SOME ENGINEERING CHARACTERISTICS OF NIGERIAN TIMBERS

BY

Danladi Slim Matawal, FNSE
Department of Civil Engineering
Abubakar Tafawa Balewa University
Bauchi.

AND

Abdulmoumouni Adamu
Department of Public Works
Niamey, Niger Republic

ABSTRACT

This paper is a presentation of the results of tests on the characteristics of some common roofing materials found in the Nigerian markets as typified by the Bauchi Timber sheds. The principal roofing material investigated is timber but there is mention of types of roofing sheets and nails. The emphasis is on engineering properties such as density, equilibrium moisture contents (EMC), and flexural, compressive and tensile resistances, of timber. The tests reveal that the three top resistances in flexure, in increasing magnitude, are: Bush Mansonia ($121.3N/mm^2$), Iroko/Loko ($127.5N/mm^2$) and Madachi/Mahogany ($131.9N/mm^2$). All the Timbers tested recorded compressive strengths above $25N/mm^2$ parallel to grain (except plywood) but Mahogany and Teak recorded appreciably higher values ($24.5N/mm^2$ and $27.2N/mm^2$, respectively) perpendicular to the grain. For obvious reasons, and from the public viewpoint also, the authors prefer Mahogany for overall strength superiority. It is heavy and other authors frequently recommend Iroko as best for superstructures because of its relative better ability to resist decay coupled with good strength properties and lower density.

The tests, which were conducted in the laboratories of Abubakar Tafawa Balewa University and the Federal Polytechnic Bauchi, are expected to provide data important for the structural design in timber using available species in the Nigerian market.

KEYWORDS: Timber, Engineering characteristics, Structure, Strength.

1.0 INTRODUCTION

Timber is one of the finest structural materials, remarkable for its beauty, versatility, strength, durability and workability. It possesses a high strength to weight ratio, it has flexibility, it performs well at low temperatures, withstands substantial overloads for short periods, has low electrical and thermal conductance, and resists the deteriorating action of many chemicals that are extremely corrosive to other building materials such as steel and concrete. General Timber properties are discussed, with much details of general nature, by authors like Desch (1981), Donald (1988), Findlay (1975) and Merritt (1976).

Timber wood as a building material has inherent characteristics with which users should be familiar. Although cut simultaneously from trees growing side by side in the forest, two boards of the same specie and size will most likely not have the same strength. Furthermore, the trunk of trees, from which timber is obtained, consists of long, vertically-elongated fibers parallel to the trunk axis which are required to conduct fluid and nutrients upwards from tree roots to the branches and leaves. It is these fibers (or grain) that produce different mechanical and physical properties in different directions (Anisotropy) within the structural timber. In addition to its usefulness as a material for permanent construction, timber has, because of its relative cheapness, also fulfilled a role in the capacity of temporary structures, allowing materials such as concrete, brick and stone to be erected in structural form that would otherwise have been vulnerable in the stage before the binding medium gained strength.

In this research, a comprehensive survey is made of the species of timber in the Nigerian market with the Bauchi timber shed as model because it contains many of the varieties in the country. The engineering characteristics of the more common varieties, listed in table 1, are determined wit some additional detail on four species namely: Black Afara, Mahogany, Obeche and Abura. The properties investigated for all ten (10) species of Timber include density, moisture content, flexural strength, compressive strengths parallel and perpendicular to the grain and, in addition, tensile strength parallel to the grain on four (4) species. All the results are based on standard laboratory test procedures, described in the report. Such data, though invaluable for designers in structural timber, is usually scanty and most often unavailable for the Timber grown in the Country and which are used intensely for engineering works in Nigeria. The results of the tests in this project on small clear specimens have revealed that the ten (10) common species in the market can be optimally chosen, based on a variety of factors, for floor, furniture, formwork, entrance and super - structural applications.

2.0 TIMBER SPECIES AND ROOFING MATERIALS IN THE MARKET

Perhaps the most comprehensive presentation of the nomenclature of Nigerian commercial timber is made in NCP 2 (1973), which lists 55 species with standard and botanical names as well as its availability. Some of the common species found in the markets are Abura, Black Afara, Alstonia, Doka, Iroko, Mahogany (or Madachi), Mansonia, Obeche, Sapele and Teak. The above names are amongst many more species identified in the Nigerian forests and comprehensively listed by Adamou (2001). However, the species found in the timber sheds and whose properties are determined in this research are listed in table 1, revealing ten (10) types.

