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Assessment of the Mechanical Properties of Various Timber Utilized In Building Construction in Auchi, Etsako West L.G.A, Edo State, Nigeria

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ABSTRACT

This study investigates the mechanical properties of various timber types commonly used in building construction in Auchi. The research holds significant relevance for structural engineers, wood technologists, and conservators—particularly in assessing timber structures, evaluating the potential for salvaging and reusing old timbers, and conserving wooden artifacts. Four timber samples were examined: Obahje (Sample 1), Melina (Sample 2), Oflora (Sample 3), and Iroko (Sample 4). The primary focus was on the variation in bending properties, as determined through practical laboratory work. Based on structural laboratory tests, the bending strengths recorded for Samples 1 through 4 were as follows:Sample 1 (Obahje): 5.71×10^{-5} KN/m², Sample 2 (Melina): 2.644×10^{-5} KN/m² ,Sample 3 (Oflora): 6.92×10^{-5} KN/m² , Sample 4 (Iroko): 1.139×10^{-2} KN/m²Moisture retention tests conducted in the civil engineering soil laboratory showed the following water holding capacities:Sample 1: 22.6 g, Sample 2: 28.6 g, Sample 3: 32.5 g Sample 4: 19.1 g The results indicated that Sample 3 (Oflora) had the highest water holding capacity, while Sample 4 (Iroko) demonstrated the greatest bending strength, making it the strongest among the tested timbers.

Keywords: Wood, Mechanical Properties, Timbers, Building Constructions, Iroko, Melina

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1. INTRODUCTION

Wood has long been recognized as a natural and traditional building material, and over the years, substantial knowledge has been accumulated in advanced countries regarding its essential properties and their impact on structural design and performance. Despite this, wood remains underutilized as a major structural material in Nigeria. A thorough understanding of wood's physical characteristics is crucial for the construction of safe timber structures (Fewell, 1997).

Globally, wood is possibly the most widely used structural material, particularly in single-family homes, bungalows, and single-story buildings. However, it is also employed in larger residential, commercial, and industrial structures.Timber offers both economic and aesthetic advantages to designers and clients. Its ease of use—with minimal need for specialized tools or equipment—gives it a competitive edge over other construction materials (Ede, 2014). Timber is known for its excellent insulating properties, lightweight nature, and visual appeal. However, in Nigeria, the extent of its application by professionals in the building industry is largely influenced by its availability and perception, rather than a deep understanding of its capabilities. Despite timber's recognized structural qualities, it remains significantly underutilized in the construction sector.

This underuse is largely due to the perception among clients, architects, and engineers that timber cannot compete with materials like concrete and steel. Limited technological development in timber construction within Nigeria has contributed to the belief that it lacks durability, reliability, and serviceability. Therefore, to realize timber's full potential as a construction material, there is a pressing need for enhanced expertise, skills, and awareness (Kohler, 2007).To address this issue, it is essential to encourage stakeholders to consider alternative building materials that are not only cost-effective but also sustainable, easy to maintain, and satisfying in terms of design and performance. In this regard, timber has been identified as a key alternative to concrete within the Nigerian building sector. This research seeks to analyze both concrete and timber from multiple perspectives, offering architects, engineers, builders, and clients in Nigeria a well-informed basis for choosing the most suitable material to meet societal needs (Adebayo, 2014).

As global population growth and economic expansion continue, the demand for wood and wood-based products is expected to rise. A global outlook by the FAO projected a 20% increase in wood product demand by 2010, highlighting the ongoing challenge of meeting this demand sustainably (FAO, 1997).Despite its inherent structural capabilities, wood remains poorly understood in terms of its mechanical performance, leading to the preference for other construction materials. This knowledge gap presents a significant challenge in engineering and construction practices, as many structural designs fail to capitalize on the originality and suitability of timber. Although a few firms specialize in timber design and application, the general lack of awareness and expertise underlines a major shortfall in the field.Therefore, the aim of this study is to evaluate the mechanical properties of various wood species used in construction, with the goal of promoting timber as a viable and effective building material in Auchi.

2.LITERATURE REVIEW

Throughout history, the distinctive qualities and relative abundance of wood have made it a preferred material for constructing homes, furniture, tools, vehicles, and decorative items. Today, these same attributes continue to make wood highly valued for a wide range of uses (Natterer, 2001). All wood consists of cellulose, lignin, hemicelluloses, and small amounts (5% to 10%) of other materials contained within a cellular structure. Variations in the amount and composition of these components, as well as differences in cellular structure, result in woods being heavy or light, stiff or flexible, and hard or soft. The characteristics of a specific wood species are relatively consistent within certain limits, meaning that choosing wood based on species alone can sometimes be sufficient (Ahmadi and Saka, 1993). However, to maximize wood's effectiveness in engineering applications, it's essential to consider specific physical properties or characteristics. Historically, some wood species were used for a variety of purposes, while others, being rarer or less desirable, were limited to one or two uses.

