses. The results showed that, generally, oven-seasoned teak wood possesses the highest mechanical strength followed by the oven-air seasoned, air-seasoned and unseasoned teak in that order. The study concluded that seasoning significantly influences the mechanical properties of teak and the shorter the time spent for seasoning to attain a given equilibrium moisture content, the stronger the teak becomes.

Keywords: Teak, compressive strength, flexural strength, fatigue, moisture content

Introduction

Timber is one of the earliest construction materials. Though it is largely superseded by concrete, steel and plastics today, its use remains quite extensive. Basically, there are 2 types of lumber for carpentry: softwoods and hardwoods. These are some-what misleading terms, because they referred not to the quality of timber, but to the types of tree the timber comes from. Softwoods generally come from trees with needle-like leaves (conifers); they are "evergreens". They are not normally highly durable unless protected by preservatives. Hardwoods come from the broad-leaved trees, mostly deciduous, although there are many broad-leaved trees that are ever green in certain climates. Many hardwoods are in general durable, and some such as teak may last for centuries without the use of preservatives. Generally, the hardwoods are harder and stronger than the softwoods. Hardwood trees are slow growing, which makes them more expensive than softwoods. Hardwoods generally are used more extensively for furniture, interior finishing, and cabinetwork than for structural purposes (Erdogan, 2002; Taylor, 2002; Keyser, 1986).

Teak (*Tectona grandis*) is a yellow to dark brown hardwood which is extremely heavy, strong and durable. Often strongly figured, teak may show straight grain, mottled or fiddle back. Teak wood is one of the strongest, most durable hardwoods in the world. It has a high oil content which gives it a natural resistance to rot and protects it against insect infestation. Teak timber is particularly valued for its durability and water resistance, and is used for boat building, exterior construction, veneer, furniture, carvings, turnings, and other small wood projects. It is also known for its ability to withstand almost any weather, which makes it a popular choice for boat building (White, 1991). It is excellent timber for bridge building and other construction in contact with water such as docks, quays, piers and floodgates in fresh water.

The compressive strength of clear, straight-grained timber is much higher when measured perpendicular to the grain, since compression causes buckling or plastic crushing of the fibers. However, in structural timber containing knots and distorted grain, the reverse is the case. Bending stresses are very commonly applied to timber in service and, as would be expected, flexural strength, as measured by the modulus of rupture, is between tensile and compressive strength (Dinwoodie, 2001; Taylor, 2002). One of the most important factors that affect the mechanical properties of timber is its moisture content. The strength of clear timber rises approximately linearly as moisture content decreases from the fiber saturation point and may increase 3-fold when the oven-dry state is reached. At a moisture content of around 15%, the strength would be approximately 40% higher than that of the saturated state, depending on the type of wood. The mechanism of the strength increase is similar to that of shrinkage in concrete; the contraction results in decreased inter-fiber spacing and, therefore, stronger bonding between fibers (Bradan, 2003; Taylor, 2002; Widehammar, 2004).

Fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit or yield stress limit. The general theory of fatigue is that when an action is repetitive, the structure of the object doing the work breaks down and it loses strength. It is pointed as the main cause of in-service failures in engineering structures and components. The process involves a continuous, confined, permanent change, occurring as a result of conditions that produce changing stress and strains in the material, which may finally result in breakings after an enough number of cycles. In general, one or more tiny cracks start in the material, and these grow as the material is subjected to repeated load until complete failure occurs (Dowling, 2007). In woods, fatigue is thought to begin at an internal or surface fault and, over a number of loading cycles, this produces intrusions and extrusions that begin to resemble a crack. Cracks may start and spread where the wood strain is higher than the average, or where the stress level is high enough to cause unchangeable deformation under cyclic loading conditions. Breaking failures are dreadful in nature; they mail lead to loss of lives and valuable properties. Thus, prevention of fatigue fracture is a vital aspect of design for machines and structures that are subjected to repeated loading or vibration (Dowling, 2007). It is therefore essential to investigate the physical behaviour of materials and structures that would be subjected to cyclic loading conditions in service.

