



## DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES OF MASQUARADE TREE

**S. B. BAKARE; S. F. ALIYU; O. J.  
OYEWIRE; A. W. ADEKEYE; & K. A.  
FOLARANMI**

Department of Civil Engineering, <sup>2,5</sup>Department of  
Building Technology, Federal Polytechnic Offa.

Corresponding Author: [liverreds2004@yahoo.com](mailto:liverreds2004@yahoo.com)

DOI: <https://doi.org/10.70382/mejedir.v8i4.041>

### Abstract

The study endeavours to investigate the physical and mechanical properties of Masquerade Tree (*Polyalthia longifolia*) with a specific focus on tensile strength, shear strength, and static bending strength. This research aimed to determine the suitability of Masquerade Tree wood for various timber applications by comparing its strength characteristics with other commonly used timber species. To achieve the study's objective, representative samples of Masquerade Tree wood were collected and prepared for testing. Tensile strength, shear strength, and static bending strength tests were conducted according to standardized protocols. Comparative analysis was carried out by referencing existing data on the

mechanical properties of other timber species. The results revealed that Masquerade Tree wood exhibited favorable ultimate tensile strength

### Keywords:

Masquerade tree,  
Tensile strength,  
Shear strength,  
Static bending  
strength, Modulus  
of elasticity

which ranges from 4.06MPa to 4.87MPa and 91.02MPa mean value of modulus of elasticity thereby displaying a substantial resistance to applied forces. It demonstrated commendable shear strength with modulus of rigidity which ranges from 20.84 to 62N/mm<sup>2</sup> indicating its potential for applications that require high resistance to parallel

forces. The static bending strength of Masquerade Tree wood can withstand maximum load which ranges from 11300N to 12360N thereby showing mean modulus of elasticity of 88.36N/mm<sup>2</sup> which was found to be within an acceptable range suggesting its suitability for load-bearing applications. The comparative analysis highlighted similarities and differences between Masquerade

Tree wood and other timber species. It indicated that Masquerade Tree wood offers a competitive strength profile when compared to commonly used timber properties.

## Introduction

### BACKGROUND OF STUDY

**T**he determination of physical and mechanical properties of plants is essential in various fields, including engineering, agriculture, and materials science. One such plant of interest is the Masquerade tree, scientifically known as *Polyalthia Longifolia*. Also commonly referred to as the Indian Mast Tree or False Ashoka, this evergreen tree is native to the Indian subcontinent and Southeast Asia. It belongs to the Annonaceae family and is widely distributed across tropical and subtropical regions due to its aesthetic appeal and various medicinal uses.

The Masquerade tree is known for its slender, tall trunk, reaching heights of up to between 10 and 18 meters, and its gracefully drooping branches covered with dense, glossy green leaves. The tree also produces small, fragrant, cream-colored flowers, adding to its ornamental value. Its wood has been traditionally used in furniture making, carpentry, and as a source of fuel due to its moderate density and workability.

In addition to its elegant appearance and ability to adapt to various environmental conditions, the Masquerade tree is frequently planted in urban landscapes, parks, and gardens, enhancing the aesthetic value of these areas.

Beyond its ornamental uses, the Masquerade tree holds substantial economic importance due to its versatile applications in various industries. Traditionally, its timber has been employed in construction for structural elements, furniture making, and crafting decorative items (Dagar JC, *et al.*, 2018). Additionally, the tree's wood pulp is used in paper manufacturing, while its leaves and bark have been utilized in traditional medicine for their medicinal properties.

Despite the widespread utilization of the Masquerade tree, a critical limitation exists in the lack of comprehensive data on its physical and mechanical properties. Existing research on this species has been limited and sporadic, leading to an inadequate understanding of its potential and limitations as a material resource. Consequently, researchers, forest managers, industrialists, and policymakers face challenges in making informed decisions regarding the tree's optimal applications and sustainable use.

The absence of standardized testing methodologies and comprehensive data on the Masquerade tree's physical and mechanical properties has also resulted in contradictory and inconsistent information in the literature (Ghosh, *et al.*, 2011). This discrepancy hampers the development of accurate design criteria for engineering applications, such as load-bearing calculations and structural analysis, which rely heavily on reliable material properties.

Moreover, as sustainable forest management gains prominence, it becomes imperative to obtain accurate knowledge about the Masquerade tree's properties. Understanding the mechanical characteristics, such as its strength, elasticity, and hardness, is crucial for determining appropriate harvesting techniques, optimizing resource utilization, and ensuring long-term conservation of the species.

