

A Comparative Study into the Engineering Properties of Neem Wood from Ghana

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How to cite this paper: Quartey, G.A., Eshun, J.F. and Attitsogbui, E. (2021) A Comparative Study into the Engineering Properties of Neem Wood from Ghana. *Materials Sciences and Applications*, 12, 475-483.

<https://doi.org/10.4236/msa.2021.1211031>

Received: September 30, 2021

Accepted: November 12, 2021

Published: November 15, 2021

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Abstract

A study into the mechanical properties of Neem wood was done to explore the possibility of its usage as a structural material. This paper presents the results of some investigations into the strength properties of Neem (*Azadirachta indica* A. Juss.) and compares them with those of Odum (*Milicia excelsa*) and European Oak (*Quercus* spp.) which are well known structural wood species in Ghana and Europe, respectively. The properties were determined using British (BS 373, 1957) and American timber testing specifications (ASTM D143, 1983) using testing methods for small, clear specimens of wood. The results showed that at 12% moisture content the wood has a density of 740 kg/m³ with a mean modulus of rupture of 8317 N/mm², compressive strength parallel to the grain of 318.8 N/mm², modulus of elasticity of 8644 N/mm², and shear strength parallel to the grain of 17 N/mm². The bending strength (MOR) of Neem is about 30% lower than that of Odum and about 2% higher than Oak. The modulus of elasticity of Neem is about 39% lower than Odum and 43% lower than Oak. The strength properties in the present work suggest that the wood of Neem has a potential for utilisation in structural applications.

Keywords

Azadirachta indica, Modulus of Elasticity, Modulus of Rapture, Lesser-Known Wood, Structural Utilisation

1. Introduction

The utilisation of well-known wood species for structural applications has gone on for ages. Ghana's tropical forest continues to face dangers and severe threats of deforestation and degradation. Ghana is currently experiencing alarming deforestation and forest degradation with an annual rate of 2% (about 135,000 hectares/year) of forest cover loss through anthropogenic causes [1]. Hence

there is an imperative need to assess the strength properties of lesser-known timbers to determine their usage in the wood industry and adopt species whose strength falls within the acceptable range for structural works. This will ultimately reduce the over-exploitation of the well-known species, ensuring sustainability whilst keeping the industry thriving. As opined by [2], the present state of Ghana's forest has resulted in the adoption of more strict control on timber exploitation, which has affected both the furniture and the construction industries. Falling volumes of timber in Ghana, coupled with a rise in illegal lumbering, have compelled the former net timber exporter to import timber to augment the demands of the industry [3].

In Ghana, timber is harvested from two main sources, namely: timber production forest reserves and areas outside forest reserves commonly referred to as off-reserve areas [4]. The first forest policy of Ghana, drawn in 1948, provided for a progressive utilization of the off-reserve timber resource, without replacement and assumed the confinement of forestry practices to the permanent forest estates. However, later developments showed that timber from off-reserve areas will be needed on a continuous basis to supplement production from the forest reserves which are capable of an annual production of only 500,000 m³ of wood. Ghana's off-reserve area is represented by a total land area of about 5.482 million hectares in the High Forest Zone. This is made up of 1,618,738 ha in the Wet/Moist Evergreen, 1,559,236 ha in the Moist Semi-deciduous Southeast, 1,071,758 ha in the Moist Semi-deciduous Northwest and 1,232,446 ha in the Dry Semi-deciduous [5]. In 1996, off-reserves supported a total tree standing volume of 95 million m³ which decreased to 37 million m³ by 2005 [5]. In the late 1980s and early 1990s, 80% of recorded timber production was from the off-reserve areas. Presently, about 30% of the recorded harvest originates from the off reserves. The resource is, however, still important to the timber industry and the treasury of the constitutional beneficiaries. Between 2003 and 2006, the off-reserve [6] resource generated between 19% and 27% of the annual timber revenue in Ghana [7].

In the tropics, one of the abundant but under-utilised species is the Neem (*Azadirachta indica* A. Juss) found both in the forest and off-reserve areas. In the almost 82,000 km² forest zone representing about 34% of Ghana's total land-mass, there exist over 420 hardwood species [8]. Besides, National volume estimates indicate that several hardwood species are being under-utilised, whilst the primary species such as Odum (*Milicia excelsa*) are over-exploited [8]. Neem (*Azadirachta indica* A. Juss) is an attractive broad-leaved evergreen tree that can grow up to 30 m tall and 2.5 m in girth. This species is abundant not only in the forest but is said to grow "almost anywhere" in the lowland tropics [9]. Neem often grows rapidly. It can be cut for timber after just 5 - 7 years. Maximum yields reported from northern Nigeria (Samaru) amounted to 169 m³ of fuel-wood per hectare after a rotation of 8 years. Yields in Ghana were recorded between 108 and 137 m³ per hectare at the same time [9].

