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# INFLUENCE OF TIMBER AGE ON THE STRUCTURAL STRENGTH OF NIGERIAN HARDWOOD SPECIES

**Michael Anthony Christopher Williams**

School of Environmental and Structural Engineering, University of Birmingham, United Kingdom

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**Abstract**

Timber is a widely used construction material known for its variability in physical and mechanical properties due to its heterogeneous nature. Its strength and durability are not uniform, as they are influenced by several factors including species type, age, site conditions, and environmental factors. Among these, age plays a critical role in determining the structural performance of timber, particularly its compressive, shear, and bending strengths. Existing studies have shown that immature timber often exhibits reduced strength and durability, while over-aged timber may experience decay and loss of structural integrity. The mechanical properties of wood are further affected by environmental growth conditions such as climate, soil characteristics, slope, and altitude, which influence annual ring development and overall timber quality.

In Nigeria, the increasing demand for construction materials due to rapid urbanization and expansion of the building industry has led to the over-exploitation of traditional timber species such as Iroko, Mahogany, and other high-quality hardwoods. This scarcity has compelled builders and engineers to increasingly rely on alternative and sometimes immature timber species for structural applications. However, the use of such materials raises concerns regarding safety, durability, and long-term performance in construction.

This study examines the influence of age on the structural durability and strength characteristics of Nigerian timbers. It synthesizes findings from previous research to establish the relationship between timber age and mechanical performance, highlighting the existence of an optimal age range for maximum strength. The study further emphasizes the need for proper timber selection and sustainable harvesting practices, recommending that timber utilization in construction should be guided by age-related strength performance to ensure safety and reliability in structural applications.

**Keywords:** Timber strength; Structural durability; Age effect; Nigerian timber; Mechanical properties

## Introduction

Timber is a complex building material owing to its heterogeneity and species diversity. Timber does not have consistent, predictable, reproducible and uniform properties, as the properties vary with species, age, site and environmental conditions (Young, 2009). Different wood species have varying strength properties, these properties are affected by the Age of timber. For instance, Wayne (1991) described how agent such has age of timber causes decay and strength loss in timber whenever they are used immature. Adebara *et al.* (2014) stated that the quality of timber in Minna is affected by species age, site and environmental condition. Umit *et al.* (2017) also recognized when comparing the strength of Oak timber to standard sized sample, factors such as tree age and growth conditions such as climate, soil characteristics, slope and altitude affect the annual ring width and the mechanical properties of wood. Further, Ojo and Idieunmah (2021) studied different ages of Iroko (*Chlorophora*

*Excelsa*), Nigerian Mahogany (*Khaya Anthotheca*) Ita (*Celti Mildbraedi*) timber. They showed that there is maximum age for compression, shear and bending strength of these timbers beyond which the strength will start diminishing. They concluded that deforestation of timber should a function of age of timber.

More so, demand for quality timber for construction is on the rise in Nigeria due to a boom in the building construction industry. With over-exploitation and scarcity of traditional timber species such as Mahogany, Iroko and other timber species, this has become a concern. Builders and Engineers have resorted to using timber not used originally as structural materials and immature (Ojo & Idieunmah, 2021).

*Brachystegia eurycoma* is called by different names by different tribe in Nigeria, such as Okuen (Edo), Okung (Efik), Achi (Igbo) (Bafor *et al.,* 2017), Dewen (Bini), Akpakpa or Apaupan (Ijaw) and Eku or Akalado (Yoruba) (Rahmon *et al.,* 2017). It is an economically valuable tree mostly grown in tropical rain forest of West Africa (Ndukwu, 2009). It is a large tree and its branches are spreading in nature and either irregular or twisted in shape (Bafor *et al.,* 2017). Studies on *Brachystegia eurycoma* includes determination of its physical properties (Ndukwu, 2009), Isolation, Characteristics and anti-oxidant activity of a Furo- Chromen-4-one from its seed (Igwe & Okwu, 2009), anti-diarrheal activity of the stem bark extract (Bafor *et al.,* 2017) and its characterization and grading (Rahmon *et al.,* 2017). However, none has compared the age and strength of the timber.

