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Evaluation of the Material and Flexural Behaviour of a Concrete Beam Reinforced with Steel, Flat and Spherical Formed Bamboo

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ABSTRACT

The Over-reliance of the construction industry on the use of concrete and steel has become a threatening issue that has over the years caused a rise in the construction value. During this work, the effectiveness of flat formed bamboo and spherically formed bamboo used separately as reinforcements in concrete beams were studied and compared. Thirty-six (36) numbers of simply supported beams of dimension 100 mm x 100 mm x 750mm made up of steel reinforcement (16 mm), and bamboo reinforcements (16 mm) that comprised of flat formed bamboo reinforcement and spherically formed bamboo reinforcements each were separately used. Beams with no reinforcements were used as control to check the results of steel and bamboo reinforced beams. The preliminary test showed that the tensile strength for steel reinforcement had an average value of 670.84 N/mm^2 while, the values for both flat and spherical bamboo reinforcements were 82.6 N/mm^2 and 54.45N/mm^2 respectively. Flexural strength of the steel reinforced beams performed better than the bamboo reinforced beams. Flat formed bamboo reinforcement performed efficiently than the spherically formed bamboo reinforcement when used in concrete beam with values of 3.34 N/mm^2 and 2.67 N/mm^2 respectively, whereas the unreinforced concrete beam had the smallest amount of flexural strength with a value of 1.63 N/mm^2. It was inferred from the results that the flexural strength of beams strengthened with flat formed bamboo reinforcement beam had a larger flexural strength than the spherically formed bamboo reinforcement beam whereas the steel strengthened beam performed most effectively.

1. INTRODUCTION

Concrete is the most generally used construction material in the world. Concrete is robust in compression however it behaves poorly once it's subjected to tensile forces. To help this defect of concrete, reinforcement is needed (Igba *et al.*, 2019). The reinforcing material ought to have adequate lastingness with the exception of alternative properties. Steel is the typical material used as reinforcement in concrete. It's necessary to rely on new construction materials. Bamboo incorporates a long and well-established artefact throughout the world's tropical and sub-tropical regions. It's widely used for several styles of construction, specifically for housing in rural areas. Bamboo may be a renewable and versatile resource. Bamboo has been found to

be an environmentally friendly plant as a result of the fact that it absorbs heaps of chemical element and carbon dioxide from the air (Steinfeld, 2001).

Bamboo as a natural material is robust in tension and compression (Rahman *et al.,* 2011). It attains its highest strength when it is three to four years once it is brown and later starts to decrease in strength (Amanda and Untao, 2001). Bamboo is incredibly lightweight compared to steel. These aspects place bamboo on the list of viable construction materials. These properties, once combined, indicate that bamboo can build a fine addition to the present choice of materials. Ghavami (2004) described bamboo as one material, which is able to have an incredible economic advantage because it reaches its full growth in only some months and reaches its optimum mechanical resistance in only a few years. Moreover, it exists in abundance in tropical and climatic zone regions of the world. For a robust, ductile and sturdy construction, the reinforcement must have the subsequent properties of at least high relative strength; high toleration of tensile strain; good bond to the concrete regardless of hydrogen ion concentration, moisture, and similar factors; and thermal compatibility, not inflicting unacceptable stresses in response to dynamic temperatures.

Many works have been done on the quality of bamboo as reinforcement in concrete for structural members. Made *et al.* (2004) investigated concrete slabs reinforced with bamboo of 600 x 300 x 75 mm^3 on testing with Universal Testing Machine, the result showed initial and final failure loads of 18 KN and 28 KN respectively for bamboo, and 22 KN and 30 KN respectively for steel. Owing to these, it was concluded that bamboo was appropriate for reinforcing structural lightweight members by which cracking was a vital serviceableness limit state for bamboo reinforced concrete at which deflection increased.

The aim of this work was to find the best alternative bamboo material compared to conventional steel that can serve as a reinforcement for beam.