Hence, this research project aims to address the existing knowledge gap by conducting a comprehensive investigation into the physical and mechanical properties of the Masquerade tree (*Polyalthia Longifolia*). Through a systematic and standardized approach to testing, the study seeks to provide reliable and precise data on the tree's properties, leading to a better understanding of its potential in different industrial applications and contributing to sustainable forest management practices.

By shedding light on the physical and mechanical attributes of the Masquerade tree, this research endeavors to offer valuable insights to stakeholders, enabling them to make well-informed decisions regarding its usage in various sectors (Nair, *et al.*, 2000). The outcomes of this study will contribute to the scientific literature, benefit industries relying on this natural resource, and support the development of environmentally responsible practices for the cultivation and utilization of the Masquerade tree.

The primary objective of this study is to determine the physical and mechanical properties of the Masquerade tree's wood in order to evaluate its suitability for various engineering applications, such as construction materials, furniture manufacturing, and other wood-based industries.

## **LITERATURE REVIEW**

### **Timber**

Timber is one of the earliest construction materials. Nowadays, it is largely superseded by concrete, steel and plastics. However, the use of timber remains quite extensive. Basically, there are two types of lumber for carpentry: softwoods and hardwoods. These are somewhat misleading terms, because they refer not to the quality of timber, but to the types of trees the timber comes from. Softwoods generally come from trees with needle-like leaves (conifers); they are “evergreens” (Taylor, 2002). They are not normally highly durable unless protected by preservatives. While the Hardwoods comprise the broad-leaved trees, mostly deciduous, although there are many broad-leaved trees that are evergreen in certain climates. Many hardwoods are in general durable, and some such as oak may last for centuries without the use of preservatives (although, exceptionally, balsa and poplar are also hardwoods and these are neither strong nor durable).

Generally, the hardwoods are harder and stronger than the softwoods. Hardwood trees are slow growing, which makes them more expensive than softwoods. Hardwoods generally are used more extensively for furniture, interior finishing, and cabinetwork than for structural purposes (Erdoğan, 2002; Keyser, 2000).

### **Biological Structure of Wood**

#### **Tree**

A living, growing tree has two main domains, the shoot and the roots. Roots are the subterranean structures responsible for water and mineral nutrient uptake, mechanical anchoring of the shoot, and storage of biochemicals. The shoot is made up of the trunk or bole, branches, and leaves (Raven, et al., 2000). When a tree is cut down and the stump is observed, several gross observations are made. The trunk is composed of various materials present in concentric bands. From the outside of the tree to the inside are outer bark, inner bark, vascular cambium, sapwood, heartwood, and the pith.

Outer bark provides mechanical protection to the softer inner bark and also helps to limit evaporative water loss. Inner bark is the tissue through which sugars (food) produced by photosynthesis are translocated from the leaves to the roots or growing portions of the tree. The vascular cambium is the layer between the bark and the wood that produces both these tissues each year.

The sapwood is the active, “living” wood that conducts the water (or sap) from the roots to the leaves. It has not yet accumulated the often-colored chemicals that set apart the non-conductive heartwood found as a core of darker-colored wood in the middle of most trees. The pith at the very center of the trunk is the remnant of the early growth of the trunk, before wood was formed.

### **Softwoods and Hardwoods**

It should be noted, not all softwoods have soft, lightweight wood, nor do all hardwoods have hard, heavy wood. To define them botanically, softwoods are those woods that come from gymnosperms (mostly conifers), and hardwoods are woods that come from angiosperms (flowering plants). In the temperate portion of the northern hemisphere, softwoods are generally needle-leaved evergreen trees such as pine (*Pinus*) and spruce (*Picea*), whereas hardwoods are typically broadleaf, deciduous trees such as maple (*Acer*), birch (*Betula*), and oak (*Quercus*).

Softwoods and hardwoods not only differ in terms of the types of trees from which they are derived, but they also differ in terms of their component cells (Oluwadare, 2007). Softwoods have a simpler basic structure than do hardwoods because they have only two cell types and relatively little variation in structure within these cell types. Hardwoods have greater structural complexity because they have both a greater number of basic cell types and a far greater degree of variability within the cell types.

The single most important distinction between the two general kinds of wood is that hardwoods have a characteristic type of cell called a vessel element (or pore) whereas softwoods lack these (Ajala, 2005). An important cellular similarity between softwoods and hardwoods is that in both kinds of wood, most of the cells are dead at maturity, even in the sapwood. The cells that are alive at maturity are known as parenchyma cells and can be found in both softwoods and hardwoods.

### **Properties of Timber**

The properties of timber are divided into physical and mechanical properties.

