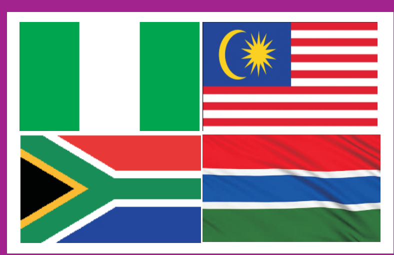
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

SCHOOL OF ELECTRICAL ENGINEERING AND TECHNOLOGY &
SCHOOL OF INFRASTRUCTURE, PROCESS ENGINEERING AND TECHNOLOGY

3rd INTERNATIONAL ENGINEERING CONFERENCE IEC 2019

THEME THE ROLE OF ENGINEERING AND TECHNOLOGY IN SUSTAINABLE DEVELOPMENT

BOOK of PROCEEDINGS



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EDITED BY

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FORWARD

The School of Engineering and Engineering Technology, Federal University of Technology, Minna, organized the 1st and 2nd International Engineering Conference in 2015 and 2017 respectively. With the emergence of the new School of Electrical Engineering and Technology and the School of Infrastructure, Process Engineering and Technology, the two schools came together to organize this 3rd International Engineering Conference (IEC 2019) with the theme: "The Role of Engineering and Technology in Sustainable Development" considering the remarkable attendance and successes recorded at the previous conferences. The conference is aimed at offering opportunities for researchers, engineers, captains of industries, scientists, academics, security personnel and others who are interested in sustainable solutions to socio-economic challenges in developing countries; to participate and brainstorm on ideas and come out with a communiqué, that will give the way forward. In this regard, the following sub-themes were carefully selected to guide the authors' submissions to come up with this communiqué.

1. Engineering Entrepreneurship for Rapid Economic Growth.
2. Regulation, Standardization and Quality Assurance in Engineering Education and Practice for Sustainable Development.
3. Solutions to the Challenges in Emerging Renewable Energy Technologies for Sustainable Development.
4. Electrical Power System and Electronic as a Panacea for Rapid Sustainable Development
5. Promoting Green Engineering in Information and Communication Technology
6. Reducing Carbon Emission with Green and Sustainable Built Environment
7. Artificial Intelligence and Robotics as a Panacea for Rapid Sustainable Development in Biomedical Engineering
8. Petrochemicals, Petroleum Refining and Biochemical Technology for Sustainable Economic Development.
9. Advances and Emerging Applications in Embedded Computing.
10. Traditional and Additive Manufacturing for Sustainable Industrial Development.
11. Emerging and Smart Materials for Sustainable Development.
12. Big Data Analytics and Opportunity for Development.
13. Building Information Modeling (BIM) for Sustainable Development in Engineering Infrastructure and Highway Engineering.
14. Autonomous Systems for Agricultural and Bioresources Technology.

The conference editorial and Technical Board have members from the United Kingdom, Saudi Arabia, South Africa, Malaysia, Australia and Nigeria. The conference received submissions from 4 countries namely: Malaysia, South Africa, the Gambia and Nigeria. It is with great joy to mention that 123 papers were received in total, with 0.9 acceptable rate as a result of the high quality of articles received. Each of the paper was reviewed by two personalities who have in-depth knowledge of the subject discussed on the paper. At the end of the review process, the accepted papers were recommended for presentation and publication in the conference proceedings. The conference proceedings will be indexed in Scopus.

On behalf of the conference organizing committee, we would like to seize this opportunity to thank you all for participating in the conference. To our dedicated reviewers, we sincerely appreciate you for finding time to do a thorough review. Thank you all and we hope to see you in the 4th International Engineering Conference (IEC 2021).

