Characterization and Grading of South Eastern Nigeria grown *Irvingia gabonensis* Timber in Accordance with BS 5268

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Abstract

The paper presents characterization and grading of South Eastern Nigeria grown Irvingia gabonensis timber in accordance with BS5268 (2002). Specimens used in the experiment were collected from a matured gabonensis in Akpugo forest, which were sliced into planks in green condition. The samples were seasoned naturally for six months and prepared according to British Standard BS 373 (1957) Methods of Testing Small Clear Specimen of Timber. The following laboratory test were carried out bending parallel to the grain, tension parallel to the grain, tension perpendicular to the grain, compression parallel to the grain, compression perpendicular to the grain, shear parallel to the grain, moisture content and density. The physical and mechanical properties of the timber specie, which were determined in the laboratory were adjusted to the values at moisture content of 12% in conformity with BS5268 (2002). The results were analysed statistically. Basic and grade stresses were computed using experimental failure stresses. The result of grade bending stress, density and mean modulus of elasticity showed that, Irvingia gabonensis can be graded and assigned to strength class D70. The timber is a strong, heavy hardwood and it is suitable for load bearing structures like railway sleepers and bridge beams.

Keywords

Characterization, Grading, Nigeria grown timber, Strength Properties, three point bending and BS 5268.

1. Introduction

Timber is a natural structural material from matured trees which serves various purposes in construction and furniture industry. Nigeria is one of the countries that have timber in surplus quantity. If this natural resources is properly utilized, it will be of immense benefit to the country in terms of reduction in the cost of construction. Irvingia gabonensis grows in forest mostly found in all the southern states of Nigeria, commonly in river banks and damp locations. Gabonensis tree grows straight up to 40metres high with diameter of 1 metre and this makes it a good source of large quantity of timber. The tree is known with local names in Nigeria (South East - *Ogbono*, South West - *Oro*, Bini - *Ogwe*, Ijaw - *Ogboin*, Efik -*oyo*).

Irvingia gabonensis timber is commonly used in Nigeria mostly in South Eastern part as roof truss materials without knowledge of its engineering properties because this specie has not been characterized and graded or listed in NCP2 (1973) or any other acceptable international code. There is need to determine the physical and mechanical properties of Irvingia gabonensis since it is locally grown and used as structural materials in construction. Some timber strength properties listed in British Standard or European code were based on timber obtained from trees in those areas and the laboratory tests were conducted there (Aguwa, 2010). The determined properties like density, grade bending stress and mean modulus of elasticity were used for grading and assigning strength class according to international code (BS 5268 part 2, 2002).

The aim of this study was to characterize and grade South Eastern Nigeria grown Irvingia gabonensis timber in accordance with BS 5268 (2002).The specific objectives were to collect, season, prepare samples of Irvingia gabonensis, determine its physical and mechanical properties according to BS 373 (1957) andto grade Irvingia gabonensis timber specie in accordance with BS 5268 (2002).

2. Materialsand Method

2.1Materials

The materials used in this study wereobtained from matured Irvingia gabonensis treeat green condition from Akpugo forest in Enugu state and sawn to size 100mm x 300mm x 3600mm. Two logs of timber were carefully selected to avoid those with defects and they were reduced to 100mm x 300mm x 1800mm for easy transportation to Minna for seasoning, preparation and testing.

2.2 Preparation of Test Specimens

The specimens were seasoned for six months to attained equilibrium moisture condition at Department of Civil Engineering Laboratory, Federal University of Technology, Minna, Nigeria. Natural seasoning method was adopted in line with Aguwa (2010). Thirty (30) samples were prepared for six different laboratory tests which include three point bending strength parallel to the grain, shear strength parallel to the grain, tension strength parallel to the grain, tension strength perpendicular to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, natural moisture content and density according to BS 373 (1957).

2.3Determination of Physical and Mechanical Properties

Physical and mechanical properties were determined using the prepared samples in the Laboratory of National Centre for Agricultural Mechanization (NCAM) Ilorin, Kwara State using Universal Testing Machine (UTM), Testometric M500-100AC of 100kN capacity. Tests carried out include three point bending strength parallel to the grain, shear strength parallel to the grain, tension strength parallel to the grain, tension strength perpendicular to the grain, compressive strength parallel to the grain, compressive strength perpendicular to the grain, natural moisture content and density according to BS 373 (1957). In each set of the tests, failure loads were recorded for computation of failure stresses, mean failure stress, standard deviation and coefficient of variation. The corresponding load deformation graphs were plotted automatically.

