Investigation into the Flexural Properties of Bamboo-Reinforced Concrete Beam

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Abstract: Problems encountered with the commonly used construction materials like steel are high cost, corrosion, etc. The urge to overcome these problems without the tensile capacity of reinforced concrete being compromised, has prompted numerous scientists and engineers to seek out locally sourced materials as a replacement for conventional steel reinforcement. Specifically, bamboo is one of the most suitable materials to substitute for reinforcing bar in concrete. This study assessed the suitability of bamboo as reinforcement in concrete. Tests were conducted on both fresh and hardened reinforced concrete. The slump value of 6mm was measure. The compressive strength of 28 days gave the value of 25.26N/mm2 which according to BS code 8110 is satisfactory. For the flexural test, three beam specimens were tested for each of steel reinforcement, bamboo reinforcement and mass reinforcement. For the steel reinforced beam, maximum deflection (4mm) occurred at failure load of 162kN, while the deflection width of beam specimen which was reinforced with bamboo is 6mm at the failure load of 102kN and the deflection width of beam specimen used as control which had no reinforcement was 15mm at the failure load of 95kN. The results showed that steel reinforced beam had the highest strength to withstand load. However, bamboo reinforced beam strength was higher than that of plain concrete beam; hence, it can be used for light load bearing reinforced concrete.

Key words: Reinforcement, Steel, Bamboo, Concrete, Flexural test, Compressive test.

1.0 Introduction

Bamboo has a long and well-established tradition as a building material throughout the world's tropical and sub-tropical regions. It is widely used for many forms of construction, in particular for housing in rural areas (*P. Sharma et al, 2014*). Bamboos are giant grasses and not trees as commonly believed. They belong to the family of the Bambusoideae.

The bamboo culm, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibres and low strength perpendicular to the fibres respectively (*Khosrow Ghavami, 2004*).

Bamboos are some of the fastest-growing plants in the world, due to a unique rhizome-dependent system. Certain species of bamboo can grow 35 inches within a 24-hour period, at a rate of 0.00003 km/h (a growth of approximately 1 millimeter (or 0.02 inches) every 2 minutes). Bamboos are of notable economic and cultural significance in South West Africa, being used for building materials, as a food source, and as a versatile raw product. Bamboo has a higher compressive strength than wood, brick or concrete and a tensile strength that rivals steel. (*wikipedia*).

In today's society, most buildings are built using such materials as steel reinforced concrete and structural steel. Steel reinforcing bars are typically used as reinforcement in concrete to compensate for weakness of concrete in tension. Even though steel reinforcement is a very suitable material for complementing concrete's low tensile strength, there are many difficulties such as economics, technique and efficiency that is needed to be addressed. To overcome these problems, many scientists and engineers have been trying to seek out new materials for increasing the tensile capacity of concrete. Specifically, bamboo is one of the most suitable materials to substitute for reinforcing bar in concrete.

Among others, *Jigar K. Sevalia et al, 2013*, evaluated the feasibility of the use of Bamboo as reinforcement in concrete members and observed that Plain Cement Concrete Beam failed suddenly without any prior notice. It was also reported that Doubly Reinforced Beam performed more elastically than Singly Reinforced Beam while performing flexural tests and that Modulus of Elasticity of the Doubly Reinforced Beam is more than twice of Modulus of Elasticity of the Singly Reinforced Beam.

J. O. Akinyele et al constructed façade panels made of rattan cane reinforcements and steel reinforcements. Based on the experimental results, it was concluded that the lower crack width formed after failure in the rattan cane reinforced panel gave it advantage over the steel reinforced panel, since it has

lower space for the ingress of water which is the main agents of corrosion.

This work aimed at assessing the suitability of bamboo as reinforcement in concrete with objectives of seeking out new materials for increasing the tensile capacity of concrete. Also, it sought to know if bamboo would be found suitable as reinforcement in concrete which would minimize the overall cost of steel bar. The research focused on the assessment of the flexural properties of beam made with bamboo and steel reinforcement and compressive strength of hardened concrete.

2.0 Materials and Methods

Materials used for production of steel and bamboo reinforced concrete beam were Ordinary Portland Cement (OPC)**,** fine aggregate (sand), Coarse aggregate/granite, Wooden mould, Bamboo**,** Steel bar (12mm) and Water (bore hole).

Figure 1: Typical 12mm steel bar

The OPC used was packed by Dangote group of company and was bought at a cement depot at Sango market, Ibadan, Nigeria. The fine aggregate used was obtained in Ibadan too while the granite used in the project work was obtained from quarry along Lagos-Ibadan expressway. The granites were of various sizes obtained from igneous, metamorphic or sedimentary or sedimentary rocks. As recommended by B.S 3797:199. Physically examined water was obtained from a bore-hole located within The Polytechnic, Ibadan and 12mm steel bar with a high yield of (460N/mm^2) was purchased at Sango market in Ibadan, Nigeria.

Slump Test was carried out on the fresh concrete by making use of apparatus such as Trowel, Spread Tray, Test mould (slump cone) and tamping rod (600mm long with 16mm diameter). The slump cone was held down against its base with the small opening at the top. It was then filled with fresh concrete in the three layers and tampered 25 times with the help of a standard 16mm diameter steel rod rounded at the bottom end. The top of the cone was then stuck off with a trowel and the split concrete around the base of the cone was cleaned off. The cone was lifted slowly and the reduction in height (slump) between the cone mould and carried concrete mould was measured.