Engr. Dr. S. M. Dauda
Chairman, Conference Organizing Committee

ACKNOWLEGEMENT

The Chairman and members of the Conference Organizing Committee (COC) of the 3rd International Engineering Conference (IEC 2019) wish to express our gratitude to the Vice Chancellor and the management of the Federal University of Technology, Minna, the Deans and all staff of the School of Electrical Engineering and Technology (SEET) and the School of Infrastructure, Process Engineering and Technology (SIPET) for the support towards the successful hosting of this conference. We also thank the entire staff of the university who contributed in one way or the other. We are sincerely grateful to you all.

3rd International Engineering Conference (IEC 2019)
Federal University of Technology, Minna, Nigeria

CHARACTERIZATION AND GRADING OF SOUTH EASTERN NIGERIAN GROWN *MANGIFERA INDICA* TIMBER IN ACCORDANCE WITH BRITISH STANDARD 5268

Mbakwe C.C[1], Aguwa J.I[2] , & Oritola S.F[3].

[1]Civil Engineering Department, Federal University of Technology, PMB 65, Minna Niger State, Nigeria.

[2]Civil Engineering Department, Federal University of Technology, PMB 65, Minna Niger State, Nigeria.

[3]Civil Engineering Department, Federal University of Technology, PMB 65, Minna Niger State, Nigeria.

Corresponding author email: mbakwechinemelum@yahoo.com, +2348061611455

ABSTRACT

The paper is aimed at characterization and grading of South Eastern Nigeria grown *mangifera indica* in accordance with British Standard 5268 (2002). The specimens used in the experiment were obtained from Oluluofo in Alor Anambra State, South Eastern Nigeria. The samples were carefully selected, personally sliced into 600mm length and 300mm width for easy transportation in its green state. Samples were seasoned naturally for six months and prepared in accordance with British Standard 373(1957). 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. In accordance with British Standard 5268 the moisture content of 12% values were determined by adjusting the laboratory experiment of physical and mechanical properties of the timber specie. The analyses of the result were done statistically and computation of basic and grade stresses were done using experimental failure stresses. The result obtained from grade bending stress, density and mean modulus of elasticity shows that, *mangifera indica* can be graded and assigned to strength class C24 (softwood) . It can be used for cladding, decking, flooring, panelling, furniture and cabinets but cannot be used for load bearing structures.

Keywords: *Characterization, Grading, Nigeria grown timber, Soft wood, and Three point bending.*

1. INTRODUCTION

. The use of timber as a structural material has been dated over centuries ago, due to its availability in nature. Timber refers to wood in the form that is suitable for construction of carpentry, joinery or for reconversion for manufacturing purposes (Aguwa, 2010). There is high demand for timber as a building material. From building construction to furniture making, timbers have numerous uses. These uses have made timber an important building material.

Timber as a structural material serves various purposes which include bridge construction, beam, trusses, girder, piles, deck member, retaining structures and railways slippers.

Different wood species have different strength characteristics. And also within a species these characteristics may vary. Therefore, in practice, a classification system of strength classes is used (Jamala, et al., 2013). The strength of a timber depends on its species and the effects of certain growth characteristics (Yeomans, 2003) therefore there is need to determine the physical and mechanical properties of each timber before it is used as structural materials in construction.

Grading of timber species is the process of grouping a timber with similar properties. Different species of timber used in construction can be grouped into two, softwood and hardwood. Softwood is the timber from conferral trees, they are gymnosperms, its leaves are needle like in shape, less dense, light in color, create more branches or shoots, they are usually wood from cones and occasionally nuts. Soft wood are used for home wood working projects , used for cladding, decking, flooring, paneling, structural framing, beams poles, bench tops, furniture and cabinets. Hardwoods are obtained from deciduous trees. They are basically angiosperms; the fibers are quite close and dense, normally these are dark coloured woods, durable and last for several decades. They are used for load bearing structures like railway sleepers and bridge beam.

