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Review on the Suitability of Bamboo as a Building Material in Nigeria

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Abstract: - Bamboo is adjudged to be a very good sustainable, versatile and eco-friendly building material. It grows naturally in most of the world's forests especially in tropics and sub-tropical regions. Bamboo is the fastest growing grass in the world and matures within three to five years. It consumes carbon (iv) oxide (the major greenhouse gas) in the environment through photosynthesis and releases oxygen to the environment thereby drastically reducing the greenhouse gases and making the environment safe. Throughout the entire globe, there is increase in human population. As the number of humans in the world increases, there is proportional increase in the need for shelter and other civil infrastructures. This increase in need for shelter and other civil infrastructures has resulted in over-consumption of traditional building materials and has created serious burden on the depleting world's natural resources. Continuous use of the traditional building materials like steel, timber, cement, has also led to increase in the burning of fossil fuels which releases greenhouse gases to the environment during their production. Nevertheless, traditional building materials are very expensive and their continuous use leads to increase in the overall cost of buildings and other civil infrastructures. The use of bamboo as a material for construction of buildings and other civil infrastructures presents a very huge relief to the aforementioned problems encountered in the construction industry. This paper x-rays the viability of bamboo as construction material in Nigeria. Increase in the use of bamboo in the construction industry will lead to reduction in the overall construction cost, growing bamboo in commercial quantity and reduction of greenhouse gases in the environment.

Keywords: Bamboo, Culm, Eco-friendly, Sustainable, Grass, Shelter, Infrastructures, Building materials.

I. Introduction

The continuous use of traditional construction materials has led to a sharp increase in global warming. There is thus, a global search for construction materials that are friendly to the environment [15]. Bamboo is adjudged to be the fasted growing grass on planet earth, thus, making it to have great potentials for a sustainable and renewable raw material [21]. It is the largest of all grasses, and has a woody stem that looks like a tree ([21], [18]). Bamboo is a tree-like grass plant that can grow as tall as 24m. It has a very high growth rate, with the highest growth rate of 1.2m in 24 hours recorded in Japan [7]. A Bamboo stem contains the following; The culm, the nodes, Internodes, and Branches.

Bamboo is a member of the Bambusoideae subfamily of the perennial grasses family Poaceae, that remains green throughout the year. It is the largest of all the grasses and also, the only grass that can diversify into a forest [18]. According to [18], the following features of bamboo makes it to be classified as a grass instead of a tree;

- As found in all grasses, the intermodal stems of Bamboo also known as culm is hollow, having a wall thickness that varies from thin to nearly solid depending on the species, growth condition and age.
- In Bamboos, there is no increase in height or stem as the Bamboo gets older. This is as a result of the lack of the vascular cambium layer which causes trees to continually increase in diameter over the years, and the meristem cell which makes trees to grow taller each year. A bamboo culm reaches its maximum height and diameter in one growing year.
- Bamboos do not have bark but rather, have leaves around the culms in their early stage of development which serve as protective cover to the culms.

Each Bamboo stem can grow up to 40m in height and up to 30cm stem (culm) diameter. Bamboo plant can remain green for up to 75 years, and is ready for harvest within 3 – 5 years thus, making it more viable than normal wood which takes up to 15 to 20 years to mature ([10], [3]). Bamboo has very high chances of surviving in harsh environment, it can grow very well in most of the lands in Nigeria that are not good for crop production like borrow pits, rocky areas, gully erosion sites, etc.

Bamboo is available in large quantity as natural vegetation in the states of the southern regions of Nigeria. States like Imo, Abia, Anambra, Enugu, Ebonyi, Delta, Edo, Rivers, Ogun, Ondo, Oyo, Oshun, Cross-River and Akwaibom states have more than 10% of their natural vegetation dominated by Bamboo while the middle belt regions of Nigeria and states like; Ekiti, Bayelsa,

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Lagos, Kogi, Kwara, Benue and Nassarawa have about 6 – 9% of their natural vegetation dominated by Bamboo. States like Niger, Taraba, Plateau and Abuja have about 3 – 5.9% of their natural vegetation dominated by Bamboo while states in the arid region of Nigeria like; Adamawa, Bauchi, Bornu, Gombe, Kano, Kaduna, Katsina, Kebi, Sokoto, Jigawa, Yobe, and Zamfara have 3% or less of their natural vegetation being occupied by Bamboo [3]. Virtually all the states in Nigeria can produce Bamboo in commercial quantity through Bamboo farming since most species of Bamboo thrive in soils that are unsuitable for crop production [9]. According to the report of the Raw Materials Research and Development Council, Nigeria [17], Nigeria is home to five indigenous species of Bamboos. One of the most common species of Bamboo in Nigeria is Bambusa Vulgaris, other species include: Bambusa arundinacea, Bambusa tulda, Dendrocalamus giganteus, and Oxynanthera abyssinica [13].

