

# Housing as a Breathing Machine: The use of Bamboo as a Main Joinery Element

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**Abstract:-** Housing, like clothing and food, is an essential need of man. Single-family houses, apartments, condominiums, and other kinds of multi-unit housing are just a few of the different housing options. Housing the urban population is key to sustainable development. The process and product of it are defined by each stage of it being conceived from the time of design to the point when it is constructed, ready for use. Man and his environment interact. Housing as a breathing machine explains the role of shelter in not just only accommodating man and his properties but helping man live an interactive life with his building which tends to be sustainable. This is achieved through basic elements of the building as wall envelopes, roof details, foundation details, doors, flooring etc. which are designed based on client's preferences. This paper thus presents the need of advancement in science and technology with the use of bamboo in housing schemes to tackle the shelter challenges among the high, middle and low classes in the society. Bamboo can suitably be used to complement /substituted for timber and other materials in construction. It has a great potential for production of composite materials and components which are cost effective, suitable for structural and non-structural applications in construction. The availability and use of this alternative building material is considered to reduce cost and helps in the provision of low-cost housing in the Benin Metropolis. Bamboo as an alternative building material is sustainable, reused, well preserved and maintained and can be used as fixtures (pipes, cabinets, furniture making) and features (roof carcass, floor, door frame, insulator) in buildings and in the industry. The use of bamboo as a joinery element will produce cost effective and qualitative buildings. Its varied uses and applications in building construction have established bamboo as an environmentally-friendly, energy efficient, sustainable and cost-effective construction material.

**Keywords:-** Low Cost Housing, Sustainable Material, Bamboo, Computational Design, Computer Aided Design (CAD), Parametric Modeling, Algorithm Generation.

## I. INTRODUCTION

The inadequate provision of housing (low cost housing) is a common challenge in many developing countries including Nigeria. This shortage of housing, though a common phenomenon, is more severe in urban centers (Arayela & Taiwo, 2010). The rates of urbanization in Nigeria have given rise to the depreciating quality and the provision of houses in Nigeria. This shortage in urban areas is partly due to high cost of land, inadequate funding from government, lack of credit mechanisms for small scale construction, poor infrastructural development and the multi-dimensional poverty of the city dwellers. Oladapo & Olotuah (2007) affirmed that the urban areas experiences more deterioration in social infrastructures, urban and communal services and downgraded state of housing in Nigeria as a result of urbanization.

Edo State, Benin City as the capital, has a population of **approximately 8 million**. It is made up of four major ethnic groups; namely Edo (Binis), Owan, Esan and Afemai (Etsako & Akoko Edo). This article explains the importance on how the use of bamboo can reduce the construction cost low-cost housing, considering the increase in cost of conventional materials. This will significantly reduce the total cost of the building without compromising the quality. Housing as a dwelling unit (containing a family) is a facility that should be of good quality as it impacts on productivity, health and well-being of the people. It should guarantee safety, security, health as enshrined in the Habitat Agenda.

Low-cost housing is provided to meet the rapid growth in urban population and having a sustainable urban development generally. To achieve this, the provision of mass housing using indigenous and alternative building materials is important (Olotuah & Taiwo, 2013).

In the ancient time, Vernacular architecture, which is the traditional way of architecture, was a concise make-up of the culture, and perceived sustainability was included in construction of places. The relationship of man and his environment is defined by the term 'Eco-system' this ranged from the natural environmental features as climate, high and low lands, vegetation, and presence of water bodies among others. And man-made environmental features as settlements, infrastructures among others.

## II. LOW-COST HOUSING SCHEME IN BENIN

The National Population Commission (1991) puts the Benin Metropolis {comprising of three Local Government Areas (LGAs) - Oredo, Egor and Ikpoba Okha} population at 780,976. In 2006, the population has risen to 1,085,676 with 542,554 to be male and 543,112 to be female. This is explained by the projected annual 3.0% growth rate in Benin metropolis. The rate of growth should be well defined from the rate of development of the study area, as the former represents number of people and the latter speaks about the way people well utilize the given environmental resources. If provision of low-cost housing units commensurate with the growth rate in the Benin metropolis is not well considered, it could lead to precarious housing situation on the environment with dire economic and social challenges. Urban growth rate is the concentration of migrants from the rural settlements to the urban settlements (cities, towns, and metropolis). Housing as a unit of the environment has great importance to man, inadequacy of this, would result in overcrowding of existing dwelling units, and the actualization of slums and squatters. Other relevant factors in the environment are: infrastructures, communal facilities, waste disposal management, education, health and commerce facilities among others. To eradicate these problems on low cost housing, alternative building materials that can be sourced locally can be used.