Timbers as a natural product are not excluded from defect. A defect is any irregularity occurring in or on the timber which may lower its strength, durability, utility value or diminish its appearance. Defects may be 'natural' which occur whilst the tree is growing, or 'artificial' as a result of poor conversion, seasoning or handling after felling. Natural defects like Knots occur where branches have grown out of the tree trunk. Seasoning is the process of adjusting the moisture content of the wood, which can be achieved through exposing the felling timber to dryness within a given period of time or by the use of kiln to achieve its reduction in moisture content, during seasoning of timber, exterior or surface layer of the timber dries before the interior surface. So, stress is developed due to the difference in shrinkage. In a perfect seasoning process, stress is kept minimum by controlling the shrinkage. The process of cutting a fell timber into different market sizes is known as conversion of timber. Artificial defects can occur in a timber as a result improper cutting or machine notches during conversion.

Nigeria is one of the countries that have timber in surplus quantity (Jimoh and Aina, 2017). There is need to determine the strength properties and grading of our locally grown timber species so as to aid in choosing a timber that is free from defect and suitable for a specific construction, and also reduce the high rate of demand of concrete and steel in construction. Construction activities based on these locally available raw materials are major steps towards industrialization and economic independence for developing countries. This explains huge interest and considerable intellectual resources being invested in understanding the mechanical or structural properties of the Nigerian timber (Aguwa and Sadiku, 2011). The demand for timber is unlimited as it continues to increase rapidly in Nigeria.

Mangifera indica is a large, evergreen tree with a dark green, umbrella-shaped crown; it can grow from 11-46 metres tall. The long bole can be 0.7-1.5 metres in diameter. Mostly planted in south eastern part of Nigeria, and north central. There is need to determine the physical and mechanical properties of *mangifera indica* 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 (British Standard 5268 part 2, 2002).

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

2. METHODOLOGY

The materials used in this study were obtained from *mangifera indica* tree at its green condition sawn to size 200mm x 450mm x 4500mm and were reduced to 100mm x 300mm x 600mm for easy transportation to university of Ilorin for seasoning, preparation and testing.

PREPARATION OF TEST SPECIMENS IN ACCORDANCE WITH B.S 373 (1957)

Test specimens were seasoned for six months to attain equilibrium moisture condition at Department of Civil Engineering Laboratory, University of Ilorin, Nigeria. Natural seasoning method was adopted in line with Aguwa (2010). Thirty (30) samples each 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).

DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES.

Physical and mechanical properties were determined on the prepared samples in the Laboratory of university of Ilorin, Kwara State using Universal Testing Machine (UTM), Testometric M500-100AC of 300kN capacity. Thirty (30) samples of each of the following test were carried out 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, total of one hundred and eighty (180) samples were carried out according to BS 373 (1957) including natural moisture content and density. 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.

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.

$$FM12 = FW + \sigma(W - 12) \quad (1)$$

Thus

FM12= failure stress at 12% moisture content, w=experimental moisture content in (%), FW = experimental failure stress, σ = correction factor (Bending = 0.05, compression = 0.04 and shear = 0.03).

MODULUS OF ELASTICITY AT 12% MOISTURE CONTENT

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).

$$EL3 = \frac{L3}{4EH3}K, \quad (2)$$

Thus

EL3 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 $\frac{\nabla P}{\Delta F}$. Minimum modulus of elasticity was determined with Equation (3) which shows the relationship between mean modulus of elasticity, Emean and the minimum modulus of elasticity, Emin.

$$Eminimum = Emean - \frac{2.33\sigma}{\sqrt{N}} \quad (3)$$

Thus

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

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 adjusted values were computed with Equation (4).

$$Em12 = \frac{Emeasured}{1 + 0.0143(12 - u),} \quad (4)$$

Thus

E measured = the modulus of elasticity at experimental moisture content, Em12 = Modulus of elasticity at 12% moisture content and U = experimental moisture content.

