EXPLORING THE POTENTIALS IN BAMBOO AS A SUSTAINABLE BUILDING MATERIAL FOR CONSTRUCTION IN SOUTH EAST NIGERIA

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Abstract
The high cost of building materials has affected the rate of housing delivering in Nigeria. Steel or reinforcement bars which are the main reinforcement element to concrete have become unaffordable due to the skyrocketing exchange rate in Nigeria. This has necessitated the need for building practitioners to look inwards towards local building materials as alternative. This is where bamboo a local building material comes into mind. Bamboo has high tensile qualities like mild steel. It is environmental friendly readily available within our environment. The aim of this study is explore the potentials of bamboo as a sustainable building material by highlighting its main properties and significance. The objective of the studies is to encourage the cultivation of Bamboo in our environment and also encourage research into various types bamboo suitable for our environment. This research was carried out through review of various literatures on bamboo as a construction materials, visit to various websites and journals articles. Oral interviews were equally conducted among local building artisans making use of bamboo for construction purposes. Findings were made on the versatility of bamboo as a sustainable construction material. Base on the findings conclusion was made on how bamboo can be used on various components of the building and as a reinforcement material for concrete. Finally, recommendation were made on the need for bamboo to widely deplored as a sustainable building materials for building constructions since they readily available, environmental friendly and can grow easily in our environment.
Keywords: Potential, Versatile, sustainable, building material construction, Bamboo, Nigeria.

INTRODUCTION

Everybody in the building profession understands so well that a house is simply a product of materials and skill; and that all the dreams of providing affordable houses for the average citizen will be elusive without recourse to locally available building materials (Chukwuali, 1992). The recent rise in exchange rate has made the importation of foreign building materials unaffordable. This ultimately has made our dreams of having affordable houses unrealistic. Under this condition, a re-appraisal or upgrading of our locally available building materials is mandatory. To this end, it becomes necessary to look into the qualities of one of these our local building materials-bamboo, with a view to exploring its potentialities towards sustainable building construction in Nigeria.

Bamboo as it is more popularly known is the tallest member in the grass family. It is one of the fastest growing woody plants on earth, growing reportedly up to 7.5cm – 40cm a day as stated by Wong (1995) with the world record being in Japan with an approximate growth of 1.2m in a day. It is a woody plant which grows about 3 times faster than most other species (Wong, 1995), Auwalu, et al; (2019). Commercially significant species of bamboo usually mature in four or five years, after which continuous harvest are possible every subsequent year, for up to 120 years in some species and indefinitely in others. Bamboo is mainly found in Asia, some parts of Africa and parts of America in different varieties. Bamboo cultivation and harvesting serve as a source of livelihood for millions of rural inhabitants in many developing countries, and in particular

women and children who do most of the harvesting. Several species of bamboo grow in sub-Saharan Africa, most notably Nigeria, but their uses have been limited to constructing traditional houses; irrigation system, handcrafts, fuel, and food. However, Nigeria's abundant bamboo resources is virtually unexploited in any significant way.

The use of bamboo as a construction material is not new and many countries have been using it to build homes for centuries. Generally, when we think of a house made of bamboo, the picture that comes to mind is a small village hut. But this concept is fast changing because of the global demand for environmentally friendly and sustainable building materials. Bamboo's unique and efficient natural design makes it a good building material.

This paper is therefore geared towards exploration of the potentials of one of traditional building materials-bamboo, to reassert its positive properties and highlights the positive qualities in the light of recent researches and developments.



Bamboo growing wild in the forest can be used for construction

Statement of Problem

Steel or reinforcement bars is a major reinforcement element for concrete when deplored for construction. This is because its high tensile qualities. But recent development in the economy has made a price to go beyond affordable rate for property developers. The resultant effect is the skyrocketing cost of construction and hence housing units. To tackle this challenge stakeholders in the building industry sought the need to look inward for alternative building reinforcement materials, hence the need for bamboo. Bamboo is not only seen as a local building material, it is renewable and a versatile resource characterised by high strength and low weight, and is easily worked on using simple tools. The tensile strength of timber is equally as good as that of the steel if not higher. The environmental friendliness of bamboo has equally made it a more sustainable building material when compared with other building materials.

