AN ANALYSIS OF BAMBOO AS A SUSTAINABLE ALTERNATIVE BUILDING MATERIAL IN NIGERIA:A CASE STUDY OF EDO STATE.

BY

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A RESEARCH DISSERTATION SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE, FACULTY OF ENVIRONMENTAL SCIENCE, UNIVERSITY OF BENIN, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (B.Sc) DEGREE IN ARHITECTURE.

DECEMBER 2025.

DECLARATION

This is to Declare that I, ABOR VICTOR CHUKWUNONSO Student of the Department of Architecture, University of Benin with MAT.NO.: ENV2103323 conducted his research on this project topic and that all the information provided in this report was taken from the proper factual sources of information.

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Signature

CERTIFICATION

This is to certify that this project report for the 2024/2025 session is written and submitted by **ABOR VICTOR CHUKWUNONSO** with matriculation number **ENV2103323** under the supervision of **ARC. HENRY OMOROGBE**, meets the required regulations governing the award of the bachelor's degree in architecture of the university of Benin, Benin City, Edo State, Nigeria. We thereby certify that it has not been submitted in this or any other university for the award of bachelor's degree and is approved for literacy presentations.

………………………….. **…………………….**

PROJECT SUPERVISOR **HOD**

DEDICATION

This project is dedicated to the Almighty God, the author and finisher of our faith who has been with me since the beginning of my life on earth. Also, I dedicate this project with great love and affection to my parents and loved ones.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to God Almighty who has done wonders for me thus far, I would also like to thank my father and my siblings for their love and support. I am also grateful to my colleagues who were always willing to share their knowledge and expertise.

ABSTRACT

The increasing cost of conventional building materials such as steel, concrete, and timber, coupled with Nigeria's growing housing deficit and environmental concerns, has intensified the search for sustainable and affordable alternative building materials. In Benin City, Edo State, rapid urban development and rising construction demand have further increased dependence on conventional materials, thereby heightening economic and environmental pressures. Bamboo, a fast-growing and renewable natural resource, has gained global recognition for its structural strength, flexibility, and environmental benefits.

This study analyzes bamboo as a sustainable alternative building material using Benin City, Edo State, as a case study, with the aim of assessing its suitability for building construction within the local context. The research specifically examines the mechanical properties of bamboo relevant to structural performance and further evaluates its economic and environmental characteristics. It also compares bamboo with commonly used conventional building materials within the city. A qualitative and comparative research approach was adopted, relying on data from existing literature, technical reports, and selected case studies of bamboo applications in both local and international construction projects. The availability of bamboo within Edo State and surrounding southern regions was also reviewed to determine its viability for application in Benin City.

Findings from the study reveal that bamboo possesses high tensile strength, favorable load-bearing capacity, cost effectiveness, and low environmental impact, making it a viable alternative material for low-rise and affordable housing construction in Benin City. However, challenges such as susceptibility to moisture, insect attack, lack of standardized building codes, and limited professional acceptance were identified as major constraints to its widespread adoption. The study concludes that bamboo has significant potential as a sustainable alternative building material in Benin City if properly treated, standardized, and integrated into architectural practice. It recommends increased research, policy support, professional training, and the development of local standards to enhance the effective utilization of bamboo within Edo State's construction industry.

TABLE OF CONTENT

LIST OF FIGURES

No table of figures entries found.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND OF STUDY

The construction industry remains a critical sector in socio-economic development due to its role in housing provision, infrastructure delivery, and employment generation. However, the industry is also recognized as one of the largest contributors to environmental degradation because of its reliance on energy-intensive materials such as cement and steel (United Nations Environment Programme [UNEP], 2018). Cement production, in particular, accounts for a significant percentage of global carbon dioxide emissions, contributing substantially to climate change (International Energy Agency [IEA], 2021).

In Nigeria, the increasing cost of conventional building materials has further complicated the challenge of affordable housing delivery. Inflation, dependence on imported construction inputs, and fluctuations in foreign exchange rates have led to persistent increases in the prices of cement, steel reinforcement, and other essential building materials. According to the Federal Mortgage Bank of Nigeria (2019), the country faces a housing deficit exceeding 17 million units. This shortage places pressure on urban centers, including Benin City, Edo State.

Benin City has experienced considerable urban expansion over the past two decades due to population growth, economic activities, and infrastructural development. The predominant construction system within the city consists of reinforced concrete frame structures with sandcrete block infill walls. While structurally reliable, these systems are associated with high embodied energy, significant environmental impact, and rising construction costs. Consequently, there is an increasing need to explore alternative materials that are locally available, cost-effective, and environmentally sustainable.

Sustainable construction emphasizes the efficient use of resources and the integration of renewable materials to reduce environmental impact throughout a building's life cycle (Kibert, 2016). Among natural materials, bamboo has gained international recognition as a viable alternative building material due to its rapid renewability, strength characteristics, and environmental benefits. Bamboo matures within three to five years, significantly faster than most timber species (Liese & Köhl, 2015). Additionally, bamboo contributes to carbon sequestration and soil stabilization, enhancing its environmental value (Food and Agriculture Organization [FAO], 2015).

From a structural standpoint, bamboo exhibits notable mechanical properties. Janssen (2000) reports that bamboo possesses high tensile strength due to the alignment of longitudinal fibers within its culm structure. Ghavami (2005) further demonstrates that bamboo's compressive and flexural strengths make it suitable for certain structural applications when properly treated and detailed. These characteristics suggest that bamboo may serve as a sustainable alternative to conventional materials in specific construction contexts.

Edo State lies within Nigeria's tropical rainforest zone, providing ecological conditions favorable for bamboo growth. Despite this natural advantage, bamboo remains underutilized in formal construction within Benin City. Its application is largely limited to scaffolding, fencing, and temporary structures. Limited technical awareness, absence of standardized building codes, durability concerns, and prevailing perceptions associating bamboo with informal construction have restricted its mainstream adoption.

Given the growing demand for sustainable building solutions in Benin City and the documented mechanical strength of bamboo, there is a need for localized academic evaluation to determine its suitability as an alternative building material. This study therefore analyzes bamboo as a sustainable alternative building material, using Benin City, Edo State, as a case study.

1.2 STATEMENT OF THE PROBLEM

The construction sector in Benin City relies heavily on conventional materials such as reinforced concrete, steel, and sandcrete blocks. While these materials provide structural stability, they are associated with high embodied energy, increasing cost, and environmental consequences (UNEP, 2018; IEA, 2021). As urban expansion continues within the city, construction affordability and environmental sustainability remain significant concerns.

Although bamboo is naturally available in southern Nigeria and possesses documented mechanical strength suitable for structural applications (Janssen, 2000; Ghavami, 2005), it remains largely excluded from formal building construction in Benin City. The absence of localized studies evaluating its mechanical performance and sustainability potential within the specific climatic and socio-economic conditions of the city contributes to its underutilization.

