

ENGINEERING PROPERTIES OF RECLAIMED FLOOR TIMBER

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Abstract: Increased demand for commercial valued timber species for structural and non- structural building elements is rapidly diminishing in quantities and qualities within Nigeria's forest and there is need to find an alternative naturally renewable material to supplement the quantity of timbers required for the infrastructural needs in the developing countries like Nigeria. Thereby, minimizes the increasingly cost and scarcity of this important materials. However, reclaimed timbers as readily available materials from demolition or reconstruction buildings can be substitute for commercial valued timber species that almost in extinction. In this study the physical and mechanical properties of reclaimed timber were studied to establish its potential for reusability. The specimens were prepared and tested using three point bending test in accordance ASTM D193 (2000). Experimental results of the study showed that the mean moisture content, air- dry density, bulk density, bending strength and modulus of elasticity were found to be 44.80%, (MC), 597.19Kg/m³ (AD), 1010.63Kg/m³, (BD), 156.08N/mm² (BS) and 20272.06 N/mm² (MOE) respectively. Conclusively, properties of reclaimed Apa (*Azelia africana*) timber were favorably compared to some of the commercial valued timber species available in Nigerian plank markets. Therefore, it proved to be suitable substitutes for structural and non-structural timber species now seriously threaten and mostly going into extinction and thereby reducing pollution of such materials in both building and construction industries.

Keywords: Reclaimed Timber, Moisture Content, Density, Modulus of Elasticity, Bending Strength, Reusability.

1. INTRODUCTION

Of all materials use for construction, timber is a unique structural material due to its renewability, density to weight property and efficient potentiality with many environmental positive attributes. From the manufacturing view point, the environmental impact of timber structures is much smaller compared to some other structure such as concrete, steel and plastic etc. Timber as a material for construction creates an initial problem for structural engineers because no permanent control over the quality like other material that are manmade and some form of quality control can be exercised during their production.

With the current modernization and globalization, the utilization of timber as construction material increases day by day for building construction, furniture making, paper and wood based composite in developing countries including Nigeria. These have resulted into consumption of large quantities of timber raw materials by processing industries coupled with forest degradation and deforestation and the increasing demand for timber products consequently lead to acute shortage of timber materials [1].

Another study relates that the fast- diminishing supply of most commercial valued timber species as constructional material inspire the forest products industry to look inward for available untapped potential timber species which may have similar or greater quality like that of commercial valued ones but not yet utilized and its utilization being based on basic properties and processing properties [2]. Local and industrial consumption also contribute to the species being extinct from Nigeria's forest. Therefore, this has necessitated an alternative for these commercial and valuable timber species, in order to salvage or minimize their total extinction. [e] However, much of timber reclaimed from demolition or reconstruction buildings is simply being underutilized for minor work like shed, fence, brace of damaged work, firewood and charcoal or otherwise left as waste.

Such reclaimed wood is assumed to be stronger one against recent wood [3] because of its weathered essence and tighter grain structure. Also, old timbers were allowed to mature to reasonable age before harvested and properly graded and compare to recent premature trees harvested for timber materials with inadequate graded. [4] Further explained that reclaimed lumber is popular for the following reason; unique appearance, its contribution to eco, the history of wood origin and its characteristics such as strength, stability, durability. These are expected characteristics of any constructional materials to perform its intended or designed or functions optimally.

[5] evaluated the mechanical properties of timber salvaged from two residential buildings in Florida, USA and their properties were compared with virgin timber tested under the same conditions. The results proved that the salvaged timber was on average of 50% denser than similar newly acquired virgin timber. More so, it was even stronger enough to meet structural requirement to be reused in building construction. In this regard, timber dealers in Nigeria started purchasing reclaimed timbers from reconstruction sites around and removing bolts, nails and metal connectors on them and also reselling them as substitute for some of the commercial valued species which are now very scarce and costly to procure in the timber markets. Though, current information on the residual properties of such reclaimed timber is inadequate thus making its utilization based only on traditional experience and conventional practice.