Saravanan *et al.* (2014), five year-old wood recorded maximum density and specific gravity. Among the age gradations five year old registered maximum value for the parameters like static bending strength, modulus of rupture, modulus of elasticity, compression strength parallel to grain, Compression Strength perpendicular to grain, hardness, shearing stress parallel to grain, tensile stress parallel and perpendicular to grain, Nail-holding power, screw-holding power, brittleness, and cleavage strength parallel to grain. The current study confirmed the suitability of five year old wood as raw material for plywood, pencil, packing cases, and light furniture industry. According to Rokeya *et al.* (2010), the timber hybrid Acacia is of medium dense having specific gravity 0.56 at green condition which is less than that of teak (*Tectona grandis*). The volumetric shrinkage of hybrid Acacia wood was found greater than that of teak but the specific gravity was found less than that of teak. From the study of physical and mechanical properties it is evident that the species is moderately strong. The species is suitable for making furniture and other household articles. Izekor and Fuwape (2011), Egbuchua and Bosah (2011), Izekor *et al.* (2010), the results of the visual observation of the study samples showed that Teak wood on exposure to outdoor weather condition was resistant to surface splitting and checking in both radial and tangential directions. Discolouration and loss of brightness was observed for all the study samples on exposure to outdoor weather conditions irrespective of the tree age and the positions from where the wood sample was collected. Plantation grown *Tectona grandis* wood of older age classes in Edo State has higher resistance to shrinkage, surface splitting and checking. Its wood is therefore recommended for use as structural material in outdoor weather conditions.

Guzmán *et al.* (2017), Solórzano *et al.* (2012), a multiple regression analysis showed that the most influential variables were height to crown base, crown weight, diameter, and total height of the tree. An evaluation of the bending *risk factor*/ was correlated with the height to crown base, crown weight, and form factor. The modulus of elasticity and chemical compositions of bent trees differed from those of straight trees. The causes of tree bending are complex, involving, among other factors, the morphology of the trees, plantation conditions, and other factors specific to the xylem, such as the specific gravity, modulus of elasticity, and presence of calcium and magnesium in the wood. Vasubabu *et al.* (2016), mass loss, tensile strength, compression strength, elongation and hardness were measured at different alkaline (NaOH) concentrations (5, 10, and 15%). The result shows that variation in mechanical properties with alkali treatment on *Tectona grandis* wood species at different concentrations. Optimum mechanical properties were obtained at 10% of alkaline treatment is discussed with its structure critically.

Olaoye *et al*. (2016), three trees of *Aningeria robusta* were obtained, and samples were collected at the base, middle and top portion of each tree to determine physical and mechanical properties of the wood species. Universal testing machine was used to obtain the mechanical properties whilst using relevant formulars. A complete randomized design was used and data obtained were analysed using descriptive statistics and ANOVA Moisture content, Wood Density, Modulus of Elasticity, and Modulus of Rupture. There was no significant difference of the physicomechanical properties along the bole. Physico-mechanical potential of *Aningeria robusta* for talking drum manufacturing was explored and compared. Thus: considered a better substitute for the scarce and popularly demanded species. Dahunsi and Adetayo (2015), this paper determined the relationship between the physical, mechanical properties, and the burning characteristics of the selected Nigeria timber species used for structural purposes. Six species out of ten identified timber species that are used for structural purposes in building construction in Southwestern Nigeria were selected for studies in this paper. The correlation coefficients of the predicted charring rate when compared with the actual charring rate were determined. Rafael *et al.* (2015), it was also observed that only sites with low fertility produce modifications in specify gravity, fiber saturation point, initial moisture content, MOR in flexion in green and dry condition, MOE in bending and resistance to termite attack. Incidence and magnitude of defects increased with drying, and were mainly affected when wood comes from younger trees from high fertility sites and growing in tropical moist forest climate.

