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DETERMINATION OF THE MODULI OF ELASTICITY AND RUPTURE, AND ENERGY CONSUMPTION OF THE OIL PALM TRUNK

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ABSTRACT: The moduli of elasticity and rupture, and the energy to cause failure under impact load of the oil palm trunk were determined. Samples for testing were obtained from the base, middle and top of the tree trunk. They were taken from both the core and outer regions of the trunk and tested under wet and dry conditions. The samples obtained from the outer layer of the base, and tested under dry conditions, gave the highest modulus of elasticity of 4,943N/mm^2 and a modulus of rupture of 42.8N/mm^2. The samples obtained from the inner section of the top and tested under wet conditions gave the lowest values of 369.7N/mm^2 for modulus of elasticity and 0.4N/mm^2 for modulus of rupture. The maximum value of energy consumption of 12.86 joules was recorded for the outer base section tested under wet conditions as against the minimum value of 0.45 joules recorded for the samples from the inner portion of the top and tested under dry conditions. There was a general decrease from the base to the top for the three parameters and from inside to the outer section.

1. INTRODUCTION

The ever-increasing human population which demands more housing has put pressure on the conventional materials of construction, and the escalating prices have made most of them unaffordable especially by the poor rural communities. It has been established that about 60% of the cost of construction projects is accounted for by the cost of materials, and an appropriate method of reducing building costs is a reduction in the cost of materials. The materials of construction which are locally available, and for which local technology may be available to effectively utilize, provide a viable option in this respect. The use of local materials has the potential of reducing the total project cost by between 30 and 80% compared with when conventional materials are used *[1]*. Palm wood is a hard timber from palm trees and it offers an alternative to rainforest timber *[2]*. The oil palm wood presents a suitable option where and when available and its utilization may be better exploited if its engineering properties are known. There is a dearth of this information in Nigeria at present.

The oil palm *(Elaeis guineensis,* Jacquin) is an upright growing tree commonly found in the tropical rainforest of West Africa where it is believed to have originated *[3, 4, 5, 6, 7, 8, 9]*. The oil palm belongs

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to warm, high-rainfall tropical forest area. It is equally found in various parts of the world beween latitudes 44^{0}S and 44^{0}N wherever the required conditions of at least 1500mm of evenly distibuted annual rainfall and temperatures of between 24^{0}C and 32^{0}C are available. Major poducers include Malaysia, Indonesia, Nigeria, China, Republic of Congo and Ivory Coast. In Nigeria, the oil palm is found mainly in south where it grows wildly as well as in established plantations.

The oil palm wood is made up opf two distinct sections from the base to the top (Plate 1). These regions are the high- and low-density portions. The high-density outer portion is usually darker in colour than the low-density inner core and it is very predominant at the base section. The high-density portion is next to the cambium, and the inner wood tissue is bounded by this strong portion of the tre which is composed of densely packed fibers. Hartley *[10]* reported that this outer region, made up of densely packed fibers, is much stronger than most hardwoods and that is why the oil palm tree is able to withstand the winds that break other trees.

In Nigeria, the main attraction for the oil palm tree is the fruit, which provides the palm and kernel oils, and pail wine from the trunk for human consumption and industrial raw materials. This provides a source of employment for a good number of the rural populace. The runk as a material is of little significance and when it either falls naturally or is removed during operations on constructionsites, it is left to rot or burnt to give way for other activities. In very rare cases, it is used as fuel or truss members for roofs or rural buildings. Generally, the truns of several million palms felled throughout the tropics are usually wasted, and it is now being suggested that the oil palm trunk should be considered as a suitable alternative to endangered hardwoods *[2, 11]*. Ratanawilai *et al [12]* reported that in Thailand and Malaysia, the increasing demand for furniture items and the declining supply of the traditional timber for construction motivated the search for alternative materials, and the oil palm trunk which is abundant but under-utilized was considered as an alternative.

The mechanical properties of a material give an indication of its response to external loading. For wood-related materials, this is known to be by density and moisture content especially below the fibre saturation point. Dinwoodie *[13]* reported that these strength properties are further influenced by the rate and direction of load application. The moduli of elasticity and rupture are two of the engineering properties that determine the potentials of a material for structural use. The modulus of elasticity, which expresses the relationship between stress and strain when the material is under load, allows the prediction of its behaviour while in service. The modulus of rupture, on the other hand, provides information on the amount of force required to break the material.

The primary objective of the work reported here was to determine the moduli of elasticity and rupture as well as the energy consumption of the oil palm trunk and their variations along the longitudinal and transverse sections of the trunk, under wet and dry conditions.

