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# Bamboo-Reinforced Concrete Column

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**Abstract**

Buildings are significant contributors to greenhouse gas emissions and energy consumption in both industrialized and developing countries. This article explores the integration of bamboo as reinforcement in concrete columns which promotes durability and energy efficiency in construction. Its incorporation aligns with Sustainable Development Goal (SDG) 7, fostering modern and sustainable energy access. The study materializes the concept through cube and prism samples, subjected to compressive and flexural strength tests following industry standards. The research methodology validates the innovation's potential by evaluating its performance against conventional concrete columns. Laboratory tests reveal distinct differences in compressive and flexural strength between bamboo-reinforced and conventional concrete columns. While conventional concrete outperforms bamboo-reinforced concrete in compressive strength, bamboo-reinforced concrete exhibits superior flexural strength. Variations in results are attributed to the orientation and arrangement of bamboo within the samples. Further enhancements through bamboo pre-treatment and stakeholder collaboration could amplify its impact in the construction industry. This research contributes to the pursuit of sustainable practices and resource-efficient solutions in the global construction landscape.

**Keywords**: Reinforced Concrete Column; Bamboo; Sustainable Building Materials

## Introduction

The building and construction industry has a substantial impact on carbon emissions, encompassing the sourcing of resources, design, manufacturing, and construction of global projects. To address this issue, sustainable building materials have been developed, aiming to reduce carbon dioxide emissions while enhancing building durability, energy efficiency, and natural light penetration (OECD, 2016). The Construction Industry Development Board

Malaysia (CIDB) has consistently taken a proactive approach to address sustainable construction and support stakeholders in its implementation. The Technical Committee 9 on Good Environmental Practices in the Construction Industry (TC9), comprising environmental specialists from government agencies, professional organizations, academia, and construction-related associations, is responsible for this matter (Rostami et al., 2015). The current development framework outlined in the Twelfth Malaysia Plan (2021-2025) prioritizes a low-carbon, clean, inclusive, and resilient development strategy. The goal is to reduce greenhouse gas emissions intensity to GDP by up to 45 percent by 2030 (based on emission levels in 2005), as part of the country's efforts to become low-carbon and transition to a circular economy (Economic Planning Unit, 2021). This strategy also brings significant benefits in terms of mitigating environmental consequences, particularly in relation to climate change. Within the framework of the Sustainable Development Goals (SDGs), the development of bamboo-reinforced concrete columns as a potential product aligns with SDG number 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Promoting sustainable industries and investing in scientific research and innovation are essential strategies to facilitate sustainable development by enhancing resource and energy efficiency (United Nations Department, 2020).

**Bamboo-Reinforced Concrete Column**

A column is a vertical structural member designed to transmit loads to other members or the foundations. A column must resist bending or collapse in multiple directions (Hore, 2017). Column buckling is a structural engineering phenomenon that occurs when narrow parts underhigh compression collapse suddenly. Design measures can, fortunately, be made to prevent this. By doing buckling load analysis, it can help to determine the maximum load a column canwithstand before it buckles (Emil, 2021). Most columns are made of steel bars that hold the concrete together and concrete. Columns can sometimes be made of wood, structural steel, or other materials. Column comes in various shapes like circular, rectangle, square, hexagonal, etc. This depends on how the building is built, how it looks, and how it is set up inside. Columns are categorized based on a number of factors, including based on types of loading, types of reinforcement, and columns that are basedon shape (Happho, 2022). Buildings constructed without an appropriate understanding of energy consumption, environmental impact, or the protection of natural resources will result in wasteful consumption, risking environmental balance (Hussin, 2013).