Aims and Objective of the Study

The major aim of this study is explore the potentials of bamboo as a sustainable building materials for construction in south east Nigeria

The objectives include but not limited to:

i) To encourage the growth of bamboo within our local environment
ii) To encourage various research institutes to carry out research on various species of bamboo suitable for environment and for various uses in construction
iii) To encourage various building practitioners to explore various uses of bamboo in constructions
iv) To find various ways to preserved bamboo for construction purposes and avoid termite attack.

Research Methodology
This research was carried out by visits to various websites where various materials on bamboo were taken. Research documents were also collected from Nigerian Building and Road Research Institute (NIBRRI), textbooks and journals. Also oral interview was equally conducted during field studies, among various local building artesian making use of bamboo.

Brief Description of Bamboo
Bamboo is a type of woody grass that grows naturally mostly in the tropics. It is mostly domiciled in Southern region of Nigeria. It is regarded as an environmentally friendly grass which is freely used in the rural areas of the country for many purposes like building construction, crafts and farming. Among about 600 different botanical species of plants in grass family bamboo is the commonest. It occurs mostly in tropical and sub-tropical areas; from sea level to snow-capped mountain peaks; with a few species reaching into temperate areas.

Outside Nigeria, bamboos are found in abundant quantities in south eastern Asia, with some species in America and some other African countries. It is not found in Australia. The plant ranges from stiff reeds of about 1m (3ft 4") tall to about 50m (164ft) in height and 30cm (12") in diameter near the base.

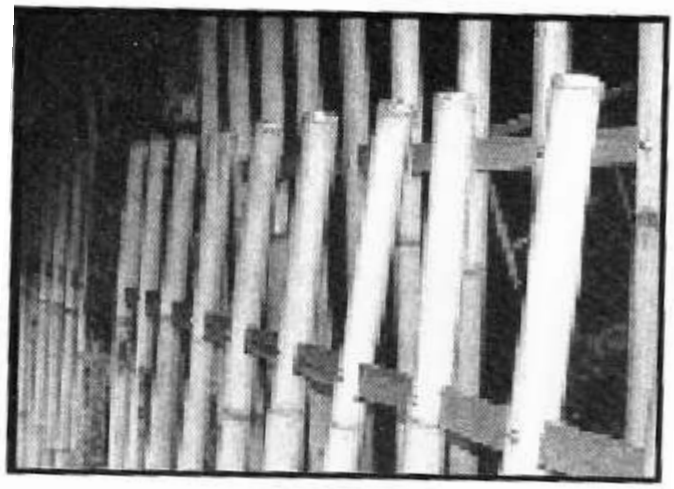
Most bamboos are erect (straight), but some have a resemblance of vines, producing impenetrable thickets in some areas. Bamboo grows naturally and uncultivated in Southern Nigeria, particularly along the coastal areas of Ogbaru, Anambra East, etc and sometimes extends inwards. Among the species of Bamboos is "bambusa vulgaries" which is the most suitable species for construction of buildings.

Technical Attributes of Bamboo as a Construction Material
A number of things like functionality, availability and expenses have made bamboo a choice for builders as a construction material; but the most important attributes or qualities of bamboo are as follows:

- **The Structure of Bamboo**: The natural structural design in bamboo is unique; it is hollow inside and the fibres run longitudinally, hence less material mass is required when compared to timber which has a larger material mass section. When considering the load-bearing mass, it functions as I-shape cr0ss-section. Bamboo can also be shaped according to the building requirements. It can been bent after freshly cut, and will remain in that shape after drying too. A few species of bamboo haven same strength ratio of steel and almost twice the compression ratio of concrete (Liese, 1986; Espiloy, 1994; Kabir et al, 1991, 1993 and Auwulu, 2019). For example, the 1999 earthquake in Colombia witnessed destruction of all concrete buildings but houses that were built from Bamboo stood still and untouched by the earthquake.
- **Tensile Strength**: The tensile attributes of bamboo is excellent (Wakchaure & Kute, 2012; Moroz et all; 2014) Most tensile strength of Bamboo depend on the species and the climatic condition in which they grow (Sekhar and Gulati, 1973). The strength of bamboo varies along with the height of culm. The compressive strength of bamboo increase with its height while bending strength has an opposite trend (Kabir et al; 1991, 1993). An increase in the strength of Bamboo is believed to occur between 3 to 4 years and after that decreases (Espiloy, 1994). The outer zone of Bamboo has a highly elastic vascular bundle which also have high tensile strength, while the fibre of bamboo run axially, making it more resistant to tension than compression. The high tensile strength of these bamboo fibres is usually higher than that of steel, but has a disadvantage of not being possible to construct connections that can transfer this tensile strength.
- **Shrinkage Attribute**: Bamboo has an attribute which makes it shrinks more than timber as it loses it water content. The canes of the bamboo can tear apart at the nodes making it shrink in the cross-section, usually between 10 – 16 % and wall thickness of between 15 –

