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Mechanical properties (bending and Compression stress) as a tool for grading stress of Acacai nilotica wood

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Abstract

The aim of this study was to determine the mechanical properties of Acacia nilotica (L.) Willd wood and classified the grades according to basic stress. Samples of wood were collected from Damazin which located in the Blue Nile States. Wood samples were prepared to measure the static bending and compression values. The Results showed that the ultimate basic stress for bending for Acacia nilotica wood was 234.86 MPa, 102.62 MPa for ultimate compression parallel to the grain. From the results obtained during this study, Acacia nilotica wood has higher average of bending stress and Compression stress and this property is recommend for using it for heavy construction, flooring, furniture, veneer, plywood, tool handles and railway sleeper production.
Keywords: Grade; Mechanical properties; Wood

INTRODUCTION

The mechanical properties of wood are its fitness and ability to resist applied or external forces. By external force is meant any force outside of a given piece of material which tends to deform it in any manner. It is largely such properties that determine the use of wood for structural and building purposes and innumerable other uses of which furniture, vehicles, implements, and tool handles are a few common examples.

Knowledge of these properties is obtained through experimentation either in the employment of the wood in practice or by means of special testing apparatus in the laboratory.

One object of such investigation is to find unit values for strength and stiffness, etc. These, because of the complex structure of wood, cannot have a constant value which will be exactly repeated in each test, even though no error is made. The most that can be accomplished is to find average values, the amount of variation above and below, and the laws which govern the variation. On account of the great variability in strength of different specimens of wood even from the same stick and appearing to be alike, it is important to eliminate as far as possible all extraneous factors liable to influence the results of the tests (Record, 1914).

Materials and Methods

The wood material used for this research obtained from Acacia nilotica trees. Acacia nilotica is a tree 5–20 m high with a dense spheric crown, stems and branches usually dark to black coloured, fissured bark, grey-pinkish slash, exuding a reddish low quality gum (H S D A, 2017). The wood has a density of about 1170 kg/m^3 (Wickens, 1995). Acacia nilotica sawn timber is used for production of railway sleeper and furniture making. Through the static bending attempt determine the maximum load which produces rupture of a sample of wood and is calculated wood strength corresponding to this task. Determination of modulus of elasticity at static bending consists in measuring the arrow of a wood sample subject to static bending loads. So, trees have been cutting in logs and from each log were obtained a number of 7 samples with form of right prism with square section, with sides of 20 ± 0.5 mm and length of 300 ± 1 mm, in accordance with Sudanese standard no. 5175/20/2012 (adopted form ISO 3133/1975). Compression parallel to the grain tests specimens were prepared with dimension 20×20 ×60 mm, Compression Parallel to the grain test was carried out according to ISO standard procedure no. 3787/1979. Before make the test, the samples were conditioned in a climatic room. The tests were made on a Universal Machine for testing of wood materials. Formulas through which we achieved results of the two mechanical properties are:

The minimum ultimate stress was obtained from the following equation:

$X_{min} = X_{mean} - k.\sigma$ ………………………………(1)

Where X_{mean} is the mean ultimate short duration stress from test results.

σ = the standard deviation.

K = a constant that depends on the selected probability (British Standard 373, 1986).

K-value for 1% probability is 2.33

$X_{min} = X_{mean} - 2.33\sigma$ …………………………………. (2)

Equation 2 applies for both bending and compression parallel to the grain, whereas the above mentioned factor varies between the two properties. X_{min} was divided by the appropriate factor for each property. According to Booth and Reece (1967) the reduction factor for bending is 2.25 and 1.40 for compression parallel to the grain. Therefore, basic stress (B.S.) for bending was calculated from the following equation:

B. S. (bending) = $X_{min} / 2.25$………………….. (3)

While basic stress for compression parallel to the grain (C//g) was calculated from:

B. S. (C//g) = $X_{min} / 1.40$………………………… (4)

Where C//g = Compression parallel to the grain

The Strength ratios % according to grading rules were suggested by Nasroun (1981); Nasroun (2005), are 80, 65, 50, 40 for grade 1, 2, 3, 4 respectively (Appendix C). From these ratios and the calculated basic stresses, grade stresses can be calculated from the following equation:

Grade stress = Basic stress x strength ratio……………….. (5)

Grade 1 stress = Basic stress X 0.8

Grade 2 stress = Basic stress X 0.65

Grade 3 stress = Basic stress X 0.5

Grade 4 stress = Basic stress X 0.4

Results and Discussion

Ultimate Stresses

Figures (1 – 4) show the results of the static bending test, figures (5 – 7) show the results of the compression parallel to the grain. And appendices A and B respectively show the results with average short duration ultimate stress values and standard deviations.