Roofing sheet selection aims at providing an ideal roof covering to any structure so as to satisfy the requirements of:

(a) Strength to support its (self) weight and that due to wind and, in some climates, snow.

(b) Fire resistance

(c) Preventing excessive loss or gain of heat.

No one material satisfies all the requirements and in general, combinations of two or more materials are employed in roofing. The rapid development of the roofing sheets industry, according to Barry (1984), started in 1883 with the introduction of Zinc galvanized corrugated iron sheets.

3.0 METHODOLOGY OF LABORATORY TEST

All tests were conducted at their natural/equilibrium moisture contents (EMC) dictated by the environment. These service average moisture contents were determined as well as the timber densities. Strength tests were conducted using the following procedure:

(a) **Flexural stress using static bending (f_{bt}):** The standard specimen of 1200mm x 70mm x 50mm supported over a span of 1100mm on roller bearings was used with the load applied to the center of beam at a constant rate. For failure in bending of a section of width, b, by depth, d, under a central load P, the flexural resistance is:

$$f_{bt} = \frac{1.65P}{bd^2}\left[because\ M = \frac{PL}{4}, Z = \frac{bd^2}{6}\ and\ L = 1.1m\right] \ldots\ldots(1)$$

[A 1st principle derivation of this expression is presented in Appendix 'A'].

(b) **Compression parallel to the grain (P_c (par.)):** The specimen size is 70mm x 60mm x 50mm and the load is applied parallel to the grain at a constant rate until failure occurs. If the load at failure is P, then P_c(par.) = P/A where A is the cross sectional area of 50mm x 60mm.

(c) **Compression perpendicular to the grain (P_c(pep.)):** It is determined using the same procedure as for the P_c(par.) except that load is now applied perpendicular to the grain.

(d) **Tension parallel to grain (f_t):** The sample size is 400mm x 70mm x 20mm. If the load at failure is P, then f_t = P/A.

The last test, in (d), is however infrequently performed since the amount of timber loaded in tension under service conditions is relatively small and confined mainly to Ties and the upper chord members of bridges and roof trusses. In determining the results of tests, an average of many readings was used. For example, density results are the average of 5 determinations while the minimum number of readings used for all the tests is three (3). All tests are conducted according to the British Standard, BS 1881 (Parts 3 and 4: 1983). Average results of the laboratory tests are shown in Table 2.

4.0 ANALYSIS OF TEST RESULTS

The fundamental and most important observation of the results of tests is that even though the average value has been presented, nonetheless, the raw values show a fluctuation from one specimen to another, even on specimens of the same specie of Timber. For example, the raw results of flexural tests on three (3) specimens, each, from four (4) species of timber are tabulated in table 3 below.

However, while the fluctuation in results was more noticeable in properties such as density, flexural and direct tensile resistances, nonetheless, many results agreed closely in the case of the compressive strengths parallel and perpendicular to the grain. For example, there was complete agreement in the results of compressive strengths perpendicular to grains for all the specimens of the Obeche specie. There was agreement of the same property, in at least two (2) specimens out of total five (5), in the Afara, Mahogany and Abura species.

Generally, comparing the results with the specifications of BS 373, part 1: 1957, and BS 5268, part 2: 1984 shows a good agreement. For example, the equilibrium moisture contents of Mahogany, Abura, Bush Mansonia, Teak, Obeche and Iroko is generally in the range of 12-25 percent specified by BS 373, part 1: 1957. The same code states an EMC range of 8-12 percent for plywood, which is in agreement with the 11.74 percent obtained. The various resistances obtained are also in the range stated in the same codes. The density of timber woods stated in BS 4978, part 1: 1984 is in the range of 400kg/m^3 to 900kg/m^3 which is in total agreement with the results obtained, which range from 445.1kg/m^3 for black Afara to 749.4kg/m^3 for bush Mansonia. The value of 452.0 kg/m^3 obtained for Iroko is however not in agreement with the quoted value of 600kg/m^3 that was reflected in table 1.

It is also important to observe that while certain timbers possess relative advantage in one property, they cannot be said to have overall overwhelming attractions in all properties. Superiority in flexure may not imply the best qualities in compression, as example. Similarly, a timber wood may have some good strength qualities but will have higher density contributing more substantially to the overall load of a truss, as further illustration. To assist users in making qualitative choice, therefore, table 4 presents analysis of the results of the tests of this research.