As a rhizomatous plant, Bamboo is a self-propagating plant. Generally, bamboo can be propagated through two different methods [5].

(i) Propagation through sexual method. This involves the use of bamboo seeds as in most of the annual crops like corn, beams, groundnut, etc. However, bamboos rarely produce seeds and it is very difficult to predict the time a bamboo plant will produce seeds, as a result, many people are not even away that bamboos produce seeds.
(ii) Propagation by asexual method or vegetative propagation. This involves the use of vegetative materials like; rhizome roots, culm or stem cuttings and branch cuttings. The stem and branch cuttings for planting should contain two to three or more nodes. It can be carried out any time of the year provided that there is sufficient water in the soil. This method of propagation is recommended when there is need for mass production of bamboo.

II Engineering Properties Of Bamboo

Due to the high cost of construction materials like; steel, concrete and mortar, there is a great need for viable alternative materials that are cheap and readily available. Bamboo is one of those alternatives. It is very cheap and available in large quantities as natural vegetation in most of the forest in the southern and middle belt regions of Nigeria. Many researchers and Engineers have thus, delved into researches on the properties of bamboo as a construction material. Adedipe et. al [1a] investigated some mechanical properties of 'Agaraba', a native Nigerian bamboo. In their work, the following values were obtained as the average compressive strength, tensile strength and hardness number respectively; 75.69N/mm^2, 295.33N/mm^{2}and 3.96.

(a) Tensile Strength: According to Sulane and Ali [20], bamboo has high strength as a result of its high elastic vascular outer/membrane fibers that runs axially, these fibers can withstand tensile strength of up to 400N/mm^2. The thinner bamboo tubes are stronger in tension than the thicker ones. However, it is difficult to construct a connection that can transfer this high tensile strength. They are stronger in tension than in compression. Thus, with the right connection, bamboos can adequately be used in concrete beams as the principal reinforcement.

(b) Compression: The thinner bamboo tubes are stronger in compression than the bigger tubes. This is because, the bigger tubes have larger hollow and a smaller part of the outer skin (which is very strong in tension) and thus, a minor portion of the material properties than the thinner tubes. Bamboo fiber is mainly composed of cellulose and this improves the buckling and tensile strength, whereas the lignin inside the bamboo culm reduces its compressive strength.

(c) Shrinkage: When bamboo loses water, it shrinks more than wood. The cross-sectional shrinkage is 10 – 16% while that of the wall thickness is 15 – 17% [20]. Mature bamboo culm shrinks less than the immature ones.

(d) Elastic Modulus: The cellulose fibers of the outer wall of the bamboo tube enhances its elastic modulus. Its high modulus of elasticity makes it a suitable construction material in places prone to earthquakes.

(e) Anisotropy: The material properties of bamboo in the transverse direction is very different from those in the longitudinal direction. Thus, bamboo is an anisotropic material. The cellulose fibers which is strong and stiff occurs in the longitudinal direction while the lignin which occurs in the transverse direction is soft and brittle.

(f) Fire Resistance: The green Bamboo plant has high content of silicate acid, this makes it to possess high fire resistance capacity. It can resist fire up to 400^{0}C.

Reference [6] carried out research on Dendrocalmus strictus which is one of the species of bamboo also found in Nigeria. According to their works, the average tensile strength of the samples tested is 95.781MPa, the compressive strength was found to be 77 – 79 MPa, The shear strength in a single shear was 85.3 MPa while that of double shear was 99.71 MPa. Their works also revealed that bamboo is a porous material with a water absorption ratio of 33%, moisture content tested in summer was found to be 6.92%.

III. Uses of Bamboo as A Construction Material

High tensile strength, compressive strength and low weight of bamboo makes it versatile for various construction purposes [20]. The numerous construction uses of bamboo include;

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(a) As Columns and beams: In most houses in the rural areas of Southern and Middle-belt regions of Nigeria, Bamboo culms are used as columns and beams.

(b) As Formwork: Bamboo culms are used in most of the building construction sites in Nigeria as supports to the deck slabs, lintels and beams during concreting to carry the fresh concrete. This is because bamboo is readily available and very cheap when compared to wood which serves the same purpose.