Under the physical property, we have:

- i. Density and Specific weight
- ii. Bulk Density
- iii. Heat Conductivity
- iv. Resistance to action of acids and alkalis

Under the mechanical properties, we have:

- i. Stress-Strain relationship
- ii. Compressive Strength
- iii. Tensile Strength
- iv. Shear Strength
- v. Static Bending
- vi. Toughness
- vii. Hardness

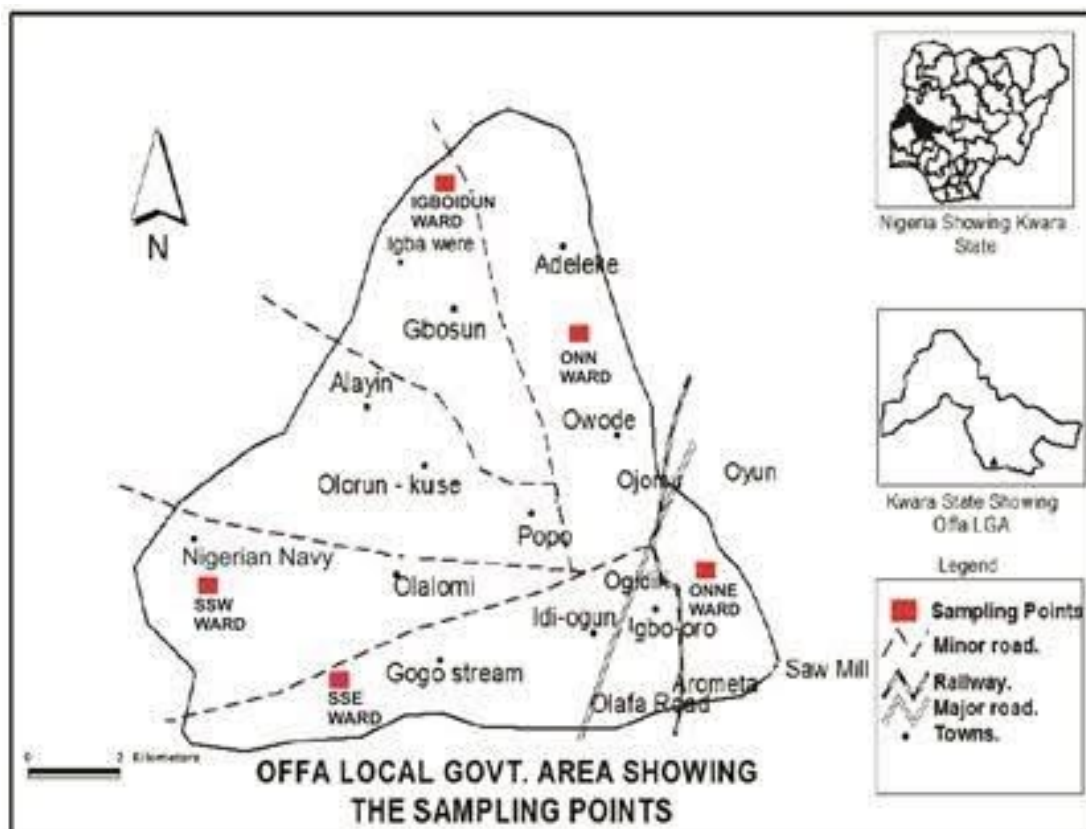
### **MATERIALS AND METHODS**

The type of research used for this project is laboratory testing and it is in accordance with British Standard BS 373 (Methods of testing small clear specimens of timber). BS 373 provides standard test methods for testing the various properties of clear wood specimens. Contained in BS 373 are procedures for conducting test in static bending, impact, compression parallel to the grain, compression perpendicular to the grain, shear parallel to the grain, tensile parallel to the grain, and tensile perpendicular to the grain.

#### **Materials**

The primary material used in this study was masquerade tree wood obtained from mature trees growing in a specific geographic region Amuyo Area, Offa, Kwara State to be precise. The selection of this region was based on the availability and abundance of masquerade tree species. The wood samples were collected in compliance with ethical guidelines and sustainable resource management

practices. The collected samples were then taking to a sawn mill to be cut into desired sizes which is then prepared and conditioned for subsequent testing and analysis using Universal Testing Machine.



**Fig. 1: Map of Nigeria showing Offa Local Government in Kwara State**

## Methods

Different methods were employed to determine the physical and mechanical properties of Masquerade tree. These include tensile test, shear strength test and static bending test.

## Determination of Tensile Tests

A total of five specimens of masquerade tree timber were prepare for carrying out the tensile test and sawn to specified sizes of 20mm (width) x 20mm (thickness) x 190mm (length). These were tested by Universal Testing Machine to determine their various tensile strength in accordance with BS373 (1957).