The Neem tree (*Azadirachta indica* A. Juss.) is widely known for its medicinal properties [10]-[18]. It is also exceptionally durable due to the presence of a

neem component, azadirachtin, which disrupts the metamorphosis of insect larvae. By inhibiting moulting, it keeps the larvae from developing into pupae, and they die without producing a new generation. Also, azadirachtin is frequently so repugnant to insects that scores of different leaf-chewing species—even ones that normally strip everything living from plants—will starve to death rather than touch plants that carry traces of it [9]. Another Neem substance, salannin, is a similarly powerful repellent. It also stops many insects from touching even the plants they normally find most delectable when Neem is sprayed on them.

For constructional work, mechanical tests of timber are most important [19]. It assesses the various strength properties, such as compressive or crushing strength, shearing strength, bending strength, stiffness strength, etc. These properties inform practitioners of the timber's load-bearing capacity. According to [20], citing from [21], knowledge of the mechanical properties of wood allows for better optimisation and the minimal use of raw material. The study of the mechanical properties of timber species is therefore indispensable if the species are to be selected and used in the various domains of engineering [20]. The knowledge of the mechanical properties of timber species allows for the characterization of their behaviour under different applications [22]. The designer of a building or any structural product must consider the types of loads the individual structural members, or groups of members, must carry so that having selected timber possessing known strength properties, the required sizes of the members can be computed [23]. However, there is a paucity of technical data on its strength properties and possible utilisation in structural applications such as furniture. Furniture is usually constructed from short-length components with small cross-sections. From an engineering point of view, the timber used for highly stressed furniture components (e.g., chair legs and rails, sofa rails, bed frame) should be defect-free.

This study investigates the strength properties viz density at 12%, Modulus of Elasticity (MOE) and Modulus of Rapture (MOR), shear and compression strength of Neem tree form Ghana. This is to ascertain its usefulness as a structural element to augment the demand in the timber industry. The study specifically seeks an answer to the following questions: 1) Whether the strength properties of Neem are within the acceptable range of strength values of wood used for structural applications? 2) Can the strength values of Neem be comparable to the already existing timber species such as Odum and Red Oak or European oak (*Quercus robur*)?

2. Materials and Methods

2.1. Sample Preparation

Wood samples for the investigation were obtained from three trees felled in Beposo off forest reserve, a suburb in the Western Region of Ghana. The preparations of the test specimens were based on BS 373:1957 [24]. The boards were cut, planed, and carefully examined for visible defects. From these boards, test specimens were prepared for the determination of basic density, static bending

(Modulus of Elasticity, Modulus of Rupture), and compression parallel to the grain. The Instron Universal Testing Machine, 50KN was used for the testing. Twenty specimens were tested for each property which was randomly selected and dressed, and tests were conducted at the timber testing laboratory of Centre for Scientific and Industrial Research of the Forestry Research Institute of Ghana (CSIR-FORIG), Fumesua-Kumasi of Ghana. The density of the timber species which was determined according to ASTM D 143-52 [25], which was based on the volumes of the specimens at the time of the test and their weights when oven dried. The test specimens were 300 mm in length with a cross-section of 50*50 mm.

2.2. Determination of Strength Properties

Static bending: The strength properties determined from the static bending test were Modulus of Elasticity (MOE) and Modulus of Rupture ((MOR). The test specimens were 300 mm long, with a 20*20 mm cross-section as recommended in BS 373:1957 [24] for clear specimens [26] [27] [28]. Twenty specimens were prepared for each set of test variables. The actual specimen dimensions were measured with digital calipers calibrated with a 25 mm \pm 0.1 mm slide. The specimens were stored in a room of relative humidity of 50% and a temperature of 23° Celsius for three weeks and equilibrated to approximately 12% Moisture Content (MC). The actual moisture content was determined after testing by using the moisture meter method and validated by the oven-dry method. The mean value for each set of the specimens was recorded.

Compression strength parallel to the grain: The compression strength parallel to the grain test was performed according to BS 373:1957 [24]. 300*50*50 mm specimens were used, and the test was performed on a compression universal machine. As in the case of the static bending test, the specimens were stored in a room of relative humidity of 50% and a temperature of 23° Celsius for three weeks to allow the moisture content to equilibrate to about 12%. The actual moisture content of the specimens was determined by an electrical moisture meter after testing. Specimen dimensions were measured to the nearest 0.001 mm before the testing.

Data analysis: The data were analysed using descriptive statistics, one-Way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS).

