

Implementation of Bamboo Chips from Pantai Labu Region in Enhancing Compressive Strength of Fiber Concrete

Rhini Wulan Dary^{a,1,*}, Muhammad Ari Subhan Harahap^{a,2}, Mizanuddin Sitompul^{a,3}, Ernie Shinta Yosephine Sitanggang^{a,3}, Josep Hadipramana^{b,5}

^aDepartement of Civil Engineering Politeknik Negeri Medan, Jl. Almamater No. 1 Kampus USU, Medan, 20155, Indonesia

^bDepartement of Civil Engineering Universitas Muhammadiyah Sumatera Utara, Jl. Kapt. Mukhtar Basri No.3, Medan, 20238, Indonesia

¹ rhiniwulandary@polmed.ac.id*; ² muhammadarisubhan@polmed.ac.id, ³ mizanuddinsitompul@polmed.ac.id,

⁴ erniesitanggang@polmed.ac.id, ⁵ josef@umusu.ac.id

*Corresponding author

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ABSTRACT

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Concrete is widely used in construction due to its high compressive strength and durability. This study investigates the use of bamboo chips from the Pantai Labu region as a fiber material mixed with concrete to enhance its compressive strength. The research evaluates the effectiveness of different percentages of bamboo fiber chips, ranging from 0% to 2.5% by cement weight. Cylindrical concrete samples with diameters of 15 cm and heights of 30 cm were tested at 7, 14, and 28 days. The results demonstrate that adding 1% bamboo chips increased the compressive strength to 31.51 MPa, compared to the normal concrete strength of 30.04 MPa. This shows the potential of bamboo chips to improve the quality and sustainability of concrete production.

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I. Introduction

Concrete is a versatile material widely used in construction due to its high compressive strength and durability. However, improving concrete performance remains a critical objective, especially with the increasing demand for sustainable and cost-effective solutions. Natural fibers, including bamboo, have attracted attention due to their abundance and environmental benefits.

Bamboo is known for its excellent tensile strength and fast growth, making it an eco-friendly alternative for enhancing construction materials. The addition of bamboo in pre-cast concrete beams using software-based finite element analysis shows the structural benefits of bamboo fibers in concrete applications [6]. In the Pantai Labu region, bamboo is readily available, and this study aims to explore whether bamboo chips can be effectively used to increase the compressive strength of concrete.

Analysis of the compressive strength of concrete with the addition of roving fibers shows the potential of natural fibers in improving concrete performance [1]. In addition, previous studies by Joshua (2022) and Kartina (2024) have shown promising results in the use of natural bamboo fibers for concrete reinforcement [2]. Advances in concrete technology provide various opportunities to integrate natural fibers such as bamboo to improve the durability and compressive strength of concrete [3]. This study continues that research by focusing on increasing the compressive strength by using bamboo chips with varying percentages.

II. Method

This study was conducted using experimental methods to evaluate the compressive strength of concrete mixed with bamboo chips from the Pantai Labu region. The following steps outline the research methodology:



A. Materials

Today's rapid development requires many types of construction materials. One of the most commonly used materials is concrete. Concrete is a mixture of Portland cement, aggregate, fine aggregate, coarse aggregate and water, where the proportion of aggregate is the largest [4]. Concrete is one of the most widely used construction materials both in the world and in Indonesia. The concrete is made up of cement, water, fine aggregate and coarse aggregate that are easily available [5].

Cement: Portland cement was used as the binder.

Aggregates: In general, aggregates consist of Natural Aggregates and Artificial Aggregates [6]. Fine aggregates (sand) and coarse aggregates (gravel) were sourced from local suppliers. The specific types used were Binjai sand and Binjai gravel.

Water: Clean water sourced from the local water supply system was used for mixing [7].

Bamboo Chips: Bamboo was harvested from mature bamboo trees (approximately 5 years old) in the Pantai Labu region [8]. The bamboo was cut into chips with lengths of 2-3 cm and then added to the concrete mix in varying percentages.

B. Experimental Design

A series of cylindrical concrete specimens were prepared for compressive strength testing. The diameter of the cylinders was 15 cm, and the height was 30 cm, conforming to standard test sizes.