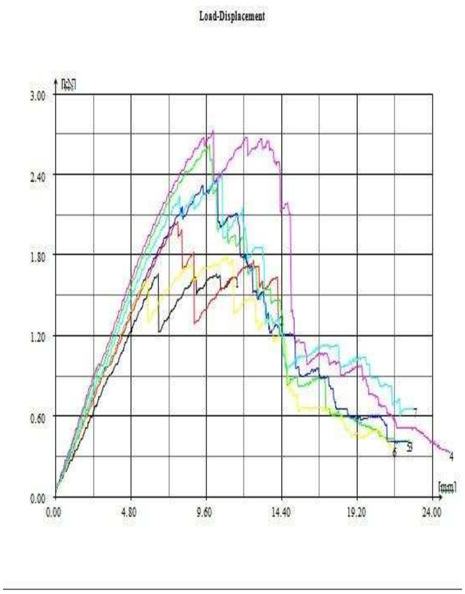
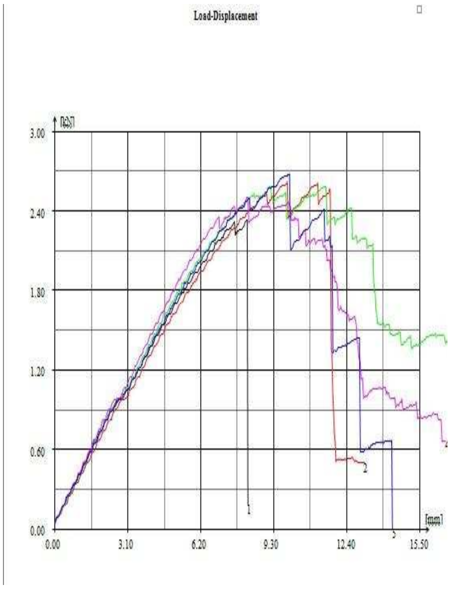


Fig (1)



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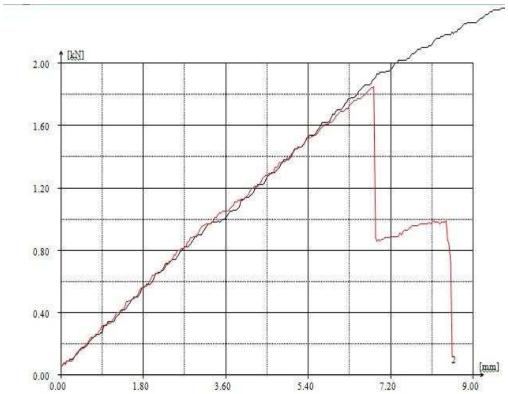

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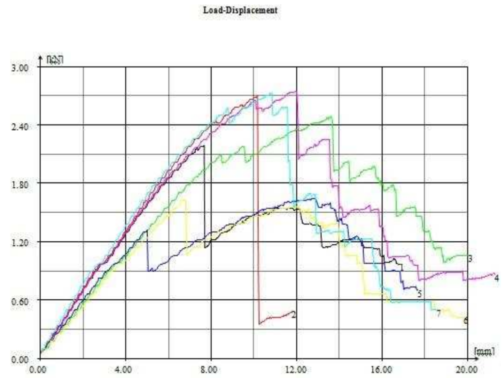

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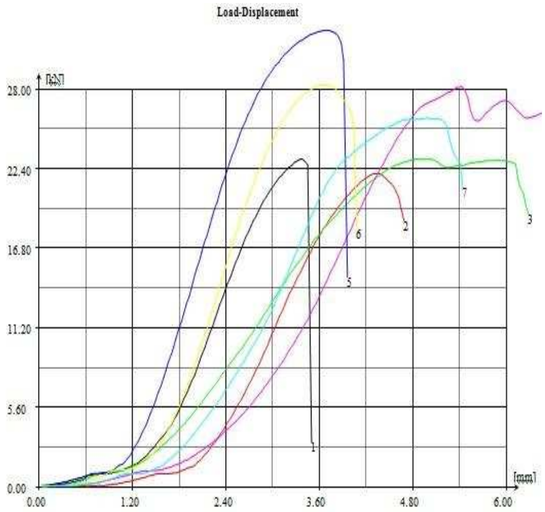