2.0 MATERIALS AND METHODS:

2.1 Collection of Samples: The samples used for this study were obtained from dura species growing naturally in swampy areas within the University of Ibadan campus, Nigeria where a cluster of the tree is found. In selecting a tree to be felled, the physical conditions of the tree such as straightness of trunk, good girth and minimum observable natural defects and physically inflicted injuries were taken into account. This was to minimize the possible effect of growth defects in reducing the mechanical properties of the trunk. Five trees were felled using a chain saw with the cutting done at an average height of 30cm above the natural ground level. The average length of the trunk between the point of cut and the crown was 20.3 meters while the average diameter varied from 30cm at the base to 24cm at the top. The trunk length was cut into 120cm bolts. Two bolts each were taken fromthe base, middle and top of the five trunks for sample production. From each bolt, four samples each of low (core) and high (outside) density were collected for test, making 240 samples. The samples were labeled for ease of identification, B, M and T; indicating the base, middle and top of the trunk, respectively.

2.2 Pre-test Treatment: The tests were to be carried out under wet and dry conditions and for this reason, the samples collected from all sections were divided into two equal parts. The set for the dry test was oven-dried to a constant weight and left in an air-conditioned room for two days to stabilize and attain an average moisture content of 12%. The second set for wet test was soaked in water for seven days to bring the samples to fiber saturation point after which they were removed and drained before being tested.

2.3 Bending Tests: Two tests, impact and static bending tests, were conducted.

2.3.1 Impact Bending Test: The impact bending test provides information on the shock resistance of the specimen tested. This was carried out using the Hatt-Turner impact testing machine and in accordance with BS 373 *[14]*. The impact load was provided by a 1.5kg metal weight hammer hung by means of a cable between two metal pipes with a clearance that was just enough for free movement of the hammer. The specimen was adequately secured at the bottom of the pipes such that there was no displacement when the impact load hit it at the centre. The initial height of the impact load was 25cm. This was increased at intervals of 5.08cm until the specimens gave signs of failure and had to be reduced to 2.54cm. The height of the impact load which caused the sample to fail was recorded. Some of these specimens are shown in Plates 2 and 3.

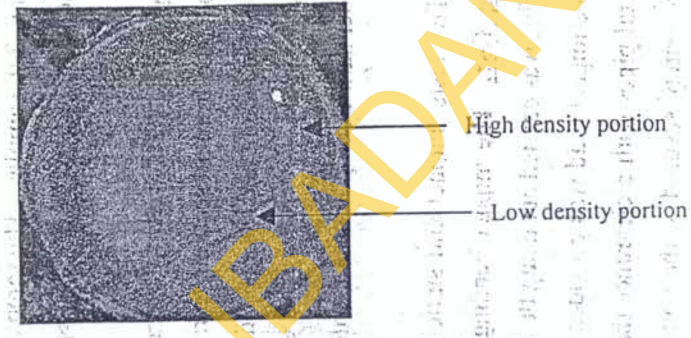

Plate 1. Transverse section of oil palm trunk

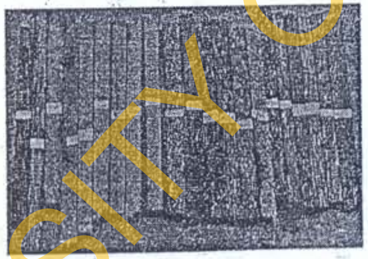

Plate 2. Cross section of samples before testing

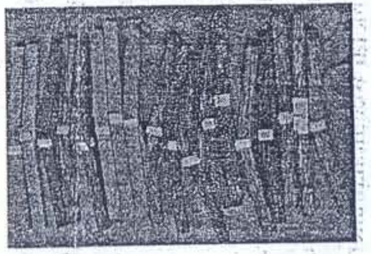

Plate 3. Cross section of samples after testing

2.3.2 Static Bending Test: The static bending test provides information on the tensile strength of the specimen as expressed by the modulus of rigidity (MOR) and modulus of elasticity (MOE), and was carried out using the Housefield tensiometer in accordance with BS 373 *[14]*. After loading the specimen, pressure was gradually applied while the movement of the mercury was observed. An extensiometer was attached to produce a load deflection graph. The application of pressure was stopped when the mercury was observed to decline. The point on the scale at which the mercury started to decline indicated the maximum load that was sustainale by the specimen and was used in calculating the MOR using the following equation:

$$MOR = \frac{3PL}{2nd^2} \text{ (N/mm}^2\text{)} \qquad \ldots\ldots\ldots\ldots(1)$$

The load deflection curve obtained with the extensiometer was used to compute the MOE using the following equation:

$$MOE = \frac{PL^3}{4Dbd^3} \text{ (N/mm}^2\text{)} \qquad \ldots\ldots\ldots\ldots(1)$$

where:

P is the maximum load sustained at failure;

L is the span of specimen

D is the deflection at point of failure in mm, and is obtained as the slope of the graph plotted by the extensiometer at point of failure; and

b and d are the width and thickness of specimen, respectively.

