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Application of Bamboo and Coconut Fibres as Reinforcements in Concrete: A Typical Way of Converting Environmental Waste to Wealth

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Abstract – ***Several researches have validated the quest for valorisation of wastes in civil engineering. This study is an investigation into the potential use of bamboo and coconut fibres as reinforcements in concrete. After batching, 1:2:4 mix of concrete was produced with varying bamboo and/or coconut fibre proportions of 0.5%, 1.0% and 2.0% as admixtures in concrete. Various blends of concrete so produced have medium workability at 0.55 water-cement ratio. The compressive strength values for 0.5%, 1.0% and 2.0% bamboo-fibre-reinforced concrete at 28days of curing were found to be 14.44N/mm²***, ***13.70N/mm² and 13.26N/mm² respectively, while those for 0.5%, 1.0% and 2.0% coconut-fibre-reinforced concrete at 28days of curing were found to be 14.59N/mm², 14.30N/mm² and 13.78N/mm² respectively and those for 0.5%, 1.0% and 2.0% bamboo-and-coconut-fibre-reinforced concrete at 28days of curing were found to be 14.96N/mm², 14.59N/mm² and 14.15N/mm² respectively as compared with that of the conventional concrete so produced which was 13.41N/mm². The statistical model proves that bamboo and/or coconut fibres can be employed to improve the compressive strength of concrete.***

Keywords: Admixtures, Compressive Strength, Fibres, Reinforcement, Waste Valorisation

1.0 Introduction

The use of natural fibres in making concrete is recommended since several types of these fibres are available locally and are plentiful. The idea of using such fibres to improve the strength and durability of brittle materials is not new; for example, straw and horse hair are used to make bricks and plaster. Natural fibres that are suitable for reinforcing concrete and are easily available in developing countries can be broadly classified as fibres from vegetable and animal origin (Sethunarayanan et al., n.d.). Plain concrete has two major deficiencies; a low tensile strength and a low strain at fracture. The tensile strength of concrete is very low because plain concrete normally contains numerous microcracks. It is the rapid propagation of these microcracks under applied stress that is responsible for the low tensile strength of the material. These deficiencies have led to considerable research aimed at developing new approaches to modifying the brittle properties of concrete (Shodganga, n.d.). Bamboo has been one of the common materials in pre-industrial architecture in Asia and South American countries, employed as structural elements. The utilization of bamboo as construction component is motivated by its widespread availability in the tropical and subtropical climatic regions, its rapid growth and the combination of elevated mechanical strength and low specific weight. Bamboo segments are used as reinforcement of concrete beams, circular columns and pillars in quadratic form of concrete, double–layer spatial and plane truss bamboo structure and special joints between the bamboo elements, which can be easily used for plane and double-layer spatial structures while Coconut has also been tested as a filler or a reinforcement in different composite materials (Sen and Reddy, 2011). Coconut (coir) fibre reinforced concrete (CFRC) with higher fibre content has a higher damping but lower dynamic and static modulus of elasticity. It is found that CFRC with a fibre length of 5 cm and a fibre content of 5% has the best properties (Ali et al., 2012). It was concluded in the study undertaken by Umoh and Jonah (2015) that coconut fibre is suitable for use as reinforcement in the production of bamboo leaf ash blended cement-based composite panels. Similarly, Hasan et al. (2012) concludes in their study that coconut fibre has the potential to be used in the conventional concrete for the production of structural lightweight concrete while Ruben and Baskar (2014) affirms that using coconut fibre in civil construction reduces environmental pollution factors, may also bring several improvements in concrete characteristics and the addition of coconut fibre also arrests the micro cracks present in the concrete. It was also reiterated in their study that coconut fibre used in cement improves the resistance of concrete from sulphate attack while the compressive strength is also improved up to certain percentage. The thrust of this study is to evaluate the effects of bamboo and coconut fibres as admixtures in concrete production.