DETERMINATION OF MOISTURE CONTENT

The pieces used for moisture content determination were from failed tested specimens. The samples were weighed and initial mass were recorded as M_1 which represent masses of wood pieces before the oven dried. The samples were reweighed after oven dried at a temperature of 103± 2ºC to a stable mass which were recorded as M_2 (final mass). The average mass of the species were recorded to determine the masses (M_1 and M_2) used for moisture content value.

$$MC = \frac{M1 - M2}{M2} \times 100\%, \quad (5)$$

Thus

M_1 (kg) =initial mass (mass of timber and moisture content)

M_2 (kg) = final mass (mass of timber alone) that is mass after oven dried.

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).

$$\rho = \frac{m}{v}, \quad (6)$$

Thus

m= the mass of the specimen, v = volume of the specimen

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.

$$\rho12 = \rho w\left[1 - \frac{(1 - 0.5)(w - 12)}{100}\right], \quad (7)$$

Thus

ρ12= density at 12% moisture content in kg/m3, ρw = density at experimental moisture content, w= experimental moisture content in percentage (%).

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) were used for the computation. Various grades stresses at 80%, 63%, 50% and 40% values respectively were calculated according to BS 5268 (2002).

$$fb = \frac{fm - kp\sigma}{kr}, \quad (8)$$

Thus

fb = Basic stress, fm = mean failure stress at 12% moisture content , σ = standard deviation of failure stress, kr =reduction factor and kp = modification factor= 2.33, Kr for bending , tension and shear parallel to the grain = 2.25. Kr for compression parallel to the grain = 1.4 while Kr for compression perpendicular to the grain = 1.2. fg80= fb80%, fg63=fb63%, fg50=fb50%, fb40=fb40%.

3. RESULTS AND DISCUSSION

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

TABLE 1: SAMPLES MASS AND MEAN DENSITY

SAMPLE NUMBER	MASS(g)	DENSITY(kg/m^3)
1	6.6	825
2	6.7	837.5
3	7.6	950
4	6.9	862.5
5	6.8	850
MEAN	6.92	865

Table 2 presents moisture content results of five (5) samples each of the following test: 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 on *mangifera indica* samples and the average moisture content of the experiments.

TABLE 2: NATURAL MOISTURE CONTENT OF MAGINERFA INDICA

Test specimen	M 1 initial mass of timber before oven drying(g)	M2 final mass of timber after oven drying(g)	$MC = \frac{m2 - m1}{m2}\%$
Compression parallel to the grain	40.6	36.2	12.154
Compression perp. to the grain	342.7	272.9	25.577
Tension parallel to the grain	62.7	53.4	17.415
Tension perpendicular to the grain	94.7	69.4	36.45
Bending parallel to the grain	337.8	280.6	20.38
Shear parallel to the grain	20.9	19	10
MEAN			20.330

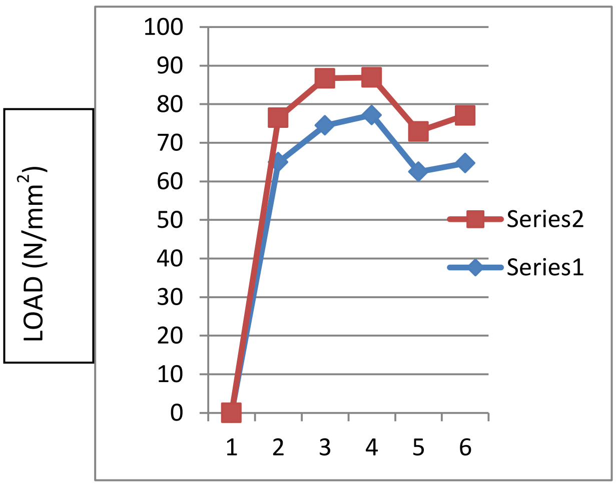
Table 3 shows modulus of elasticity of five (30) samples at experimental moisture content, sample 12 have the least modulus of elasticity 8292.802 N/mm^2 while sample 22 with the highest value 15473.257 N/mm^2. The summary graph of bending test that was used for modulus of elasticity computation was used to confirm the samples with the values.