2.4 Stresses at 12% Moisture Content

Failure stresses for bending parallel to the grain, tension parallel to the grain, compression parallel to the grain, compression perpendicular to the grain and shear parallel to the grain were adjusted to values at 12% moisture content in accordance with BS 5268 (2002). Equation (1) was used for the adjustment.

$$f_{12} = f_w + \sigma(W - 12) \quad (1)$$

wheref_{12}= failure stress at 12% moisture content, w=experimental moisture content in (%), f_w = experimental failure stress, σ = correction factor (Bending = 0.05, compression = 0.04 and shear = 0.03).

2.5 Modulus of Elasticity

Based on three points bending test, Equation (2) from the strength of materials applied to straight beams was used, in conformity with Izekor et al. (2010).

$$E_{L3} = \frac{l^3}{4eh^3}k \qquad (2)$$

where E_{L3} is the three point bending modulus of elasticity, ℓ is the distance between the two supports (280mm), e is the width of the beam (20mm), h is the height of the beam (20mm) and k is the slope of load deformation graph that is $\frac{\Delta p}{\Delta f}$. Minimum modulus of elasticity was determined with Equation (3)which shows the relationship between mean modulus of elasticity, E_{mean} and the minimum modulus of elasticity, E_{min}.

$$E_{minimum} = E_{mean} - \frac{2.33\sigma}{\sqrt{N}} \qquad (3)$$

where N is the number of specimens, σ is the standard deviation

2.6 Modulus of Elasticity at 12% Moisture Content

Moduli of elasticity at experimental moisture content were adjusted to values at 12% moisture content in conformity with BS 5268 (2002). The adjustedvalues were computed with Equation (4).

$$E_{m12} = \frac{E_{measured}}{1 + 0.0143(12 - u),} \qquad (4)$$

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.

2.7Determination of Moisture Content

The samples of size 20mm x 20mm x 40mm were cut from the seasoned timber and used for the determination of the moisture content in accordance with BS 373 (1957). The oven temperature was maintained constantly at

$103 \pm 2^{\circ}C$ for several hours until a stable mass was obtained. Equation (5) was used for the calculation of moisture content

$$MC = \frac{m_1 - m_2}{m_2} \times 100\%, \tag{5}$$

where MC = moisture content, m_1 = Initial mass of timber before oven dried, m_2 = final mass of timber after oven dried.

2.8 Determination of Density

Five samples of the timber with size 20mmx20mmx20mm were used for the determination of the density in accordance with BS 373 (1957). Density was calculated using Equation (6).

$$\rho = \frac{m}{v} \tag{6}$$

Where, m = the mass of the timber specimen, and v = volume of the timber specimen.

2.9 Density at 12% Moisture Content

The densities computed from test results in kg/m^3 were adjusted to values at 12% moisture content in accordance with BS 5268 (2002). Equation (7) was used for the adjustment.

$$\rho_{12} = \rho_W \left[1 - \frac{(1 - 0.5)(u - 12)}{100}\right] \tag{7}$$

Where ρ_{12} is density at 12% moisture content in kg/m^3, ρ_W = density at experimental moisture content U = experimental moisture content in %.

2.10 Basic and Grade Stresses

Basic stresses for bending , tensile, compressive, shear parallel to the grain, compressive stress perpendicular to the grain, were calculated from failure stresses. Equations (8) was used for the computation. Various grade stressesat 80%, 63%, 50% and 40% values respectively were calculated according to BS 5268 (2002).

$$f_b = \frac{f_m - k_p \sigma}{k_r} \quad (8)$$

where f_b = basic stress, f_m = mean failure stress at 12% moisture content , σ = standard deviation of failure stress, k_r =reduction factor and k_p = modification factor= 2.33, K_r for bending , tension and shear parallel to the grain = 2.25. K_r for compression parallel to the grain = 1.4 while K_r for compression perpendicular to the grain = 1.2

3. Results and Discussions

Density of Irvingia gabonensis

Table 1 shows the mass of five samples of size 20mmx20mmx20mm for Irvingia gabonensis, the mean mass and mean density at experimental moisture content are equally shown in the table..

Table 1: Samples mass and mean density

Sample No	Mass (g)	Density (kg/m^3)
1	9.45	1191
2	9.67	1180
3	9.31	1187
4	9.49	1188
5	9.57	1179
Mean	9.5	1,187

Table 2 presents moisture content results of the following test: Bending parallel to the grain, tension parallel to the grain, compression parallel to the grain, compresssion perpendicular to the grain and shearparallel to the grain on Irvingia gabonensis samples and the average moisture content of the experiments.