## III. FACTORS THAT AFFECT LOW COST HOUSING

According to Sheibani & Havard (2016), the factors, amongst others, that affect low cost housing include:

- Industrial and economic developments in cities resulting in rural-urban migration thereby creating slums and squatters as the demand for dwelling units' skyrockets.
- The continuous increase in rate of rural-urban migration in the last two and half decades is alarming and at a big disadvantage to the given infrastructures, basic social or communal services in those urban cities migrated to.
- Finance capability is of utmost importance to own a house. Finance is the barrier or catalyst to help in restricting or implementing of housing provision to the citizens. The cost of owning quality housing is not affordable by most people in this country (Olotuah, 2012), because housing is capital-intensive.
- The involvement of Private developers by the government in an attempt to eradicate or reduce housing problems – though with good intentions - but the main goal of these private initiatives is to make cut – throat profit.
- Cost of land is expensive in cities. The price of land increases rapidly in the urban areas. This explains why Land is most sorted out than other commodities in the urban areas translating to the total cost of the design and construction.

## IV. HOUSING AS A BREATHING MACHINE

A dwelling unit is a house consisting of one family (the man, his wife or wives and children) that is considered sustainable based on their relationship between the natural elements of the surrounding environment and its inhabitants. Housing as a breathing machine is a concept that explains the relationship between natures, wellness of those that live in the building before such building can be regarded as sustainable. Knowing fully well that the current day design in architecture should be able to sort the challenge of increase in urbanization, need for adaptive designs and sustainability, there is a need to for faster solutions. Breathing Machine literally signifies occupants enjoying fresh ventilation in their building. In the Benin Metropolis, earth (mud) buildings prevalent in construction, but in recent times it is seen that sandcrete block is mostly used. Bamboo is one of the oldest traditional building materials that is light but strong for construction and has a good elasticity property with high compressive strength. It contains a good amount of starch, hemi cellulose, and moistured that can allow breeding of micro organisms. This micro organisms can be in form of fungi, the rot (white, soft, and brown), and insects (termites) (Nwoke & Ugwuishiwu, 2011). It can fit well as an alternative building material for building purpose. Other features of Bamboo include its having a high tensile strength, proportional stability, and can be easily manipulated into any form by a machine. It is not only a building material but also a construction material.

## V. BAMBOO AS A LOCAL AND ALTERNATIVE BUILDING MATERIAL

Adeosun (2017) opined that 'Nigeria's housing deficit is estimated at about 17 million dwelling units with an estimated increase of about 900,000 yearly. Construction with local materials speaks aloud in the building expression in less developed countries of the world, with advancement in technology of construction and sustainable design. Building construction materials are environmental friendly, low energy consumption and reuse, and carbon dioxide emissions, good indoor and outdoor qualities, renewable or non-renewable resource consumption.

Bamboo is a renewable raw material resource, a valuable Non-Timber Forest Product (NTFP) that can be harvested, cut and laminated into sheets and planks by cutting stalks into thin strips, planning it flat, and drying up the strips; they are then glued, compressed, finished and could be left in its physical state as it is.

According to Farrelly (1984) and Guinness (2014), bamboos have a special rhizome-dependent mechanism that makes them some of the world's fastest-growing plants. A certain kind of bamboo may reach a height of 890 mm in less than 24 hours. A component made of bamboo can have a decent life of 30 to 40 years if it is treated properly and industrially produced. It has a variable natural durability depending on the species. There are recognized types of treatments, numerous uses, and applications in building construction.

For the purpose of this article, Bamboo will be looked at as a building material to complement but not the main material of constructing a structure hence bamboo serving for an objective for a ‘breathing house’.

Bamboo has a broad range of uses in building construction, including wall and roof panels as well as structural components like columns, beams, and trusses. It is the perfect option for regions that are vulnerable to earthquakes because it is also lightweight.

The durability and resistance to insects and moisture can be improved by processing and treating bamboo, which is also a very adaptable substance. In order to build stronger and longer-lasting buildings, it can also be used in conjunction with other materials, such as concrete.

Overall, bamboo is a highly pertinent building material because of its affordability, strength, versatility, and sustainability. Bamboo is likely to become a more frequently chosen material by architects and builders as interest in ecological and green building techniques grows.