[6] Noted that determination of some important timber properties such as moisture content, density, dimensional stability and MOE and MOR allow construction activities using vast quantities of locally available raw materials towards major steps in industrialization and economic independence for developing countries that are emphasizing more interesting in timber. In these sense, there is need for accurate and proper determination of strength properties of these reclaimed timbers prior to the promotion of the reusability and recycle purposes.

2.0 MATERIALS AND METHODS

2.1 Materials Collection and Preparation

The timber specimens for this study were obtained from 45years old Apa (*Afzeliaafricana*) timber floor members reclaimed during reconstruction of timber framed offices inside Wood Workshop at Faculty of Technology University of Ibadan, Nigeria. The number and dimension of floor members removed from old timber framed floor was 25 mm x 150 mm x 3000mm of 50 grooved and tongued members. Thereafter, a total of twenty members were randomly selected and processed by using circular and planning machines to a dimension of 410mm x 20mm x 20mm (L X W X T) for modulus of elasticity and bending strength (mechanical property) and 50mm x 50mm x 20mm (L X W X T) for timber moisture content and density in accordance with [7].

2.1.1 Moisture Content of Reclaimed Timber

Twenty numbers of 50mm x50mm x20mm timber samples were submerged in water for 24 hours to make in green conditions and naturally air- dried for six months and the weight afterward was recorded. Loss of weight of the timber samples on drying was noted. Calculation of the loss in weight as percentage of the samples weight after drying was done by using the formula below.

$$MC = \frac{W_w - W_o}{W_o} \times 100 \quad (1)$$

Where, MC is Moisture Content; W_w is Green Weight; W_o is Air- Dry Weight

2.1.2 Air-Dry Density of Reclaimed Timber

Twenty numbers of 50mm x50mm x20mm timber samples were used to determine density of timber samples, thereby the volume of the samples at green weight was recorded and the air-dry density calculated using equation 2.

$$D_d = \frac{W}{V} \text{ (Kg/m}^3\text{)} \quad (2)$$

Where, D_d is Air-Density; W is Dry weight and V is Green Volume.

2.1.3 Bulk Density of Reclaimed Timber

Bulk density was obtained using green volume and initial weight of each sample before air-drying according to equation 3.

$$D_b = \frac{W_i}{V} \text{ (Kg/m}^3\text{)} \quad (3)$$

Where, D_b is Bulk Density; W_i is Green Weight and V is Green Volume.

2.1.4 Determination of Strength Properties

This followed the three point bending testing using universal testing machine at the Department of Agricultural and Environmental Engineering University of Ibadan. Twenty numbers of 410mm x 20mm x 20mm samples were subjected to static bending loading at rate of 60KN/min at center of 300mm span of each timber sample until failure occurs, as shown in figure 1. The failure load in respect of the individual sample was recorded. The bending strength and modulus of elasticity were calculated using equations 4 and 5 respectively according to [5].

$$MOR = \frac{3PL}{2bd^2} \text{ (N/mm}^2\text{)} \quad (4)$$

$$MOE = \frac{PL^3}{4\Delta bd^2} (N/mm^2) \quad (5)$$

Where, MOR is Modulus of Rupture; MOE is Modulus of Elasticity; P is Load at Failure (N); L is Length between (two) Supports (mm); b is Width of the Material (mm); d is Thickness of the Material (mm); Δ is Deflection at Proportional Limit of the Material (mm).

2.1.5 Comparison of Reclaimed Timber

Data of selected physical and mechanical properties of timber species considered acceptable for structural components in construction industries in Nigeria, Africa was sourced from literature review and comparison were made with obtaining data from reclaimed Apa (*Afzelia africana*) timber used in this study.

3.0 RESULTS AND DISCUSSION

3.1 The physical properties

Tables 1 and 2 and figures 2 and 3 shows the results obtained from the laboratory work carried out on the physical and mechanical properties of the reclaimed Apa (*Afzelia africana*) timbers under investigation.

Timber density has been traditionally factored on which the utilization of timber species are based [8, 9, 10] and [11]. Density is a good predictor for bending strength and modulus of elasticity, these strength properties are very important consideration for structural elements [12]. In this study, values of density for all the timber samples were computed based on weights as shown in Table 1. At 44.8 % moisture content, results indicated that air-dry density variation ranged from 500kg/m³ to 750kg/m³ with mean value of 568.8kg/m³. It was also observed that the mean air-dry density for the saturated timber sample was lower than the bulk density for the same samples and that was accounted for as a result of the bigger volume of samples at the fiber saturation point. [13] Concluded that density and moisture content are of great important properties of timber, because as the moisture content increases, the timber density also increases.