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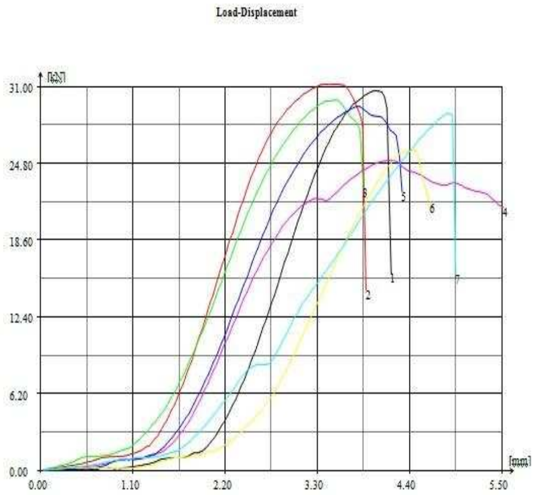

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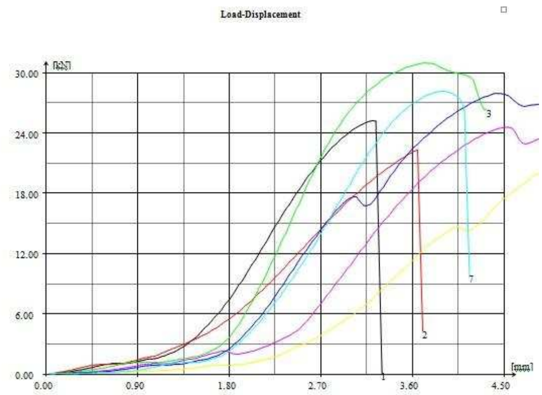

Fig (7)

Form equations (2) $X_{min} = X_{mean} - 2.33\sigma$

X_{min} for bending = 234.64 – (2.33*35.68) = 151.5

X_{min} for Compression = 102.62 – (2.33* 11.26) = 26.24

Table1. Ultimate Stresses and Modulus of elasticity / MPa

Property	Ultimate Stresses (MPa)			MOE (MPa)	
	Min.	Mean	St.D.	Mean	St.D.
Bending	151.5	234.64	35.68	25601.02	932.89
Compression	76.37	102.62	11.26	3446.63	3086.02

From the results shown in table 1 the Ultimate bending stress for Acacia nilotica wood is 234.64 MPa and Ultimate compression stress is 102.62 MPa. However, the results are comparable to results obtained by Nasroun, (2005) for home-grown Balanites aegyptiaca with regards to the mean ultimate bending stress (104 MPa) and mean ultimate compression parallel to the grain (52 MPa) and for Khaya senegalensis the mean ultimate bending stress (97.1 MPa) and mean ultimate compression parallel to the grain (75..3 MPa). The results of this research indicate that this wood was very heavy and this consistent with Nasroun (1979), who classified the commercial species based on four of mechanical properties into four groups (A- D), according to this classification Acacia nilotica came in strength group A (high). Base on this grouping Acacia nilotica wood can recommended for heavy construction, flooring, furniture, veneer, plywood and tool handles.

Basic Stresses

Form equation (3) the basic stress for bending was as follows:

Basic stress (bending) = $\frac{151.5}{2.25}$ = 67.33 MPa

From Equation (4) the basic stress in compression parallel to grain was as follows:

Basic stress(C//g) = $\frac{76.37}{1.40} =$ 54.55 MPa

Grade Stresses

As clear wood is not available for structural sizes, grade stresses were calculated for the two properties as follows:

Bending grade (design) stresses (MPa)

$\text{Grade}_1 = 67.33 \times 0.8 = 53.86$

$\text{Grade}_2 = 67.33 \times 0.65 = 43.76$

$\text{Grade}_3 = 67.33 \times 0.5 = 33.67$

$\text{Grade}_4 = 67.33 \times 0.4 = 26.93$

Compression parallel to the grain grade stresses (MPa)

$Grade_1 = 54.55 \times 0.8 = 43.64$

$Grade_2 = 54.55 \times 0.65 = 35.46$

$Grade_3 = 54.55 \times 0.5 = 27.28$

$Grade_4 = 54.55 \times 0.4 = 21.82$

These results can be summarized in table (2).