For example, white oak, known for its toughness, strength, and durability, was highly valued for shipbuilding, bridges, cooperage, barn timbers, farm tools, railroad ties, fence posts, and flooring. Woods like black walnut and cherry were primarily used for furniture and cabinetry, while hickory was made into sturdy, hard, and resilient striking-tool handles. Black locust was prized for barn timbers. Builders and craftsmen, through trial and error, learned which species were best suited for particular purposes based on their characteristics. It was widely accepted that wood from trees grown in certain locations and under specific conditions was stronger, more durable, easier to work with, or had a finer grain than wood from trees in other regions. Modern research on wood has confirmed that location and growth conditions do indeed play a significant role in influencing wood properties (Anderson, 1970).

The gradual decline in the use of old-growth forests in the United States has reduced the supply of large, clear logs for lumber and veneer. However, the importance of high-quality logs has decreased as new approaches to wood utilization have been developed. Second-growth wood, the remaining old-growth forests, and imports continue to meet the demand for wood of the necessary quality. Wood remains a valuable engineering material, and in many instances, technological advancements have made it even more versatile (Apus, 2003).

2.1 Structure of Wood

The fibrous nature of wood strongly influences how it is used. Wood is primarily composed of hollow, elongate, spindle-shaped cells that are arranged parallel to each other along the trunk of a tree. When lumber and other products are cut from the tree, the characteristics of these fibrous cells and their arrangement affect such properties as strength and shrinkage as well as the grain pattern of the wood (Sturges, 1991). This chapter briefly describes some elements of wood structure.

2.1.1 Bark, Wood, Branches, And Cambium

A cross section of a tree (Fig. 2.1) shows the following well defined features (from outside to center): bark, which may be divided into an outer corky dead part (A), whose thickness varies greatly with species and age of trees, and an inner thin living part (B), which carries food from the leaves to growing parts of the tree; wood, which in merchantable trees of most species is clearly differentiated into sapwood (D) and heartwood (E); and pith (F), a small core of tissue located at the center of tree stems, branches, and twigs about which initial wood growth takes place. Sapwood contains both living and dead tissue and carries sap from the roots to the leaves. Heartwood is formed by a gradual change in the sapwood and is inactive.

The wood rays (G), horizontally oriented tissue through the radial plane of the tree, vary in size from one cell wide and a few cells high to more than 15 cells wide and several centimeters high. The rays connect various layers from pith to bark for storage and transfer of food. The cambium layer (C), which is inside the inner bark and forms wood and bark cells, can be seen only with a microscope.(Gregory, 1994) As the tree grows in height, branching is initiated by lateral bud development. The lateral branches are intergrown with the wood of the trunk as long as they are alive. After a branch dies, the trunk continues to increase in diameter and surrounds that portion of the branch projecting from the trunk when the branch died. If the dead branches drop from the tree, the dead stubs become overgrown and clear wood is formed.

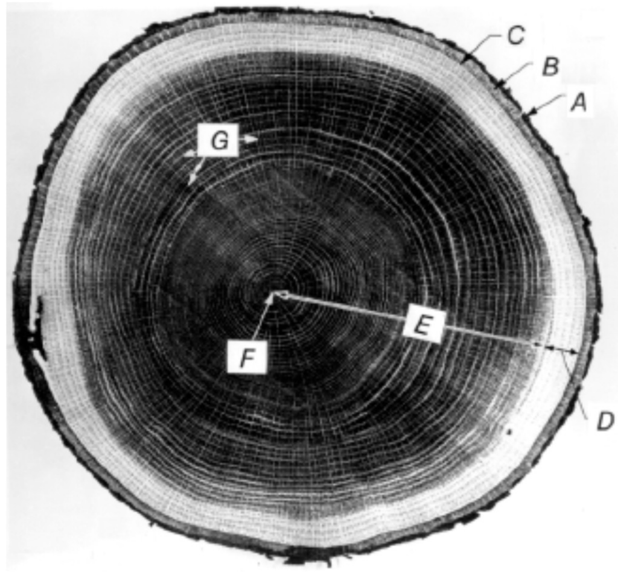

Figure 2.1. Cross section of white oak tree trunk: (A) outer bark (dry dead tissue), (B) inner bark (living tissue), (C) cambium, (D) sapwood, (E) heartwood, (F) pith, and (G) wood rays.