Nowadays, with the emergence of global warming and sustainability concerns, bamboo as a building material is being widely discussed and reviewed. This is because deforestation has made high-quality wood for construction increasingly rare. Wood also requires a long time to regrow and become ready for use as construction material. In contrast, bamboo can be harvested within a short span of 3-5 years (Nurdiah, 2016). Additionally, when bamboo is planted, it releases oxygen into the air, a unique ability not found in industrial materials such as steel, plastic, and concrete. As a building material, bamboo exhibits high compressive strength and is also lightweight. It offers numerous applications and advantages. Drawing inspiration from traditional timber framing, bamboo architecture adheres to the same building principles as conventional wooden structures, utilizing vertical posts or columns (Goutham, 2021).

Bamboo possesses exceptionally durable fibers. Its compressive strength is twice that of concrete, and its tensile strength is comparable to steel. This characteristic is particularly advantageous in reducing buckling within the structure, especially in columns. Bamboo also exhibits higher shear stress resistance and a longer lifespan compared to wood. Moreover, bamboo has the ability to be bent without breaking. Its tensile strength exceeds or is equivalent to 28,000 N per square inch, while steel's tensile strength is 23,000 N per square inch (Anagal et al., 2014). According to Wulandari (2014), understanding the physical properties of bamboo, such as moisture content, density, and shrinkage, is crucial to avoid issues related to cracks. Processing bamboo when it has a low moisture content and a high density is essential to prevent excessive shrinkage and dimensional changes. Bamboo is a hygroscopic material, meaning it has the tendency to absorb and release water depending on the temperature and humidity of its environment (Suriani, 2020). Therefore, this paper investigates and discusses the current state of a conventional reinforced concrete column and explores the potential of bamboo as a reinforcement for concrete columns in domestic buildings.

**Research Methodology**

The innovation idea was materialized by constructing a cube and prism sample of the innovation. To assess its performance, laboratory tests were conducted. Due to equipment limitations, only two tests were performed for this research. First, a 150mm x 150mm x 150mm cube containing bamboo-reinforced concrete underwent a compressive strength test to determine its breaking strength under compression. In the second experiment, a prism was utilized to assess the flexural strength of the sample. These tests were conducted following industry standards such as BS EN 12390-4:2000 for compressive strength and BS EN 12390-5:2019 for flexural strength. The results of these tests provide crucial insights into the strength characteristics of the samples and validate the potential of the innovation.

**Results and Findings**

**Components and Materials of Bamboo-Reinforced Concrete Column**

The bamboo-reinforced concrete column consists of five materials as shown in Table 1. In order to prepare for the prototype and specimens, a Grade 20 concrete with mix ratio of 1:1.5:3, cement, sand and aggregate have to be weighted according to the ratio respectively. In addition to that, water to cement ratio was set to be at 0.5.

Table 1: Components and Materials of Bamboo-Reinforce Concrete Column

| **Components and Materials** | **Descriptions** |
|---|---|
| 1. Concrete Grade 20 (Cement, Sand, Aggregate) | Grade 20 concrete has a notional cement-to-sand-to-aggregate- to-water ratio of roughly 1:1.5:3, with the water-cement ratio being kept between 0.4 and 0.6. It is composed of a mixture of cement, and coarse aggregate. |
| 2. Water | For this particular study, the water to cement ratio was set at 0.5. |
| 3. Bamboo | Sliced Bamboo will be placed in mixed concrete to boost the column's mechanical properties. |
| 4. Cube Mould | The compressive test experiment will use 150mm x 150mm x 150mm cube moulds to place the specimen. |
| 5. Prism Mould | The flexural test experiment will use 500mm x 100mm x 100mm prism mould to place the specimen. |

Table 2 shows a breakdown of materials needed for the preparation of concrete for prototype, specimen for compressive strength (cube) and specimen for flexural strength test (prism). It is interesting to note that the weight of the concrete materials for prototype and cube sample were the same as they take the same shape and size.