Therefore, the problem addressed by this study is the limited analytical evaluation of bamboo's mechanical properties and sustainability potential as a viable alternative building material within Benin City, Edo State.

1.3 AIM OF THE STUDY

The aim of this study is to analyze bamboo as a sustainable alternative building material, using Benin City, Edo State, as a case study.

1.4 OBJECTIVE OF THE STUDY

The objectives of this study are to:

1. Examine the mechanical properties of bamboo relevant to building construction.
2. Assess the availability of bamboo within Benin City and surrounding areas of Edo State.
3. Evaluate the sustainability potential of bamboo as a building material within the context of Benin City.
4. Compare bamboo with conventional building materials commonly used in Benin City.
5. Identify the challenges affecting bamboo utilization in Benin City.

1.5 RESEARCH QUESTIONS

The study seeks to answer the following research questions:

1. What are the key mechanical properties of bamboo that influence its structural performance in building construction?
2. How available is bamboo within Benin City and surrounding areas of Edo State?
3. To what extent does bamboo satisfy sustainability principles when used as a building material in Benin City?
4. How does bamboo compare with conventional building materials used in Benin City in terms of structural performance, cost, and environmental impact?
5. What challenges limit the effective utilization of bamboo in Benin City?

1.6 SIGNIFICANCE OF THE STUDY

This study contributes to knowledge on sustainable construction materials within the context of Edo State. It provides localized insight into bamboo's structural and environmental performance and may inform architects, engineers, policymakers, and researchers interested in alternative building materials. The findings may also support sustainable development initiatives promoting environmentally responsible construction practices (Kibert, 2016).

1.7 SCOPE OF STUDY

This study focuses on the analysis of bamboo as a sustainable alternative building material within Benin City, Edo State. Emphasis is placed on its mechanical properties, availability, sustainability characteristics, and comparison with conventional materials used in the city. The research relies on secondary data and does not include laboratory testing or experimental procedures.

1.8 LIMITATION OF STUDY

Despite the relevance and significance of this research, certain limitations are acknowledged.

First, this study relies primarily on secondary data obtained from published laboratory tests, academic journals, textbooks, and institutional reports. No independent laboratory testing of bamboo samples from Benin City was conducted. As a result, mechanical property values discussed in this research are based on documented findings from previous studies and may not fully capture variations in locally available bamboo species in Edo State.

Second, bamboo exhibits variability in mechanical performance depending on species, age at harvest, moisture content, treatment method, and environmental conditions (Janssen, 2000; Liese & Köhl, 2015). Since this study does not involve controlled material testing, the findings are analytical rather than experimentally verified within the Benin City context.

Third, availability assessment within Benin City is based on documented ecological reports and observational evidence rather than a comprehensive field inventory or plantation mapping. Therefore, quantitative data on exact supply volumes and commercial distribution networks remain limited.

Fourth, economic comparisons between bamboo and conventional materials are based on existing market trends and literature rather than a detailed cost modeling analysis for specific building prototypes.

Finally, the absence of established building codes and standardized regulatory frameworks for bamboo construction in Nigeria limits the extent to which practical implementation recommendations can be made.

Despite these limitations, the study provides valuable analytical insight into bamboo's mechanical properties and sustainability potential within Benin City, thereby contributing to localized academic discourse on alternative building materials.

1.9 JUSTIFICATION OF STUDY

Benin City was selected as the case study area due to its growing urban development, increasing construction activities, and favorable climatic conditions for bamboo growth. The city represents an appropriate urban context for evaluating the viability of bamboo as a sustainable alternative building material within Edo State.

1.10 DEFINITION OF TERMS

Bamboo: A fast-growing woody grass with high tensile strength and versatility, used for structural and non-structural building applications (Janssen, 2000).

Alternative Building Material: A material used in place of conventional materials due to sustainability, cost, or availability considerations (Ghavami, 2005).

Sustainable Construction: Construction practices that minimize environmental impact while meeting social and economic needs (UNEP, 2018).

Affordable Housing: Housing that is economically accessible to low- and middle-income earners (Olayiwola et al., 2016).

Mechanical Properties: The physical characteristics of a material that define its behavior under applied forces. In this study, mechanical properties refer specifically to tensile strength, compressive strength, flexural strength, shear strength, and strength-to-weight ratio of bamboo.

Tensile Strength: The maximum stress a material can withstand when subjected to pulling or stretching forces before failure.

Compressive Strength: The capacity of a material to resist loads that reduce its size or cause crushing when subjected to axial forces.

Flexural Strength: The ability of a material to resist deformation or failure under bending forces.

Shear Strength: The ability of a material to resist sliding failure along a plane parallel to an applied force.

Strength-to-Weight Ratio: The ratio of a material's strength relative to its weight, indicating structural efficiency and performance.

Embodied Energy: The total energy required for the extraction, production, transportation, and installation of a building material (UNEP, 2018).

Alternative Building Material: A material used in place of conventional construction materials such as steel, concrete, or fired bricks, often characterized by local availability, cost-effectiveness, and environmental sustainability.

Case Study: A research strategy that involves in-depth investigation of a specific geographic area, group, or phenomenon. In this study, Benin City serves as the case study location.

Benin City: The capital of Edo State, Nigeria, serving as the geographical focus of this research.

CHAPTER TWO : LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews existing literature relevant to bamboo as a sustainable alternative building material. The review is structured to examine: the concept of sustainable building materials, global and Nigerian perspectives on bamboo use, detailed analysis of the mechanical properties of bamboo, comparative laboratory-based performance data, sustainability characteristics, and the research gap this study intends to fill.

2.2 CONCEPT OF ALTERNATIVE BUILDING MATERIALS

Sustainable building materials are materials that minimize environmental impact across their life cycle, from extraction through production, usage, and disposal (Kibert, 2016). According to the United Nations Environment Programme (UNEP, 2018), the building sector accounts for nearly 40% of global energy-related carbon emissions, largely due to cement and steel production.

Sustainable materials are typically characterized by:

a. Low embodied energy
b. Renewable or recyclable content
c. Local availability
d. Reduced carbon footprint
e. Durability and structural efficiency

Natural materials such as bamboo, rammed earth, stabilized laterite blocks, and engineered timber have gained attention as environmentally responsible alternatives.

2.3 BAMBOO AS A NATURAL BUILDING MATERIAL

Bamboo is a perennial woody grass belonging to the family *Poaceae*. Unlike trees, bamboo regenerates naturally after harvesting and does not require replanting, making it a highly renewable resource (Janssen, 2000). Some bamboo species can grow up to one meter per day and reach maturity within three to five years, compared to timber species that may take several decades to mature.