17% (Rehman and Ishaq, 1947). Therefore, when using bamboo as a material for building construction, it is necessary to take precautionary measures aimed at preventing water loss.

- **Anisotropic Attributes**: Bamboo is an anisotropic material. The properties of Bamboo in the longitudinal direction are entirely different as that of the transversal direction. The longitudinal direction has cellulose fibres that are durable and stiff whereas the transverse direction has lignin, which is soft and brittle.
- **Compressive Attribute**: Bamboo with slimmer tubes has a higher compressive strength value than bamboos with larger tubes as regard to their cross-section. Bamboo with slimmer tubes possesses better material properties because larger tubes of bamboo usually have a disadvantage of having a minor part of the outer skin that is highly resistant to tension. Hence, compressive strength is affected by the portion of lignin inside the culms and the large portion of cellulose influences buckling and the tensile strength because it represents the building substance of the bamboo fabrics.
- **Elastic Modullus Attribute:** The accumulation of highly durable fibres in the outer parts of the bamboo tube wall works positively in connection with the elastic modulus like it does for the tension, shear and bending strength of bamboo. The higher the elastic modulus of bamboo, the higher the quality. This enormous elasticity of bamboo makes it an advantageous material for building construction in areas with very high risk of earthquake.



Bamboo for fencing

- **Fire Resistance Attributes:** Bamboo has an excellent fire resistivity attribute due to the high content of silicate acid it possesses. Bamboo which in filled up with water can usually withstand a temperature of 400^{0C} while the water cooks inside. It also possesses high moisture content, which is influenced by the age, species as well as the season of harvesting. Although unlike timber, bamboo starts shrinking above the fibre saturation point, but the use of Ecology Diversity Synergy Technology has remedied this weakness, as EDS treated bamboo is as durable as solid timber for building construction (UNIDO, 2009).

Bamboo as Environmental Friendly Material

The most important quality of bamboo is its environmental friendliness. It is renewable and bamboo forests can be grown in few years. Its naturally waxy surface does not require painting; making it safe from health hazards caused by paints (paints contain toxic substances). Bamboo can be grown in a variety of climates and houses made of bamboo do not require use of other materials like concrete, steel, etc. Pesticides and other chemicals need not to be used while

cultivating bamboo, making it more eco friendly. Pollution is also reduced up to 35% carbon dioxide in the atmosphere and produces more oxygen. Studies have shown that of all the building materials that are used in construction, bamboo in the least hazardous in terms of waste as it can be recycled and does not have disposal problems. The roots in bamboo help control soil erosion as it creates a water barrier. Developing countries use bamboo to protect their crops and villages from being washed away. Bamboo consumes high quantities of nitrogen and this can help reduce water pollution. Bamboo is also known to desalinate sea water, thereby making it domestically useful.

Advantages and Disadvantages of Bamboo

Advantages: Bamboo has the following advantages over other building materials used in construction industry:-

- Bamboos strong natural fibre makes it a superior material over hardwood.
- The versatile quality of bamboo makes it a good material for flooring, roofing, concrete reinforcement, scaffolding, piping and for walls.
- Bamboo is very flexible, and hence where it grows, it can be defined to grow into specific shapes. Its shock absorption capacity makes it a great building material for earthquakes resistant homes.
- Bamboo can also stand hurricane with wind speed of up to 170mph.
- It is environmental friendly.
- It is speedily growing and highly productive.
- It is light in weight and thus transportation of bamboo is easy. Unlike other materials, which require the use of cranes and heavy machinery, none is required when building with bamboo.
- When bamboo is properly maintained, it can last for a very long time unlike wood.
- Bamboo is cheap and readily available in areas where it cultivated.