Table 2: Components and Materials of Bamboo-Reinforced Concrete Column

| Type | Material (kg) | | | |
|---|---|---|---|---|
| | Cement | Sand | Aggregate | Water |
| 1. Prototype | 1.507 | 2.508 | 5.071 | 0.753 |
| 2. Cube Sample | 1.507 | 2.508 | 5.071 | 0.753 |
| 3. Prism Sample | 2.100 | 5.000 | 2.030 | 1.100 |

**Preparation of Cube Sample**

The bamboo-reinforced concrete column was constructed from Grade 20 concrete and a 500mm x 100mm x 500mm formwork. Due to the fact that just half of the formwork will be concreted to expose the product, the same admixtures will be utilized as in the 150mm cube mould sample. Figure 1 below shows the preparation process of the cube sample.

1. After all raw materials have been prepared, a 150mm cube mould must be disassembled, cleaned, and oiled to prevent wet concrete from sticking to it.

2. After the cube mould has been reinstalled, materials such as cement, sand, aggregate, and water can be weighed using the weighing scale according to the calculation.

3. After all the components have been weighed, they will be combined using a concrete mixer before being poured into the cube mould.

4. The concrete mixture will be poured alongside with sliced bamboo into the cube mould. To prevent porosity, the mixture must be applied layer by layer with bamboo before being compacted with a compacting rod.

5. After filling each cube mould with a concrete containing bamboo, each cube mould must be compacted using a vibration table.

6. After the concrete mixture has been compacted, it will be allowed to harden for at least 24 hours before the cube mould is removed and the cube is placed in a curing tank.

8. Cubes of concrete will be examined with a universal testing machine, and the results will be recorded.


7. After the concrete cube have hardened, the cube mould will be disassembled, and the cubes will be placed in a curing tank for 28 days prior to testing.

Figure 1. Preparation of Cube Sample

**Preparation of Prism Sample**

The bamboo-reinforced concrete sample was constructed from Grade 20 concrete and a 500mm x 100mm x 500mm mould. Figure 2 shows the preparation process of the prism sample.

1. Following the preparation of all raw materials, a prism mould must be disassembled, cleaned, and oiled to prevent wet concrete from sticking to it.

2. After the prism mould has been reinstalled, materials such as cement, sand, aggregate, and water can be weighed according to the calculation using the weighing scale.

4. Along with sliced bamboo, the concrete mixture will be put into the prism mould. The mixture must be placed layer by layer using bamboo before being compacted with a compacting rod in order to prevent porosity.

3. After weighing all of the components, they will be mixed using a trowel and then poured into the prism mould.

5. After filling each cube mould with bamboo-infused concrete, each prism mould must be compressed using a vibration table.

6. After compacting the concrete mixture, it will dry for at least 24 hours before the prism mould is removed and the sample is placed in a curing tank.

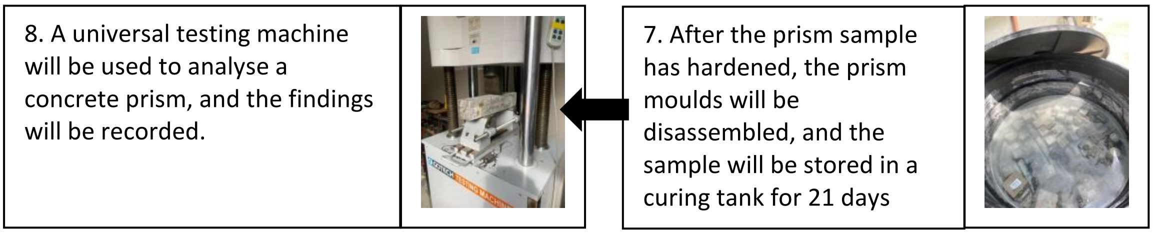


Figure 2. Preparation of Prism Sample

**Performance of Bamboo-Reinforced Concrete Column**

**a. Compressive Strength**

The cube samples of conventional concrete, C1 and bamboo-reinforced concrete, S1 were cured for 7, 14, 21, and 28 days, respectively. In this test, both strength and durability are measured at a rate of 5Nm/mm2/minute until the cube breaks. Both cubes are made with the same quantity grade, containing the same quantities of cement, water, sand, and aggregates. Due of the presence of bamboo within the cube mould, S1 requires a less amount of concrete compared to C1.