Structurally, bamboo is a natural composite material consisting of longitudinal fibers embedded in a lignin matrix. This internal structure gives bamboo a high strength-to-weight ratio, excellent tensile strength, and flexibility (Sharma et al., 2015). These properties make bamboo particularly suitable for construction in areas prone to dynamic loads such as wind and earthquakes.

Historically, bamboo has been used for housing, bridges, scaffolding, flooring, roofing, and furniture across Asia, Africa, and Latin America. In recent years, modern treatment techniques and engineered bamboo products have expanded its application in contemporary architecture and structural engineering.

2.4 MECHANICAL PROPERTIES OF BAMBOO

Mechanical properties determine the structural suitability of a material. Bamboo has been widely studied due to its unique fiber-reinforced natural structure. According to Janssen (2000), bamboo behaves as a naturally engineered composite material, with strong longitudinal cellulose fibers embedded in lignin.

2.4.1 Tensile Strength

Tensile strength is the ability of a material to resist pulling forces. Bamboo demonstrates high tensile strength due to the alignment of vascular bundles along the culm length.

Laboratory studies indicate tensile strength values ranging between 140–280 MPa (Janssen, 2000). Ghavami (2005) reported that some bamboo species exhibit tensile capacities comparable to mild steel in low-stress applications.

The high tensile capacity makes bamboo suitable for:

a) Truss members
b) Reinforcement in low-cost housing
c) Tension elements in lightweight structures

2.4.2 Compressive Strength

Compressive strength measures resistance to crushing. Studies show compressive strength values between 40–80 MPa, depending on species and moisture content (Liese & Köhl, 2015).

Compared to residential concrete (20–40 MPa), bamboo shows competitive compressive performance for low-rise applications.

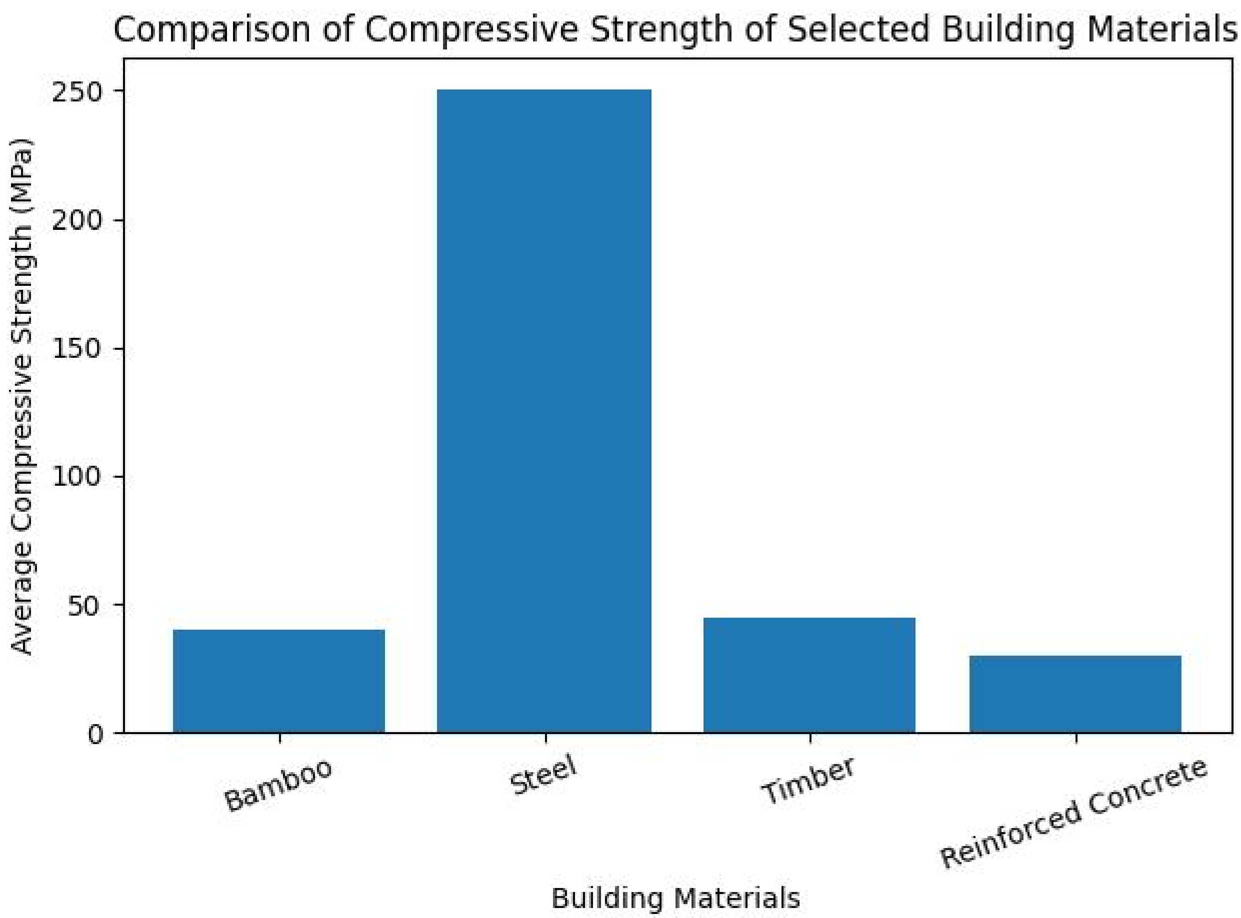

Figure 2.5

Comparison of compressive strength of selected building materials.

Note. Data compiled from Janssen (2000); Ghavami (2005); Liese and Köhl (2015).

2.4.3 Flexural Strength

Flexural strength reflects resistance to bending forces. Bamboo's hollow cylindrical form increases structural efficiency. Flexural strength ranges from 50–150 MPa (Ghavami, 2005).

The outer fibers, where fiber density is highest, resist tensile stresses during bending, contributing to strong flexural performance.

2.4.4 Shear Strength

Shear strength ranges between 5–20 MPa. Failure in shear often occurs near nodes or due to poor joint detailing. Proper connections are therefore critical.

2.4.5 Modulus of Elasticity

Bamboo's modulus of elasticity ranges between 10–20 GPa, indicating moderate stiffness suitable for low to medium structural applications (Janssen, 2000).

2.4.6 Strength-to-Weight Ratio

With density between 600–800 kg/m³, bamboo has a superior strength-to-weight ratio compared to concrete and steel. This makes it highly efficient for lightweight structural systems.

Table 2.1: Mechanical Property Comparison

Material	Tensile Strength (MPa)	Compressive Strength (MPa)	Density (kg/m³)
Bamboo	140–280	40–80	600–800
Reinforced Concrete	2–5 (concrete only)	20–40	2400
Structural Timber	70–140	30–50	500–700
Steel	250–550	250–550	7850

Observation: Bamboo outperforms concrete in tension and has far lower density than steel, giving it structural efficiency advantages.