**Fig. 2: Universal Testing Machine showing Tensile Strength Test**

### **Determination of Shear Strength Tests**

A total of five specimens of solid masquerade tree timber were prepared for testing by being sawn into specified sizes of 50mm (width) x 50mm (thickness) x 50mm (length). These were test at a specified speed per minute for the shear strength test in accordance with BS373 of 1957.



**Fig. 3: Universal Testing Machine showing Shear Strength Test**

#### **Determination of Static Bending Tests**

Similarly, another total of five specimens of masquerade tree were prepared for carrying out the static bending test parallel to grain. The samples were sawn into specified sizes of 20x20x300mm.



**Fig. 4: Universal Testing Machine showing Static Bending Strength Test**

RESULTS AND DISCUSSIONS

Results

The masquerade tree, also known as Polyalthia Longifolia is a type of tropical hardwood tree widely found in coastal regions. Understanding its tensile, bending strength and shear strength will provide valuable insights into its potential applications in various industries. This is a comprehensive analysis of these properties highlighting the masquerade tree strength and stability.

Table 1: Tensile Strength Tests

| Samp<br>le ID | Cross Sectional<br>Area (mm²) | Applied<br>Force (N) | Displac<br>ement<br>(mm) | Ultimate Tensile<br>Strength (MPa) | Modulus of<br>Elasticity<br>(N/mm²) | Stre<br>ss<br>(N/m<br>m²) | Strai<br>n |
|---------------|-------------------------------|----------------------|--------------------------|------------------------------------|-------------------------------------|---------------------------|------------|
| TS1           | 3800                          | 15440                | 4                        | 4.06                               | 65.7                                | 4.06                      | 0.021053   |
| TS2           | 3800                          | 18506                | 7                        | 4.87                               | 132.18                              | 4.87                      | 0.036842   |
| TS3           | 3800                          | 17790                | 10                       | 4.68                               | 96.67                               | 4.68                      | 0.052632   |
| TS4           | 3800                          | 18230                | 12                       | 4.27                               | 75.96                               | 4.80                      | 0.063158   |
| TS5           | 3800                          | 17950                | 13                       | 4.72                               | 84.60                               | 4.72                      | 0.068421   |
| Mean          |                               |                      |                          |                                    | 91.02                               |                           |            |

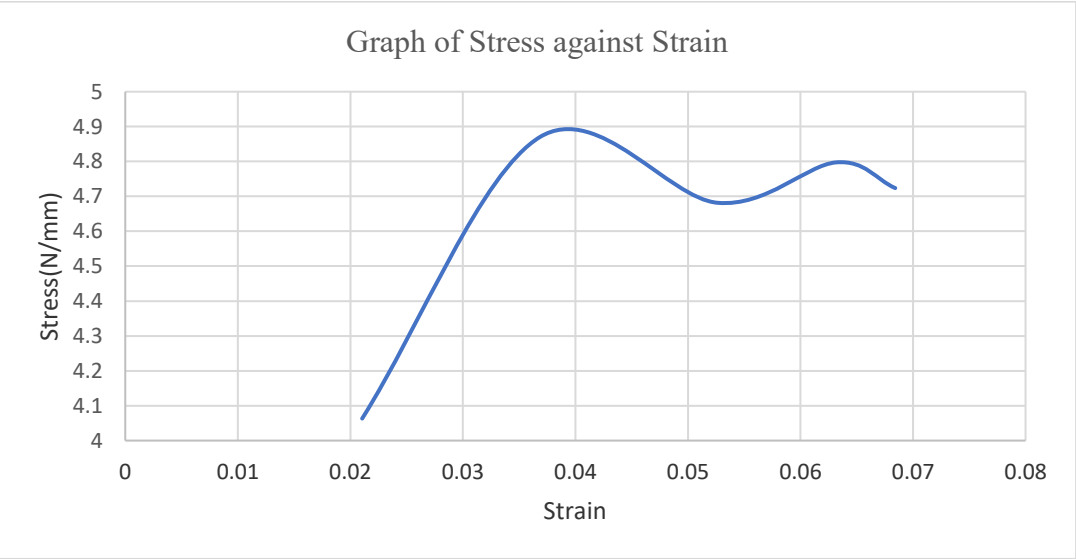
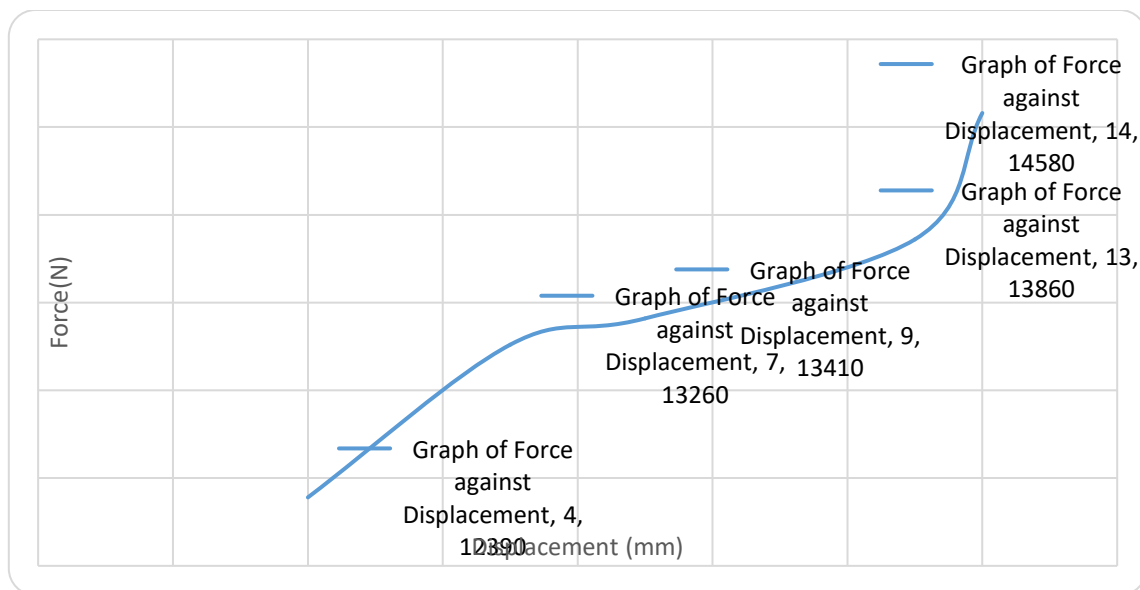