2.0 Materials And Methods

2.1 Materials and equipment used for the study

Materials used for the study include Ordinary Portland Cement (OPC), fine aggregates (with 75% of the aggregates passing Sieve size 2mm), coarse aggregates (of hard, durable granite of size 19mm), bamboo and coconut fibres (obtained from a farm settlement at Oyo town in Oyo State Nigeria) and potable water free of impurities. The coconut fibres and bamboo fibres cut in 15-20mm lengths were used in varying percentages of 0%, 0.5%, 1% and 2% by weight of total concrete constituents as admixtures in concrete. The apparatus and equipment used in the study include the metal moulds (with internal dimension of 150mm x150mm x150mm), Set of BS sieves and mechanical sieve shaker, Tamping rod, Weighing balance, Hand shovel, Slump cone, Compaction factor machine and Compression testing machine.

2.2 Experimental procedure

Batching and Mixing

The method of batching by weight was used and 1:2:4 mix was adopted as proportions of cement, sand (sharp sand), and coarse aggregate (granite), and bamboo and/or coconut fibres were batched manually. The materials were thoroughly and uniformly mixed together using shovel and 0.55 water-cement ratio was adopted.

Sampling

The fresh concrete was now placed in the mould already coated with engine oil and this was done in three layers as a standard practice prescribed by BS 1881: Part 108: 1983. One third of the mould was first filled with the fresh concrete and then compaction was done using a compaction rod for about twenty-five blows and this was repeated in three layers in order to reduce the void ratio. The surface of the concrete cubes formed was then smoothened using a hand trowel. This is shown in Plate 1.

Plate 1: Concrete cubes placed in moulds

Curing
After 24 hours of casting, then the concrete cubes were demoulded and weighed. And the concrete cubes were cured in water so that the hydration process of cement used in preparing the concrete could continue.

Determination of workability of concrete
The workability of the conventional concrete and fibre-reinforced concrete was determined through slump test (performed in accordance with BS1881) and compaction factor test.
Determination of compressive strength of concrete
The concrete cubes (after being cured in water for 7, 14, 21 and 28 days) were placed in the compressive machine and load at failure was then determined.

3.0 Results And Discussion

Workability of the concrete
Both the slump test and the compaction factor test (represented in Figures 1 and 2) confirm that the bamboo fibre-reinforced, coconut fibre-reinforced, composite bamboo/coconut-reinforced concrete and the conventional concrete have a medium workability at the water - cement ratio of 0.55 chosen.