Victor *et al.* (2015), *t*his work aimed to evaluate the influence of three ages in apparent specific gravity and janka hardness of teak wood (teak) aiming its use in the manufacture of floors. They Were determined the apparent specific gravity at 12% of moisture for ages 10, 13 and 17 years, according to the NBR (11941) and COPANT Standard 465 for the janka hardness test . To analyze the results we used a completely randomized design. The specific gravity and the Janka hardness showed an increasing trend with age increase. Both properties have shown correlation. The properties meet the requirement for floor, and may probably be improved with increasing age. Hossain and Abdul Awa (2012), test results revealed that Sal, Teak and Jam were the best species of using as compression member while Sal and Teak showed the best performance in tension. In static bending Sal, Sil Korai, Teak and Jam have been found suitable. With respect to durability acidic environment has been shown to be the most aggressive agent. Saline water was comparatively safer for all kinds of timber species. Overall, the Rain Tree showed excellent performance in all chemical environments having minimum loss of strength, and Sil Korai has been found to be the most vulnerable one to the same environments among all the timber species.

Yulianto *et al.* (2012), Loulidi *et al.* (2012), this paper, authors showed substitute wood materials for Javanese timber houses from tropical timber. A total of 840 specimens made from 9 tropical timber species were tested. All tropical timber specimens showed that the MOE (Modulus of elasticity) had strong relationship with density. There was a clear trend that smaller density indicated smaller MOE. Yield stress described strong relationship with densities. From all specimens tested, shear modulus, shear strength and MOR showed quite strong relationship with densities. Though teak has grown into a worldwide favourite with its superb stability, ease of workability and outstanding resistance to decay and rot, its behaviour in terms of mechanical properties is not well known. This work reports a study of the compressive strength, hardness and fatigue life parallel to grain, and the flexural strength perpendicular to the grain of teak wood. This study work was aimed at determining selected physico-mechanical properties of *A. robusta* wood with the view of exploring its suitability for the manufacture of talking drum. It is believed that exploring *A. robusta* will reduce pressure on the overexploited and scarce wood species.

Material and Method

Wood seasoning methods

The teak wood used for this study was gotten from a sawmill at Ondo road, Ile-Ife, Osun State, Nigeria and cut to dimensions of 80 x 80 x 300 mm sizes for easy machining and drying. These dimensions were used to produce specimens for all the seasoning methods studied. The wood samples used for this study were subjected to three different types of seasoning processes: air, oven and air-oven seasoning.

Air Seasoning took three months. The wood was stack logged such that free air could circulate through the timber vertically and horizontally. The plank was raised to keep the wood away from the vegetation damped ground. Plank and log ends were wrapped or sealed to prevent excessive moisture loss through the area. Oven seasoning of the wood took 24 h in an oven which was set at 103±2ºC. In air-oven seasoning, a stack of logs were placed outside on pallets in such a manner that air can circulate vertically and horizontally through the timbers, just for one and half months; the moisture content at the end of this first stage was about 50 to 55%. Then, oven (kiln) method followed which accelerated the process of removal moisture. Drying took 12 h. Oven temperature control was set at 103 ± 2ºC. Moisture content of specimens for all seasoning methods was monitored with a wood moisture meter until the EMC fell between 12-15%, dry basis.

For the oven-seasoned specimens, the moisture content (MC) was also monitored using the gravimetric method. The loss in weight during the seasoning process expressed as a percentage of the final oven-dry weight of the wood was taken as the moisture content of each test piece. The green weight (W) of the specimen was determined and it was then dried in an oven until a constant weight (D) was attained. The moisture content (MC) was then calculated according to the formula:

$$MC = \frac{W - D}{D} \text{x } 100\% \qquad 1$$

After the seasoning to an MC of 12 - 15% dry basis, the material was machined on a convectional lathe machine to the geometry and dimensions required by the fatigue testing machine, universal testing machine and hardness testing machine. Sequel to machining, the gauge portion of each specimen was polished in order to remove all forms of surface irregularities and discontinuities that were unavoidably introduced during machining.