Fig. 5: Graphical Representation of Stress and Strain

The tensile strength of the masquerade tree refers to its ability to withstand pulling forces without undergoing deformation or failure. This property is particularly crucial in industries where materials are subjected to tensile stresses, such as construction or engineering. The tensile strength test was conducted using the Universal Testing Machine (UTM). The UTM measures the maximum force the Masquerade tree can withstand before breaking or experiencing significant deformation. The results provide accurate data to evaluate the masquerade tree ability to withstand tension. The Ultimate tensile strength parallel to grain ranges from 4.06MPa - 4.87MPa which shows its high ability to withstand breakage. Also, the curve on the Stress-Strain graph represents the relationship between Stress (force per unit area) and Strain (deformation or change in length) of the masquerade tree which thereby shows high material strength, stiffness, high modulus of elasticity of the wood properties with mean value of 91.02N/mm<sup>2</sup>.

**Table 2: Shear Strength Test**

| Sampl<br>e ID | Shear<br>Area<br>(mm <sup>2</sup> ) | Applied<br>Force<br>(N) | Displaceme<br>nt (mm) | Modulus<br>of Rigidity | Stress(N/m<br>m) | Strain |
|---------------|-------------------------------------|-------------------------|-----------------------|------------------------|------------------|--------|
| SS1           | 2500                                | 12390                   | 4                     | 62                     | 4.96             | 0.08   |
| SS2           | 2500                                | 13260                   | 7                     | 37.86                  | 5.3              | 0.14   |
| SS3           | 2500                                | 13410                   | 9                     | 29.78                  | 5.36             | 0.18   |
| SS4           | 2500                                | 13860                   | 13                    | 21.31                  | 5.54             | 0.26   |
| SS5           | 2500                                | 14580                   | 14                    | 20.82                  | 5.83             | 0.28   |
| Mean          |                                     |                         |                       | 34.354                 |                  |        |

