Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(RESEARCH ARTICLE)

Check for updates

Bamboo and palm leaves as sustainable alternative to steel reinforcement in concrete beams

Amel Mohammed Abd El Rahman *, Abdul Majeed Bushara Omer and Mustafa Faisal Mustafa

Department of civil engineering, Sudan University of Science and Technology, Khartoum, Sudan.

Global Journal of Engineering and Technology Advances, 2024, 20(01), 018–023

Publication history: Received on 29 May 2024; revised on 07 July 2024; accepted on 10 July 2024

Article DOI: https://doi.org/10.30574/gjeta.2024.20.1.0119

Abstract

A massive urban development is recognized worldwide, resulting in an increased demand for building materials such as reinforcing steel, which is one important material in the construction industry. Due to the high cost of reinforcing steel and its scarcity in many countries, researchers leaned towards finding an alternative, less expensive, renewable and environmentally friendly material. Synthetic and natural fibers, such as glass fiber, bamboo and plam leave, had been under study to serve as reinforcing steel alternatives. This research studies the bending behavior and strength of concrete beams reinforced with bamboo and palm leaves. Six samples were prepared, three of which were reinforced with palm leaves and three with bamboo. A reference beam sample was also prepared for comparative purposes. Three-point bending test was carried out and bending behavior and collapse mechanism were studied. The results showed that the use of palm leaves and bamboo as an alternative to steel reinforcement in concrete improves the beams' structural behavior. The palm leaves and bamboo reinforced samples showed distinctly different patterns of failure.

Keywords: Bamboo; Palm leave; Bending behaviour; Concrete beam

1. Introduction

Reinforced concrete consists of two materials: brittle plain concrete, and ductile steel bars. This combination creates a composite material with high compressive and tensile strengths. Reinforced concrete, due to its reliable behavior under different loading conditions, had become the most used structural material. The increasing demand on reinforced concrete can lead to raw material scarcity, especially steel bars, if alternatives were not introduced. Other problems threatening the reinforcing steel is the corrosion and other environmental related issues (Karlsson, 2014). Many researchers tend to use an alternative material to replace steel bars in reinforced concrete, such as aluminium, non-ferrous materials and natural materials like bamboo.

In past times bamboo has been effectively used in construction and paper industries, and currently research is taking place to study the properties of bamboo and its suitability to use as reinforcing material (Karlsson, 2014 and Divya et al, 2021). As stated by Khosrow Ghavami (2005), bamboo is classified as composite orthotropic material with cylinder-shaped shell and good mechanical properties (Ghavami, 2005). Some researchers studied the properties of bamboo fiber composite. Senthilkumar et al (2021) studied the properties of hybrid bamboo-basalt fiber reinforced composite, the results showed good mechanical properties and recommended to use the composite in structural applications (Senthilkumar, et al, 2021). Karlsson (2014) studied the possibility of avoiding corrosion in reinforced concrete by substituting the reinforcement with carbon fiber reinforced polymer and bamboo, good mechanical properties were achieved (Karlsson, 2014).

* Corresponding author: Amel Mohammed Abd El Rahman

On the other hand, palm tree is cultivated in many countries over the world. According to Momoh and Osofero (2020), palm tree waste aquires good properties that qualifies it to be considered as a source of natural fibers. The researcher studied the chemical properties, thermal degradation and strength of palm fiber-cement composites. The results showed improvement in properties when palm fibres were used between 1% and 3% of cement volume (Momoh and Osofero, 2020).

2. Material and methods

2.1. Bamboo

As stated by Ramish et al. (2021), bamboo is considered an important building material because of its substantial features like availability, rapid growth, low price and sustainability. Furthermore, because bamboo fibers have a uniform distribution, this increases its tensile and flexural strength (Ramish et al, 2021).

In this research straight samples of bamboo were used, completely dry, free of cracks and weevils, and clean of any dirt or impurities. The samples were cut using a hacksaw into smaller length and prepared for testing.

2.2. Palm Leaves

Palm leave is considered a local and economic alternative to reinforcing steel, as reported by many researchers the tensile strength of palm leaves is about 80% of that of steel bars. They are also non-conductive to heat and have high flexibility. The Arab world owns approximately 100 million palm trees and annually produces 956,000 tons of palm leaves, which can be used in low-income projects.

In this research palm leave samples with a length ranging from 2.5 to 3 meters were cut by a hand saw from randomly selected palm trees. They were thence cleaned from the side leaves leaving only the leaf petioles to increase cohesion with concrete. The leaves were placed under the sun to dry at a medium temperature of 38 °C for 10 days.