Mechanical tests

Three mechanical property tests (compression, flexural and hardness tests) were carried out using the Universal Instron testing machine while the Avery-Dennison 7303 fatigue machine was used for fatigue test.

Hardness: the hardness test was made on specimens machined to dimensions 50 x 50 x 150 mm. Three replications were carried out for each seasoning method, resulting in a total of 12 specimens for the hardness test experiment. The hardness was assessed by the wood's resistance to impregnation of a special hardened steel tool rounded to a diameter of 11.3 mm which is embedded to half of its diameter. The rate of penetration of the hardness tool for each specimen was 0.11 mm/s. The applied load was immediately removed when the correct depth had been detected by a sensor fitted to the Instron machine.

Compression strength parallel to the grain: test specimens of dimensions 18.67 x 18.67 x 18.67 mm machined such as to be loaded parallel to grains were used. Three replications were carried out on specimens obtained from each seasoning method, resulting in a total of 12 specimens for the compression test experiment. The compressive strength was obtained by dividing the maximum load (P_{max}) recorded during test by the cross- sectional area (A) of the specimen.

Flexural strength perpendicular to the grain: test specimens of dimensions 4.28 x 11.44 x 65.00 mm machined such as to be loaded perpendicular to grains were used. Three replications were carried out on specimens obtained from each seasoning method, resulting in a total of 12 specimens for the flexural test experiment. The flexural strength perpendicular to the grain of each piece was calculated by dividing the maximum load (P_{max}) recorded during test by the cross-sectional area (A) of the specimen.

Fatigue test: the specimens were subjected to fatigue test at ambient temperatures under a constant amplitude loading of the Avery-Dennison 7303 machine. Stress levels were chosen at 60, 70 and 80 percent of ultimate strength of test material. The stress levels were chosen in accordance with the theory of finite life estimation as presented by Lipson and Sheth (1973). Tests were conducted on groups of raw, air-seasoned, oven-seasoned, air-oven-seasoned specimens; and the numbers of stress cycles to failures were recorded. At each stress level, five replications of the test were carried out on specimens obtained from each seasoning method, resulting in a total of 60 specimens for the fatigue test experiment.

Results and Discussions

Hardness: Figure 1 presents the hardness test result and average hardness strength of air, air-oven, air and raw specimens. From the results the overall average hardness values for the oven seasoned, air-oven seasoned, air seasoned and raw (unseasoned) specimens at 12% MC were 3650 N, 3190 N, 3033 N and 2600 N, respectively. Overall, the oven-seasoned teak is harder than the air-oven-seasoned, the air-seasoned and the raw teak in that order. According to Green (2001), hardness values for red oak and yellow popular at 12% MC are 5700 N and 2400 N respectively. Thus, on the average, red oak was harder than all seasoned and unseasoned teak woods which in turn are harder than yellow popular.