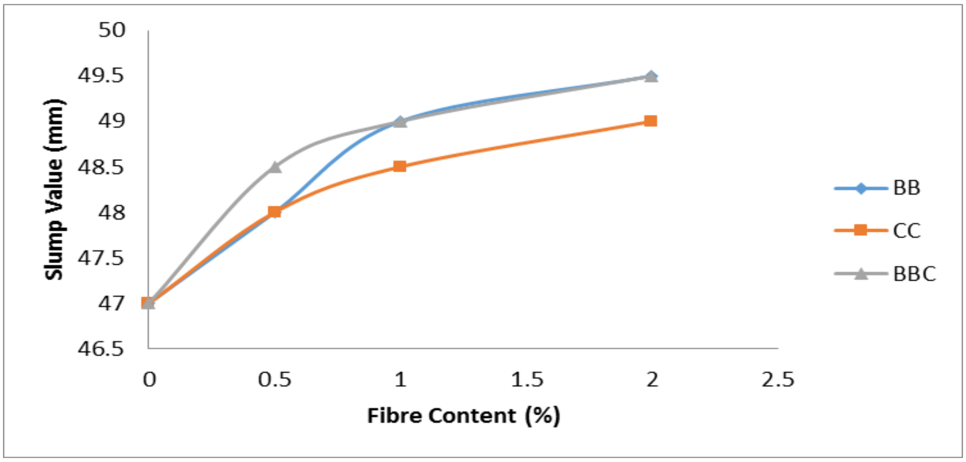

Figure 1: Slump Value – Fibre Content Characteristics for the Concrete Cubes

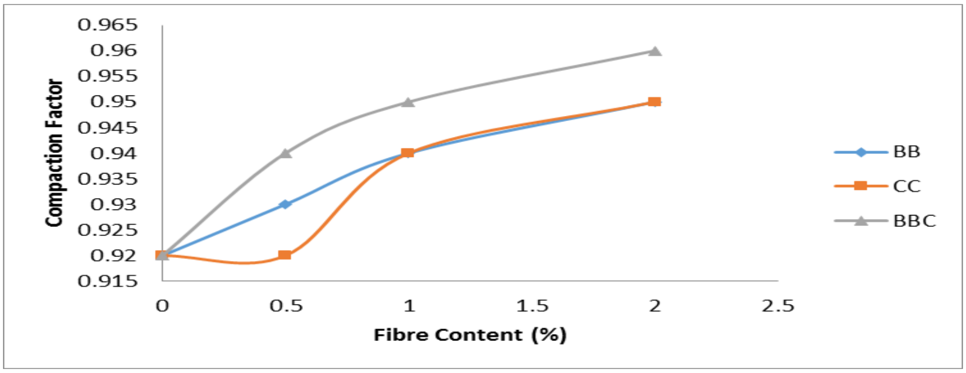

Figure 2: Compaction Factor – Fibre Content Characteristics for the Concrete Cubes

Compressive strength of the concrete

The compressive strength of the cube specimen was calculated by dividing the maximum load at which the specimen fails by the cross sectional area. Average values of the three cube samples crushed at each age of curing were taken as the representative value. The compressive strength values are represented in Table 1 while it was evident from Figure 3 that the fibres have significant effect on the compressive strength of concrete as the strength of the concrete increases in relation to increase in proportion of each of the fibres.

Table 1: Compressive Strength Values (N/mm^2) at 28days

	BB Concrete	CC Concrete	BBC Concrete
0% Fibre	13.41	13.41	13.41
0.5% Fibre	14.44	14.59	14.96
1.0% Fibre	13.70	14.30	14.59
2.0% Fibre	13.26	13.78	14.15

Note: BB means Bamboo, CC means Coconut and BBC means Bamboo and Coconut

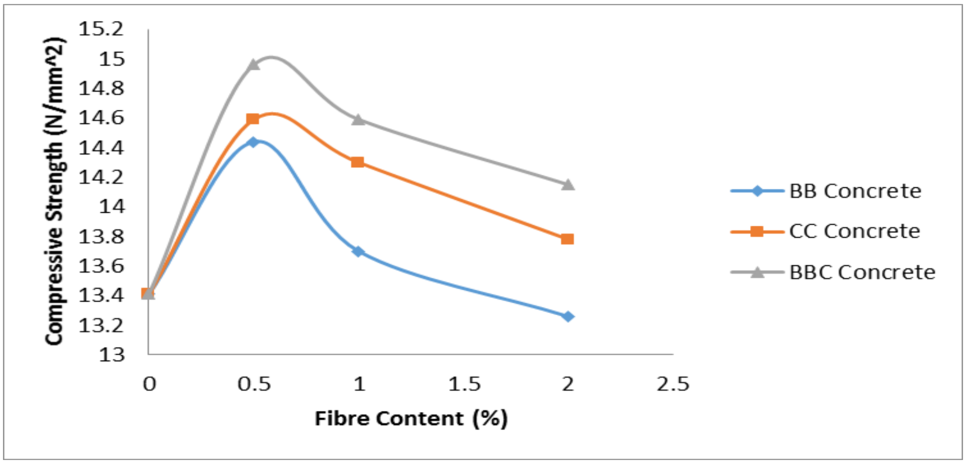

Figure 3: Compressive Strength – Fibre Content Characteristics for the Concrete Cubes

Statistical Analysis (Analysis of Variance)

Possibility of significant differences between the compressive strength values of the concrete cubes was determined through Analysis of Variance, the compressive strength values of the cubes at 7, 14, 21 and 28 days (as shown in Table 1) for the conventional and fibre-reinforced concrete at varying fibre contents were used in preparing Table 2. Table 3 rounds off the computation of two F values as the ratio of mean square between treatments to mean square between residual variations and the ratio of mean square between blocks to mean square between residual variations.