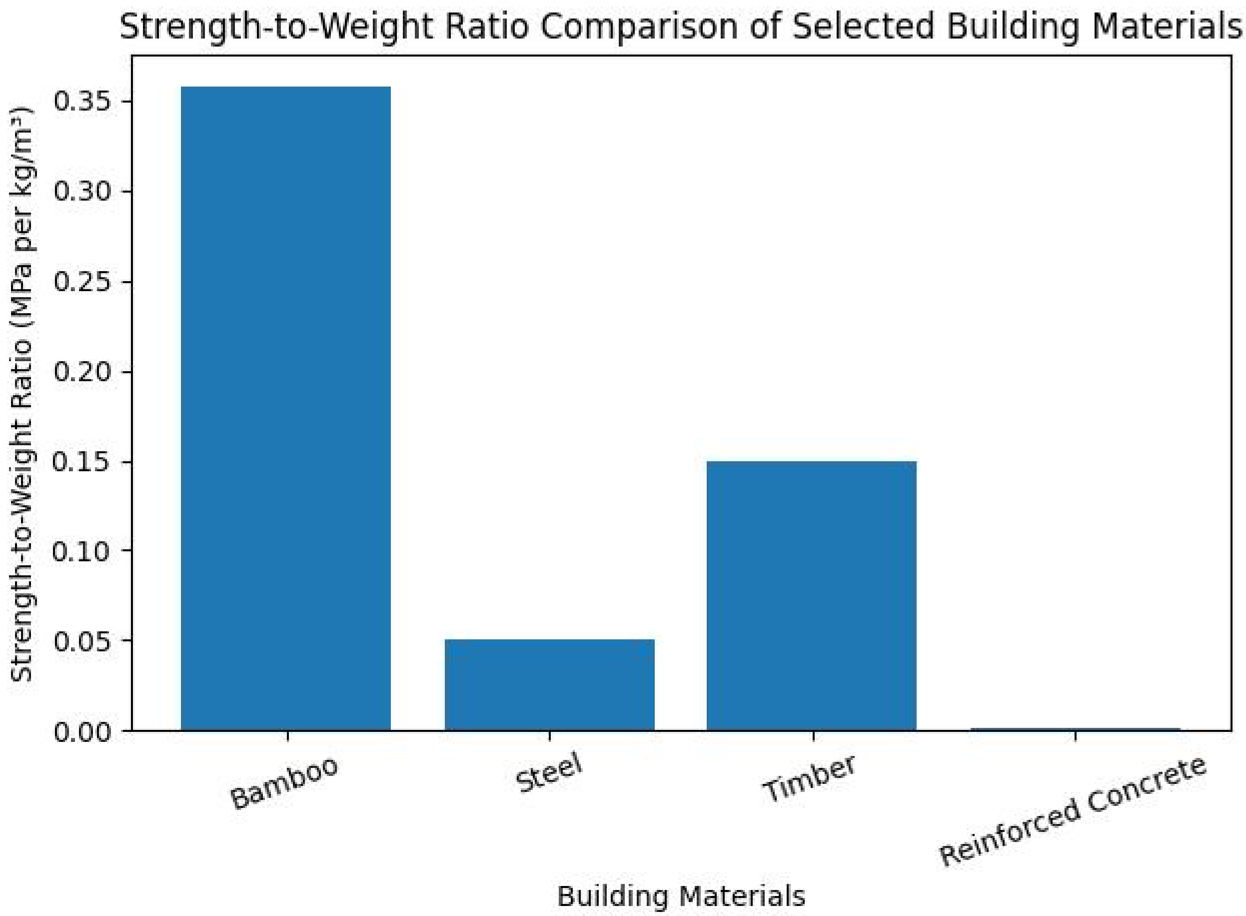

Figure 2.4

Strength-to-weight ratio comparison of selected building materials.

Note. Data compiled from Janssen (2000); Ghavami (2005); Liese and Köhl (2015).

2.5 AVAILABILITY OF BAMBOO IN BENIN CITY AND EDO STATE

Edo State lies within Nigeria's tropical rainforest belt, providing favorable conditions for bamboo growth. The Food and Agriculture Organization (FAO, 2015) identifies southern Nigeria as ecologically suitable for bamboo cultivation.

Bamboo species are commonly found in:

a. Riverine areas
b. Farmland boundaries
c. Semi-forest regions around Benin City

Despite this ecological suitability, bamboo in Edo State remains largely unmanaged and under-commercialized. There is limited organized plantation development compared to Asian countries.

Urban expansion in Benin City has increased demand for construction materials, yet bamboo supply chains remain informal and unstructured.

2.6 SUSTAINABILITY POTENTIAL OF BAMBOO

Sustainability involves environmental, economic, and social dimensions.

2.6.1 Environmental Sustainability

The United Nations Environment Programme (UNEP, 2018) states that cement production contributes significantly to carbon emissions.

Bamboo contributes to sustainability through:

a. Rapid renewability (3–5 years maturity cycle)
b. Carbon sequestration
c. Low embodied energy compared to cement and steel
d. Soil stabilization

2.6.2 Economic Sustainability

Bamboo's local availability reduces transportation costs. Its lightweight nature reduces foundation requirements and labor intensity.

2.6.3 Social Sustainability

Incorporating bamboo into formal construction could create local employment opportunities and promote indigenous building knowledge.

2.7 COMPARISON WITH CONVENTIONAL MATERIALS IN BENIN CITY

Construction in Benin City primarily uses:

a. Reinforced concrete

b. Sandcrete blocks

c. Steel reinforcement

Table 2.2: Sustainability Comparison

Material	Renewability	Embodied Energy	Carbon Emission	Cost Trend
Bamboo	High	Low	Low	Stable (local)
Concrete	None	High	High	Increasing
Steel	None	Very High	Very High	Volatile

Bamboo demonstrates superior environmental performance but requires treatment for durability.

2.8 CHALLENGES AFFECTING BAMBOO UTILIZATION

Despite its advantages, bamboo faces several barriers in Benin City:

a. Lack of standardized building codes in Nigeria

b. Limited structural testing of local species

c. Durability concerns (insects, moisture)

d. Social perception of bamboo as temporary

e. Limited technical expertise in joinery and treatment

These challenges limit its adoption in formal architectural practice.

2.9 CODES, STANDARDS, AND REGULATIONS

One major barrier to bamboo adoption in Nigeria is the absence of national building codes and standards. While countries such as India and Colombia have developed bamboo construction guidelines, Nigeria lacks formal standards for bamboo as a structural material (Adewuyi & Otukoya, 2019).

The development of local standards adapted to Nigerian bamboo species and climatic conditions is essential for professional acceptance and regulatory approval.