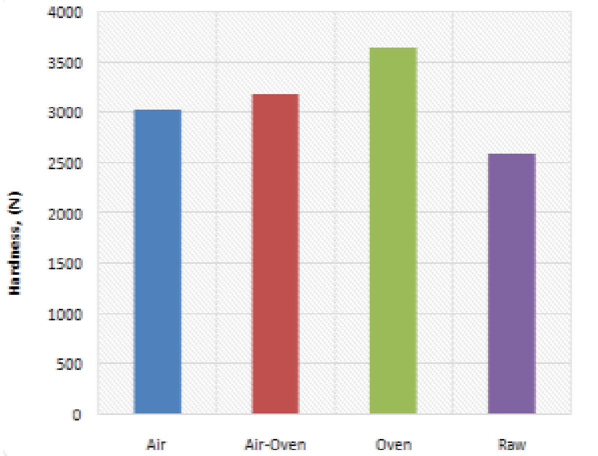

Fig. 1: Average hardness for seasoned and unseasoned test specimens

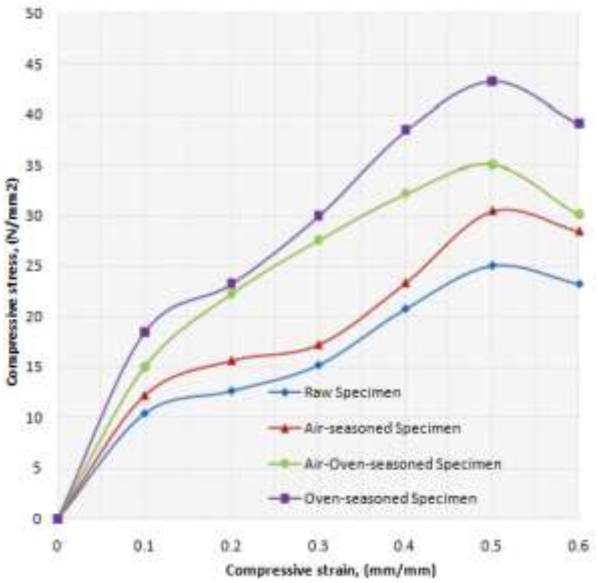

Fig. 2: Compressive stress-strain curves for seasoned and unseasoned teak

Compression strength: Figure 2 shows the compressive stress-strain curves for oven-seasoned, air-oven-seasoned, air-seasoned and raw teak. The means and standard deviations (in bracket) of maximum compressive strength for the oven-seasoned, air-oven-seasoned, air-seasoned and raw (unseasoned) specimens at 12 - 15% MC were 34.98 N/mm^2 (15.80 N/mm^2), 32.74 N/mm^2 (8.06 N/mm^2), 27.18 N/mm^2 (10.898 N/mm^2) and 19.79 N/mm^2 (7.16 N/mm^2), respectively. The means and standard deviations (in bracket) of load at maximum compressive stress at 12 - 15% MC for oven seasoned, air-oven-seasoned, air-seasoned and raw (unseasoned) teak were 12194.57 N (5507.89 N), 11412.29 N (2810.13 N), 9475.62 N (3798.94 N), 6897.67 N (2493.87 N), respectively.

The compression strength parallel to the grain at 12% MC have been classified according to Farmer (1972) as very low, low, medium, high, and very high when the strength values are under 20 N/mm^2, ranging from 20-35 N/mm^2, 35-55 N/mm^2, 55-85 N/mm^2 over 85 N/mm^2 respectively. This classification consequently rates the oven seasoned teak as medium in compressive strength, the air-oven and air seasoned teak as low and the raw unseasoned teak as very low in compressive strength.

Flexural strength: Figure 3 shows the flexural stress-strain curves for air-seasoned, air-oven-seasoned, air-seasoned and raw teak. The mean of the flexural strength perpendicular to the grain varied between the variously seasoned specimens. The observed means and standard deviations (in bracket) of maximum flexural strength for the oven-seasoned, air-oven-seasoned, air-seasoned and raw specimens at 12 - 15% MC are 111.82 N/mm^2 (49.62 N/mm^2), 110.08 N/mm^2 (41.94 N/mm^2), 87.39 N/mm^2 (17.34 N/mm^2), 86.05 N/mm^2 (7.80 N/mm^2), respectively. The mean and standard deviation (in bracket) of load at maximum flexural stress for the oven, air-oven, air seasoned and raw specimens at 12 - 15% MC were 240.34 N (106.64 N), 236.59 N (90.15 N), 208.70 N (37.27 N), 184.96 N (16.77 N), respectively.