2.2 Physical Properties of Timber

(Specific Gravity (SG) Weight, and Density

The density of wood, exclusive of water, varies greatly both within and between species. Although the density of most species falls between about 320 and 720 kg/m^3. Generally, specific gravity (SG) and the major strength properties of wood are directly related. SG for the major usually used structural species ranges from roughly 0.30 to 0.90. Higher allowable design values are assigned to those pieces having narrower growth rings (more rings per inch) or more dense latewood per growth ring and, hence, higher SG.

Moisture Content (MC) and Shrinkage:

Moisture content of wood is defined as the weight of water in wood expressed as a fraction, usually a percentage, of the weight of oven dry wood. Weight, shrinkage, strength, and other properties depend upon the moisture content of wood. Undoubtedly, wood's reaction to moisture provides more problems than any other factor in its use. Wood is hygroscopic; that is, it picks up or gives off moisture to equalize with the relative humidity and temperature in the atmosphere. As it does so, it changes in strength; bending strength can increase by about 50% in going from green to moisture content (MC) found in wood members in a residential structure, for example. Wood also shrinks as it dries, or swells as it picks up moisture, with concomitant warpage potential. Critical in this process is the fiber saturation point (fsp) , the point (about 25% moisture content, on oven-dry basis) below which the hollow center of the cell has lost its fluid contents, the cell walls begin to dry and shrink, and wood strength begins to increase.(McDonald e tal, 1997) The swelling and shrinkage processes are reversible and approximately linear between fiber saturation point and 0% MC.

Wood decay or fungal stain does not occur when the MC is below 20%. There is no practical way to prevent moisture change in wood; most wood finishes and coatings only slow the process down. Thus, vapor barriers, adequate ventilation, exclusion of water from wood, or preservative treatment are absolutely essential in wood construction (Oyetola, 2001).

(iii) Thermal Properties/Temperature Effects:
Four important thermal properties of wood are thermal conductivity, heat capacity, thermal diffusivity, and coefficient of thermal expansion. Although wood is an excellent heat insulator, its strength and other properties are affected adversely by exposure for extended periods to temperatures above about 100°F. The combination of high relative humidity or MC and high temperatures, as in unventilated attic areas, can have serious effects on roof sheathing materials and structural elements over and above the potential for attack by decay organisms. Simple remedies and caution usually prevent any problems (Sliker, e tal, 1994) At temperatures above 220°F, wood takes on a thermoplastic behavior. This characteristic, which is rarely encountered in normal construction, is an advantage in the manufacture of some reconstituted board products, where high temperatures and pressures are utilized.

(iv) Environmentally friendly
Timber is the most environmentally responsible building material. Timber has low production energy requirements and is a net carbon absorber. Timber is a renewable resource. Well-managed forests produce timber on a sustained continuous basis, with minimal adverse effects on soil and water values.

(v) Easy to install
Increasingly specialist timber frame and truss manufacturers use high tech prefabrication enabling accurate and speedy installation. Recyclable - Timber is a forgiving material that can be easily disassembled and reworked. If demolition or deconstruction of a wooden building is necessary, many wood-based products can be recycled or reused. Timber trusses and frames, factory fabricated from sawn timber and toothed metal plate connectors, have come to dominate roof construction for small buildings such as houses and large industrial buildings where clear spans up to 50 metres are required. Timber trusses compete with other roof structural systems on cost, high performance, versatility and ready availability, supported by design software packages supplied by the plate manufacturers to the fabricators

(vi) Strong and lightweight
Timber is strong, light and reliable making timber construction simpler and safer than steel or concrete construction. A comparison with steel and concrete shows that radiata pine structural timber, for example, has a strength for weight ratio 20 percent higher than structural steel and four to five times better than un-reinforced concrete in compression. The lightweight structures possible in wood confer flow-on advantages in terms of reduced foundation costs, reduced earthquake loading and easier transport. Building components and complete constructions are simple and safe to erect, and cheaper to deconstruct or reuse at the end of a building ís useful life.

2.3 Use of Wood in Buildings and Bridges

(i) Foundations
Light-frame buildings with basements are typically supported on cast-in-place concrete walls or concrete block walls supported by footings. This type of construction with a basement is common in northern climates. Another practice is to have concrete block foundations extend a short distance above ground to support a floor system over a “crawl space.” In southern and western climates, some buildings have no foundation; the walls are supported by a concrete slab, thus having no basement or crawl space (Whiltelaw, 1990). Treated wood is also used for basement foundation walls. Basically, such foundations consist of wood-frame wall sections with studs and plywood sheathing supported on treated wood plates, all of which are preservatively treated to a specified level of protection.