It is an established fact that knowledge of density of any timber species is vitally necessary in the preliminary selection and utilization of timber for structural purposes [1]. Generally, structural members for buildings such as rafters, tie beams, and purlins should be able to withstand stresses, to strength ratio. So that pieces could be easily handled by one or two men and that such structural timber element should have density ranges from 400-750kg/m³ as reported by [14]. Therefore, the range for mean density for the *Afzelia Africana* species obtained in this study is from 500.10 to 750.50Kg/m³. This agrees with mean density of 680Kg/m³, 718 kg/m³ and 716 kg/m³ obtained by [14], [15] and [16], respectively.

3.1.2 Strength Properties

The MOR and MOE are important parameters for timber utilization as a structural material. MOR indicates bending strength of a structural element either timber, steel and concrete while MOE indicates stiffness properties of mentioned structural elements [17]. When timber structure is loaded to high stress levels beyond the elastic range, plastic deformation or failure occurs, so before such member or component fails, it should be able to withstand stress generated to reasonable level or showed signs of failure thus, [18] concluded that structural timber strength properties must has MOE of 6860-14700N/mm², MOR of 39-132N/mm² and should be durable, easy to plane and nail). Therefore, the MOR and MOE of reclaimed Apa (*Afzelia africana*) timber with mean values of 156.08N/mm² and 20272.06N/mm² are higher than ranges specified by [18] in their study.

4.0 Comparison of Reclaimed Timber

The density of reclaimed Apa (*Afzelia Africana*) as revealed in this study favorably compares with timber species specification as stipulated in the standards of [19] and some of valued commercial tropical Africana timbers sourced for structural construction. Example of the timbers and their densities listed in [20,21] include; *Triplochiton scleroxylon* (400Kg/m³), *Pycanthus angolensis* (480kg/m³), *khayai vorensis* (485Kg/m³), *Gosweilerodendron bal samiferum* (497Kg/m³), *Terminalia ivorensis* (550Kg/m³), *Mitragynasiliata* (560Kg/m³), *Cordiapatythyrsa* (410Kg/m³), *Tectonagrandis* (480Kg/m³), *Millicia excelsa* (550Kg/m³) and *Entandrophragma cylindricum* (460Kg/m³). Therefore, the density of reclaimed Apa (*Afzelia africana*) timber fall within the limit of past research. However the density of reclaimed timber was lower than what reported by [22] for *A. africana* from Zaria 813.27Kg/m³ while [23] recorded a timber density value of (823.81Kg/m³) for the same timber specie from Akure. Age and location could have contributed to the difference.

Results for bending strength MOR showed that reclaimed *A. africana* timber with mean value of 156.08N/mm² has a very high static bending strength which can compare favorably with some valued commercial timber species in Nigeria. For instance; Abura-*Mitragyna ciliate* (79N/mm²), Afara- *Terminalia superb* (106N/mm²), *Afromosia-Pericopsis* (128N/mm²), Iroko- *Chlorophora exelsa* (130N/mm²), Mahogany-*Khaya ivorensis* (110N/mm²), Obeche-*Triplochiton scleroxylon* (77N/mm²), Omo-*Cordiaafricana* (73N/mm²), [24] and MOR of reclaimed timber was higher than those of Apa- *Azalia africana* (57.33N/mm²) and *Mansonia-Mansonia altissima* (52.09N/mm²) recorded by [22]. This implies that reclaimed *Apa A.africana* timber can possibly substitute these species where stiffness of wood is important.