Sapele (*Entandrophragma Cylindricum*) is a species of mahogany produced widely in West and Central Africa. It occurs in drier habitats, including abandoned field but does not respond to burning. It is a large tree growing to 50m in height with flowers growing directly from the trunk and major branches (Dadzie & Amoah 2015; Rogers 2015). There is paucity of literature on *Entandrophragma Cylindricum*. Melina (*Gmelina Arborea)* is a fast-growing forest species that produces high quality timber used for manufacturing (Vallejos *et al*., 2015; Ogunsanwo & Akinlade, 2011). This species is widely used in commercial quantity in tropical countries in Africa and South America for lumber, pulp, and energy production (Dvorak, 2004; Tenorio *et. al.,* 2016). It has been used for commercial purposes in countries like Costa Rica (Dvorak, 2004) and Nigeria for structural purposes. Therefore, this study assessed on the effect of Age of timber on the structural strength of different species of timber. The timber studied are *Brachystegia eurycoma* (popularly called Eku in South Western Nigeria), *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina).

**Materials and Methods Materials**

A reconnaissance survey was carried in government forest-reserve in Ado-Ekiti. The reserve is divided into two: natural and plantation forests. The natural forest is made up of indigenous species such as Eku (Brachystegia), Sapele (Entandrophragmacylindricum), Iroko (Militia Excelsa), Mahogany (KhayaAnthotheca),Ita (CeltisMildbraedii), among others while the plantation forest is made up of mainly exotic species such as Melina (Gmelinaarborea) and Teak (Tectonagrandis). Lots of hardwood species were discovered,

out of which three most utilized were chosen for the research. They are Sapele (Entandrophragmacylindricum); Eku (Brachystegia); Melina (Gmelinaarborea).
The researchers had to follow the saw miller to government forest reserve where the log of wood was fetched newly, so that the annual growth ring can be counted easily. Magnified glass of about 60mm was used to identify tiny pieces of wood or lumber for easy counting.
Timber section samples were obtained at the breast height (log 1) of the species for all specimens for the determination of compressive strength parallel to grain and static shear strength test are being replicate to derive average mean of each sample age, the Compressive strength test on 20 x 20 x 60mm, Static Shear strength parameters on 20 x 20 x 20mm, while
Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were carried out on the 20 x 20 x 300mm samples in accordance with BS 5268: part 2 (2002). The samples were tested at the Timber Mechanics Unit, Forestry Research Institute of Nigeria (FRIN) situated at Jericho, Ibadan, Oyo State where the Hounse Field Tensometer machine was used.

**Methods**

*Determination of age of timber*

When the seasonal growth commenced the dominant function is conduction while in the latter part, the dominant factor is support. This change in emphasis manifest with the presence of thin-walled tracheid (about 2micrometer) in the early part of the season (the wood being known as early wood) and thick-walled (up to 10micrometer), slightly longer (10%) in the latter part of the season (the late wood). The combination of the early wood and late wood constitute the annual growth ring, and this is produced yearly (Dinwoodie, 2011; Ojo & Idieunmah, 2021). In other to select each sample of timber for this study, the annual growth rings (consisting of early wood and late wood) were counted. The annual growth rings are easily counted if the logs were fetched newly, although magnifying lens was used for easy counting. For the purpose of this research, sampling employed is sequential sampling. This is because different ages of timber were picked sequentially, although in order to give a distinct difference in strength value a minimum of five years space were given for each timber. In addition, determination of timber ages was according to availability. Some timbers were only available for the ages sampled.
Mechanical parameters of timber sections were determined with the appropriate sizes in accordance with BS 5268: part 2 (2002). Timber section samples were obtained at the breast height of the species for all specimens.

*Determination of compressive strength parallel to grain*

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 crosssectional area of the test specimen to obtain value for maximum compressive strength parallel to grain.

The formulae in Equation (1), below was used to compute the maximum compression strength parallel to grain, using standard size of 20 x 20 x 60 mm. (Ogunsanwo & Akinlade, 2011). Different ages of timber tested are 30, 35, 40, 45 and 50 years for *Brachystegia eurycoma(*Eku*)*, 20, 30, 40, 50, 60 and 70 years for *Entandrophragma cylindricum* (Sapele) and 5, 10, 15, 20 and 25 for *Gmelina Arborea* (Melina).
The compressive strength was determined according to
BS 5268: part 2 (2002) MCS//= $\frac{p}{bd}\ N/mm^2$

Where: p = load (N) b = breath of the sample (mm) d = thickness of the sample (mm) bd is the cross-section area(A)

*Determination of the bending strength*

The bending strength of wood expressed as Modulus of Rupture (MOR), which is the equivalent fibre stress in the extreme fibres of the specimen at the point of failure. This was then calculated using the expression in Equation (2) below. Same ages variation tested for compressive strength were maintained in the bending strength for *Brachystegia eurycoma* (Eku), *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina). The sample size tested is 20 x 20 x 300mm.