2.3. Concrete Mix Design

Concrete mix was designed to have a compressive strength of 25 N/mm^2. Table (1) below shows the properties of the concrete mix.

Table 1 Concrete Mix Properties

Max design grade	**25N/mm²**
Cement content	350 kg
Water/cement ratio	0.49
Type of course aggregate	Natural aggregate
Type of fine aggregate	Natural sand
Type of cement	OPC class 42.5N/mm²
Type of curing	Immersed in water tank
Sampling Producer	BS 1881 part 101.1983
Number of cubes	3

2.4. Preparations of Beams

Seven plywood formworks with dimensions 50cm*10cm*10cm were prepared for beam specimens. Concrete mix was poured and compacted in formworks. Table 1 shown the materials and bar diameters of samples. Sample one was the reference sample with steel bar of 12mm diameter and concrete cover of 15mm, the other six samples prepared by complete replacement of steel bar with bamboo and palm leave as shown in Table 2. Specimens were demoulded after 24 hours and the seven samples were put in a curing tank for 28 days. Then flexural strength test was carried out on the cured specimens.

Table 2 Beam Samples Reinforcing and Diameter

Beam sample	Reinforcing material	Bar Diameter (mm)
B01	Steel bar	12.000
B02	Palm leave	13.350
B03	Palm leave	14.950
B04	Palm leave	17.030
B05	Bamboo	14.720
B06	Bamboo	16.040
B07	Bamboo	19.310

3. Results and discussions

3.1. Compressive Strength of Concrete Cubes

Six cubes of concrete were prepared to measure the compressive strength in 7 and 28 days of curing age. Tables 3 and Table 4 show the results of compressive strength test.

Table 3 Compressive Strength of Concrete in 7 Days

Ref No	Age days	Slump in (mm)	Dimension (mm)	Weight in (kg)	Failure load (kN)	Strength (N/mm^2)
1	7	180	150*150*150	8350	500	22.2
2	7	180	150*150*150	8300	510	22.6
3	7	180	150*150*150	8250	520	23.1

Table 4 Compressive Strength of Concrete in 28 Days

Ref No	Age days	Slump in (mm)	Dimension (mm)	Weight in (kg)	Failure load (kN)	Strength (N/mm^2)
1	28	180	150*150*150	8300	620	27.5
2	28	180	150*150*150	8350	660	29.3
3	28	180	150*150*150	8200	610	27.1

From Table 4 above, the average concrete strength in 28 days was 27.9N/mm^2.

3.2. Flexural Strength of Concrete Beams

Three-point loading test was carried out for all samples and the results were as follows:

- For reference beam (B01): maximum load at collapse obtained from flexural test was 23.01 kN, which is 65% more than the design load, 8.8 kN, and 30% more than the calculated collapse load, 16.3 kN.
- The reference beam failed with a shear collapse shown by a crack at an angle of 45 degrees, as shown in Figure 1.

Figure 1 Failure Mode of Reference Beam

Table 5 shows the load at collapse obtained from the flexural test of the palm leaves-reinforced beams.

Table 5 Failure Load of Palm Leave Reinforced Beams

Sample name	Diameter (mm)	Load of failure (kN)
B02	13.350	14.73
B03	14.950	12.98
B04	17.030	13.35

The maximum collapse load obtained from the beams in which the reinforcing steel was replaced with palm leaves is 14.7 kN, which is 46% higher than the design load and is 64% of the collapse load of the reference beam.

The mode of failure of these beams was a vertical crack in the middle of the beam. The crack appeared at the bottom and the width of the crack increased with continuous loading until collapse, as shown in Figure 2.

Figure 2 Failure Mode of Palm Leaves-Reinforced Beam

The loads at collapse obtained from the flexural test of the bamboo-reinforced beams are presented in Table 6.

Table 6 Failure Load of Bamboo Reinforced Beams

Sample name	Diameter (mm)	Load of failure (kN)
B05	19.31	13.94
B06	16.04	10.88
B07	14.72	6.4

The maximum collapse load obtained from the beams in which the reinforcing steel was replaced with bamboo is 13.94 kN, which is 42% higher than the design load and is 61% of the collapse load of the reference beam.

The mode of failure was a vertical crack in the middle of the beam. The crack initiated at the bottom of the beam and increased in width with time until collapse as shown in Figure 3.

Figure 3 Failure Mode of Bamboo Reinforced Beam

From the flexural test results, it was noted that the collapse load increases with the increase in diameter of the bamboo, which indicates an improvement in strength with bigger diameter of the reinforcing sample (Figure 4). The collapse mode of bamboo-reinforced beams, with a crackdown in the middle, indicates that the specimens are weak in bending and the maximum resistance to bending has not yet reached, while in the reference beam a shear collapse occurred.