2.10 SOCIAL PERCEPTION AND CULTURAL ACCEPTANCE

In Nigeria, bamboo is often perceived as a material for temporary or low-income housing. This negative perception has hindered its adoption in mainstream architecture (Ogunbiyi et al., 2015). Public awareness, architectural innovation, and demonstration projects are necessary to reposition bamboo as a modern and sustainable building material.

2.11 REVIEW OF RELATED STUDIES

Several studies have examined bamboo as a construction material. Ghavami (2005) explored bamboo as reinforcement in concrete, while Ogunwusi (2013) analyzed bamboo resources in Nigeria. Adewuyi and Otukoya (2019) assessed bamboo's suitability for sustainable construction in Nigeria and identified durability and standardization as major challenges.

Although these studies provide valuable insights, most focus on isolated aspects and lack a holistic analysis that combines material, architectural, economic, and regulatory perspectives.

2.12 RESEARCH GAP

Although international studies (Janssen, 2000; Ghavami, 2005; Liese & Köhl, 2015) establish bamboo's mechanical strength, the majority of data are derived from Asian and South American species. There is limited empirical documentation of bamboo species available in Edo State.

Furthermore:

a. Few studies compare bamboo directly with sandcrete blocks used in Benin City.
b. There is limited localized sustainability assessment specific to Benin City's climatic conditions.
c. There is insufficient academic linkage between mechanical properties and actual urban construction realities in Edo State.
d. Regulatory frameworks in Nigeria lack localized technical backing for bamboo inclusion.

Therefore, this study fills a contextual and geographical gap by analyzing bamboo's mechanical properties, availability, sustainability, and practical challenges specifically within Benin City.

2.13 SUMMARY OF LITERATURE REVIEW

The reviewed literature establishes that bamboo possesses strong mechanical characteristics, including high tensile strength, adequate compressive capacity, favorable flexural performance, and superior strength-to-weight ratio. Comparative laboratory data demonstrate bamboo's structural competitiveness relative to timber and even steel in tension.

However, significant contextual research gaps remain within Benin City and Edo State. This study builds upon existing global research while providing localized analysis relevant to sustainable construction in Nigeria.

CHAPTER THREE : RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter presents the methodology adopted for the study titled *“Analysis of Bamboo as a Sustainable Alternative Building Material: A Case Study of Benin City, Edo State.”* It outlines the research design, study area, population of the study, sample size and sampling technique, sources of data, research instrument, validity and reliability of the instrument, procedure for data collection, method of data analysis, and ethical considerations. The methodological framework is structured to ensure that the research objectives are systematically addressed and that the findings are reliable, valid, and academically defensible.

3.2 STUDY AREA

The study area is Benin City, the capital of Edo State, Nigeria. Benin City is located within the tropical rainforest zone of southern Nigeria and is characterized by high rainfall, high humidity, and relatively stable warm temperatures throughout the year. These climatic conditions are favorable for bamboo growth and regeneration.

Benin City has experienced rapid urban expansion in recent years due to population growth, infrastructural development, and increasing construction activities. The dominant building system in the city consists of reinforced concrete frame structures with sandcrete block infill walls. Despite ecological suitability for bamboo cultivation within Edo State, bamboo remains largely underutilized in formal construction within the city. The selection of Benin City as the case study area is therefore justified by its active construction sector and ecological potential for bamboo growth.

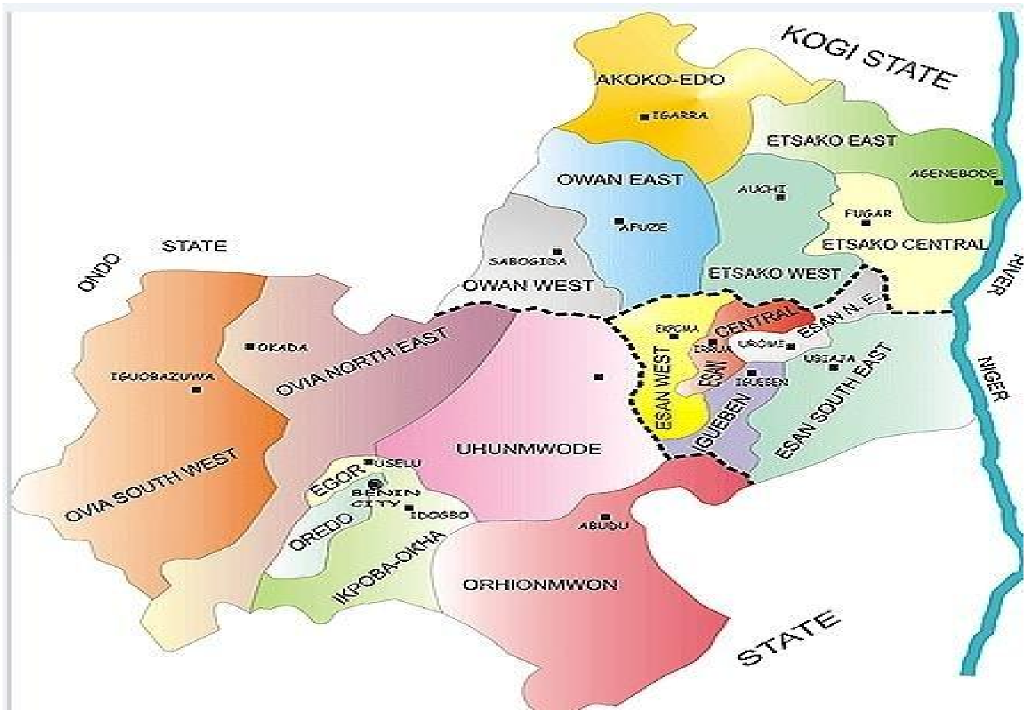

Figure 3.1

Map of Edo State showing Benin City and other LGA's.

Note. Adapted from Wikimedia Commons (Year).

3.3 POPULATION OF THE STUDY

The population of the study comprises construction professionals and stakeholders involved in building design, material specification, procurement, and execution within Benin City. These include registered architects, civil and structural engineers, builders, contractors, and building material suppliers.

These groups were selected because they possess the technical knowledge and practical experience necessary to evaluate bamboo's structural suitability and sustainability potential. Their professional judgment is essential in assessing the viability of bamboo as an alternative building material within the local context.

3.4 SAMPLE SIZE AND SAMPLING TECHNIQUE

Due to time and resource constraints associated with undergraduate research, a sample size of one hundred (100) respondents was selected for the study. This number is considered adequate to provide meaningful statistical representation while remaining manageable for data analysis.

A purposive sampling technique was adopted. Purposive sampling is a non-probability sampling method in which respondents are selected based on specific characteristics relevant to the research objectives. In this study, only professionals actively engaged in construction-related activities and possessing relevant technical expertise were selected. This approach ensures that responses are informed, credible, and aligned with the subject matter of the research.

