CHARACTERISATION OF THE NIGERIAN-GROWN *EUCALYPTUS CAMALDULENSIS* TIMBER SPECIE ACCORDING TO EN 338 (2009) AND NCP 2 (1973)

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ABSTRACT

In this work, the Nigerian-grown Eucalyptus camaldulensis timber specie was characterized based on the NCP 2 (1973) and EN 338 (2009) code. The specie was obtained from timber markets in Sabon Gari, Zaria and Fanteka, Kaduna, North-western Nigeria. The elastic modulus, bending strength (using four-point flexural test) and density of the timber as stated in EN 384 (2004) were determined at their various moisture contents with which other respective derived properties were obtained. The experiments were carried out using a 500 kN capacity Universal Testing Machine at the Department of Civil Engineering laboratory, Ahmadu Bello University, Zaria. Results obtained indicate that the mean density of Eucalyptus camaldulensis timber is 975.9 kg/m^3 at an adjusted moisture content of 18%. The flexural strength of Eucalyptus camaldulensis timber species was determined to be 69.02 N/mm^2 and the mean Modulus of Elasticity of 5409.4 N/mm^2. With these results, Eucalyptus camaldulensis was allocated to strength class D60 based on EN 338 (2009) and strength class N1 based on NCP 2 (1973) classification systems which makes it suitable for bridge construction, railway sleepers, pier construction as well as heavy duty flooring.

Keywords: *Characterization, Eucalyptus camaldulensis, EN 338 (2009), NCP 2 (1973), Grading, Mechanical properties, Physical properties.*

INTRODUCTION

With reference to its structural qualities and wide availability as a natural resource in various climates worldwide, timber is recognized as an effective construction material. There is potential for this natural resource to be continuously and uninterruptedly available in the future thanks to effective management practices (Porteous and Kermani, 2007). Timber is one of the numerous sustainable resources that Nigeria, a developing country, has. Timber is an eco-friendly building material that has low labor, cost, and energy needs during manufacture. It also works well as a carbon absorber. Because it comes from sustainable sources and has a low embodied energy, timber is recognized as a sustainable building material (Chanakya, 2009; Porteous and Kermani, 2007; Robert, 2009), as well as additional attributes. This suggests that compared to other building construction materials, timber constructions need fewer carbon-emitting heating and cooling systems. Timber construction amongst other construction materials has a negligible negative environmental impact due to its low energy use and low level of pollutants associated with its fabrication and construction

(Porteous and Kermani, 2007). Timber has an advantage over steel in terms of strength to weight ratio since it is stronger per unit of weight than steel (Porteous and Kermani, 2007). Because of its anisotropic nature, timber exhibits greater strength along its grain than across it or perpendicular to it

(Adeyemi, 2016). Timber is still frequently used in building, including for floors, paneling, doors, interior and exterior woodwork, furniture, and other purposes in a typical home (FPL, 1999). Traditionally, large timber frames have been used to construct timber structures, and the walls have been made of a variety of materials, including split logs and interlaced branches in the first iterations of these types of constructions (as early as 6500 BC), and later plastered panels and bricks (Foliente et al., 2001). Roof structural systems, which have traditionally been composed of structural timbers as integral elements of buildings, are still widely used today, notably in Nigeria. For a variety of structural systems used in construction, material-based experts and designers have continuously created and adapted newer forms of materials that can be used in conjunction with traditional building materials like steel, concrete, and sawn timber. This has sparked the development of stronger, larger, more durable, energy-efficient, and aesthetically pleasing structures (Jobin, 2007). Many studies have been conducted to establish the characteristics, grades, and attributes of timber. According to Zziwa et al. (2009), Ugandan building construction uses defined timbers. According to the applicable Ugandan code of practice, seventeen timber species were identified. In light of the anticipated loading categories in building construction, four strength classes—SG4, SG8, SG12, and SG16—were established and publicized as a result of the study. Mohd et al., (2013) presented a paper that focuses on measuring the flexural strength and modulus of elasticity of structural-size timber planks using tiny transparent test specimens. The standard of tiny clear specimen values was used to evaluate stresses. According to the research, larger planks have lower bending strength than smaller ones, and in terms of elastic modulus, larger planks often have greater values than tiny planks. In a comparative study of the mechanical properties of Gmelina arborea, Parkia biglobosa, and Prosopis africana timbers for structural use, Ataguba et al. (2015) came to the conclusion that all three species had physical and mechanical characteristics that made them suitable for structural engineering use as hardwoods by grading. them into strength classes between D30 – D70 when compared with Table 8 of BS 5268-2 (2002). Wilson *et al.,* (2021) characterized and graded *Vitex doniana (Dinya), Diospyros mespiliformis (Kanya), Parkia biglobosa (Dorowa) and Isoberlinia doka (Doka)* according to BS 5268 (2002) and NCP 2 (1973), the species of which can be utilized for both structural and non-structural applications. The absence of *Eucalyptus camaldulensis* classification in the Nigeria Code of Practice, NCP 2 and EN 338 therefore necessitated the need for this research.