Calculations were made for each of the ten replicates in a group from which an average value was obtained.

3.0 RESULTS AND DISCUSSION

3.1 Energy Absorbed: Data on the energy required to cause failure under impact loads are presented in Fig. I for all conditions of test. The energy decreased from the bottom to the top but increased from the core to the outside. The values for dry conditions were generally lower than for wet conditions. This may be attributed to the fact that when a wooden material dries, it becomes more brittle and less resistant to impact load.

3.2 Static Bending: Data collected from these tests were used in the calculation of MOE and MOR which are presented in Fig. 2 and 3. Both parameters were observed to decrease from the base towards the top of the tree and also from the pith to the cambium. The pattern of variation of the MOE

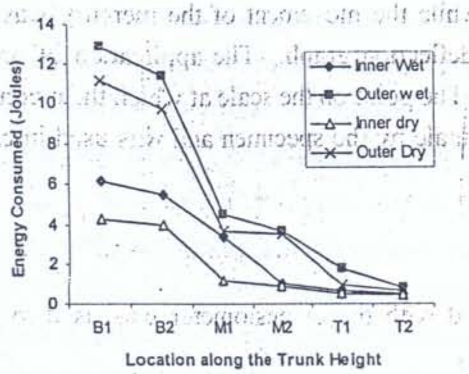

Fig.1. Energy Consumption

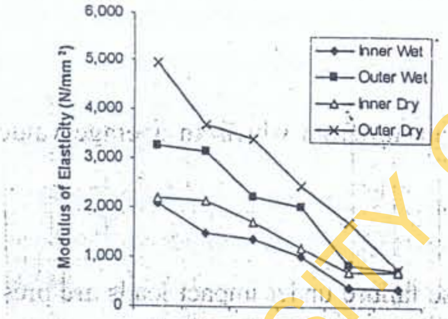

Fig.2 Modulus of Elasticity

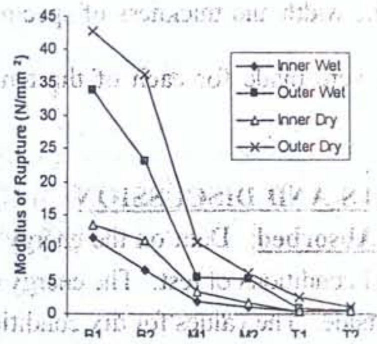

Fig. 3 Modulus of Rupture

and MOR from the base to the top is similar to what other workers such as Ratanawilai *et al* [12] have observed.

While MOR is an indication of the utilimate strength of the sample, the stiffness is indicated by the MOE. The observations made in this study imply that the outer base section of the palm wood tree is the strongest and expectedly the stiffest while the inner top is the weakest. When this material is to be used for load-bearing structures, preference should be given to materials obtained from the base. The values for dry condtions were generally higher than for wet condtions for all the cases investigated. This is attributable to the fact that when a wooden material is dry, the gaps in-between the cell-wall materials, decreases. The fibers are able to reinforce one another thereby strengthening the wood more. In wet samples, the wood fibers are farther apart as the water comes in-between them and this reduces the effective strength under gradual loading. In general and below the fiber saturation point, the strength of wood including the oil palm wood is increased as the moisture content decreases *[15]*.

4. CONCLUSIONS:

- For samples obtained from the core and tested under wet conditons, the energy consumption varied from 6.2 joules at the base to 0.52 joules at the top; the MOE and MOR varied from 2,075 N/mm^2 to 369.7N/mm^2, and 11.5N/mm^2 to 0.4N/mm^2, respectively.
- For samples obtained from the core and tested under dry conditions, the energy consumption varied from 4.26 joules at the base to 0.45 joules at the top. MOE and MOR varied from 2,209N/mm^2 to 700.3N/mm^2, and 13.4N/mm^2 to 0.5N/mm^2, respectively.
- For samples obtained from the outer section and tested under wet conditions, the energy consumption varied from 12.86 joules at the base to 0.82 joules at the top. MOE and MOR varied from 3,251.5N/mm^2 to 774.5Nmm^2, and 33.9N/mm^2 to 0.6N/mm^2, respectively.
- For samples obtained from the outer section and tested under dry conditions, the energy consumption varied from 11.14 joules at the base to 0.67 joules at the top. MOE and MOR varied from 4,943N/mm^2 to 42.8N/mm^2, and 771.8N/mm^2 to 1.0 N/mm^2, respectively.
- The properties investigated decreased from the base towards the top of the trunk but increased from the pith towards the cambium.
- Moisture content was found to influence the properties investigated. While dry samples were less resistant to impact load, they were more resistant to gradual loading as exhibited by their higher stiffness and ultimate strength than the wet samples.

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