TABLE 3: MODULUS OF ELASTICITY AT NATURAL MOISTURE CONTENT

SAMPLE NO	M.O.E. (N/mm^2)
1	10100.617
2	13702.312
3	13391.999
4	10095.912
5	10413.145
6	13218.253
7	12011.994
8	12070.981
9	11147.251
10	8337.247
11	9381.749
12	8292.802
13	8953.258
14	13877.897
15	9451.386
16	14345.333
17	9282.586
18	11784.363
19	9929.698
20	9342.541
21	10881.638
22	15473.257
23	11223.954

24	9670.227
25	11437.090
26	9847.927
27	13313.685
28	8814.105
29	7013.942
30	3856.050
MINIMUM	3856.050
MEAN	10688.773
MEDIAN	10256.881
MAXIMUM	15473.257
STANDARD DEVIATION	2422.420
C. OR V.	22.663

Figure 1 (graph of Load on Y- Axis against Deflection on X-Axis).The graph shows the relationship between load and deflection of Timber beams (*mangifera indica*) 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.



DEFLECTION (mm^2)

Table 4 shows modulus of elasticity and density of *mangifera indica* timber at 12% moisture content. *mangifera indica* properties are comparable with those timbers in strength class C24 because it has density of 865kg/m^3, mean modulus of elasticity 10688.773N/mm^2 that is within the range of C24 in BS 5268 (2002). Based on these results *mangifera indica* belongs to timber strength class C24.

TABLE 4: MODULUS OF ELASTICITY AND DENSITY 0F MANGIFERA INDICA AT 12% MOISTURE CONTENT

MODULUS OF ELASTICITY (N/mm^2)	VALUE
EMINIMUM (N/mm^2)	3856.050
EMEAN (N/mm^2)	10688.773
DENSITY (Kg/m^3)	865

table 5 shows basic stresses of mangifera indica 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: VALUES GOTTEN FROM BASIC STRESSES OF MANGIFER INDICA AT 12 % MOITURE CONTENT.

TYPE OF STRESS	VALUE
BENDING PARALLEL TO THE GRAIN (N/MM^2)	70.6685
TENSION PARALLEL TO THE GRAIN (N/MM^2)	51.2605
COMPRESSION PARALLEL TO THE GRAIN	21.1435
COMPRESSION PERPENDICULAR TO THE GRAIN	226.1115
SHEAR PARALLEL TO THE GRAIN	9.8349

Table 6 shows basic stresses parallel and perpendicular to the grain as well as grade stresses at 12% moisture content. *mangifera indica* has grade bending stress of 18.096N/mm^2 which is comparable to range of grade bending stress of strength class C24 listed in Table 8 of BS 5268 (2002).

TABLE 6: VARIOUS STRESS FOR *MANGIFERA INDICA* AT 12% MOISTURE CONTENT.

TYPE OF STRESS	VALUE (N/mm^2)
MEAN FAILURES BENDING STRESS PARALLEL TO THE GRAIN	70.252
BASIC BENDING STRESS PARALLEL TO THE GRAIN	18.09
STANDARD DEVIATION OF FAILURE BENDING STRESS PAR. TO GRAIN	12.676
GRADE BENDING STRESS (80%) PARALLEL TO THE	14.477