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

Where P is load in Newton (N) L is length of sample in (mm) b is breath in (mm)
d is width in (mm)

*Determination of shear strength*

The shear strength was computed using sample size 20 x 20x 20 mm (Rahmon *et al.,* 2017) with the formula in Equation (3) below. The timber samples and timber ages tested are the same as tested for compressive and bending strength.

Shear Strength = $\frac{p}{bd}\ N/mm^2$ (3)

Where p = load (N) b = breath of the sample (mm)
d = thickness of the sample (mm)

**Results and Discussion**

**Compressive strength parallel to grain** Tables 1, 2, and 3 presented the results of the mean compressive strength parallel to grain for *Brachystegia eurycoma*(Eku), *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina). The maximum value as observed were 49.31N/mm$^2$ (at 45 years), 45.89N/mm$^2$ (at 60 years), and 11.30N/mm$^2$ (at 25years) for *Brachystegia eurycoma*(Eku), *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina) respectively. The results show that *Brachystegia eurycoma* (Eku) is better in compression.

However, previous studies gave MCS values as follows, Iroko as 47N/mm$^2$; Nigerian Mahogany as 41N/mm$^2$; Ita as 44N/mm$^2$ (Ojo & Idieunmah,2021),

Bush Mango 65.58N/mm$^2$ and Ire 19.32N/mm$^2$ (Rahmon *et al.*, 2020), Apa 28.59N/mm$^2$ (Adefemi, 2015). The results were within 71.97N/mm$^2$ >20.01N/mm$^2$ except for *Gmelina Arborea* (1) (Melina) where the ages tested are low. According to BS 5286-2 (2002), these timbers are well above the maximum stress (D70) stated in the code for Hardwood except Melina which can be classified as D35.

**Bending strength or modulus of rupture (MOR)** In Tables 1, 2, and 3, the maximum Bending Strength at 35years is 187.55N/mm$^2$ for *Brachystegia eurycoma*, at 70years is 278.79N/mm$^2$ for *Entandrophragma cylindricum* (Sapele) and at 20years is 176.36N/mm$^2$ for *Gmelina Arborea* (Melina). The results reveal that among the three, *Entandrophragma cylindricum* (Sapele) has the highest bending strength of 278.79N/mm$^2$. Previous results by Ojo & Idieunmah (2021) show Iroko has 95.90N/mm$^2$; Nigerian Mahogany has 52.00N/mm$^2$; Ita has 77.20N/mm$^2$. Rahmon *et. al.*, (2020) reported the bending strength value of 190.40N/mm$^2$ and 60.33 N/mm$^2$ for Bush mango and Ire respectively, while 50.13N/mm$^2$ bending strength was reported for Black Afara by (Kaura *et.al.*, 2020). Duju and Badorul (2002) reported bending strength of 65.14 N/mm$^2$ and 61.32N/mm$^2$ for D. Fusca and D. Rappa but 39.36 N/mm$^2$ was reported for Ahun (Mohammed 2014).

**Shear strength**

The Maximum Shear Strength results for all the three timber samples (Table 1, 2 and 3) were *Brachystegia eurycoma* (50 years) is 10.05 N/mm$^2$,

*Entandrophragma cylindricum* (Sapele) (70 years) is 9.22 N/mm$^2$, and *Gmelina Arborea* (Melina) (25 years) is 10.91 N/mm$^2$. *Gmelina Arborea* (Melina) is better in shear resistance. Previous results however reported Iroko had 14.00N/mm$^2$; Nigerian Mahogany had 8.14N/mm$^2$; Ita had 13.40N/mm$^2$ (Ojo & Idieunmah, 2021); Bush Mango is 4.48 N/mm$^2$ and Ire is 3.69 N/mm$^2$ (Rahmon *et al.*, 2020).

According to Table 1, compressive strength of *Brachystegia eurycoma* (Eku in Yoruba) increases as the age increase until 50 years when there was a decline in strength. This is due to the timber tested, more heartwood was produced as the age increased which is poor in compression. In the same vein, the bending strength value is highest at 35years irrespective of the timber tested. The shear strength showed no significant difference, as the age increased strength increased.

**Conclusion**

It could be concluded that the older the age of timber the better the strength properties. However, timbers are generally good in bending strength. Eku timber is better among the three timbers studied in compression, Sapele is better in bending strength and there is no significant difference in the shear strength. In addition, the three timbers showed good strength properties when compared to other timber samples used in previous studies. This information on the strength properties could aid the choice of any of these three timbers for use as structural member. Further, there is a need for more tests to be conducted at higher age for all the timbers to have more information on shear strength to ascertain the age of the true maximum shear strength above which there will be a decline, specifically for compressive strength of Melina and Bending strength of Sapele.

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