2. METHODOLOGY

Materials

Dangote 3x Grade 42.5 R PLC was obtained and used to meet the specifications of the Nigerian Industrial Standard NIS 441-1: 2014 collected for both Steel Reinforced and Bamboo Reinforced concrete. Materials needed for Reinforcement cement concrete were cement, fine aggregate, coarse aggregate, steel rod, bamboo and water. The aggregates, fine aggregate (FA) and coarse aggregate (CA) used were obtained from Alabata Abeokuta, Nigeria. They were both prepared and used in conformity with BS EN 12620-2013. Water was used for mixing and production process which was obtained from the Civil Engineering Laboratory of the Federal University of Agriculture Abeokuta, Nigeria in conformity with BS 1008: 2002. Steel was obtained with from a local construction material supplier 16 mm size in diameter at Oshodi area, Lagos State, Nigeria. Moreover, bamboo was obtained locally by harvesting within the premises of Muslim high school Isolu area Odeda local government along Alabata road in Abeokuta Ogun State. The size of reinforcements used in this experimental work was 16 mm in diameter.

In selecting the bamboo reinforcements for use in the concrete beam, the following factors recommended by Francis and Paul (1966) were considered:

(a) The only bamboo showing a pronounced brown colour was used. This confirmed that the plant was at least three years of age.
(b) The largest diameter culms available were selected.
(c) Whole culms of green, unseasoned bamboo were not used.
(d) Bamboo that was to be used was not cut in spring or early summer. These culms are generally weaker due to increased fibre moisture content

Experimental Procedures

Beam design

Modulus of Elasticity of steel E_s = 200 kN/mm^2

W= failure load

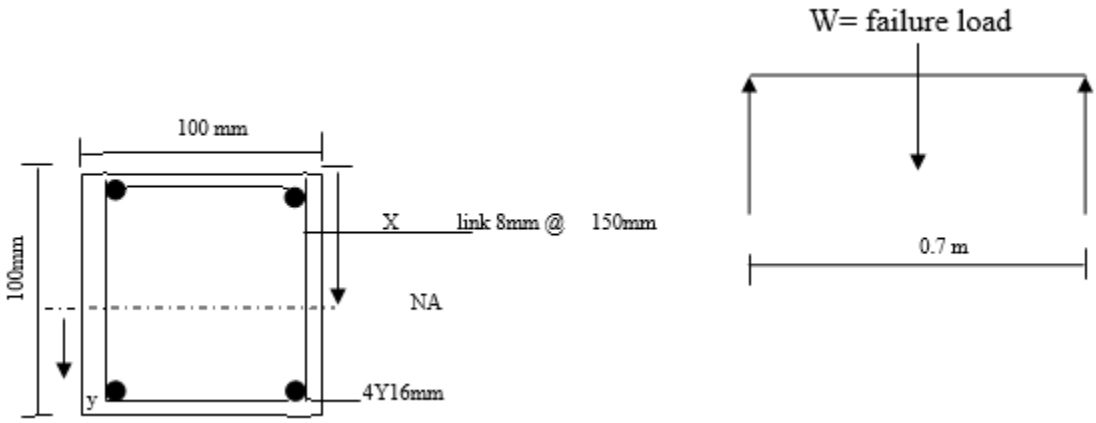

Fig. 1: Section of reinforced concrete beam

Concrete mix design

The mix ratio that was used for this research was 1:2:4 having a water-cement ratio was 0.55 to achieve a target strength of 25 N/mm^2.

Tensile strength test

Tensile strength test was done as a pre-test on steel and bamboo re-bars having a size of 16 mm diameter as shown in fig.2 by subjecting them to controlled tension under failure to work out their tensile properties before using them for casting beams in accordance with BS EN ISO 6892-1:2016. The tensile strength at the ultimate for bamboo is of great importance in helping to calculate the highest allowable tensile stress of the bamboo, once the bamboo is being employed as reinforcement in concrete beams to cater for the tensile loads. The load obtained when the concrete beam yielded was divided with the cross-sectional area to get the ultimate tensile strength of the concrete beam specimen. Stress and strain values were calculated with the use of the load and displacement values.

Stress (σ) = Load (P) / cross sectional area (A) (1)

Strain ($\in$) = Displacement (Δ) / Gauge Length (L) (2)

Flexural strength test

Test done to obtain the flexural strength enabled the measurement of the force that was required to break a material also the extent at which the material is elongated before breaking was done as shown in Fig. 3. Flexural tests were done for 7, 21 and 28 days of curing in accordance with EN 12390 -5 2009. The average flexural strength of the beams cast was determined by applying the formula illustrated in Eq. 3.

$$f = \frac{PL}{bd^2} \quad (3)$$

Where
f = Flexural strength (in N/mm^2)
P=Load in N applied to the specimen
L=Length in mm of the span on which the specimen is supported (700)
b=measured width in mm of the specimen (100)
d=measured depth in mm of the specimen (100)