GRAIN	
GRADE BENDING STRESS (63%) PARALLEL TO THE GRAIN	11.40
GRADE BENDING STRESS (50%) PARALLEL TO THE GRAIN	9.048
GRADE BENDING STRESS (40%) PARALLEL TO THE GRAIN	7.2384
MEAN FAILURES TENSILE STRESS PARALLEL TO THE GRAIN	50.844
BASIC TENSILE STRESS PARALLEL TO THE GRAIN	4.625
STANDARD DEVIATION OF FAILURE TENSILE STRESS PAR.	17.355
TO GRAIN	
GRADE TENSILE STRESS (80%) PARALLEL TO THE GRAIN	3.7
GRADE TENSILE STRESS (63%) PARALLEL TO THE GRAIN	2.915
GRADE TENSILE STRESS (50%) PARALLEL TO THE GRAIN	2.3125
GRADE TENSILE STRESS (40%) PARALLEL TO THE GRAIN	1.85
MEAN FAILURES COMP. STRESS PARALLEL TO THE GRAIN	20.727
BASIC COMPRESSIVE STRESS PARALLEL TO THE GRAIN	9.098
STANDARD DEVIATION OF FAILURE COMP. STRESS PAR. TO GRAIN	3.429
GRADE COMPRESSIVE STRESS (80%) PARALLEL TO THE GRAIN	7.27
GRADE COMPRESSIVE STRESS (63%) PARALLEL TO THE GRAIN	5.73
GRADE COMPRESSIVE STRESS (50%) PARALLEL TO THE GRAIN	4.55
GRADE COMPRESSIVE STRESS (40%) PARALLEL TO THE GRAIN	3.64
MEAN FAILURES COMP. STRESS PERPENDICULAR TO THE GRAIN	225.695
BASIC COMPRESSIVE STRESS PERPENDICULAR TO THE GRAIN	-3.536
STANDARD DEVIATION OF FAILURE COMP. STRESS PERP. TO GRAIN	98.686
GRADE COMPRESSIVE STRESS (80%) PERP. TO THE GRAIN	-2.8288
GRADE COMPRESSIVE STRESS (63%) PERP. TO THE GRAIN	-2.227
GRADE COMPRESSIVE STRESS (50%) PERP. TO THE GRAIN	-1.768
GRADE COMPRESSIVE STRESS (40%) PERP. TO THE GRAIN	-1.4144
MEAN FAILURES SHEAR STRESS PARALLEL TO THE GRAIN	9.585
BASIC SHEAR STRESS PARALLEL TO THE GRAIN	0.1501
STANDARD DEVIATION OF FAILURE SHEAR STRESS PAR. TO GRAIN	3.968
GRADE SHEAR STRESS (80%) PARALLEL TO THE GRAIN	0.121
GRADE SHEAR STRESS (63%) PARALLEL TO THE GRAIN	0.094
GRADE SHEAR STRESS (50%) PARALLEL TO THE GRAIN	0.075
GRADE SHEAR STRESS (40%) PARALLEL TO THE GRAIN	0.060

Table 7: shows the summary results of the experiment for grading of maginfera indica 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, maginfera indica was assigned to strength class C24 due to its grade bending stress parallel to the grain of 14.477N/mm^2, mean density of 865kg/m^3 and mean modulus of elasticity of 10688.773N/mm^2. This is in agreement with strength class C24 listed in BS 5268-2 (2002) of grade bending stress of 7.5N/mm^2 and above, mean density of 420kg/m^3.

TABLE 7: STRENGTH CLASS FOR MAGINFERA INDICA ACCORDING TO TABLE 8 BS 5268-2 (2002) .

GRADE STRESS OF BASIC BENDING PARALLEL TO THE GRAIN (80%) (N/mm^2)	14.477

DENSITY (kg/m^3)	865
MEAN MODULUS OF ELASTICITY (N/mm^2)	10688.773
MINIMUM MODULUS OF ELASTICITY	3856.050
STRENGTH CLASS	C24

4. CONCLUSION

Maginfera indica is softwood (C Class) of C24 strength class according to BS 5268 (2002) with poor Engineering properties and cannot be used for a load bearing structures.

RECOMMENDATION

Having successfully characterized and grade this specie, *maginfera indica* timber can be compared with other species on international basis; hence this timber is recommended to engineers to be used according to its strength class. Further research can be carried out on characterization and grading of *mangifera indica* by comparing Euro code and British code.

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5. REFERENCES

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