The flexural strength perpendicular to the grain at 12% MC according to Farmer (1972), is rated very low when it is under 50 N/mm^2, low if it ranges from 50-90 N/mm^2, medium if it ranges between 90-120 N/mm^2, high and very high if it ranges from 120-175 N/mm^2 and over 175 N/mm^2, respectively. According to this rating, the maximum flexural strength at 12 – 15% MC obtained in this study is low for air seasoned and raw (unseasoned) teak and medium for oven seasoned and air- oven seasoned teak.

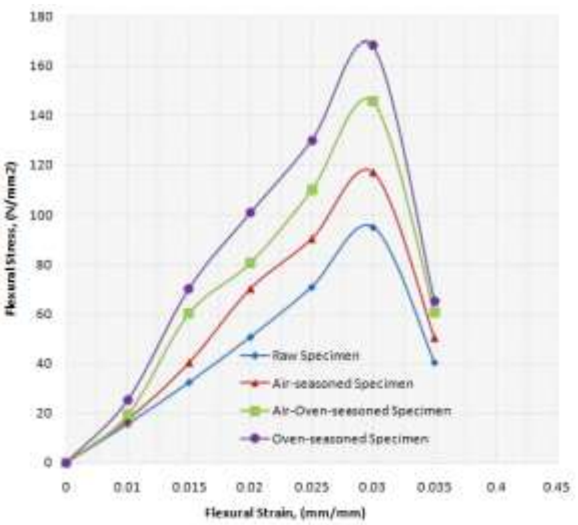

Fig. 3: Flexural stress-strain curves for seasoned and unseasoned teak tests

Table 1: Average fatigue life data for teak wood specimens

Seasoning treatment method	Average fatigue life (cycles)
Raw	**116**
Air	144
Air-Oven	239
Oven	370

Fatigue Life: the average fatigue life of the variously seasoned teak, as presented in Table 1, is a representation of the average fatigue behavior of the teak wood. On the basis of these data, it is clearly evident that the oven seasoned teak possesses the highest average fatigue life (the highest number of stress cycles to failure) followed by air-oven-seasoned, air-seasoned and raw specimens in that order.

Conclusion

The results of this study show that seasonings significantly influence mechanical properties of teak. It is clearly evident that generally, oven seasoned teak possesses the highest fatigue life and compressive, flexural and hardness strengths, followed by air-oven-seasoned, air-seasoned and unseasoned raw teak in that order. Also, it may be concluded that the shorter the time spent for seasoning to attain a given equilibrium moisture content, the stronger the teak becomes. However, provided there is time for seasoning, teak wood may be air-seasoned before it is subjected to any engineering usage because of the high cost of oven-seasoning and air-oven seasoning.

Acknowledgement

The authors acknowledge the facilities support at Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

Conflict of Interest

Authors declare that there is no conflict of interest in this study.

References

Baradan B 2003. *Materials for Civil Engineering.* DEU Engineering Faculty Press, Turkish.

Dahunsi BIO & Adetayo OA 2015. Burning characteristics of some selected structural timbers species of Southwestern Nigeria. *J. Mechanical and Civil Engr.* (IOSR-JMCE), 12(4): 112-120, www.iosrjournals.org

Dinwoodie JM 2001. Construction Materials-Their Nature and Behavior. Taylor and Francis Group, London and New York.

Dowling, N. E., (2007. *Mechanical Behaviour of Materials*, Pearson Prentice Hall, New Jerse, 3rd Edition, pp: 7 – 9.

Egbuchua CN & Bosah BO 2011. Characterization of some forest soil under teak (*Tectona grandis*) plantation in a humid forest region of Nigeria. *Int. J. Sci. and Nature* (IJSN), 2(3): 821 – 825.

Erdogan TY 2002. Materials of Construction. METU Press, Ankara.

Guzmán N, Moya R & Murillo O 2017. Evaluation of Bent Trees in Juvenile Teak (*Tectona grandis* L.F.) Plantations in Costa Rica: Effects on Tree Morphology and Wood Properties, Forests, 8, 79-85, MDPI, Basel, Switzerland.