Table 1 Relationship between use of Conventional Building Materials and Low Cost Housing in the Benin Metropolis (Nominal Logistic Regression)

Independent variables	Standardized Coefficient	Standard Error (S.E)	t. value	Exp (β)
Bamboo (roof)	0.819	0.288	2.844	2.26823
Wood panels (door)	-0.356	0.153	-2.327	0.700473
Wood slats (ceiling)	-0.381	0.184	-2.071	0.683178
Brush wood (fence)	0.585	0.246	-2.378	1.794991
Wooden panels (window)	-0.474	0.299	-1.585	0.622507
Model Chi-Square	131.782			
Nagelkerke R <sup>2</sup>	0.52			
Correct Prediction (%)	91.4			

Source: Author’s Field Survey, (2021).

The result from the above table shows that bamboo as a roofing material is significant and has a positive relationship (β = 0.819) with low cost housing with an odd ratio of 2.268. This means the use of bamboo for roofing can minimize the cost of construction. By this, the likelihood of low cost housing is 2.3 times possible when roofing are done with bamboo material.

**VI. SAMPLES OF BAMBOO PANELS AND BAMBOO SHEETS**

The samples of bamboo panels and sheets are given in three techniques namely;

- The Natural Vertical Grain Bamboo Plywood Sheets.
- The Carbonised Vertical Grain Bamboo Plywood Sheets.
- The Natural Horizontal Grain Bamboo Plywood Sheets.
- The Carbonised Horizontal Grain Bamboo Plywood Sheets



Plate 1 Samples of Bamboo Panels and Bamboo Sheets. Source: Pacific Western Wood Products. 2011-2020.

Bamboo is one of the best roofing materials that with advancement of science and technology if studied well and refined in production can help in deriving composite materials and that are cost effective, suitable for structural and of non-structural uses in construction purpose. It can be well processed to make it more durable and more usable in terms of building materials. Other Products made from bamboo laminate includes ceiling panels, pillars, flooring construction profile, floor finishing, fencing, cabinetry, furniture and even aesthetics.

Bamboo as a raw material of crafts can be used to make boards, pulp, paper, and other household products.

Bardelline (2009) researched that in the mid-1990s, laminated bamboo for constructions have been developed in Asian countries as Japan and China and sold to the Western world with an estimation of \$25 billion by 2012. By this, bamboo can suitably be used to complement/substituted for timber in building process and construction procedure. Bamboo has good attribute of strength-weight ratio making it suitable as a highly resilient material in earthquake prone areas or where high velocity winds are experience.

As the rate of urbanization increases, there are needs to provide more shelters for settlers. This warrants the cutting down of trees and affecting the soil by erosion, eviction of some animals, and deforestation among other. Timbers are not much or allowed to mature in most cases because it has to be harvested and used for building process. The re-introduction of bamboo in replacing timber can sort a reasonable amount of challenge as stated earlier at the same time adding value to the place it is been used within the Benin metropolis.

By way of legislation, the Government adopted local content in housing scheme programmes to help reduce cost, give job opportunities and increasing the Gross Domestic Product (GDP) of the Nation.

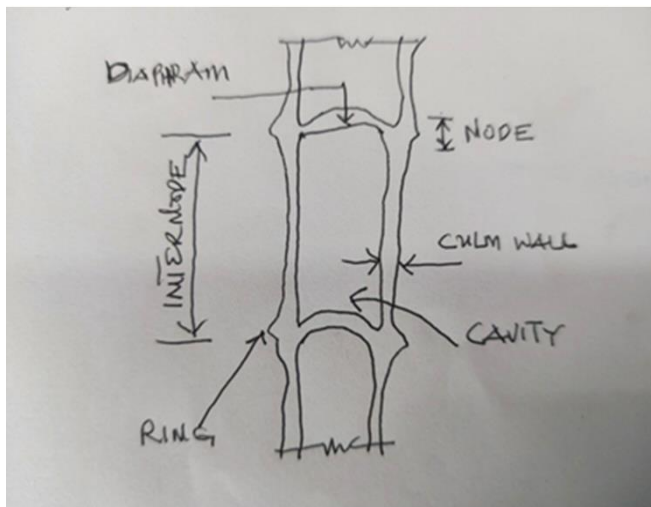


Fig 1 Section through a Bamboo  
Source: Author's Field Work (2021)

## VII. PRESERVATION AND TREATMENT OF BAMBOO AS AN ALTERNATIVE BUILDING MATERIAL

Bamboo been protected from decay is important and considerable as a sustainable local building material. Kaminski et al (2016). By this, bamboo must be stored dry and treated. Bamboo can react to the forces of nature like any other organic matter, hence the need to store and utilize it well. It helps in achieving low cost housing. Through Research Centers, the Government deemed improvement of alternative building materials by using modern and advanced technologies with the main purpose of providing affordable and low cost houses for all.