For the Flexural Test, Nine beams were made. Three were used as control, three for beam reinforced with steel bar, while the last three for the beam reinforced with bamboo, with the sizes of 150 mm x 150mm x 1800mm each. The specimens were placed in the bottom of flexural test machine in an equilibrium state. The pressure rod was placed at the center of the beam to ensure that the three point load was established. The flexural test machine was powered on to test specimens. As the load was acting on the specimen the crack was established in the specimen gradually. Carefully, the reading of the cracking width was measured with the help of a gauge and the crushing load also recorded. This test was carried out one after the other with all other specimens.

Figure 2: Beam Specimens

For compression tests, (150mm x 150mm x 150mm) cube specimens were prepared, and filled fully with the same concrete used in flexural. Compressive strength tests were conducted for 7 days, 14 days, 21 days and 28 days, three specimens were made for each of the number of days, and the average compressive strengths of the test specimens were recorded for reporting as compressive strength for each day of the curing process.

After the slump test was carried out, the true slump test was established and measured to be 6mm. With this result of true slump test, it means the workability of the fresh concrete used for this project meets up to standard.

The analysis of data collected for the Flexural Test resulted in the graph shown below. The results showed that maximum deflection of 4mm occurred at a failure load of 162kN for steel-reinforced beam, while a 6mm deflection occurred at a failure load of 102kN for bamboo-reinforced beam and a deflection of 15mm occurred at a failure load of 95kN for the mass concrete beam.

The implication of this result is that steel reinforced beam had the highest strength and ability to withstand load. However, Bamboo-reinforced beam had strength higher than that of the plain mass concrete beam.

The compressive strength of 28 days gave the value of 25.26N/mm^2 which according to BS code 8110 is satisfactory.

In general sample failure was caused by node failure and splitting failure. Steel bar samples exhibited more strength and ductility. Almost all the samples of specimen without reinforcement failed earlier than the samples with steel reinforcement mostly at the grip. The samples with steel bar failed at slightly higher load. According to the average data for

the bamboo flexural test compared to steel tests reported in the literatures.

3.0 Conclusion and Recommendation

In this research, the feasibility of the use of bamboo as a reinforcing agent in concrete was evaluated through compressive and flexural test results with three different concrete i.e. (a) specimen with bamboo, (b) specimen with steel bar and (c) specimen with no reinforcement which was used as control beam.. The compressive strength of concrete cubes with (150 mm x 150 mm x 150 mm) was evaluated. The main purpose of the tests was to evaluate the possibility of using bamboo as reinforcement instead of steel. The tests were processed through an extensive, systematic experimental method in which 9 specimens were manufactured and tested until failure by a monotonically increasing load. Though bamboo cannot totally replace reinforcement steel, but could be used in light load bearing structural member (i.e. concrete).
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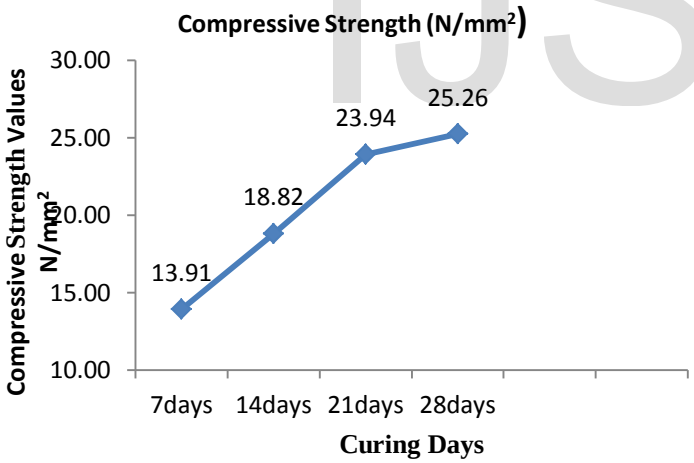

Figure 3: Concrete Compressive Strength

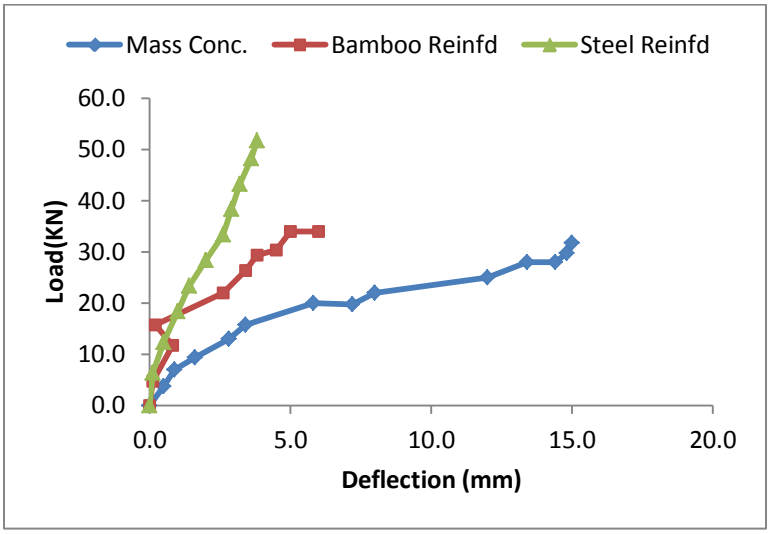

Figure 4: Deflection against Load

It is recommended that various flexural tests should be conducted to investigate the relationship between the flexural strength of bamboo and its performance as reinforcements in concrete such as composite bamboo and waterproofed bamboo.

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