Disadvantages of Bamboo

Bamboo as a construction material also has its limitations which is disadvantageous to its use in construction. They include:

(i) Not all types of bamboo can be used for construction.
(ii) Bamboo cannot be used to make skyscrapers that we all love.
(iii) Wet Bamboo deteriorates faster.
(iv) It requires preservation.
(v) It is shaped by nature.
(vi) Bamboo, if left untreated is subject to attack by fungi, insects, termites etc. As a result of this, untreated bamboos are not durable for construction purposes, and they have expected life span of not more than 5 years.
(vii) Jointing-although many jointing techniques exist, their structural efficiency is low with bamboo.
(viii) Lack of design guidance and code.
(ix) Despite all these drawbacks, the sustainable and environmental friendly features of bamboo make it a great building material. These few drawbacks that bamboo has can be mitigated with research and use of bamboo as an alternate building material should be encouraged to make our earth more green and pollution free.



Cage made of Bamboo

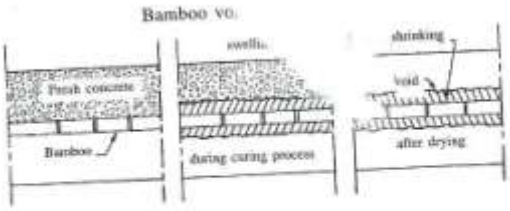
Findings

Various uses of bamboo as a building element

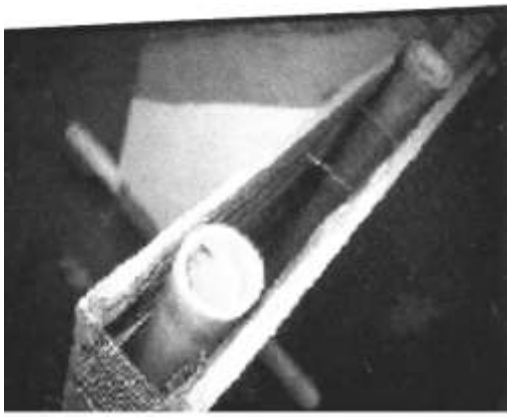
Bamboo is a versatile material in building construction because of its high strength – to – weight ratio, easy workability and availability.

Sakaray et al (2012) and Salzer et al (2016) has ascribed the use of bamboo for building construction to be diverse, but presently, only a part of temporary structures or buildings in rural and semi-urban areas utilise the use of bamboo for construction in Nigeria. This limited use does not exploit the full potential of bamboo as a sustainable building material. Before use, Bamboo needs to be chemically treated due to their low natural durability. Various areas in building construction where bamboo can be effectively used are:-

Foundations



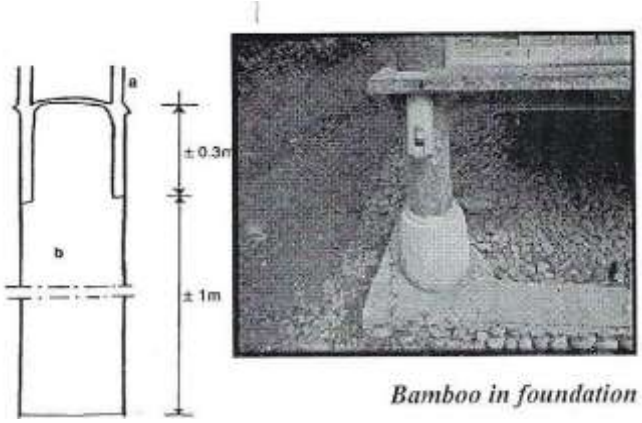
Behaviour of Bamboo as reinforcement to concrete



The use of bamboo has been limited for foundation purpose mainly because bamboos deteriorates and decay quickly when in contact with the damp ground. However, despite this disadvantage of deterioration, the use of bamboos for foundation or supporting posts in building is possible when treated with some effective preservatives and built on raised platforms. Bamboo for foundation can be handled in different construction processes, some of which include:

(a) Using bamboo in direct contact with the ground. This entails placing the bamboo directly on the ground surface or buried to the ground. Bamboo with rods that are closely spaced, but having large diameters and thick sections are used to achieve the best strength and stability. Moreover, smaller sections of bamboos can be tied together and preservative applied to reduce the process of deterioration that usually occurs between 6 to 24 months (Koko and Zhejiang University, 2019).
(b) Bamboo can be erected on concrete footings or base rocks:- Here the stiffest and largest section of bamboos are used for bearings and are placed on footings of either rock or preformed concrete without direct contact with the ground.