Table 2 Natural moisture content of irvingia gabonensis

Test specimen	M_i initial mass of timber before oven drying(mg)	M_2 final mass of timber after oven drying	M.C $\frac{m_1-m_2}{m_2}$(%)
Compression parallel to the grain	27.14	23.68	14.61
Compression perp. to the grain	111.93	98	14.21
Tension parallel to the grain	56.12	49.07	14.37
Tension perpendicular to the grain	131.27	115	14.15
Bending parallel to the grain	140	120.78	15.91
Shear parallel to the grain	9.5	8.3	14.46
Average			14.42

Table 3 shows modulus of elasticity at experimental moisture content, sample 3 have the least modulus of elasticity 21,235N/mm^2 while sample 4 with the highest value. The summary graph of bending test that was used for modulus of elasticity computation was used to confirm the samples with the values.

Table 3: Modulus of Elasticity at Naturalmoisture content

Sample No	M.O.E. (N/mm^2)
1	21,558
2	26,569
3	21,235
4	27,724
5	26,265
E_{mean}	24,630
$E_{minimum}$	21,797
Standard. Deviation	2,718

Figure 1 shows the relationship between load and deflection of Timber beams (Irvingia gabonensis) under static bending load. Loads were applied at a constant speed of 0.11mm/s until the materials failed. These graphs confirm timber as an elastic structural material which does not undergo plastic stage of deformation (Aguwa, 2012). It was observed that deformation increased as load on the beam increased until elastic limits were reached.

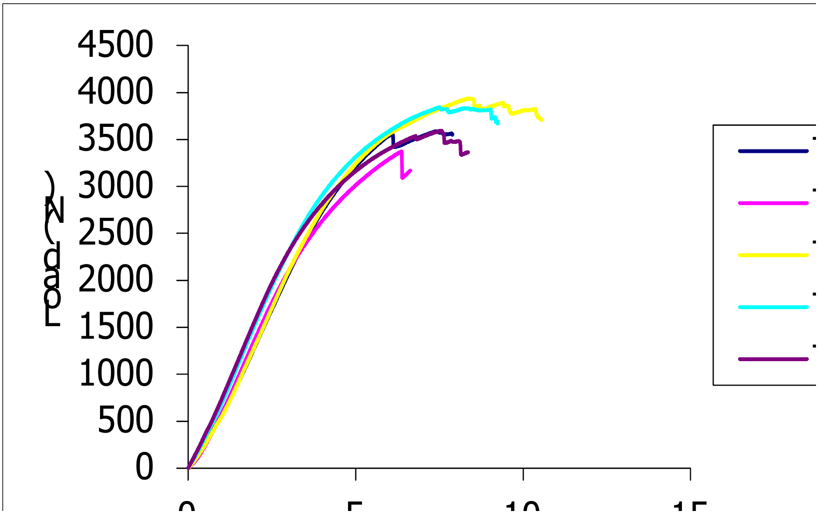

Figure 1: Load-deflection graph of Irvingia gabonensis under static bending load

Table 4 shows modulus of elasticity and density of Irvingia gabonensis timber at 12% moisture content. Irvingia gabonensis properties are comparable with those timbers in strength class D70 because it has density of 1.173kg/m^3, mean modulus of elasticity 25,513N/mm^2 that is within the range of D70 in BS 5268 (2002). Based on this results Irvingia belongs to timber strength class D70.

Table 4:Modulus of elasticity and density of Irvingia gabonensis at 12% moisture content

Modulus of Elasticity (N/mm^2	Value
Eminimum (N/mm^2)	22,579
Emean (N/mm^2)	25,513
Density (kg/m^3)	1,173

Table 5 shows basic stresses of Irvingia gabonensis at 12% moisture content calculated from mean failure stresses and standard deviation of failure stresses. Basic stresses calculated were basic bending stress parallel to the grain, basic tensile stress parallel to the grain, basic compressive stress parallel to the grain, basic shear stress parallel to the grain and basic compressive stress perpendicular to the grain

Table 5: Basic stresses of Irvingia gabonensis at 12% moisture content

Type of stress	Value
Bending Parallel to the grain (N/mm^2)	36.6
Tension Parallel to the grain (N/mm^2)	37.04
Compression Parallel to the grain	29.91
Compression Perpendicular to the grain	14.17
Shear Parallel to the grain	1.07

Table 6shows basic stresses parallel and perpendicular to the grain as well as grade stresses at 12% moisture content. Irvingia gabonensis has grade bending stress of 29.33N/mm^2 which is comparable to range of grade bending stress of strength class D70 listed in Table 8 of BS 5268 (2002).