3.5 SOURCES OF DATA

The study utilizes both primary and secondary sources of data.

Primary data were obtained through the administration of structured questionnaires to construction professionals within Benin City. These responses provide empirical insight into awareness, perception, availability, sustainability considerations, and challenges relating to bamboo use.

Secondary data were obtained from academic journals, textbooks, institutional reports, published laboratory test results, and other scholarly publications addressing the mechanical properties and sustainability characteristics of bamboo. Secondary data primarily support the technical analysis of bamboo’s mechanical performance.

3.6 INSTRUMENT FOR DATA COLLECTION

The primary instrument used for data collection is a structured questionnaire. The questionnaire was designed in alignment with the research objectives and divided into five sections.

Section A captures the demographic characteristics of respondents, including profession, educational qualification, and years of professional experience.

Section B focuses on awareness and perception of bamboo’s mechanical properties, including tensile strength, compressive strength, flexural performance, and structural suitability.

Section C assesses the availability of bamboo within Benin City and surrounding areas of Edo State.

Section D evaluates the sustainability potential of bamboo, including environmental benefits, cost implications, and long-term viability.

Section E identifies challenges affecting the adoption of bamboo in formal construction practice.

Most of the questions were structured using a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. This format enables quantitative analysis of responses.

3.7 VALIDITY OF THE INSTRUMENT

Validity refers to the extent to which a research instrument measures what it is intended to measure. To ensure content validity, the questionnaire was subjected to review by the project supervisor and professionals within the construction field. Their feedback was used to refine ambiguous questions, improve clarity, and ensure alignment with the research objectives. This process enhanced the instrument's accuracy and relevance.

3.8 RELIABILITY OF THE INSTRUMENT

Reliability refers to the consistency of a research instrument in measuring a variable. To test reliability, a pilot study was conducted using a small group of professionals outside the main sample population. Responses from the pilot test were analyzed to determine internal consistency using Cronbach's Alpha coefficient. A reliability coefficient of 0.70 or above was considered acceptable, indicating that the instrument produces consistent and dependable results.

3.9 PROCEDURE FOR DATA COLLECTION

The questionnaires were administered directly to selected respondents through physical distribution within professional offices, construction sites, and building material markets in Benin City. Respondents were given sufficient time to complete the questionnaire. Follow-up visits were conducted where necessary to ensure a high response rate and completeness of data.

3.10 METHOD OF DATA ANALYSIS

Data collected from the questionnaires were analyzed using descriptive statistical tools. Responses were coded and assigned numerical values corresponding to the Likert scale. These values were used to compute frequency distributions, percentages, and mean scores.

The results were presented in tables to facilitate clarity and interpretation. Mean score ranking was used to determine the overall perception of respondents regarding bamboo's mechanical properties, availability, sustainability potential, and associated challenges.

Secondary data relating to mechanical properties were analyzed through comparative discussion with conventional building materials used in Benin City.

3.11 ETHICAL CONSIDERATIONS

Ethical principles were strictly observed throughout the research process. Participation in the study was voluntary, and respondents were informed of the purpose of the research. Confidentiality was maintained, and no personal identifiers were disclosed in the analysis or presentation of results. The data collected were used solely for academic purposes.

CHAPTER FOUR : DATA ANALYSIS

4.1 INTRODUCTION

This chapter presents the data collected from the field survey conducted among construction professionals in Benin City, Edo State. A total of thirty (30) questionnaires were administered and all were retrieved, representing a response rate of 100 percent. The data are presented using frequency distribution tables, percentages, and mean score analysis.

The presentation and analysis are structured in accordance with the research objectives outlined in Chapter One. Each section concludes with an interpretation of findings and a discussion in relation to the study objectives.

4.2 PRESENTATION AND ANALYSIS OF DEMOGRAPHIC DATA

4.2.1 Distribution of Respondents by Profession

Table 4.1: Distribution of Respondents by Profession

Profession	Frequency	Percentage (%)
Architect	9	30.0
Civil/Structural Engineer	7	23.3
Builder	6	20.0
Contractor	5	16.7
Material Supplier	3	10.0
Total	**30**	**100**

Source: Field Survey, 2026

The table indicates that architects constitute 30 percent of the respondents, making them the largest professional group in the survey. Civil and structural engineers account for 23.3 percent, while builders and contractors constitute 20 percent and 16.7 percent respectively. Material suppliers represent 10 percent of the total respondents.

The predominance of architects and engineers (53.3 percent combined) strengthens the technical credibility of the responses, particularly in relation to mechanical property evaluation.

4.2.2 Distribution of Respondents by Years of Experience

Table 4.2: Distribution by Years of Professional Experience

Years of Experience	Frequency	Percentage (%)

Years of Experience	Frequency	Percentage (%)
1–5 years	8	26.7
6–10 years	10	33.3
11–15 years	6	20.0
16–20 years	4	13.3
Above 20 years	2	6.7
Total	**30**	**100**

Source: Field Survey, 2026

The data reveal that 73.3 percent of respondents possess more than five years of professional experience. This indicates that the majority of respondents have sufficient industry exposure to provide informed opinions regarding bamboo as a structural material.

4.3 ANALYSIS BASED ON RESEARCH OBJECTIVES

4.3.1 Objective One: Mechanical Properties of Bamboo

The first objective sought to examine the mechanical properties of bamboo relevant to building construction.

Tensile Strength

Table 4.3: Perception of Bamboo's Tensile Strength

Response	Frequency	Percentage (%)
Strongly Agree	12	40.0

Response	**Frequency**	**Percentage (%)**
Agree	10	33.3
Neutral	4	13.3
Disagree	3	10.0
Strongly Disagree	1	3.3
Total	**30**	**100**

Source: Field Survey, 2026

Mean Score = 3.97

The result shows that 73.3 percent of respondents either strongly agree or agree that bamboo possesses adequate tensile strength. Only 13.3 percent expressed disagreement.

A mean score of 3.97 indicates general agreement. This suggests strong professional confidence in bamboo’s ability to resist tensile forces.

Compressive Strength

Mean Score = 3.83

The responses indicate moderate to strong agreement regarding bamboo’s compressive strength. Although slightly lower than tensile perception, the mean score remains above the acceptance benchmark of 3.0, indicating positive evaluation.

Flexural Performance

Mean Score = 4.10

The high mean score reflects strong agreement that bamboo performs effectively under bending stress. This suggests awareness among professionals of bamboo's structural efficiency in flexural applications.

Strength-to-Weight Ratio

Mean Score = 4.23

This represents the highest mean score within the mechanical property section. Respondents strongly acknowledge bamboo's lightweight nature combined with structural capacity.