(c) Integrated bamboo concrete footings:- This entails the placement of poles of bamboo directly into concrete footing which can take the form of a single post or strip footings.
(d) Composite bamboo/concrete columns:- In this method, a bamboo with a post that is integral and durable is achievable through the use of a concrete extension to the bamboo by using a plastic tube with the same diameter of the bamboo.
(e) Bamboo pile: Bamboo piles are used to reduce settlements of building and stabilise soft soils. This is done through the use of bamboo poles that are split into sections and treated by filling them with coconut coir stands wrapped with jute and tied with wire, sandy materials are used to cover the area after installation of the piles.

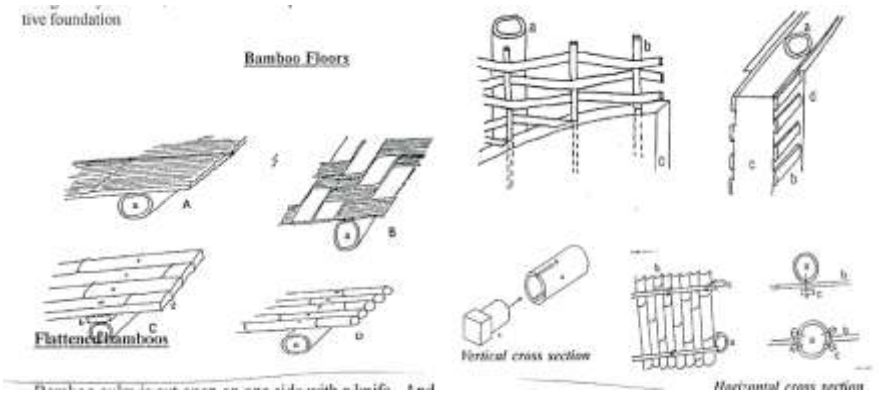


Bamboo in foundation

Bamboo Floors

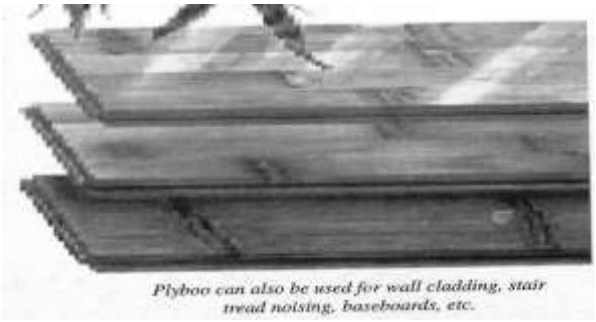
Bamboo can be used as a building material for flooring due to its wear and tear resistance as well as the resilience properties it possesses. The flooring covering is done using bamboo boards, mats, etc, employing wire-mesh to the frame. There are various construction processes in which bamboo flooring undergoes: They include:

(a) ***Use of small bamboo culms:*** This involves direct tying or nailing bamboo culms together.
(b) ***Split Bamboo:*** In this type, bamboo culms are splitted into strips of various several centimetres wide along their lengths.
(c) ***Flattened Bamboo****:* After splitting, the bamboo culms, the diaphragms are removed, the splitted culms are rolled and flattened so that the revolting board is laid and fixed by nailing or tying them across the joists. After that they are screed with cement mortar to make it easy to clean.
(d) ***Bamboo mats:*** In this process, thin steps of bamboo which vary in sizes between 5-6mm or 10-15mm and thickness between 0.6-12mm are woven into mats of different sizes according to construction demand and specification.
(e) ***Bamboo plastic composites:*** this is an innovative bamboo flooring technology which combines bamboo fibre and plastic as a core material for flooring. It has the advantage of higher water resistivity and dimensional stability than other types of bamboo floorings.