The experimental design included five different mix proportions of bamboo chips as a percentage of the weight of cement:

0% bamboo chips (control group)

1.0% bamboo chips

1.5% bamboo chips

2.0% bamboo chips

2.5% bamboo chips

C. Mix Proportion and Preparation

The job mix design (JMD) was calculated based on standard guidelines (SNI-7656-2012) to ensure a target concrete strength of 30 MPa. The concrete mix consisted of:

Cement: 32.78 kg

Fine aggregates: 52.43 kg

Coarse aggregates: 90.11 kg

Water: 14.33 kg

Bamboo chips: varying between 0% to 2.5% of cement weight (up to 0.82 kg at 2.5%).

The bamboo chips were mixed into the concrete at the designated percentages. The mixing process involved adding cement, aggregates, and bamboo chips in a mechanical mixer, followed by water. The mixture was stirred until a uniform consistency was achieved.

D. Casting and Curing

Once the mixing was completed, the fresh concrete was poured into cylindrical molds in three layers. Each layer was compacted 25 times using a tamping rod to remove air pockets and ensure proper compaction. After casting, the samples were left to set for 24 hours at room temperature.

The concrete cylinders were then removed from the molds and submerged in water for curing at 25°C for 7, 14, and 28 days, following standard curing practices to ensure full hydration and strength development.

E. Testing Procedure

The compressive strength tests were conducted at 7, 14, and 28 days using a hydraulic compression testing machine [9]. Each concrete cylinder was positioned centrally in the machine, and a gradual load was applied until the sample failed.

The compressive strength (σ) was calculated using the following formula: $\sigma=F/A$; Where:

F is the maximum load applied (in Newtons).

A is the cross-sectional area of the specimen (in cm^2).

The compressive strength results were recorded and compared across the different bamboo chip percentages to determine the optimal mix for enhancing concrete strength.

F. Data Analysis

The experimental data was analyzed by calculating the average compressive strength for each mix at different curing ages (7, 14, and 28 days). Statistical analysis was performed to evaluate the impact of the bamboo chip content on the compressive strength of the concrete [10]. The results were plotted in graphical form to visually compare the performance of each mix variation.

III. Results and Discussion

A. Compressive Strength Results

The compressive strength tests were conducted at 7, 14, and 28 days for each mix variation, with bamboo chip content ranging from 0% to 2.5%. The results of these tests are summarized in Table 1 below:

Table 1: Compressive Strength Results of Concrete with Bamboo Chips

Bamboo Chip Content (%)	Compressive Strength (MPa) at 7 Days	Compressive Strength (MPa) at 14 Days	Compressive Strength (MPa) at 28 Days
0.0%	28.53	30.68	30.04
1.0%	28.12	30.48	31.51
1.5%	26.02	25.58	25.74
2.0%	25.45	27.74	28.28
2.5%	23.92	27.21	25.96

B. Discussion

The results of the compressive strength tests show that the addition of bamboo chips significantly impacts the strength of the concrete, with different levels of effectiveness depending on the percentage of bamboo added.

1. Early-Age Strength (7 Days)

At 7 days of curing, the concrete without bamboo chips (control mix) showed a compressive strength of 28.53 MPa. The 1% bamboo mix achieved a slightly lower strength at 28.12 MPa, which indicates that bamboo does not have a significant adverse effect on the early compressive strength. However, mixes with higher bamboo content (1.5%, 2%, and 2.5%) showed a clear decline in strength, with the 2.5% mix reaching only 23.92 MPa.

This early decrease in strength for higher bamboo content may be attributed to the increased porosity or air voids introduced by the bamboo chips, which hinder the compactness and hydration of the concrete matrix in the early stages.

2 Mid-Age Strength (14 Days)

At 14 days, the control mix achieved 30.68 MPa, while the 1% mix reached a close 30.48 MPa, showing that the 1% bamboo mix performs comparably to the standard concrete. However, the 1.5% mix saw a notable reduction in strength to 25.58 MPa, indicating that exceeding 1% bamboo chips can negatively affect the performance of the concrete.

The 2.0% and 2.5% mixes, while improving slightly over their 7-day results, still showed weaker performance compared to the control mix. This suggests that while bamboo chips provide some

reinforcement, excessive amounts compromise the bond between cement and aggregates, leading to lower overall strength.