Bamboo poles must be properly dried and cured once harvested as it can eventually split and decay if left untreated. This preservation can be by natural techniques useful for short to medium term protection or the chemical application which is used for long term protection. Stacking is the best natural way to store harvested bamboo. As the bamboo is well aligned on each other as a layer and opened to air causing it to experience drying.

There are two major ways to treat bamboo and these are, Chemical Treatment (CT) and Non-Chemical Treatment (NCT).

### ➤ *Chemical Treatment (Chemical Treatment):*

Chemical treatment is the practical administration of chemicals like creosote oil, Borax and Boric Acid on the bamboo to cause a permanent preventive treatment method from insect and fungal penetrating..

Chemical Treatment can be done through, Internodes Injection Chemical Treatment and Diffusion Process Chemical Treatment.

### • *Internodes Injection Chemical Treatment:*

This method is used in treatment of dry bamboo whereby a 6mm hole is bored in each node of the bamboo culm and then the Creosote oil is poured into the drilled hole and closed with wax. This will once every other day for a week be turned clockwise or anticlockwise helping the oil to absorb through the inner walls and the cross structural area of culm walls and cavity before it can be used through this process.

### • *Diffusion Process Chemical Treatment:*

This method is used in treatment of fresh bamboo. Here, they are left in a quantity amount of preservative solutions for 12-24 hours and afterwards stacked under shade for 10 – 15 days. And used for its main purpose.

### ➤ *Non-Chemical treatment*

Bamboo can be given a number of non-chemical treatments to increase its toughness and resilience to weathering and pests. Here are a few illustrations:

- **Heat treatment:** Bamboo can be heat-treated in a kiln to eliminate moisture and sugars, making it more robust and decay- and pest-resistant. The bamboo's pigment also becomes darker and more uniform due to the heat.
- **Compression treatment:** Bamboo can be compressed under strong pressure to improve its density and tensile strength. The bamboo may become more water and decay immune after this treatment.
- **Boiling:** Bamboo can be made more immune to decay and pests by boiling it in water to remove moisture and sugars. The bamboo's hue may also become darker after this treatment.
- **Smoking:** Bamboo can be smoked to eliminate moisture and sugars, as well as to add a layer of defence against decay and pests.
- **Chemical treatment:** Bamboo can be preserved by being treated with toxic and more powerful chemicals. Even though it might not be eco-friendly, this can provide security for up to 50 years. Metal compounds such as copper chrome arsenic, copper chrome boron, copper chrome acetic, and zinc chrome fall under this group of toxic chemicals. Although these chemicals are very effective, the results might cast doubt on the advantages of bamboo's sustainability and natural allure as a building material. Since creosote is less toxic, it is frequently used on telephone, telegraph, and railroad tying. The oily nature of the chemical guarantees protection against insects, water, and fungi, making it primarily suitable for outdoor use. A naturally occurring mineral called boron can be used to safely clean bamboo. It can be sprayed on the bamboo's surface as a solution to avoid decay and deter pests.

It's imperative to stop the problem of increasing homelessness plaguing Nigeria and Benin metropolis in particular. Alternative materials (wall and roof) with intrinsic and extrinsic qualities that will increase their durability, cheap cost, and acceptability by their employees are needed to solve this deficiency. The analysis will include the typical building components, such as windows, doorways, sanitary

fixtures, roof covering, floor finishes, and wall finishes while keeping in mind the intended users. The provision of these homes should not be seen solely in terms of number; it should also be seen in terms of quality; otherwise, it will fail as soon as it is implemented.

Quality planning, privacy, adequate space, community service buildings, playgrounds, drainage, access to water and electricity supply, good infrastructure, and green areas will be provided, among other things. Housing is more than just a

roof over one's head and walls enclosing the surrounding space; it also guarantees comfort, security, and good health. Respondents' preference for assessing housing conditions and the durability of the alternate building materials proposed to reflect their expectations of the type of low-cost housing that will be acceptable. As a result, the research aimed at using materials with excellent thermal and acoustic qualities of earth walls will significantly contribute to lower maintenance costs for buildings made of them.