3. Results and Discussion

Mechanical Properties of Neem

Mean values of the mechanical properties of Neem were calculated and are presented in **Table 1**. At a moisture content of 12%, it had a density of 740 kg/m³ with a compression parallel to the grain of 39.82 Mpa. The MOR and MOE were 54.07 and 8317 Mpa respectively. The density of Neem was found to be 740 kg/m³ which is within the range reported by [29]. This density is significant

since in general, the strength of wood increases with increasing density [30]. According to [31], in general, depending on the species, wood has MOE and MOR values of between 5515 Mpa - 17,236.9 Mpa (800,000 - 2,500,000 psi) and 34.47 Mpa - 103.42 Mpa (5000 - 15,000 psi), respectively. The MOR and MOE values of Neem (Table 1) are within the range acceptable for use in construction. The MOR of Neem of 54.07 Mpa is even higher than the MOR of Red Oak of 53 Mpa with its maximum value of 76.56 Mpa. The shear parallel to the grain is 17 N/mm². The coefficient of variation was in the range of 34% to 11% for the various properties. The results have also been compared, with published data by U.S. Forest Products Laboratory and Chris Messier—Messman [32] on Odum and European oak at 12% moisture content (Table 2) and depicted graphically in (Figure 1). Statistical analysis (One-Way ANOVA) indicated, however, that the differences among the properties of the wood are not statistically significant with the adjusted sums of squares (AdjSS) giving the p-value (p-value = 0.00) (Table 3). The bending strength (MOR) of Neem is about 30% lower than that of Odum and about 2% higher than Oak. The modulus of elasticity is about 39% lower than Odum and 43% lower than Oak. Nonetheless, Neem possesses comparable strength as Odum and Oak. The compression strength of the three species was not significantly different (Figure 1).

Table 1. Bending, compression and shear strength properties of Neem.

	Moisture Content	Density	Compression parallel to the grain	MOR	MOE	Shear parallel to the grain
	%	Kg/m ³	(Mpa)	(Mpa)	(Mpa)	N/mm ²
Mean	12	740	39.82	54.07	8317	864
Standard deviation			7.16	18.63	1083	137
Minimum value			30.7	15.25	6562	566
Maximum value			54.45	76.56	10,210	1190
Co. Var (%)			17.97	34.45	13.03	11.72

Table 2. Comparative strengths values of Neem, Odum, and Red Oak.

Wood species	Moisture Content (%)	Density Kg/cm ³	Static Bending, Modulus of Elasticity (Mpa)	Impact Bending, Height of drop causing failure (Mpa)	Compression Parallel to Grain, Max crushing strength (Mpa)
Neem	12	740	8317	54.07	39.82
Odum	12	660	12,840	87	54
Oak, Red	12	675	10,600	53	46.3

(Source: Values for Odum and Red Oak taken from U.S. Forest Products Laboratory and Chris Messier—Messman).

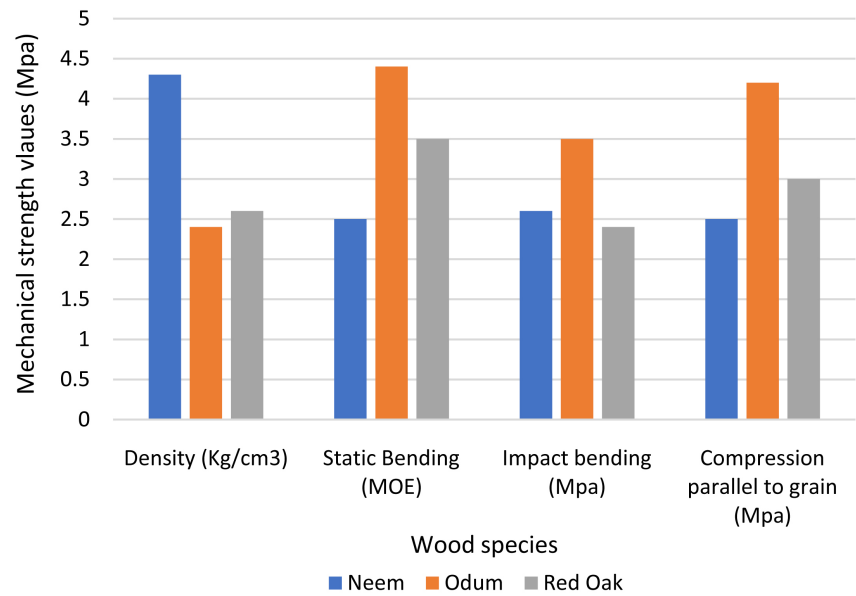


Figure 1. Comparative strengths of Neem, Odum, and Red Oak.

Table 3. Analysis of variance.

Source	DF	Adj	SS	Adj	MS	F-Value	p-Value
Factor	4	1154	8913	2887	228	761.47	0.000
Error	95	360	207	3792			
Total	99	1190	9120				

Model Summary			
S	R-sq	R-sq (adj)	R-sq (pred)
61.5764	96.98%	96.85%	96.65%

Means				
Factor	N	Mean	StDev	95% CI
load at	20	42.51	6.49	(15.18, 69.85)
displacement	20	3.064	1.334	(-24.270, 30.399)
stress	20	17.005	2.595	(-10.330, 44.339)
strain	20	0.06129	0.02668	(-27.27342, 27.39600)
modulus	20	864.4	137.5	(837.1, 891.8)

4. Conclusion

The results show that the strength properties of Neem are within the strength values for wood for structural purposes. Neem wood also compares favourably with those of Odum and European oak and can be used for some structural applications where these two known kinds of wood are used. Since Neem is widely

distributed in both the forest and off forest areas and it is also durable coupled with its strength properties, it seems to justify its use for structural applications and general construction works.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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