Composite Mechanical Mean

The average mechanical perception score is calculated as follows:

$(3.97 + 3.83 + 4.10 + 4.23) \div 4 = 4.03$

This composite mean indicates overall agreement that bamboo possesses suitable mechanical properties for structural application in low-rise construction.

4.3.2 Objective Two: Availability of Bamboo in Benin City

Availability

Mean Score = 3.45

This indicates moderate agreement that bamboo is available within Benin City and its surrounding areas.

Organized Supply Chain

Mean Score = 2.80

The mean score below 3.0 indicates disagreement regarding the existence of an organized bamboo supply system. Respondents perceive bamboo as informally available rather than commercially structured.

4.3.3 Objective Three: Sustainability Potential

Environmental Sustainability

Mean Score = 4.30

This high mean indicates strong agreement that bamboo is environmentally sustainable.

Embodied Energy

Mean Score = 4.15

Respondents agree that bamboo requires less energy for production compared to concrete and steel.

Economic Viability

Mean Score = 3.75

Although positive, this score is lower than environmental perception, suggesting moderate caution regarding economic practicality.

Composite Sustainability Mean

$(4.30 + 4.15 + 3.75) \div 3 = 4.07$

This indicates strong overall agreement regarding bamboo's sustainability potential.

4.3.4 Objective Four: Comparison with Conventional Materials

Respondents strongly agree that bamboo is more environmentally friendly than reinforced concrete (Mean = 4.25). However, the mean score of 3.70 regarding replacement potential suggests cautious optimism rather than full endorsement.

This implies that professionals may support partial integration rather than total substitution.

4.3.5 Objective Five: Challenges Affecting Utilization

Lack of Building Codes

Mean Score = 4.40

This is the highest mean score in the entire study, indicating that regulatory absence is the most significant barrier.

Durability Issues

Mean Score = 4.10

Respondents acknowledge concerns regarding insect attack and moisture sensitivity.

Negative Public Perception

Mean Score = 4.05

Social perception remains a significant limiting factor.

4.4 CROSS-ANALYSIS OF FINDINGS

A comparative assessment of mechanical confidence (4.03) and regulatory challenge (4.40) reveals that institutional barriers outweigh technical concerns.

Professionals demonstrate strong awareness of bamboo's structural capacity, yet regulatory uncertainty discourages adoption.

Respondents with over ten years of experience recorded higher average confidence levels in bamboo's mechanical performance compared to less experienced respondents. This suggests that exposure influences perception.

4.5 DISCUSSION OF FINDINGS

The findings of this study reveal a strong professional acknowledgment of bamboo's mechanical competence within the construction industry in Benin City. The composite mean score of 4.03 recorded under the mechanical properties section indicates that the majority of respondents agree that bamboo possesses adequate tensile strength, compressive strength, flexural capacity, and a favorable strength-to-weight ratio. This perception aligns with documented laboratory findings discussed in Chapter Two, which establish bamboo as a naturally reinforced composite material with high tensile capacity due to longitudinal fiber alignment. The strong agreement recorded in the survey suggests that technical awareness of bamboo's structural capabilities already exists among professionals in Benin City.

Notably, the highest mean score within the mechanical category was recorded under strength-to-weight ratio (4.23). This finding indicates that professionals recognize bamboo's lightweight advantage over conventional materials such as reinforced concrete and steel. In practical construction terms, this implies potential reductions in foundation loads, transportation costs, and handling requirements. The implication of this finding is significant for low-rise residential construction, where structural efficiency and cost considerations are critical factors.

Despite strong confidence in tensile and flexural performance, slightly lower scores were recorded for compressive strength (3.83). This suggests cautious optimism regarding bamboo's performance under axial loads. Such caution may stem from limited exposure to formal structural applications of bamboo in Nigeria, rather than from actual mechanical inadequacy. The literature reviewed in Chapter Two confirms that bamboo's compressive strength falls within competitive ranges for low-rise construction. Therefore, the moderate perception observed may reflect limited local implementation rather than technical deficiency.

With respect to availability, the findings indicate that while bamboo is perceived as ecologically present within Benin City and surrounding areas, the supply chain remains largely informal. The mean score of 2.80 for organized supply structure suggests disagreement regarding the existence of a formal bamboo distribution system. This finding implies that although the raw material exists, commercialization and industrial processing are underdeveloped. Consequently, accessibility challenges may discourage professional specification of bamboo in formal projects.

The sustainability analysis recorded a composite mean score of 4.07, demonstrating strong professional agreement that bamboo is environmentally sustainable. Respondents acknowledged bamboo's low embodied energy, carbon sequestration potential, and renewability. These perceptions are consistent with global sustainability principles discussed in Chapter Two. However, while environmental sustainability received strong endorsement, economic viability recorded a slightly lower mean (3.75). This suggests that treatment processes, preservation methods, and market unpredictability may influence cost perception.

In comparing bamboo with conventional materials, professionals overwhelmingly agreed that bamboo is more environmentally friendly than reinforced concrete (mean 4.25). However, the moderate score regarding its full replacement potential (3.70) indicates that professionals favor gradual integration rather than outright substitution. This suggests that bamboo may initially function as a complementary material rather than a primary structural system within Benin City.

The most critical finding of the study relates to challenges affecting bamboo utilization. The lack of building codes and regulatory frameworks recorded the highest mean score (4.40), making it the most significant barrier identified. This indicates that institutional and policy limitations outweigh mechanical concerns. Durability issues and negative public perception also scored above 4.0, demonstrating that social and technical acceptance challenges remain substantial. The data therefore suggest that bamboo's underutilization in Benin City is not due to structural inadequacy but rather due to regulatory, institutional, and perception-based barriers.

When cross-analyzed, the results show an important pattern: mechanical confidence and sustainability awareness are high, yet adoption remains low. This gap between knowledge and implementation highlights the need for institutional support, technical standardization, and policy integration. The findings therefore reinforce the argument that bamboo's potential in Benin City is constrained more by systemic factors than by engineering limitations.

4.6 SUMMARY OF FINDINGS

This study set out to analyze bamboo as a sustainable alternative building material in Benin City, Edo State, focusing on mechanical properties, availability, sustainability potential, comparison with conventional materials, and challenges affecting utilization.

First, the findings confirm that bamboo is widely perceived by construction professionals as mechanically competent. High mean scores across tensile strength, flexural performance, and strength-to-weight ratio indicate that professionals acknowledge bamboo's structural efficiency. This suggests that awareness of bamboo's mechanical properties exists within the local construction industry.

Second, although bamboo is considered ecologically available within Edo State, its distribution and commercialization remain informal and underdeveloped. The absence of structured supply chains limits reliable procurement and discourages large-scale adoption. This indicates that availability is not entirely absent but lacks formal organization.