Fig. 2: Tensile testing of flat bamboo reinforcement

Fig. 3: Flexural strength test of round bamboo reinforcement beam

3. RESULTS AND DISCUSSION

Tensile Strength Results

Steel and bamboo were analyzed to obtain the tensile strength as shown in Fig. 4 below. It was discovered that 16 mm of steel reinforcement bar had a mean value of 670.84 N/mm^2 whereas flat formed bamboo reinforcement had mean of 82.60 N/mm^2 and also the spherically formed bamboo reinforcement had a mean value of 54.45N/mm^2. The flat bamboo performed better than the spherically formed bamboo because there was a void at the middle present in the spherically formed bamboo. The spherical bamboo was smoother in nature than the flat bamboo therefore it had little bond property.

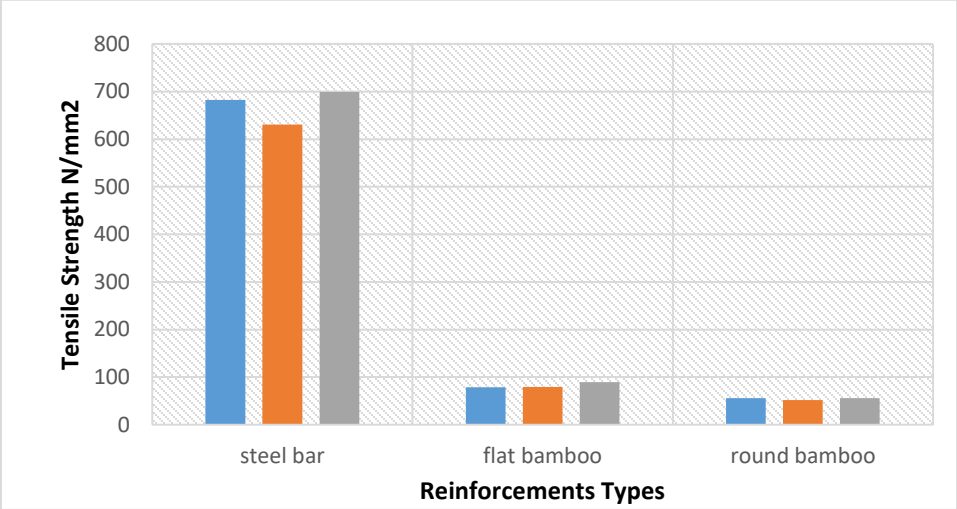

Fig. 4: Tensile strength test on different reinforcement types

Compressive Strength Results

From Figure 5, the compressive strength of the concrete mixes used for the purpose of this study it showed that the compressive strength increased with an increase in curing days for the concrete mixes with values of 8.44, 18.10 and 25.20 N/mm^2 for 7, 21 and 28 curing days respectively. Hence, it was concluded that the curing ages of concrete mixes was directly proportional to the compressive strength and the targeted strength of 25 N/mm^2 was met.