To distribute the load, the plates are laid on a layer of crushed stone or gravel. Walls, which must be designed to resist the lateral loads of the backfill, are built using the same techniques as conventional walls (Townsend, 2000). The exterior surface of the foundation wall below grade is draped with a continuous moisture barrier to prevent direct water contact with the wall panels.

(ii) Floors

For houses with basements, the central supporting structure may consist of wood posts on suitable footings that carry a built-up girder, which is frequently composed of planks the same width as the joists (standard 38 by 184 mm to 38 by 286 mm (nominal 2 by 8 in. to 2 by 12 in.)), face-nailed together, and set on edge. Because planks are seldom sufficiently long enough to span the full length of the beam, butt joints are required in the layers. The joints are staggered in the individual layers near the column supports. The girder may also be a glulam beam or steel I-beam, often supported on adjustable steel pipe columns. Similar details may be applied to a house over a crawl space. The floor framing in residential structures typically consists of wood joists on 400- or 600-mm (16- or 24-in.) centers supported by the foundation walls.

(iii) Ceiling and Roof

Roof systems are generally made of either the joists-and-rafter systems or with trusses. Engineered trusses reduce on-site labor and can span greater distances without intermediate support, thus eliminating the need for interior load-carrying partitions. This provides greater flexibility in the layout of interior walls. Prefabricated roof trusses are used to form the ceiling and sloped roof of more than two-thirds of current light-frame buildings. For residential buildings, the trusses are generally made using standard 38- by 89-mm.

(iv) Wood Decks

A popular method of expanding the living area of a home is to build a wood deck adjacent to one of the exterior walls. Decks are made of preservatively treated lumber, which is generally available from the local building supply dealer and, depending upon the complexity, may be built by the “do-it yourselfer.”To ensure long life, acceptable appearance, and structural safety, several important guidelines should be followed. Proper material selection is the first step. Then, proper construction techniques are necessary. Finally, proper maintenance practices are necessary.

3. MATERIALS AND METHOD

Materials

(i) Wood sample
(ii) Scale rule
(iii) Pen
(iv) Diaguage
(v) Load display unit

Theory

The structure performance of strength graded timber is a measure of how the timber will contribute to the mechanical stability of a building typically as part of a floor, wall or roof system. Strength graded timber is assigned to a strength class which contains a range of characteristic that are required by structural engineers. Initial type testing to assign a timber species to a strength class for the first time requires a sizeable test programme. It is more common to commission a smaller test programme to verity that a strength grading machine has been installed and set up correctly a part of a certification process. The tests of structural timber use specimens that are similar in size to timber used in practice.

The tests are carried out on representative sample of graded timber as manufactured for end use. The result obtained from such tests are analysed to determine the characteristic capacities required to design in accordance with the European Design code for timber.

Procedure

- The apparatuses were set up. This was done by switching on the bending strength of timber machine, making sure that then load applicator is at zero and also the diaguage is at zero.
- The measurement of the sample (obache wood) was taken, that is the length, width and depth of the sample. Also determine the mid point of the sample scale rule and pen were used to measure and mark the sample respectively.
- Slot in the sample in the load display unit, making sure that the load applicator is at the centre of the sample. The diaguage was pushed aside to allow the sample to be fixed.
- Start applying the load by turning the steering anti-clockwises
- Take note of the corresponding force and the displacement by allowing the diaguage to turn one revolution = 1mm and read the load from the load display unit. This was done continuously until the load started reducing the stop turning the steering and note the highest value of the load.

The strength of the sample was calculated using the formula.

$$\gamma \frac{m}{I}\ x\ y_{max}\ where\ M = \frac{wL}{4}\ and\ I = \frac{bh^3}{12}$$

Length of sample = 30mm (150mm centre) of sample 27mm
Width of sample = 25mm
Depth of sample = 25mm
Moment of inertial

I = $\frac{bd^2}{12}$

$$\frac{25\ x\ 25^2}{12} = 1302.0mm^4$$

Bending strengthobhaje

(1) σ = $\frac{m}{I}\ x\ Y_{max}$
W = 124N = 0.124kN
M = 0.124 x 0.3 = 1.0093kN/m
β = $\frac{0.0093\ x\ 8}{1302} = 0.0000571kN/m^2$