(c) As Perimeter Fence: In most of the rural areas of Southern and Middle-belt regions of Nigeria, series of green bamboo culms are used as struts in the perimeter fence. This is because, the green bamboo culm planted in the soil will not decay nor rot, rather, it germinates and start growing, this would require regular trimming, thus increasing the durability and stability of the perimeter fence against lateral forces from wind and also as a fire resistant, prevents wild fire from entering the compound.

(d) As Scaffolds: The fact that bamboo is readily available, very cheap and has desirable engineering properties makes it a very good material for preparing the framework on which workmen stand to carry out construction activities at heights. The entire structure (comprising struts, beams and braces) of the scaffold used at most of the building construction sites in Nigeria is made up of bamboo culms.

(e) Roof Trusses: Seasoned and treated bamboo culms are used in the construction of roof trusses. Most of kitchens in the rural areas where wood/charcoal fire is used are constructed using bamboo trusses. The smoke from wood/charcoal fire helps in seasoning the bamboo and also preserving the bamboo culms from insects attack.

(f)In the construction of make- shift / temporary houses, and ornamental houses: Bamboo culms are used in the construction of the entire skeletal work for make – shift houses like; event podiums, farm houses, etc and ornamental houses like; bush bars, etc.

(g) **Soil Stabilization:** Bamboo culms are used in stabilizing slopes, river banks and roads [2]. Bamboo culms when planted on slopes and river banks will germinate and produce a network of fibrous root which helps in preventing the soil from collapsing.

(h) **Silt Fencing:** Series of bamboo culms are used to create a barrier along a flood route to intercept runoff, reduce the velocity of the runoff, making the sediment-laden runoff to drop its sediments, thus preventing soil erosion.

(i) **As reinforcements in concrete:** The use of bamboo as reinforcement was first adopted in the early stages of human civilization where bamboo stems were sandwiched in clayey soils and used in building walls and roof decks.

The bamboo stems in this case acts as the reinforcement. In Nigeria today, some rural areas in Enugu, Imo, Cross – Rivers, Akwaibom, Delta, Edo, Ondo, Kogi, Osun, Benue, Ogun, Oyo, etc still have houses built with a mixture of clayey soil and bamboo stems, with the bamboo acting as the reinforcement. In modern days, after the invention of concrete, bamboo has been used as concrete reinforcement in many buildings in India and other Asian Countries.

IV. Previous Research Works on The Use of Bamboo as Reinforcement in Concrete

Rahim et. al. [16] investigated the properties of Bamboo reinforced concrete beams. In their work, they split the bamboo culm to get strands of 10mm x 20mm x 700mm dimension as reinforcement in the beam to test for its flexural strength. Tack coat was applied on the surfaces of the bamboo reinforcement a day before its use to checkmate the effect of high water absorption rate of bamboo and also to improve the bond strength between the surface of bamboo and concrete. In their work, three beam specimens of design load of 25KN/m were used; beam reinforced with two strips of 12mm steel, beam reinforced with six strips of (10 x 20mm) bamboo splints and beam reinforced with two strips of (10 x 20mm) bamboo splints. The results from the flexural test obtained after 28 days curing showed an ultimate load of 110.37KN, 85.83KN and 76.8KN respectively. Thus, even the beam reinforced with two strips of bamboo strands gave an ultimate flexural load of 76.8KN which is higher than the design strength.

Adewuyi et.al. [1b] compared the flexural properties of concrete beams when Bamboo, Rattan or Steal is used as Reinforcement. They used 3 years old greenish – brown bamboo culm sliced into 10mm bars as reinforcement, 10mm rattan stems and steel bars were equally used as reinforcements while 8mm mild steel bars were used as stirrups in each of the three different beams. They equally tested for the tensile strength of the steel, bamboo and rattan bars. They observed that the yield strength of the bamboo and rattan reinforcements were 13% and 45% of that of the Steel respectively, while the ultimate tensile strength of the bamboo and rattan reinforcements were 16% and 62% of that of the Steel respectively. Also, their results showed that the flexural stiffness of bamboo and rattan reinforced concrete beams were 32% and 14% of that of steel reinforced concrete beams respectively. They inferred that bamboo reinforcements are suitable for light-load bearing structural elements like lintels, etc.

Archila et.al. [2] used small diameter whole bamboo culms in a prototype three bay portal frame as an alternative to steel bars in concrete and asses the structural performance of the bamboo reinforced concrete in comparison to steel reinforced concrete.