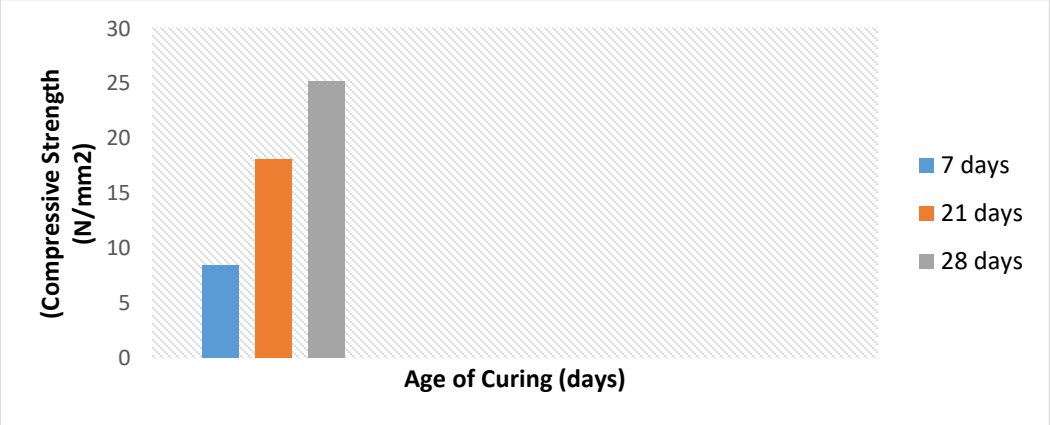

Fig. 5: Compressive strength test chart

Flexural Strength Results

The flexural strength results in Fig. 6 showed a mean flexural strength of 4.88 N/mm^2, 6.19 N/mm^2 and 6.44 N/mm^2 at curing days of 7, 21 and 28 respectively. The flexural strength rose in respect to the age of curing for both the steel reinforcement and bamboo formed reinforcements. The flat formed bamboo reinforcement beam had the next highest flexural strength with a mean of 2.86 N/mm^2, 3.17 N/mm^2 and 3.35 N/mm^2 for 7, 21 and 28 days respectively. The spherically formed bamboo reinforcement beam had flexural strength 2.21 N/mm^2, 2.52 N/mm^2 and 2.67 N/mm^2 smaller than flat formed bamboo reinforcement beam but larger than the zero reinforcement beam having a flexural strength 1.34 N/mm^2, 1.48N/mm^2 and 1.63 N/mm^2 at 7, 21 and 28 days respectively.

The results agreed with Adewuyi *et al.* (2015) having flexural strengths of 12.22, 6.22 and 2.56 N/mm^2 respectively for Steel, bamboo and rattan RC beam at 168 days using a mix ratio and water cement ratio of 1:3.1:5.26 and 0.45.

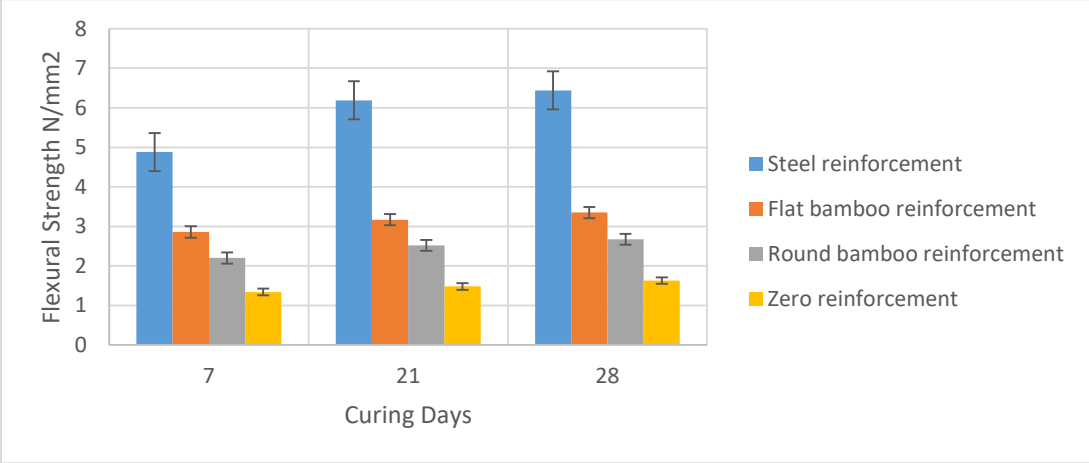

Fig. 6: Average flexural strength of beams with different reinforcement types

4. CONCLUSION

This work investigated the tensile and flexural strengths of the concrete beam that was reinforced with both steel reinforcement of 16mm size, and bamboo formed reinforcement of 16mm size. Subsequent conclusions were noted on the reinforcements employed in this study as follows:

i. Flexural strength of the concrete beam strengthened with reinforcements increased with the days of curing. Steel reinforcement beams had the very best flexural strength of 6.44 N/mm^2 at 28 days. The flat formed bamboo reinforcement beam had the next best performance with a flexural strength of 3.35 N/mm^2 while the spherically formed bamboo reinforcement beam had a flexural strength of 2.67 N/mm^2. The smallest amount of flexural strength was seen in the zero-reinforcement beam with a value of 1.63 N/mm^2.

ii. Steel reinforcement had the most strength value in tensile of 670.02N/mm^2, which was followed by flat formed bamboo reinforcement and spherically formed bamboo reinforcement with values of 84.10 N/mm^2 and 54.45 N/mm^2.

iii. The considerable performance will still be achievable if an additional quantity of bamboos is employed in the production of light-weight concrete beam structures such as those seen in public bathrooms, sunshades, decking of the roof in automotive parks, etc.

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