Bamboo Walls and Partitions

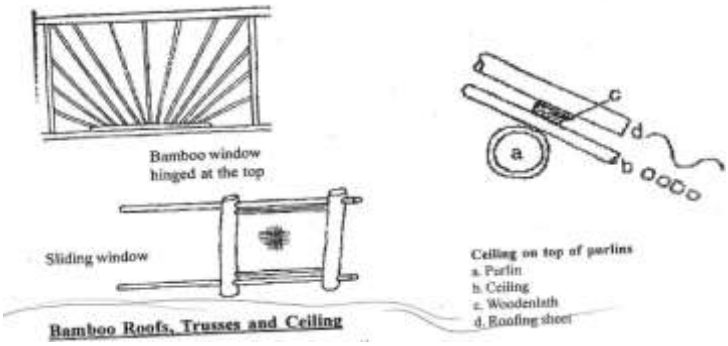
The most commonly adopted use of bamboo for building construction is for the wall and partitions Bamboo as a building element is used for columns and beams, which generally constitute the structural framework. They are used to carry the self-weight of building and the imposed loads exerted by the building occupants. An infill between framing members in necessary to protect the wall against rain, wind, and also to offer privacy. The infill in-wall aims to provide in-plane bracing and ensure the overall stability of the overall structure when subjected to horizontal forces.



Plyboo can also be used for wall cladding, stair tread noising, baseboards, etc.

Doors and Window

Bamboo is also used for doors and windows in buildings. The use of bamboo usually replaces the conventional timber frames often used for doors. Bamboo malt shutters are than fixed to the bamboo frame to serve as the door when hanged to the wall. Also, small bamboo frame can be used to serve as windows when hanged to the top of a wall.



Scaffolding

The use of bamboo for scaffolding has been in existence for centuries in African and Asia countries and despite competition with many metal-scalding systems, it remains one of the most preferred systems (Fu, 1993). Also due to the low construction cost of bamboo and its high

adaptability, it can be constructed in any layout to follow various irregular architectural features of a building within a relatively short period (Chung et al, 2003). They are used in construction sites in Nigeria to provide temporary access, working platforms for site workers and supervisory staff, and to prevent construction debris from falling onto passer-by. They are either used as single-layered bamboo scaffolds (SLBS) for light work or a double layered Bamboo scaffolds (DLBS) for heavy works. Therefore, for Bamboo scaffolding like any other scaffolding must be laterally stable and must possess integrity.



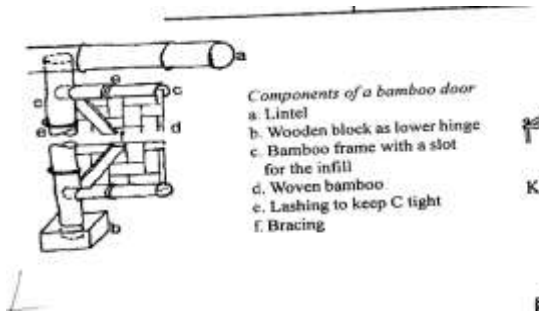
Bamboo for fencing

Bamboo Roof Trusses

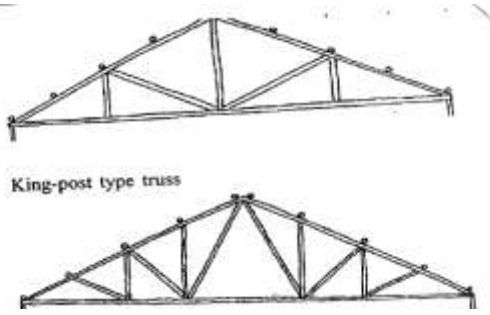
Bamboo plays an important role in the fabrication of roof trusses during building construction. Because Bamboo has a high strength/weight ration this makes it an excellent materials for roof framing. Achieving any span of truss is possible with bamboo because of its light weight property alongside its strength and stiffness. The use of bamboo for trusses also results in considerable savings due to the non-use of heavy lifting equipment.

Bamboo Roofing

The roof of buildings serves as protection against weather of varying conditions including sun, rain, and wind and also functions as a shelter for the usable space underneath the roof canopy. The roof should be able to withstand the tremendous forces generated by wind and roof coverings. This makes bamboo suitable roof coverings. This makes bamboo a suitable roofing material because of its lightweight and durability. The structure of the bamboo roof can be made of bamboo trusses, rafters and purloins.