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Omaliko and Ubani [14] studied the effects of nodes and physical properties on the compressive strength of bamboo culms and concluded that the compressive strength of bamboo culms largely depends on its physical properties.

Ogunbiyi et.al. [12], studied and compared the tensile strength of various sizes of bamboo culm splints with the tensile strength of steel reinforcements of same sizes. In their work, they suggested that bamboo splints have low breaking strength and therefore should not be used as the main reinforcements in high-load bearing structural elements.

Durga et.al. [8] studied the flexural strength and split tensile strength of concrete reinforced with bamboo strips. From their work, they observed that the bamboo reinforced concrete deflects more under load as a result of low density of bamboo when compared with steel reinforced concrete.

V. Advantages of Bamboo Over Other Construction Materials

(a) Bamboo is a renewable and sustainable building material. It is easily propagated, it does not require much effort to replant, it can be propagated through its rhizomes, or by planting the cuttings of the stems and branches or by planting its seeds. In general, it is a self-propagating plant, ones you plant one seedlings or shoot in the ground, after a litle period of one to two years, it will cover a large area with other bamboo plants through the spreading of its rhizome roots.

(b) Bamboo is readily available. Bamboos grow naturally all over the world but are found in larger quantities in Africa, Asia and South America [7]. They have a very high growth rate and mature within very short time (3 to 5 years) and thus are in great abundance.

(c) Reduces the overall construction cost. Use of bamboo at various stages of building construction drastically reduces the overall construction cost. Bamboos are very cheap when compared with alternative construction materials like; wood, metal pipes and frames, steel reinforcements, etc.

(d) It is an eco-friendly building material. As eco-friendly building material, the production, use and disposal of bamboo in building industry does not cause any harm to the environment. Using more bamboo in the construction industry encourages growing more bamboo plants in the farm. The bamboo plants in the farm will take up carbon (iv) oxide from the environment in the presence of sunlight and water to produce its food through a process called photosynthesis and releases oxygen as a bye product to the environment for animal and human consumption.

(e) Does not consume energy during its production. Production of bamboo does not consume energy unlike alternatives like metals whose production consumes much energy.

VI. Challenges to The Use of Bamboo In Construction

Though bamboo has desirable qualities, there are several challenges to the use of bamboo in the construction industry.

(a) High moisture content and Shrinkage. Fresh green bamboo has high moisture content and this makes it susceptible to rot. According the works of [11], the presence of moisture weakens the mechanical properties of bamboo. Mature bamboo contains less water than immature bamboo [20]. When bamboo loses moisture, it shrinks more than wood. Thus, to avoid shrinkage, mature bamboo after harvesting should be seasoned before being used in construction.

(b) They are easily attacked by insects and fungi. Bamboos are easily attacked by insects and fungi especially when they are harvested during the rainy seasons. The insects and fungi attacks on bamboo reduces its durability, an untreated bamboo structure will not last more than five years and thus, is seen as a temporary structure [20]. Thus to prevent this, it is recommended to harvest them during the dry season since insects are less active in the dry seasons. Also to prevent the insects and fungi attack, while harvesting the bamboo canes, care should be taken in removing the branches from the culm so that the outer skin of the culm is not damaged which further exposes the culm to attacks. After harvesting, the culms should the protected from direct contact with soil moisture and rain to reduce attacks by insects [15]. Bamboo canes after harvesting should be seasoned and preserved before use in construction to enhance its durability.

(c) Irregular Structure. Most of the bamboos in Nigeria are not perfectly straight in structure. They do not have constant culm diameter and uniform wall thickness. This sometimes, poses difficulty to its application in the construction industry [4].

(d) Difficulty in Jointing. There is difficulty in joining one bamboo culm to another for effective transfer of forces from one member to another [19].

(e) Unavailability of design code. There is no standard design code for design of bamboo structures.

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VII. Conclusion

Bamboo is a promising renewable construction material. In a world of increasing human population but depleting natural resources, bamboo offers a tremendous relief to the shortage and lack of construction materials. It grows fast, and regenerates faster than any wood and hence, is readily available. It possesses good engineering properties and thus is very suitable for use as a construction material.

For optimum performance, mature bamboos after harvesting should be seasoned and treated with certain wood preservatives to enhance its durability and bonding with concrete. Bamboo reinforced concrete experienced more deflections when load is applied it due to the fact that bamboo has low density, hence they are recommended for low load bearing structural members like lintels, partition walls, etc. From their work, they observed that the bamboo reinforced concrete deflects more under load as a result of low density of bamboo when compared with steel reinforced concrete.

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