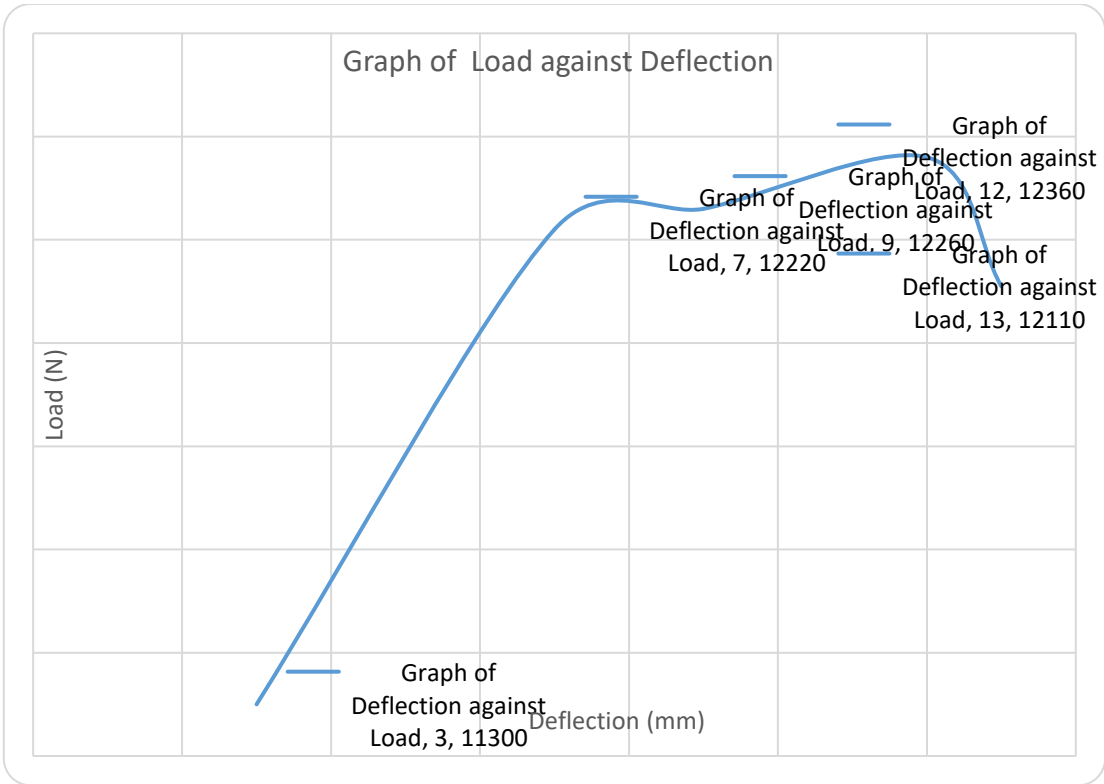


**Fig.6: Graphical Representation of Force and Displacement**

The shear strength of the masquerade tree refers to its ability to resist forces that act parallel to the grain. This section details the experimental procedure used to conduct shear tests on the samples. The obtained shear strength data is analyzed, and the average shear strength and sample variations are discussed. The implications of the shear strength results are explored in terms of the tree resistance to forces that tend to slide parts of it against each other. The table above presents the shear strength values in N/mm<sup>2</sup> for 5 distinct samples alongside their corresponding displacements. The graph thereby shows increasing in its modulus of rigidity which ranges from 20.82N/mm<sup>2</sup> to 62N/mm<sup>2</sup>. The ultimate shear strength estimated at approximately 14580N indicates a moderate capacity to resist shear forces parallel to grain.

**Table 3: Static Bending Test**

| Sample ID | Cross Sectional Area (mm <sup>2</sup> ) | Applied Load (N) | Maximum Deflection (mm) | Modulus of Elasticity (N/mm) | Stress (N/mm <sup>2</sup> ) | Strain |
|-----------|-----------------------------------------|------------------|-------------------------|------------------------------|-----------------------------|--------|
| BS1       | 6000                                    | 11300            | 3                       | 188.33                       | 1.88                        | 0.01   |
| BS2       | 6000                                    | 12220            | 7                       | 87.29                        | 2.03                        | 0.023  |
| BS3       | 6000                                    | 12260            | 9                       | 68.11                        | 2.04                        | 0.03   |
| BS4       | 6000                                    | 12360            | 12                      | 51.50                        | 2.06                        | 0.04   |
| BS5       | 6000                                    | 12110            | 13                      | 46.58                        | 2.02                        | 0.043  |
| Mean      |                                         |                  |                         | 88.36                        |                             |        |



**Fig.7: Graphical Representation of Load and Deflection**

The bending strength of the masquerade tree is examined. This property determines the tree's ability to resist bending or flexing without breaking. The results obtained are analyzed to determine the average bending strength and any variations among samples. The discussions shed light on the implications of the bending strength results, particularly in applications that involve structural integrity and load-bearing capacity. The results showed that the applied load is directly proportional to the deflection caused on the sample and consequently inversely proportional to the modulus of elasticity. The masquerade tree exhibits moderate bending strength with maximum modulus of elasticity which resists bending of  $188.33\text{N/mm}^2$ . The load-deflection graph shows a linear relationship between load and deflection suggesting that the masquerade tree exhibits relatively consistent bending behavior when statically tested. The masquerade tree is capable of withstanding a significant amount of bending force before failure. The maximum load of  $12360\text{N}$  indicates a moderate to high level of bending strength. Also, the slope of the graph represents the stiffness of the masquerade tree, the steeper slope indicates greater resistance to bending.