Hossain MB & Abdul ASM 2012. Mechanical Properties and Durability of Some Selected Timber Species. *Malaysian J. Civil Engr.*, 24(1): 67-84.

Izekor DN & Fuwape JA 2011. Performance of teak (*Tectona grandis* L.F) wood on exposure to outdoor weather conditions. *J. Appl. Sci. Environ. Mgt.* JASEM, 15(1): 217– 222, www.bioline.org.br/ja.

Izekor DN, Fuwape JA & Oluyege AO 2010. Effects of density on variations in the mechanical properties of plantation grown *Tectona grandis* wood. *Archives of Applied Science Research*, 2(6): 113-120, *http://scholarsresearchlibrary.com/archive.html*.

Keyser CA 1986. *Materials Science in Engineering*. Charles E. Merrill Publishing Company, Columbus, USA.

Lipson C & Sheth NJ 1973. *Statistical Design and Analysis of Engineering Experiments*. McGraw Hill Book Company, New York, pp: 262 – 290.

Loulidi I, Famiri A, Chergui M & Elghorba M 2012. The physical and mechanical properties of Eucalyptus hybrid *E. camaldulensis x E. grandis:* Comparison with its parental specie. *Int. J. Engr. and Sci.*, 1(1): 01-07, www.researchinventy.com

Olaoye KO, Ariwoola OS & Ibiyeye DE 2016. Selected physico-mechanical properties of aningeria robusta (A.Chev) wood for the manufacture of talking drum. *Journal of Agriculture and Veterinary Science* (IOSR-JAVS), 9(2): 57-63, www.iosrjournals.org

Rafael SM, Roger M, Alexander B, Guillermo GT & Rafael CF 2015. General, physical and mechanical properties, termites resistance and drying defects of lumber of *Tectona grandis* from plantations of different climatic and sites fertility condition. *J. Indian Acad. Wood Sci.*, 12(1): 63–73, DOI 10.1007/s13196-015-0145-3

Rokeya UK, Akter HM, Rowson AM & Paul SP 2010. *Physical and mechanical properties of (Acacia auriculiformis × A. mangium) hybrid acacia. J. Bangladesh Acad. Sci.*, 34(2): 181-187.

Saravanan V, Parthiban KT, Thirunirai R, Kumar P, Vennila S & Umesh KS 2014. *Comparative study of wood physical and mechanical properties of Melia dubia* with *Tectona grandis* at different age gradation. *Res. J. Recent Sci.*, 3: 256-263.

Solórzano SN, Moya R & Chauhan S 2012. Early genetic evaluation of morphology and some wood properties of *Tectona grandis* L. clones. *Silvae Genetica*, 61: 58 – 65.

Taylor GD 2002. *Materials in Construction Principles, Practice and Performance*, Pearson Education Limited, Malaysia.

Vasubabu M, Harish SB, Narendrudu T & Anjaneyulu CH 2016. Alkaline treatment effect on mechanical properties *Tectona grandis* wood species. *Int. J. Chem. Tech. Res. IJCRGG*, 9(05): 314-320.

Victor GC, Linéia RZ, Ricardo JK, Marcio PR & Morgana CF 2015. Influence of the age on specific gravity and janka hardness in the wood of teak (*Tectona grandis* L.F.) for floor. *Australian J. Basic and Appl. Sci.*, 9(35): 300-305, www.ajbasweb.com.

White KJ 1991. *Teak Some Aspects of Research and Development*. FAO, Regional Office for Asia and the Pacific, (RAPA), Bangkok.

Widehammar S 2004. Stress-Strain Relationships for Spruce Wood: Influence of Strain Rate, Moisture Content and Loading Direction. *Society for Experimental Mechanics*, 44: 44-48.

Yulianto PP, Akihisa K, Satoru M & Kohei K 2012. Study on mechanical properties of tropical timber hardwood species: Promoting javanese inferior timbers for traditional wooden houses. *Wood Research Journal*, 3(1).