METHODOLOGY

Eucalyptus camaldulensis specie, which is commercially available in the open market of Nigeria and widely used especially in roof truss and timber bridge construction was locally sourced from Sabon Gari Zaria and Fanteka Kaduna timber sheds (Plate 1). The tested specimens were produced from the planks.

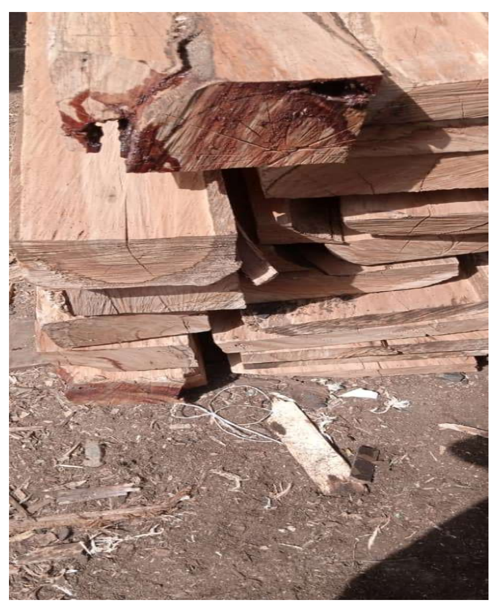

Plate 1: Eucalyptus Timber planks

2.1 Determination of the physical properties of the timber species

The physical characteristics of twenty (20) pieces of uniformly sized 100 x 38 x 38 mm solid timber samples were examined. Before placing the specimens in a universal hot air electric oven set at 100°C for 24 hours, in accordance with EN 13153-1 (2002), their weight was calculated. Using Equations (1) and (2), the result was utilized to calculate the densities and moisture contents of the samples respectively.

Dry density (ρ_d) = $\frac{M_o}{V}$ (1)

Moisture content (%) = $\frac{M_b - M_o}{M_o} \times 100$ (2)

Where M_b = bulk mass of sample in kg, M_o = oven dry mass in kg, V = volume of sample in m^3, ρ_b = bulk density and ρ_d = dry density in kg/m^3. Plates 2 and 3 show the specimens in the oven and before testing respectively.

Plate 2: Specimen ready for placing in dry oven

Plate 3: Specimen in the dry

2.2 Determination of flexural (static bending) properties

Forty (40) rectangular beams were subjected to four Point bending test in accordance with the provision of EN 408 (2004). The test was performed at the Civil Engineering Department Laboratory, Ahmadu Bello University, Zaria using 500 kN Capacity Universal Testing Machine.

a. Derived properties of timber species

The reference qualities of the lumber codes in EN 384 (2004) and JCSS were compared to the material properties as determined by the laboratory results (2006). Derived Material Properties are additional strength and stiffness characteristics that were calculated from the reference material characteristics in accordance with the codes' recommendations. Relationships between generated material attributes and the reference properties of wood (tension parallel and perpendicular to grain, compression parallel and perpendicular to grain etc.) given in the codes are given in Nos. i - viii:

i. $f_{t,0,k}$ (Tensile strength parallel to the grain) = $0.6f_m$
ii. $f_{t,90}$ (Tensile strength perpendicular to the grain) = $0.015\rho_{den}$
iii. $E_{t,0}$ (Tensile modulus of elasticity parallel to the grain) = f_m
iv. $E_{t,90}$ (Tensile modulus of elasticity perpendicular to the grain) = $E_m/90$
v. $f_{c,0}$ (Compressive strength parallel to grain) = $5(fm)^{(0.45)}$
vi. $f_{c,90}$ (Compressive strength perpendicular to the grain)
vii. f_v (Shear Strength) $= 0.2(fm)^{0.8}$
viii. G_v (Shear Modulus) $=E_m/16$

Where, f_m = bending strength parallel to grain, E_m= modulus of elasticity and ρ_{den} = density. The three are the reference material properties generated from the laboratory test data.

b. Adjustment of bending strength

According to EN 384, 2004, the bending and tensile strength were adjusted to 150 mm reference depth by dividing by an adjustment factor K_h given in Equation 3 by:

$$K_h = (\frac{150}{h})^{0.2} \quad (3)$$

Also, for length other than that specified in (EN 408, 2004), the bending strength was adjusted using Equation 4

$$K_L = (\frac{Les}{Let})^{0.2} \quad (4)$$

Where, h = actual depth of the test piece in mm. L_{es} and L_{et} were calculated as shown in Equation 5:

$$L_{es} \text{ and } L_{et} = L + 5a_f \quad (5)$$

Where a_f = the distance between the point load, L = the overall length of the piece, having the values of the standard test procedure and for the practical test piece. Since the standard test depth of 150 mm was not achieved, 120 mm was adopted instead.

RESULTS AND DISCUSSION

Moisture Content of *Eucalyptus camaldulensis*

The results of the moisture content test are shown in Table 1. The table provides the mean, standard deviation, and coefficient of variation for the moisture contents. The wood species examined in this study had equilibrium moisture contents that were in compliance with the 18% standard moisture content recommended by the Nigerian Code of Practice for Timber Structural Design (NCP 2, 1973).