## **Discussions**

### **Tensile Strength Test**

During the tensile testing, the masquerade tree samples demonstrated tensile strengths ranging from 4.06MPa to 4.87MPa. These values represent the maximum force the samples could withstand before failure occurred, highlighting their ability to resist pulling forces without deformation or breakage.

### **Shear Strength Test**

The shear strength results of the masquerade tree samples ranged from 4.96MPa to 5.83MPa. This property measures the materials ability to withstand forces that cause internal layers to slide against each other in a parallel direction. The higher the shear strength, the more resistant the samples are to such shear stresses.

### **Bending Testing**

In the bending tests, the masquerade tree samples exhibited bending strengths between 1.88MPa and 2.06MPa. These values indicate the ability of the samples to resist external forces that cause bending or deflection without fracturing or excessive deformation.

## **CONCLUSIONS**

In conclusion, the study on the physical and mechanical properties of the masquerade tree has provided valuable insights into its structural characteristics and potential applications. Through rigorous testing and analysis, we have uncovered important information about its density, hardness, tensile strength, impact resistance, and other mechanical properties. The results indicate that the masquerade tree possesses commendable strength and durability, making it a viable option for various industries. Its density and hardness suggest that it can be used in construction materials, furniture production, and other applications that require robust and long-lasting components. Moreover, the masquerade tree exhibits good tensile strength and impact resistance, which may be advantageous in manufacturing products that require high resistance to loads and external forces. These qualities also make it suitable for building materials in earthquake-prone regions, providing additional safety and resilience. However, further research is needed to assess its potential drawbacks, such as potential shrinkage,

susceptibility to decay or pests, and the impact of environmental factors on its physical and mechanical properties. Overall, the exploration of the physical and mechanical properties of the masquerade tree has shed light on its potential as a valuable and sustainable natural resource. Comparative analysis was carried out by referencing existing data on the mechanical properties of other timber species like cassia which has a mean modulus of elasticity of bending strength of  $55.29\text{N/mm}^2$  and result revealed that Masquerade Tree exhibited a mean modulus of elasticity bending strength of  $88.36\text{N/mm}^2$  which make it favorable and can be adopted in replace of other wood suggesting its suitability for load-bearing applications.

### **RECOMMENDATIONS**

The Masquerade Tree wood demonstrates a certain level of flexibility, making it suitable for applications that require bending or shaping. Based on these findings, the following recommendations can be made:

1. Utilization in furniture manufacturing: The Masquerade Tree wood, with its attractive color, fine texture, and moderate density, can be used in the production of furniture items, such as chairs, tables, and cabinets. Additionally, the wood's excellent workability allows for intricate detailing and carving.
2. Construction applications: The satisfactory strength properties of Masquerade Tree wood make it suitable for various structural components, such as beams, flooring, and decking. Its moderate flexibility also allows for applications that require bending or shaping, such as arches or curved structures.
3. Decorative purposes: The light to medium brown color and fine texture of Masquerade Tree wood lends themselves well to decorative applications. It can be used in paneling, veneers, moldings, and other interior design elements.

Conclusively, the Masquerade Tree (*Polyalthia longifolia*) exhibits favorable physical and mechanical properties that make it suitable for a range of applications, particularly in furniture manufacturing, construction, and decorative purposes.