5.0 RECOMMENDATIONS

In the search for the most suitable Timber to use for any peculiar situation, there is a need to highlight the fact that other considerations, beyond stress resistances alone, could be fundamental. For example, such factors like resistance to fungal attack and decay, shrinkage, easy availability of the specie in the markets, weight limitations, abrasion resistance, commercial lengths, etc., come into play when deciding on the best option for peculiar situations. Some investigators like Emmanuel (2000) make some recommendations that are discussed below:

(i) ***Floors:*** The timber woods best used for flooring are Abura, Gmelina, Iroko, Mahogany and Teak.

(ii) ***Furniture and Cabinet Works:*** Since these are for the household, the timber should be light and of medium strength only. Thus Black Afara, Iroko, Mansonia (Bush), Obeche, Teak and Abura are suitable.

(iii) ***Formwork and Shuttering:*** These are temporary support mechanisms in the construction Industry for the placement of concrete to set and hydrate to desired shapes. Strength is not a primary priority and Obeche, Gmelina and Plywood are often used. Plywood is however more expensive than the others in the group.

(iv) ***Doors and windows:*** These openings in buildings useful for entrance, exit and ventilation do not carry heavy loading but they need to be rigid to withstand cyclic excessive usage as well as be resistant to decay in the presence of moisture. Abura, Black Afara, Iroko, Gmelina and Mahogany are recommended.

(v) ***Superstructures:*** They carry heavy loading frequently designed, with factors of safety, to the limits of resistances/strength of the timbers. They are mostly in compression, frequently in flexure and sometimes in tension as Ties and upper chords of trusses.

6.0 CONCLUSION

The results of tests conducted in this study reveal that the characteristics of timber wood do not only vary from specie to specie; it also depends on where the specie is grown. Characteristics such as strength, in particular, vary with the orientation of the specimen and will depend on whether the loading is parallel or perpendicular to the grain. It is also clear that an important factor such as the equilibrium moisture content, EMC, does not only depend on environmental factors such as temperature, humidity, wind characteristics, clouds, sunlight, etc., but is also dependent on the Timber specie, particularly its void capacity. The results of studies enumerated in this report will however, provide some firm design data for the structural analysis of timber structures in Nigeria on which much of the important information is usually lacking to the design Engineer. Nonetheless for better and very reliable data bank for the future, it is recommended that specimens of the same species be obtained from different markets, representing a variance in the forest sources, for tests. It is also to be emphasized that in spite of the excellent mechanical and physical properties for structural purposes as well as the transparent abundant forests, the demand of Timber in Nigeria has since exceeded supply. The West African Technical Review (1985) reveals that the Nigerian unreserved forests dropped from 4.23 to 3.0 million hectares from 1980 to 1985. The main support for

Nigeria's demand for all kinds of wood products has been the reserved forest. It managed to cope with growth in demand of 2.2 million m^3 of logs in 1976 to 4.0 million m^3 in 1981. However, it did not meet with demand/calls for over 5.0 million m^3 in 1985, or the rising higher levels of 10 to 11 million m^3 in 1995. These aspects of timber are outside the scope of this research and needs to be addressed by relevant researchers and Institutions in due course.

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APPENDIX A: PROOF OF EXPRESSION (1)

For a simple span of 'L' units with a central point load of 'P', the maximum bending moment, which occurs at the position of the load is: PL/4.

The above value, substituted in the standard equation for flexural tension of $f_{bt} = M/Z$, with L = 1.1m, and $Z = bd^2/6$ gives the expression: $f_{bt} = 1.65P/bd^2$; which is expression (1) in the text.