Plate 2 Air Drying of Bamboo.  
Source: Shelter /NFI Sector Project (2020).



Plate 3 Bamboo as Roofing Materials (Trusses Detail) in a Restaurant: Serena Resort Bamboo Restaurant, HoaBinh, Vietnam.  
Source: BambuBuild (2019) <http://www.bamubuild.com/en>



Plate 4 Bamboo as Roofing and Walling Materials in a Resort and spa: Ami Resort and Spa, BinhDinh, Vietnam.  
Source: BambuBuild (2019) <http://www.bamubuild.com/en>



Plate 5 Two-Storey Building using Bamboo and Nominal Rods as Reinforcement.  
Source:<https://timesofindia.indiatimes.com/city/nagpur/pwd-allows-bamboo-as-mainstream-construction-material/articleshow/79189140.cms>

### VIII. CONVERGENCE OF COMPUTER SCIENCE WITH BAMBOO JOINERY IN HOUSING

The fusion of computer science with bamboo joinery in housing is a fascinating meeting point of age-old workmanship and cutting-edge technology. Since ancient times, bamboo has been utilized in building because it is durable and adaptable, especially in areas where it is readily available. Hauptman et al., (2022) the application of computer science to bamboo joinery techniques has a number of advantages and opportunities.

- **Structural Analysis and Optimization:** Computer science tools may simulate and examine the structural characteristics of bamboo and its joinery methods. Designers can then see how various connections and configurations affect the structure's overall stability and ability to support loads. Zhou et al., (2021)
- **Generative algorithms and parametric design:** Computer algorithms can provide parametric designs for bamboo buildings while taking into account site conditions, material availability, and desired appearances. This makes it possible for architects and designers to swiftly examine a variety of design alternatives.
- **Digital prototyping:** Before producing a physical prototype, designers can envision and improve their ideas using computer-aided design (CAD) software. This aids in seeing possible problems and implementing fixes early in the design phase.
- **Precision and Reproducibility:** Using computer-aided manufacturing (CAM) techniques, bamboo components may be produced precisely and consistently, enhancing the quality of joinery connections and lowering assembly mistakes.
- **Complex Geometries:** Computer science can help with the design of intricate and complex geometries that make use of the flexibility and strength of bamboo in its natural state. These plans can produce constructions that are both aesthetically pleasing and structurally sound.
- **Optimized Joinery Methods:** Using computational analysis, creative joinery methods can be created that increase the interlocking strength of bamboo components while consuming the least amount of material.
- **Structural Simulation:** Through the use of computer simulations, it is possible to predict how bamboo structures will react to various loads, environmental factors, and geophysical pressures. This helps to guarantee the security and sturdiness of the structures.
- **Energy Efficiency and Environmental Impact:** By evaluating the thermal performance of bamboo structures through computer simulations, architects can create the best ventilation, insulation, and passive cooling plans.
- **Cultural Preservation:** By combining computer technology with conventional bamboo joinery skills, it is possible to maintain and revive traditional indigenous building traditions while also modernizing them.

### IX. RECOMMENDATIONS

There is the need to go back to the basics of building process. In ancient days, different factors influenced the settlement style and building patterns of people. The advent of synthetic and conventional building materials also affected idea of housing condition from different classes of people. Just the same way human exchange gases with trees and plants for benefits of man, so the house which is his dwelling unit can be used as an avenue to facilitate organic living. Bamboo through this article is a satisfactory alternative option when going back into alternative materials for building. Earth constructions has a tendency to have low tensile strength, bamboo roofing structure becomes more ideal due to its light weight. Though the option of hardwood structure is not ruled out if it becomes desirable. Columns with bamboo reinforcement in concrete in the framework will suffice.

### X. CONCLUSION

Housing is a clear indication of the economic, socio-cultural and historical values (heritage) of a society. It has an influence in the environment even as the environment influences the building (housing scheme). Living in below standard housing conditions can result in higher risk of crime, infectious and chronic disease transmission. The provision of basic physical infrastructures in the built environment will impact positively on the mental and physical health of the people.

In the Benin metropolis, conventional building materials have significant increment on cost of housing. The use of Bamboo is studied and had been shown considerable as an alternative building material for construction.

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