Table 6: Various Stresses for Irvingia gabonensis at 12% Moisture Content

Type of Stress	Value (N/mm^2)
Mean failures bending stress parallel to the grain	106.31
Basic bending Stress parallel to the grain	36.66
Standard deviation of failure bending stress par. to grain	10.27
Grade bending Stress (80%) parallel to the grain	29.33
Grade bending Stress (63%) parallel to the grain	23.10
Grade bending Stress (50%) parallel to the grain	18.33
Grade bending Stress (40%) parallel to the grain	14.46
Mean failures tensile stress parallel to the grain	181.60
Basic tensile Stress parallel to the grain	38.18
Standard deviation of failure tensile stress par. to grain	41.07
Grade tensile Stress (80%) parallel to the grain	30.54
Grade tensile Stress (63%) parallel to the grain	24.05
Grade tensile Stress (50%) parallel to the grain	19.09
Grade tensile Stress (40%) parallel to the grain	15.27
Mean failures comp. stress parallel to the grain	54.97
Basic compressive Stress parallel to the grain	29.91

Standard deviation of failure comp. stress par. to grain	5.62
Grade compressive Stress (80%) parallel to the grain	23.93
Grade compressive Stress (63%) parallel to the grain	18.88
Grade compressive Stress (50%) parallel to the grain	14.99
Grade compressive Stress (40%) parallel to the grain	11.99
Mean failures comp. stress perpendicular to the grain	18.97
Basic compressive Stress perpendicular to the grain	14.17
Standard deviation of failure comp. stress perp. to grain	1.05
Grade compressive Stress (80%) perp. to the grain	11.25
Grade compressive Stress (63%) perp. to the grain	8.86
Grade compressive Stress (50%) perp. to the grain	7.03
Grade compressive Stress (40%) perp. to the grain	5.62
Mean failures shear stress parallel to the grain	7.35
Basic shear Stress parallel to the grain	1.07
Standard deviation of failure shear stress par. to grain	2.12
Grade shear Stress (80%) parallel to the grain	0.86
Grade shear Stress (63%) parallel to the grain	0.68
Grade shear Stress (50%) parallel to the grain	0.54
Grade shear Stress (40%) parallel to the grain	0.43

Table 7: shows the summary results of the experiment for grading of the Irvingia gabonensis in accordance with BS 5268 (2002). According to BS 5268 (2002), strength class may be assigned to a specie, if its characteristic value of grade bending stress and mean density equal or exceed the value for that class giving in Table 8 of BS 5268-2 (2002) and its mean modulus of elasticity in bending equal or exceed 95% of the value given in that strength class. Based on these criteria, Irvingia gabonensis was assigned to strength class D70 due to its grade bending stress parallel to the grain of 29.33N/mm^2, mean density of 1,173kg/m^3 and mean modulus of elasticity of 25,513N/mm^2. This is in agreement with strength class D70 listed in BS 5268-2 (2002) of grade bending stress of 23N/mm^2 and above, mean density of 1,080kg/m^3 and above and mean modulus of elasticity 21,000N/mm^2.and above.

Table 7: Strength class for Irvingia gabonensis according to Table 8 BS 5268-2 (2002)

Grade Stress (80%) (N/mm^2)	29.33
Density (kg/m^3)	1,173
Mean Modulus of Elasticity (N/mm^2)	25,513
Strength Class	D70

4.Conclusion

Irvingia gabonensis is a hardwood (D Class) of D70 strength class with good Engineering properties and can be used as railway sleepers and timber bridge materials. Having successfully characterised and graded this specie, Irvingia gabonensis timber can be compared with other species on international basis, hence this timber is recommended to engineers for use in design of load beaming structures.

References

Aguwa, J.I.(2010),Reliability studies on the Nigerian timber as an orthotropic structural material, Thesis submitted to Department Civil Engineering, Federal University of Technology, Minna. pp.50-67, 102-103.

Aguwa, J.I.(2012), Reliability assessment of the Nigeria Apa(Afzelia bipindensis) timber bridge beam subjected to bending and deflection under limit state of loading, International Journal of Engineering and Technology vol.2 No6 pp..1076-1087.

Aguwa, J.I., Sadiku, S (2012). Structural reliability analysis on the Nigeria Ekki timber bridge beam subjected to shearing force under Ultimate limit state, Research Journal in Engineering and Applied Sciences vol.1 No4 pp..240-246.

British standards 373, (1957), Method of testing small Clear Specimens of Timber, British Standard Institute, London.

British Standards 5268 (2002), Structural use of timber. Part 2 code of practice for permissible stress design, materials and workmanship. British Standard institute, London.

BS EN338 (2003), Structural timber-Strength classes. European committee for standardization, CEN, 2009, Brussels, Belgium

NCP2 (1973), Nigerian standard code of practice; the use of timber for construction, Nigeria Standard Organisation , Federal Ministry of Industries, Lagos, Nigeria. pp.10-18.

Ogunwusi, A.A., Onwualu, A.P. and Ogunsanwo, O.Y. (2013), Comparative analysis of wood properties of Afzelia Africana and Anogeissus leiocarpus growing in Nigeria. Chemistry and Material Research, Vol.3, No.3 pp.8-13.