From the results obtained from this research, as shown in Table 4, Acacia nilotica wood can be classified to four grades according to the basic stress value. Therefore, on the first grade the static bending and compression values are (53.86, 43.64) respectively and the static bending and compression values are (26.93, 21.81) respectively on grade four. Hence, we find that grade four of the Acacia nilotica is better than grade one for the Boswellia papyrifera (Del.) Hochst and Faidherbia albida wood as stated in Nasroun, et.al (2018).

Table 2. Grade stresses / MPa for the two properties.

Property	Basic stress	Grade1	Grade2	Grade3	Grade4
Bending stress	67.33	53.86	43.76	33.67	26.93
Compression stress	54.55	43.64	35.46	27.28	21.82

Wood properties are important for commercial purposes and raise the need for wood quality research, which determined the future markets by define classes of timber to be produced. Furthermore, the application of wood quality research is to ensure that hardwood plantations provide the greatest economic return to producer and that requires an understanding of the influence of tree age, genotype, environment and silviculture on wood properties of commercial importance.

Conclusion:

From the results obtained during this study, Acacia nilotica wood has high average of bending stress and compression stress and this proposed Acacia nilotica as qualify wood for being the major species for structural purposes, furniture, veneer, plywood and railway sleeper production.

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Appendix A. Test results for static bending:

Serial number	**Maximum load(kN)**	**Ultimate bending stress (MPa)**	**Modulus of elasticity (MPa)**
1	1.660	162.033	22768.469
2	2.050	202.270	22304.604
3	2.620	261.136	25856.189
4	2.730	264.777	24957.156
5	2.350	238.865	24090.131
6	1.780	181.412	31360.993
7	2.400	254.797	27335.466
8	2.330	227.897	23382.261
9	2.620	254.565	23318.361
10	2.580	249.605	27391.896
11	2.500	261.245	30012.812
12	2.680	255.012	23651.372
13	2.480	264.281	23820.578
14	1.850	184.899	25983.280
15	2.190	229.275	25667.036
16	2.700	277.206	26196.259
17	2.490	232.320	19684.572
18	2.740	281.137	25728.140
19	1.650	178.624	26825.846
20	1.620	201.542	32962.960
21	2.730	264.493	24322.966
Average	2.321429	234.6377	25601.01652
SD	0.394034	35.68035	3086.020993

Appendix B. Test results for compression parallel to the grain:

Serial number	**Maximum load (kN)**	**Ultimate compressive stress(MPa)**	**Modulus of elasticity(MPa)**
1	23.080	87.099	3343.981
2	22.050	84.814	2828.614
3	23.100	86.603	1835.245
4	28.140	102.831	2189.137
5	32.150	123.146	4591.309
6	28.280	113.604	4078.220
7	30.660	115.792	4744.034
8	31.220	116.154	4823.784
9	29.930	110.461	3859.814
10	25.050	94.577	3599.871
11	29.400	107.775	3909.789
12	25.820	99.276	3617.739
13	28.830	108.717	2825.180
14	25.240	95.454	3882.421
15	22.320	88.040	2359.011
16	30.970	116.887	5036.393
17	24.590	90.335	3068.833
18	27.940	109.113	3465.702
19	24.940	92.756	2201.819
20	28.140	108.168	3703.042
21	25.970	103.321	2415.330
Average	27.039	102.6157	3446.632
SD	3.103682	11.62628	932.8903

Appendix C. Tentative grading rules*****

Defect	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**
Slope of grain for bending	1/16	1/12	1/9	1/6
Slope of grain for compression parallel	1/12	1/10	1/8	1/6
Face knot ratio Marginal knot ratio	1/4 1/8	3/8 1/6	1/2 1/4	5/8 1/3
Strength ratios %	80	65	50	40

*Modified from British Standard 3819. 1964.