From the findings, it is clear that reclaimed *Apa A. africana* timber with a modulus of elasticity value of 20272.08N/mm² satisfies the requirements of [20] in respect of the standards stipulation for structural application in the country. Values of modulus of elasticity of some valued commercial timber species in Nigeria include; *Ceiba pentandra* (4280N/mm²), *Triplochitons cleroxylon* (5500N/mm²), *Antiaris Africana* (5800N/mm²), *Alstonia boonei* (6700N/mm²), *Gossweiloredendron balsamiferum* (7600N/mm²), *Daniellia klainei* (8100N/mm²), *Pycanthus angolensis* (8445N/mm²), *Khayaivorensis* (10000N/mm²), *Eribroma oblonga* (10070N/mm²), *Chlorophora exelsa* (11000N/mm²) and *Mansonia altissima* (11175N/mm²) [25]. In the study carried out by [25], concluded that timber for structural use should have MOE of between 6260 and 14700 N/mm², MOR of 39-132 N/mm² and should be durable. In this study reclaimed *Apa A africana* had properties within the specified ranges, thus can be re-used for making structural elements such as tie beams, rafters and purlins in roof truss construction.

According to [25], they had earlier recorded the following properties of Modulus of Rupture and Modulus of Elasticity of some timber as follows: *Celtis mildbraedii* (149.94 and 7088.69) N/mm²; *Azalia Africana* (136.71 and 6313.58) N/mm²; *Khaya ivorensis* (94.82 and 8192.54) N/mm²; *Meliceae excels* (90.41 and 5765.63) N/mm²; and *Triplochiton scleroxylon* (30.87 and 3937.50) N/mm². From this study, it can be deduced that *Azalia africana* has a MOR and MOE of 156.08 and 20272.06 N/mm² at 44.8% M.C which is higher than all other timber suggested by [25]. The modulus of elasticity of reclaimed timber was greater than 12560.5N/mm² obtained from study carried out on the same timber specie by [22]. This implies that reclaimed *Apa A. africana* timber is better implored when elasticity is considered importance due to the nature of its elastic ability to resist plastic deformation or when materials needed that produced deformations by low stress with completely recoverable after loads are removed.

Table 1. Physical Properties

Property	Mean	Min	Max
Air-Dry Density (Kg/m ³)	597.19	500.10	750.30
Bulk Density (Kg/m ³)	1010.63	582.04	1125.20
Moisture Content (%)	44.80	16.60	55.560

Table 2. Strength Properties

Property	Mean	Min	Max
MOR (N/mm ²)	156.08	85.50	173.63
MOE (N/mm ²)	20272.06	13342.02	36639.01



Figure1. Sample under Static Bending Loading.

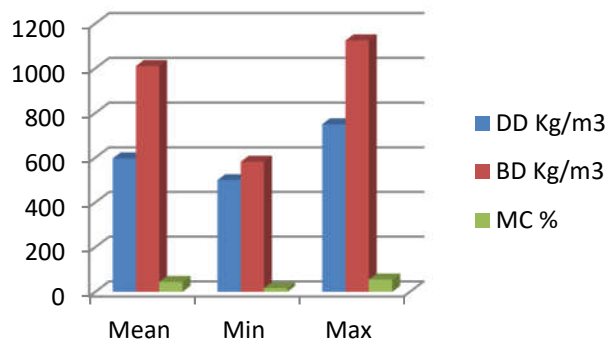


Figure 2: Physical Properties.

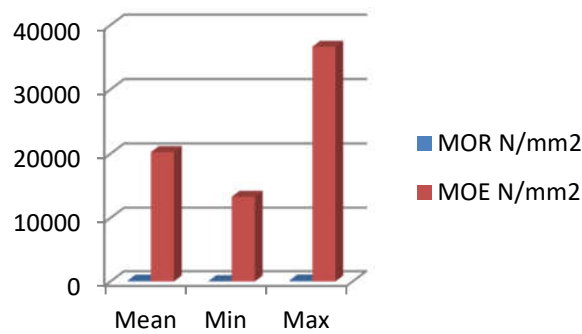


Figure 2: Strength Properties.

5.0 CONCLUSIONS

Results obtained from this study revealed that the properties of reclaimed Apa (*Azelia africana*) timber was favorably compared to some of the commercial valued timber species available in Nigerian plank markets. Therefore, it proved to be suitable substitutes for the existing commercial valued for structural and non-structural timber species now seriously threaten and mostly going into extinction and thereby reducing pollution from such materials in both building and construction industries.

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