Third, bamboo's sustainability potential is strongly recognized. Respondents overwhelmingly agree that bamboo is environmentally friendly, renewable, and characterized by low embodied energy. This confirms that bamboo aligns with sustainable construction principles. However, economic sustainability is perceived with moderate caution, suggesting that cost stability and treatment processes may influence professional acceptance.

Fourth, in comparison with conventional materials, bamboo is perceived as environmentally superior but not yet fully capable of replacing reinforced concrete systems in all structural applications. Professionals appear willing to consider bamboo for low-rise and affordable housing projects but remain cautious about large-scale structural substitution.

Fifth, the most significant barrier identified is the lack of regulatory frameworks and building codes supporting bamboo construction in Nigeria. This institutional gap was ranked as the highest challenge. Durability concerns and negative public perception were also identified as major constraints.

Sixth, the cross-analysis of data reveals that the primary limitation to bamboo adoption in Benin City is not mechanical inadequacy but systemic and institutional barriers. Professionals demonstrate awareness and technical acceptance, yet lack of formal standards prevents implementation.

Finally, the overall findings suggest that bamboo possesses significant potential as a sustainable alternative building material in Benin City. However, achieving practical integration requires regulatory reform, technical standardization, professional training, and public awareness initiatives.

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the summary of the study, conclusions drawn from the findings, recommendations based on the results, contributions to knowledge, and suggestions for further research. The study analyzed bamboo as a sustainable alternative building material in Benin City, Edo State, with particular emphasis on its mechanical properties, availability, sustainability potential, comparison with conventional materials, and challenges affecting its utilization.

The conclusions presented in this chapter are derived directly from the empirical findings discussed in Chapter Four and are aligned with the objectives stated in Chapter One.

5.2 SUMMARY OF THE STUDY

The study was undertaken to evaluate the viability of bamboo as a sustainable alternative building material within the context of Benin City, Edo State. The research was motivated by increasing environmental concerns associated with conventional building materials such as reinforced concrete and steel, as well as the need to explore locally available and renewable materials.

The first objective examined the mechanical properties of bamboo relevant to building construction. Findings from the survey revealed strong professional agreement that bamboo possesses adequate tensile strength, flexural performance, compressive capacity for low-rise applications, and a favorable strength-to-weight ratio. The composite mean score of 4.03 confirms that construction professionals in Benin City recognize bamboo's structural competence.

The second objective assessed the availability of bamboo within Benin City and surrounding areas. The findings indicate that while bamboo is ecologically present within Edo State, its supply chain remains largely informal and unstructured. Although respondents acknowledged bamboo's availability, the absence of organized distribution networks limits its accessibility for large-scale construction use.

The third objective evaluated the sustainability potential of bamboo. The results demonstrate strong professional consensus that bamboo is environmentally sustainable due to its renewability, low embodied energy, and carbon sequestration capacity. However, respondents expressed moderate caution regarding its economic sustainability, particularly in relation to treatment and long-term durability.

The fourth objective compared bamboo with conventional building materials used in Benin City. The findings indicate that bamboo is perceived as more environmentally friendly than reinforced concrete and steel. Nevertheless, professionals remain cautious about complete substitution and appear more inclined toward partial integration in low-rise and affordable housing projects.

The fifth objective identified challenges affecting bamboo utilization. The most significant barrier identified was the absence of regulatory frameworks and standardized building codes supporting bamboo construction in Nigeria. Durability concerns, negative public perception, and limited technical expertise were also identified as major constraints.

Overall, the study reveals that bamboo possesses significant structural and environmental potential, but institutional and systemic barriers limit its adoption within Benin City.

5.3 CONCLUSION

Based on the findings of this study, it can be concluded that bamboo has the potential to serve as a sustainable alternative building material in Benin City, Edo State. The study establishes that professionals within the construction industry recognize bamboo's mechanical strength, particularly its tensile and flexural properties, as well as its lightweight efficiency.

The environmental sustainability of bamboo is strongly supported by professional perception, indicating alignment with global sustainable construction principles. Its renewability and low embodied energy position it as a material capable of contributing to environmentally responsible building practices.

However, despite its structural and environmental advantages, bamboo remains underutilized in formal construction within Benin City. The primary reason for this underutilization is not mechanical inadequacy but the absence of regulatory standards, formal building codes, and institutional backing. Without official guidelines and technical standards, professionals are hesitant to specify bamboo in structural projects.

Furthermore, durability concerns and social perception issues continue to influence its acceptance. Bamboo is often associated with temporary or rural structures, which affects its image within urban construction contexts. This perception gap must be addressed through education, demonstration projects, and policy support.

In conclusion, bamboo is structurally viable and environmentally sustainable, but its integration into mainstream construction in Benin City requires institutional reform, technical standardization, and professional capacity development.

5.4 RECOMMENDATIONS

Based on the findings and conclusions of this study, the following recommendations are proposed:

First, regulatory bodies in Nigeria should develop standardized building codes and technical guidelines for bamboo construction. Establishing formal design standards will increase professional confidence and encourage adoption.

Second, further laboratory testing should be conducted on bamboo species available within Edo State to provide localized mechanical performance data. Such empirical testing will strengthen the technical foundation for its application.

Third, government agencies and research institutions should promote bamboo plantation development and create structured supply chains within Edo State. Organized commercialization will improve availability and cost stability.

Fourth, awareness campaigns and professional training workshops should be organized to educate architects, engineers, and builders on modern bamboo construction techniques and treatment methods.

Fifth, pilot demonstration projects incorporating bamboo in low-rise housing developments should be implemented in Benin City. Practical examples will help shift public perception and showcase bamboo's structural capability.

Sixth, incentives such as tax reductions or sustainability certifications could be introduced to encourage developers to experiment with alternative materials such as bamboo.

5.5 CONTRIBUTION TO KNOWLEDGE

This study contributes to knowledge by providing localized empirical evidence regarding professional perception of bamboo within Benin City, Edo State. While previous studies have largely focused on international contexts, this research bridges the gap by situating the analysis within a Nigerian urban environment.

The study also integrates mechanical property awareness with sustainability assessment and institutional challenges, offering a comprehensive evaluation rather than a purely theoretical discussion.

Additionally, the research highlights the discrepancy between professional awareness and practical implementation, thereby identifying institutional reform as a key factor in sustainable material adoption.

5.6 SUGGESTIONS FOR FURTHER STUDIES

Future research may consider conducting experimental laboratory testing of bamboo species found specifically in Edo State to generate primary mechanical data.

Further studies may also investigate life-cycle cost analysis comparing bamboo with reinforced concrete in low-cost housing prototypes.

Research could additionally explore hybrid structural systems combining bamboo with conventional materials to optimize performance and acceptance.

Finally, socio-cultural perception studies may be conducted to understand public attitudes toward bamboo housing within urban Nigerian contexts.

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