Table 2: Analysis of Variance in Compressive Strength at 28 days

	BB Concrete	**CC Concrete**	**BBC Concrete**	**Row Total**	**Row Mean**
A (0% Fibre)	13.41	13.41	13.41	40.23	13.41
B (0.5% Fibre)	14.44	14.59	14.96	43.99	14.66
C (1.0% Fibre)	13.70	14.30	14.59	42.59	14.20
D (2.0% Fibre)	13.26	13.78	14.15	41.19	13.73
Column Total	54.81	56.08	57.11	**GRAND TOTAL = 168**	
Column Mean	13.70	14.02	14.28	**GRAND MEAN = 14.00**	

$V_R = b\sum(\text{Row Mean-Grand Mean})^2$
$V_R = 3[(13.41-14.0)^2 + (14.66-14.0)^2 + (14.2-14.0)^2 + (13.73-14.0)^2] = \mathbf{2.6898}$
$V_C = a\sum(\text{Column Mean-Grand Mean})^2$
$V_C = 4[(13.7-14.0)^2 + (14.02-14.0)^2 + (14.28-14.0)^2] = \mathbf{0.6752}$
$V = \sum(X - \text{Grand Mean})^2$
$V = [(13.41-14.0)^2 + (13.41-14.0)^2 + (13.41-14.0)^2 + (14.44-14.0)^2 + (14.59-14.0)^2 + (14.96-14.0)^2 + (13.7-14.0)^2 + (14.3-14.0)^2 + (14.59-14.0)^2 + (13.26-14.0)^2 + (13.78-14.0)^2 + (14.15-14.0)^2]$
$= \mathbf{3.8567}$
$V_E = V - V_R – V_C$
$V_E = 3.8567 – 2.6898 – 0.6752 = \mathbf{0.4917}$

Table 3: Analysis of Variance in Compressive Strength (F Computation)

Variation	Degrees of Freedom	Mean Square	F
Between Treatments $V_R = 2.6898$	a-1=3	$S_R^2 = \frac{VR}{a-1}$=0.8966	$F=\frac{SR^2}{SE^2}$=10.9341
Between Blocks $V_C = 0.6752$	b-1=2	$S_C^2 = \frac{VC}{b-1}$=0.3376	$F=\frac{SC^2}{SE^2}$=4.1171
Residual or Random V_E= 0.4917	(a-1)(b-1)=6	$S_E^2 = \frac{VE}{(a-1)(b-1)}$=0.082	
Total V = 3.8567	ab-1=11		

$F_{0.95}$=4.76 and $F_{0.99}$=9.78 at degrees of freedom of 3 and 6.
$F_{0.95}$=5.14 and $F_{0.99}$=10.9 at degrees of freedom of 2 and 6.

First, the values of F at 5% and 1% confidence levels are less than the computed value, hence the null hypothesis is hereby rejected, and there are significant differences between the compressive strength values of the concrete produced due to fibre content (rows). Moreover, the values of F at 5% confidence level are greater than the computed value, hence the null hypothesis is hereby accepted that is, there are no significant differences between the compressive strength values of the concrete produced due to change in fibre type (columns). The statistical model proves that bamboo and/or coconut fibres improve the compressive strength of concrete.

4.0 CONCLUSION

The compressive strength values of the 0.5% fibre-reinforced concrete at 28days of curing were found to be 14.44N/mm^2, 14.59N/mm^2 and 14.96N/mm^2 (for bamboo, coconut and bamboo-and-coconut fibre-reinforced concrete respectively), while those of the 2.0% fibre-reinforced concrete at the same age of curing were found to have lower compressive strength values as the values were 13.26N/mm^2, 13.78N/mm^2 and 14.15N/mm^2 (for bamboo, coconut and bamboo-and-coconut fibre-reinforced concrete respectively). The conventional concrete was found to have compressive strength of 13.41N/mm^2, hence the fibre-reinforced concrete compares favourably with the conventional concrete. Statistically, there are no significant differences between the compressive strength values obtained as a result of change in fibre type. This establishes that bamboo and/or coconut fibres can be employed to improve the compressive strength of concrete and the research work also confirms that fibres of between 0.5% and 1.0% composition can be utilised to reinforce concrete, though concrete of 0.5% fibre composition possesses the maximum compressive strength values. This use of bamboo and/or coconut fibres in the improvement of concrete's compressive strength as validated by this research is a typical way of valorising waste.

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