Table 1: Moisture content of *Eucalyptus camaldulensis*

Timber Specie	Moisture Content		
	Mean (%)	**Standard Deviation (%)**	**Coefficient of Variation (%)**
Eucalyptus	12.5	4.5	36

Density of Eucalyptus camaldulensis

As shown in Table 2, the mean density of the Eucalyptus camaldulensis timber species was determined to be 975.9 kg/m^3 at an adjusted equilibrium moisture content of 18%, with a standard deviation of 75.6. This agrees with

Babatola and Abubarkar (2011), which showed 977.58 kg/m^3 at 12% moisture content. The Nigerian Code of Practice for Timber Structural Design (NCP 2, 1973) did not classify the Eucalyptus camaldulensis timber specie, however its density is 99% similar to that of Okan timber specie. (Cylicodiscus gabunensis) of 976 kg/m^3.

Tables 2: Density of Eucalyptus camaldulensis

Timber Specie	Sample size	Mean value (kg/m^3)	Standard Deviation (N/mm^2)	Coefficient of Variation (%)
Eucalyptus camaldulensis	20	975.9	75.6	8

Strength Allocation

If the characteristic mean modulus of elasticity in bending equals or exceeds 95% of the value for that strength class and the characteristic values of bending strength and density equal or exceed the values for that strength class given in EN 338 (2009), a population of wood may be assigned to that strength class. Here, Table 3 displays the upper and lower limits of the reference material attributes from Table 1, EN 338 (2009).

According to research, the species' mean flexural strength was found to be 69.02 N/mm^2 on average, with a standard deviation of 18 N/mm^2, and its mean modulus of elasticity was 5409.4 N/mm^2. So, as shown in Tables 4, the Eucalyptus timber specie was assigned to the proper timber strength classes. The tested timber species was assigned to strength class N1 according to the Nigerian Code of Practice for Timber Structural Design (NCP 2, 1973) classification systems and strength class D60 according to the European Solid Timber Strength Classification Systems (EN 338, 2009).

Table 3: Limiting Values for Classification into Hardwood Classes (EN 338, 2009)

S/No.	Strength Class	Limits of Characteristic Bending Strength (N/mm^2)	Limits of Characteristic Density (kg/m^3)	Limits of Mean Modulus of elasticity (kN/mm^2)
1	D18	$f_{m,k} \leq 18$	$\rho_k \leq 475$	$E_{mean} \leq 9.5$
2	D24	$18 < f_{m,k} \leq 24$	$475 < \rho_k \leq 485$	$9.5 < E_{mean} \leq 10$
3	D30	$24 < f_{m,k} \leq 30$	$485 < \rho_k \leq 640$	$9.5 < E_{mean} \leq 10$
4	D35	$30 < f_{m,k} \leq 35$	$640 < \rho_k \leq 670$	$9.5 < E_{mean} \leq 10$
5	D40	$35 < f_{m,k} \leq 40$	$670 < \rho_k \leq 700$	$10 < E_{mean} \leq 11$
6	D50	$40 < f_{m,k} \leq 50$	$700 < \rho_k \leq 780$	$11 < E_{mean} \leq 14$
7	D60	$50 < f_{m,k} \leq 60$	$780 < \rho_k \leq 840$	$14 < E_{mean} \leq 17$
8	D70	$70 \leq f_{m,k}$	$1080 \leq \rho_k$	$20 \leq E_{mean}$

Table 4: Strength Allocation for *Eucalyptus camaldulensis* by NCP and EN 338

Reference Material Properties	18% MC adjusted Values	NCP 2 Dry Basic Stress (18% MC)	NCP2 Strength Class	Allocated Strength Class (EN338, 2009)
Bending Strength (N/mm^2)	40	35.5 (factored)		
Density (kg/m^3)	975.9	976 (factored)	N1	D60
Modulus of Elasticity (kN/mm^2)	5409.4(mean)	15.0 (factored)		

CONCLUSION

From the outcome of this study, the mean density of Eucalyptus timber specie (*Eucalyptus camaldulensis)* was found to be 975.9 kg/m^3 with a standard deviation of 75.6 kg/m^3 at 18% adjusted equilibrium moisture content. Though the Eucalyptus timber specie was not classified in the Nigerian Code of Practice for timber structural design (NCP 2, 1973) its density is quite akin to that of Okan timber specie (*Cylicodiscus gabunensis*) of 976 kg/m^3. The mean flexural strength of the specie was determined to be 69.02 N/mm^2 with a standard deviation of 18 N/mm^2 and the mean Modulus of Elasticity was 5409.4 N/mm^2. The tested timber specie was allocated to strength class D60 based on the European solid timber strength classification systems (EN 338, 2009) and strength class N1 based on the Nigerian Code of Practice for timber structural design (NCP 2, 1973) classification systems. It is therefore recommended that Eucalyptus timber specie be placed in the D60 strength class of the EN 338 classification scale and Class N1 of NCP 2. By implication, the Nigerian-grown Eucalyptus timber can be used for bridge construction, sleepers for railways, pier construction as well as heavy duty flooring.

CONFLICT OF INTEREST

There is no conflict of interest so far traceable to any content of this research work.

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