(2) Melina
M = 270N
Y = 17m
M = $\frac{wL}{4} = \frac{0.270\ x\ 0.3}{4} = 0.02025kN/m$
σ = $\frac{m}{I}\ x\ y_m$
= $\frac{0.02025}{1302}\ x\ 17m = 0.0002644kN/m^2$

(3) Oflorah
M = 1502N = Y = 8mm
M = $\frac{wL}{4} = \frac{0.1502\ x\ 0.3}{4} = 0.011265$
σ = $\frac{m}{I}\ x\ y_{max}$ (Bending strength

$\frac{0.011265}{1302}\ x\ 8 = 0.0000692/kNm^2$

(4) Iroko

M = 1012N = 0.1012N

Y = 6mm

M = $\frac{wL}{4} = \frac{0.1012\ x\ 0.3}{4} = 0.00759$

Bending strength

σ $=\frac{wL}{I}\ x\ y_{max}$

$\frac{0.00759+6}{4} = 0.011385kN/m^2$

Observations

1. It was observed that as the load was applied the timber was bending gradually.
2. It was also observed that as the applied load increases, the bending increases also.
3. It was observed that as the timber got to its elastic limit, it deformed.

Precaution

(1) It was ensured that the machine was set to 0.00, before turning of the steering wheel

(2) It was ensured that the load was applied at the midpoint of the wood sample

(3) It was also ensured that error due to parallax was avoided when reading the diaguage during the load application.

Conclusion

From the experiment, it can be concluded that "Iroko" is the strongest among the experimented wood sample.

Apparatus

i) Bow of water

ii) Electronics weigh

iii) Wood samples (oflora, Iroko obahja&Gmohina

Aim:

To determine the moisture holding capacity the different sample

Procedures

1. Acquire wood sample size 300mm/m³ 25mm x 25mm thick
2. Dry sample in oven for about 5min in temperature of 30⁰c to remove existing moisture (water) from the sample
3. Weigh samples on the electronic scale to obtain weight of woods sample.
4. Obtain result from the weighted samples and repeat process for remaining samples
5. immerse the sample in water and leave for 24 hours
6. obtain sample after 24hrs and weigh on the electronic scale and obtain reading

4. RESULTS AND DISCUSSIONS

4.1 Results

Table 1: Moisture capacity

Sample	Dry wood	Wet wood	Weight of moisture absolve
Obahje	74.4g	97.0g	22.6g
Melina	49.6gg	68.7g	19.1g
Oflora	105.8g	137.9g	32.5g
Iroko	98.7g	127.3g	28.6g

To obtain weight of moisture content absolved weight of dry sample – wet sample.

Conclusion

From the experiment (practical) the woods sample has different holding moisture content and dry density and can be used for different construction process. Among samples, Oflora (32.5g) had the highest water content and Gmelina (19.1g) had the least.
This shows that among the samples considered, Melina will be most suitable for out+door construction, when wet.

5. CONCLUSIONS AND RECOMMENDATION

5.1Conclusions

The assessment of the mechanical properties of various timber species commonly used in building construction within Auchi, Etsako West Local Government Area, Edo State, has yielded critical insights into their structural performance and suitability for different construction applications. Key conclusions drawn from this study include:
The tested timber species exhibited significant variation in their mechanical properties, indicating that not all timbers are equally suitable for structural applications. Species such as iroko and Melina demonstrated higher strength values, making them more appropriate for load-bearing elements.Moisture content was found to have a considerable effect on the strength properties of timber. Timbers with higher moisture content showed reduced mechanical performance, emphasizing the need for proper seasoning and moisture control during storage and use. Timber remains a valuable and accessible construction material in Auchi and its environs, its safe and effective use requires a deeper understanding of its mechanical properties. Ensuring quality through testing, proper seasoning, and adherence to standards will enhance structural integrity and prolong the lifespan of timber-based constructions in the region.

5.2Recommendation

The following recommendations are proposed to improve the quality, durability, and sustainability of timber usage in the region. Construction professionals, including architects, engineers, and builders, should prioritize the use of timber species with verified mechanical strength properties that meet national and international building standards. Timber should be selected not just based on availability or cost, but on scientific evaluations of strength, density, elasticity, and resistance to environmental factors.

Local artisans and builders should undergo regular training on timber grading, preservation techniques, and structural applications. Awareness programs should be organized to educate them on the importance of using timber with appropriate mechanical properties for different structural components.A locally-based material testing laboratory should be established or improved in Auchi or within Etsako West to provide accessible mechanical testing services. This will allow for easy verification of timber strength properties before use in construction projects.

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