Components of a bamboo door
a. Lintel
b. Wooden block as lower hinge
c. Bamboo frame with a slot for the infill
d. Woven bamboo
e. Lashing to keep C tight
f. Bracing



King-post type truss



A cage made of Bamboo

Other Areas Bamboo can be used for Building Construction include

(a) Disaster Mitigation: The lightness and availability of bamboo abundantly as well as the possibility of using bamboo to construct shelters from modular units lead to its use for post disaster shelter construction. An example is a project by the UNHCR in which temporary shelters are fabricated from A-shaped bamboo frames and supported with horizontal members at the apex and mid-height of the A-shaped frame. A waterproof sheet is then used as draping over this frame for covering.

(b) Bridges: Bamboo materials are also used for the construction of bridges. The bamboo used for such construction purposes requires specific constructional techniques, which limit vibration, bending and twisting due to its property of being much more elastic than solid timber. Such bridges, when constructed with bamboo, are usually covered to reduce their exposure to severe weather conditions. According to Jayaneti and Follet (1998), the various bamboo bridges construction consist of:

- Footbridges; which are simple bamboos cross braced frames with the walkway formed at the crutch. Bamboo lashings bind the culms of diameter 50 – 75mm. These bridges are suitable for rivers with sandy or muddy base where the height above bed does not exceed five(5) meters, while the crossing length may be as long as 20 meters.
- Handcart bridges have more elaborate construction process, by having abutments and pilings. These abutments are formed from pairs of culms of bamboo that are staked into the ground while the bridge assembling is stabilised by horizontal culms which form the pile cap and diagonal braces. Three longitudinal bamboo beams of 100mm diameter which are lashed to the caps and tied together at the centre of each bay with cross-member are used to form the roadway.



Conclusion

Bamboo is the fastest growing plant on planet earth, which grows naturally in the southern part of Nigeria, is one of the strongest building materials. As a building material, it possesses excellent qualities, of environmental friendliness, durability readily available. All these qualities make it to stand out among the committee of local building materials. Other properties of bamboo that make a good building material include environmental sustainability, physical and aesthetic qualities, workability, flexibility of space arrangements, its dry construction and comparative cost-effectiveness. These properties of bamboo make it a suitable material for use in various construction purposes like foundation, floors, walls and partitions, doors and windows, scaffolding, trusses, roofing as well as other purposes like disaster mitigation and bridge construction its high valued utilization not only promotes the economic development, but also saves forest resources to protect our ecological environment as a wood substitute. As an economic material, bamboo's rate of productivity and cycle of annual harvest outstrips any other naturally growing resource. If today, you plant three or four structural bamboo plants, then in

four or five years later, you will have mature clumps, and in eight years, you will have enough mature material to build a comfortable, low cost house.

Also appropriate technical knowledge of bamboo, its properties as well as its preservation and treatment techniques is necessary for its use as a sustainable building materials for construction in order to avoid attacks by insects and fungi biodegradation, and possible failure or collapse of bamboo structures, it is necessary to subject bamboo to series of either chemical or non-chemical treatments.

In Nigeria, research institutes, products of which industries use to develop their plants have not made genuine effort at doing research works on bamboo. In some countries in Asia like Vietnam and Hawaii, plants have been constructed for manufacturing of bamboo building products the local industry and for export purposes. The Government policy on housing for all can be achieved if Government and private entrepreneurs go into cultivation and production of low cost bamboo building products. Standard codes should also be developed in the Nigerian Building Codes on the use of Bamboo as a local building material for construction.

Recommendations

Having explored the qualities and potentials in Bamboo, I highly recommend that Government and private enterprises should invest into production and harvesting of bamboo as a local building material for provision of low cost houses. Research institutes and tertiary institutions should be encouraged on research on how to improve the quality of available bamboo in the country as an alternate building material. Bamboo Industry when fully developed can provide cheap building and other products for the populace and help boost the economy through exports. Moreover, such industries, when fully developed can provide employment for the teeming population of unemployed youths. Foreign investors should be encouraged to partner with our local entrepreneurs to establish such industries in the country

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