As shown in figure 5, the smaller diameter of palm leaves resulted in beam specimens with higher flexural strength.

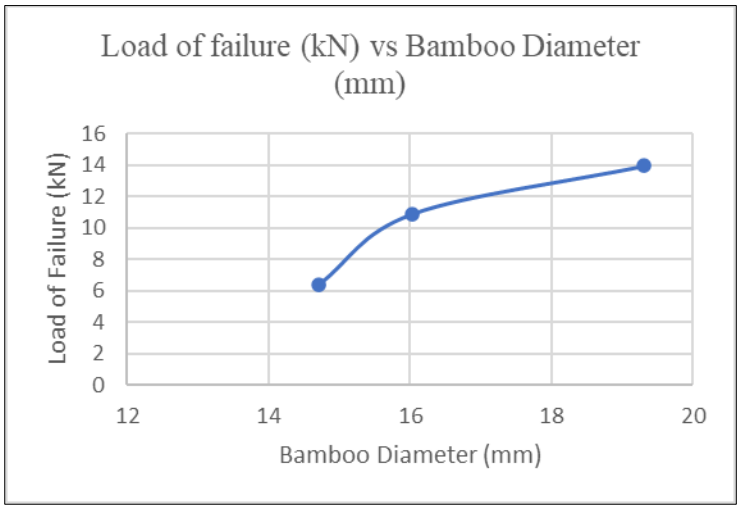

Figure 4 Relation Between Bamboo Diameter and Load of Failure

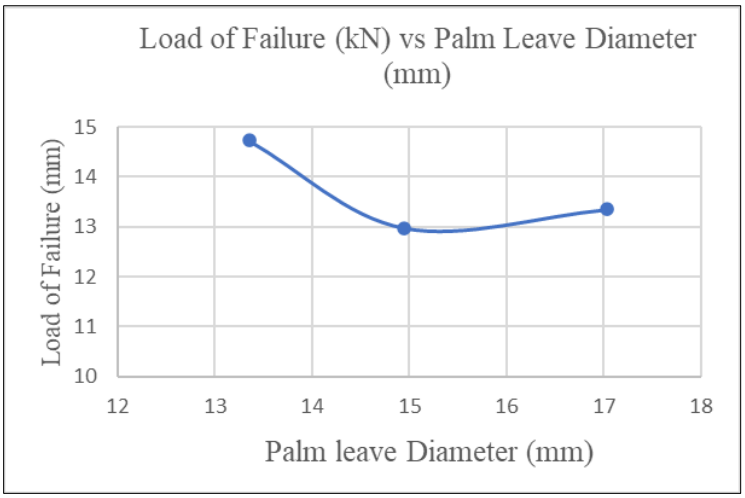

Figure 5 Relation Between Palm Leave Diameter and Load of Failure

4. Conclusions

Based on the findings of this research, the following conclusions can be drawn:

- Successful replacement of steel bars in concrete beams by bamboo and palm leaves was accomplished.
- The reference sample gave a collapse load of 23.01 kN, an increase of 65% from the design load.
- The palm leaves with diameter 17.03 mm produced a specimen with the highest collapse load among all other samples.
- The beam prepared by 17 mm-diameter palm leaves had a flexural strength that is 64% of the reference beams.
- Finally, the results stated above showed that the use of palm leaves and bamboo as reinforcing materials improves the flexural properties of the concrete beams.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Divakaran Divya, Suyambulingam Indran, and Kurki Nagaraja Bharath, 2021. Bamboo Fiber Composites. Composites Science and Technology. Singapore, 15-37.

[2] Ghavami, Khosrow, 2005. (Bamboo as reinforcement in structural concrete elements), Cement & Concrete Composites, 27 (2005) 637–649.

[3] Karlsson, Johan 2014, Alternative Reinforcement Approaches, 1-3, Chalmers University of Technology, Göteborg

[4] Momoh Emmanuel and Osofero Adelaja, 2020. (Recent developments in the application of oil palm fibers in cement composites). Front. Struct. Civ. Eng. 14(1): 94–108.

[5] Ramesh M, RajeshKumar L, an. Bhuvaneshwari V, 2021. Bamboo Fiber Composites. Composites Science and Technology. Singapore, 1-13.

[6] Senthilkumar K, et al, 2021 Bamboo Fiber Composites. Composites Science and Technology. Singapore, 97-110.