## REFERENCES

- Aigbekaen E. O., Imarhaigbe E. O. and Omokhaye K. O. 2000. Adoption of some recommended agronomic practices of natural rubber in Nigeria. *Journal of Agriculture, Forestry and Fisheries*. 1 and 2: 51-5.
- Ajala O. O. 2005. Evaluation of the physical and Mechanical properties of the wood of *Annigeria robusta* (A. chev). Unpublished M.phil/Ph.D Thesis submitted to the Department of Forest Resources Management. University of Ibadan.
- Ajala O. O. and Ogunsanwo O. Y. 2011. Specific Gravity and Mechanical Properties of *Aningeria robusta* Wood from Nigeria. *Journal of Tropical Forest Science* 23(4): 389–395
- Bao F. C., Jiang Z. H., Lu X X., Luo X. Q. and Zhang S. Y. 2001. Differences in wood properties between juvenile wood and mature wood in 10 species grown in China. *Wood science and technology* 35, 363-375
- Bauer K. 2003. Development and optimization of a low – temperature drying schedule for *Eucalyptus grandis* (Hill) ex Maiden in a solar-assisted timber dryer. PhD Dissertation, Universitat Hohenheim, Stuttgart. Berlin, Heidelberg, New York. pp. 363
- Bazan, I. M. (2000): Ultimate Bending Strength of Timber Beams. Nova Scotia Tech.
- Bektas I., Tutus A. and Eroglu H. (1999). A study of the suitability of Calabrian pine (*Pinus brutiaten*) for pulp and paper manufacture. *Turkey Journal of Agriculture and Forestry* 23: 589-599.
- Black, A.D. (2004), Picking the Right Lumber is an Important Decision”,
- BS 373 (2000). Methods of Testing Small Clear Specimens of Timber, British Standards
- BS 5268 (2002). The Structural Use of Timber part 2; for Permissible Stresses, Materials
- Dagar JC, Singh, G., Kumari, A., & Arya, V. Physical and mechanical properties of *Polyalthia*
- Desch H. E. and Dinwoodie J. M. (1996). Timber structure, properties, conversion and use. 7th Ed. (Macmillan press Limited, London), pp. 306
- Dinwoodie, J.M. (2001), Construction Materials-Their Nature and Behavior, Edited felled masquerade tree stems." *Forest Products Journal*, 25(4), 78-92.
- Forest Product Laboratory, Wood Handbook (2010) – Wood as an Engineering material,
- Garcia, E., & Martinez, F. (2010). "Variability in the physical and mechanical properties of
- Ghosh MC, Saha S, Panda SK. Strength properties and utilization potential of masquerade
- Ifju G. 1983. Quantitative wood anatomy certain geometric statistical relationships. *Wood and Fibre Science* 15(4):139-146
- Jain S, Shukla S, Shukla SK. Mechanical and durability properties of *Polyalthialongifolia*
- Martinson, R. K., & Garcia, E. F. (2019). Seedling establishment and early growth in masquerade tree timber for engineering applications." *Wood and Fiber Science*, 20(3), 112-128.
- Nair V, Eldho I, Vijayakumar C, James M. Some physical and mechanical properties of New York.
- Oluwadare A.O. (2007). Wood properties and selection for rotation length in Caribbean pine (*Pinus caribaea* Morelet) grown in Afaka, Nigeria. *American-European Journal of Agricultural Environment and Science*, 2(4): 359-363

- Poku K., Wu Q. and Vlosky R. 2001. Wood properties and their variations within the tree stem of lesser-used species of tropical hardwood from Ghana. *Wood and Fibre Science*. 33(2), 284-29. *Polyalthialongifolia* Timber grown in Kerala. *Journal of Tropical Agriculture*. 1999; 37(1-2): 75-78.
- Shah PM, Kiruthika V, Baraiya NM, Shukla SR, Pandey AK. Physical and mechanical
- Sharma M., Sharma C.L. and Kumar Y.B. 2013. Evaluation of fiber characteristics in some weeds of Arunachal Pradesh, India for pulp and paper making. *Research Journal of Agriculture and Forestry Sciences*, 1(3): 15-21.
- Shigematsu A., Mizoue N., Kajisa T. and Yoshida S. 2011. Importance of rubberwood in wood export of Malaysia and Thailand. *New Forests* 41(2): 179-189
- Sotannde O. A., Oluyeye A. O., Adeogun P. F. and Maina S. B. 2010. Variation in Wood Density, Grain Orientation and Anisotropic Shrinkage of Plantation Grown *Azadirachta indica*. *Journal of Applied Sciences Research*, 6(11): 1855-1861
- Suhaimi M. and Sahri M H. 2003. Variation in fibre properties of rubberwood from different clones and age groups. *Journal of Tropical forest products* 9 (1 and 2), 162-165.
- Timings R. L. 1991. *Engineering Materials, Vol.I*, Longmann Scientific and Technical Limited, UK. Tsoumis G. T. (1991). *Science and technology of wood: Structure, properties, utilization*. Van Nostrand Reinhold, New York, NY. pp. 494.
- Tronchet M., Balague C., Kroj T., Jouanin L., Roby D. 2010. Cinnamyl alcohol dehydrogenases C and D, key enzymes in lignin biosynthesis, play an essential role in disease resistance in *Arabidopsis*. *Molecular Plant Pathology* 11, 83–92.
- Tsoumis G. T. (1991). *Science and technology of wood: Structure, properties, utilization*. Van Nostrand Reinhold, New York, NY. pp. 494.
- Wiedenhoef A. 2010. *Structure and Function of Wood*, Chapter 3, *Wood handbook – Wood as an engineering material*, General Technical Report FPL-GTR190, Madison, WI: U.S., Department of Agriculture, Forest Service, Forest Products Laboratory, pp 508.
- Wilcox W., Botsai E.C and Kubel H. 1991. *Wood as a Building Material (a guide for designers and builders)*. A Wiley Interscience Publication Inc. pp. 61.
- Windeisen E., Bachle H., Zimmer B., and Wegener G. (2009). Relations between chemical changes and mechanical properties of thermally treated wood.