Table 1: Available Timber Species in Bauchi Sheds

S/No	NAMES		GENERALLY QUOTED CHARACTERISTICS
	LOCAL	SCIENTIFIC	
1.	Iroko (Yoruba) Oji (Igbo) Loko (Hausa)	Chlorophara OR Mora Excelsa	Golden brown in color, very durable, average weight of 660 kg/m^3 when dried, has very large size up to 45m, and above, in length and 2.7m in diameter.
2.	Black Afara	Terminalia Ivorensis	***Medium hard*** straight grained and easy workability wood. Brownish-yellow in colour often with dark grey streaks. Very large tree of 18-45m, length, and 1.5m diameter.
3.	Ofun (Yoruba)	Bush Mansonia Altissima	Very dark wood of grayish purple colour with close straight grains of easy workability. The dust from this wood is an irritant to sensitive skin.
4.	Mahogany (English) Oganwo (Yoruba) Ono (Igbo) Madachi (Hausa)	Khaya Senegalensis	Moderately ***hard*** and reddish brown colour. Easy workability used for veneers on black boards and chipboards.
5.	Obeche (Bini) Arere (Yoruba) Okpobo (Igbo)	Triplochiton Scleroxylon	Rather ***soft wood*** of creamy white straw. Light weight and not very strong. Used for making blackboards.
6.	Abura	Mitragyna Ciliata	Attains height of 30-40m with diameter of 1.0-1.2m. Pale, reddish brown to light brown with straight to interlocked grain with sometimes spiral grain present. Fairly resistant to acids but not very strong to decay.
7.	Teak	Tectona Grandis	Resistant to all forms of decay, highly durable, dark brown in colour. Used in ships and for the tops of science laboratory benches where acid may spill.
8.	Gmelina	Gmelina Arborea	Whitish grey in colour with straight grains. Easy workability used for general purpose construction and for cabinet and furniture.
9.	Plywood	Plywood	Moisture content ranges from 8-12%. Moisture resistant plywood is used for wall cladding and paneling, roofing, flooring, gussets and webs for 'In-built' beams. It is made from various types of wood susceptible to 'lyctus' attack but can be immunized.
10.	Ashuwole	Daniella Ogea	Light brown in color with coarse grains and easily workable.

Table 2: Average Engineering Properties obtained from Tests

Para-Meter	Average Result for Timber Specie (by common names)									
	1	2	3	4	5	6	7	8	9	10
EMC (%)	13.49	14.00	12.85	13.24	12.90	14.10	12.81	11.24	11.74	12.78
Density, kg/m^3	452.0	445.1	749.4	722.7	459.4	661.6	675.1	492.9	563.3	557.5
F_{bt}, N/mm^2	127.5	58.5	121.3	131.9	64.0	97.4	48.4	93.7	105.0	48.4
P_c (Par), N/mm^2	26.6	37.0	56.8	35.8	28.8	38.8	59.9	37.9	6.1	31.3
P_c(Pep.) N/mm^2	14.1	11.3	16.7	24.5	10.8	16.1	27.2	6.3	4.4	12.5
F_t, N/mm^2	*	12.3	*	32.6	21.6	13.7	*	*	*	*

The numbers in the columns mean: 1 = IROKO/LOKO, 2 = BLACK AFARA, 3 = BUSH MANSONIA, 4 = MAHOGANY/MADACHI, 5 = OBECHE, 6 = ABURA, 7 = TEAK, 8 = GMELINA, 9 = PLYWOOD, 10 = ASHUWOLE.

E.M.C = Equilibrium moisture content, f_{bt} = flexural strength

P_c(Par) = Compressive strength parallel to grain, * = Not tested.

P_c(Pep) = Compressive strength perpendicular to grain

f_t = Tensile resistance parallel to grain.

Table 3: EXPERIMENTAL RESULTS OF FLEXURAL TESTS PARALLEL TO GRAIN OF TIMBER SPECIMENS (N/mm^2)

Timber Specie	Afara			Madachi			Obeche			Abura		
Specimen	1	2	3	1	2	3	1	2	3	1	2	3
Resistance	57.57	70.71	47.14	113.14	160.01	122.57	82.57	62.29	47.14	122.57	122.57	47.14

Table 4: Qualitative analysis of timber woods

Property		Density Kg/m^3	f_{bt} N/mm^2	P_c(Par) N/mm^2	P_c(Pep) N/mm^2	*f_t N/mm^2
Minimum Value	Timber Specie	Black Afara	Teak and Ashuwole	Plywood	Plywood	Black Afara
	Value	445.1	48.4	6.1	4.4	12.3
Maximum value	Timber Specie	B. Mansonia	Mahogany	Teak	Teak	Madachi
	Value	749.4	131.9	59.9	27.2	32.6
Mahogany (Madachi)	Value	722.7	131.9	35.8	24.5	32.6

- Only four (4) species; namely Black Afara, Mahogany (Madachi), Obeche and Abura, were tested for direct tensile resistance.