Table 3. Results of Compressive Test

| **Day** | **C1 Concrete Strength (MPa)** | **B1 Concrete Strength (MPa)** |
|---|---|---|
| 7 | 19.4 | 9.9 |
| 14 | 20.5 | 14.2 |
| 21 | 24.7 | 16.8 |
| 28 | 26.5 | 18.3 |

Table 3 displays the compressive test results obtained from samples C1 and B1 after 7, 14, 21, and 28 days, respectively. In terms of strength and grade, there is a noticeable difference between C1 and B1. The conventional concrete performs better in terms of strength and durability than bamboo supported concrete sample. The position of horizontally oriented bamboo withinthe tested cube sample may also influence to this finding. This is due to the limitation of laboratory testing machine that cannot withstand the strength of bamboo that are placed vertically which can damage the machine. The outcome of this test may differ if the bamboo is put vertically within the cube, which might result in a better outcome than horizontal bamboo placement. On the 28th day, the strength of conventional concrete increased by 6.5 MPa over its normal value of 20 MPa. Due to the presence of bamboo, which might weaken the bonding properties of concrete, B1 fell short of expectations and could be considered a failure. The bamboo surface may diminish the bonding potential of the concrete. Therefore, the structure was considered porous and lacked in mechanical strength due to the misplacement of the bamboo inside the sample. In accordance to that, the self-movement occurs between the bamboos in the structure of the concrete leading to the porosity of the innovated concreted.

**b. Flexural Strength**

The samples of a conventional prism, C1, and a prism reinforced with bamboo, B1, were successively cured for 7, 14, 21, and 28 days. This test measures the elastic modulus (MPa), maximum load, flexural strength, and durability of fracture or deformation at a rate of 3mm/minute until the prism breaks. Both prism examples are created with the same amount ofgrade 20 concrete mixture, which contains the same amounts of cement, water, sand, and aggregates. Table 4 below states the maximum load for sample before it breaks.

Table 4. Results of Flexural Test

| Day | C1<br>Max Load (kN) | B1<br>Max Load (kN) |
|---|---|---|
| 7 | 3.44 | 5.81 |
| 14 | 4.51 | 7.96 |
| 21 | 5.96 | 9.32 |
| 28 | 7.85 | 11.18 |

Table 4 displays the flexural test results obtained from samples C1 and B1 after 7, 14, 21, and 28 days, respectively. In terms of elastic modulus and maximum load for both prism sample, there is a noticeable difference between C1 and B1. It demonstrates that bamboo-reinforced concrete performs better in terms of flexural strength and modulus of elasticity than ordinary concrete. Due to the limitations of laboratory testing equipment, the absence of reinforcement bars within both samples may impact the outcome of this test. Consequently, if the original concept of this study, which is to link bamboo with reinforcing bar, can be investigated during this test, the proposed idea will result in much improved performance. It reveals that the presence of bamboo within the B1 prism sample provides twiceas much time and stress before the sample begins to fracture or cracks compared to the C1 sample. The position of horizontally oriented bamboo within the sample cube may also affect this result. The flexural and elastic properties of bamboo are primarily responsible for sample B1's capacity to absorb greater loads. Consequently, sample B1 meets the requirements and might be called a success.

**Conclusion**

Sustainable building materials have been chosen to maximize profitability and stimulate further research in the construction industry, economy, and the region. The incorporation of bamboo within column structures serves as a prime example of a field that underscores the imperative for addressing greenhouse gas emissions. To mitigate the exacerbation of non-renewable natural resource depletion, bamboo has been employed not as a replacement for reinforcing bars, but as a complementary material to reduce the need for steel in construction superstructures. One notable improvement for this product could involve pre-treating the bamboo, thereby enhancing its durability and long-term performance. This recommendation is just one of several potential avenues for enhancing the solution. Conducting surveys among relevant industry stakeholders could unlock additional breakthroughs, further augmenting the innovation's existing impact.

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