3. Long-Term Strength (28 Days)

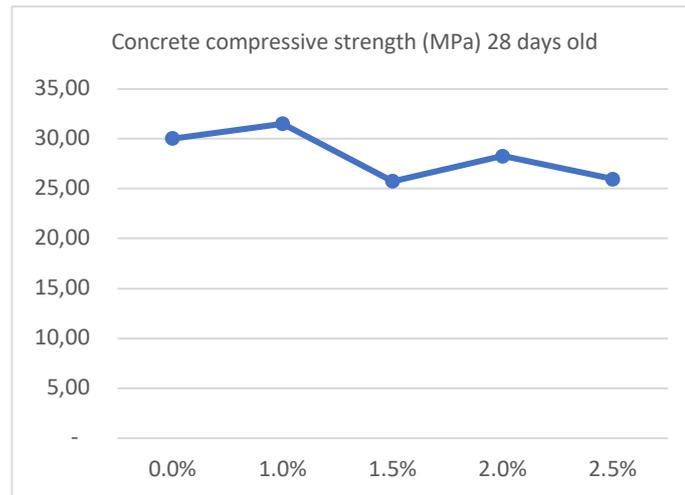


Fig 1. Concrete compressive strength (MPa) 28 days old

Based on Figure 1, the most important observation comes from the results of 28 days of compressive strength. The control mixture reaches 30.04 MPa, consistent with its target strength. However, the 1% bamboo mixture exceeded expectations, reaching the highest strength of 31.51 MPa, an increase of 4.89% from the control mixture. These results show that the addition of bamboo flakes in small quantities can increase the long-term compressive strength of concrete.

On the other hand, higher bamboo chip contents (1.5%, 2.0%, and 2.5%) resulted in lower strengths than the control mix, with the 1.5% mix showing a significant drop to 25.74 MPa. This indicates that there is an optimal level of bamboo content that enhances strength, but exceeding this limit leads to strength degradation.

The decline in strength at higher bamboo percentages could be due to several factors, including the introduction of excessive voids or reduced cohesion between the cement paste and aggregates. Bamboo, as a natural fiber, can absorb water, which may impact the hydration process of the cement and reduce the density of the concrete.

C. Optimal Bamboo Chip Content

The analysis of the data suggests that 1% bamboo chip addition is the optimal mix for enhancing the compressive strength of concrete. This mix not only maintains early-age strength but also improves long-term performance, reaching a compressive strength of 31.51 MPa at 28 days.

The performance of the 1.0% bamboo mix highlights the potential of bamboo chips as a sustainable additive that can improve concrete properties without requiring synthetic fibers or chemical additives. It also offers a cost-effective solution for regions where bamboo is readily available, such as Pantai Labu.

D. Environmental and Economic Implications

Fiber concrete made from steel processing waste demonstrates the potential for using non-traditional materials to enhance the properties of concrete [7]. Incorporating bamboo chips into concrete presents a sustainable approach to construction. Bamboo is a renewable resource, grows rapidly, and is widely available in tropical regions. Using bamboo chips as a substitute for traditional concrete additives could reduce the environmental impact of concrete production, which is a significant source of CO₂ emissions. Additionally, utilizing locally sourced materials like bamboo chips can lower construction costs, especially in rural areas where industrial additives are less accessible.

However, the results also show that excessive amounts of bamboo chips can reduce concrete strength, underscoring the importance of careful mix design. Future research could focus on optimizing the treatment of bamboo fibers to reduce water absorption and further enhance their reinforcing properties in concrete.

IV. Conclusion

This research demonstrates that bamboo chips from the Pantai Labu region can be effectively utilized to enhance the compressive strength of fiber concrete. The optimal mix was found to be with a **1% bamboo chip** addition, which resulted in the highest compressive strength of **31.51 MPa**, surpassing the control concrete's strength of **30.04 MPa**. This indicates that the incorporation of bamboo chips in small percentages can improve the structural integrity of concrete without the need for synthetic or chemical additives.

However, the study also revealed that higher percentages of bamboo chips (1.5%, 2.0%, and 2.5%) reduce the compressive strength of the concrete, suggesting that the amount of bamboo must be carefully controlled to avoid adverse effects on the concrete's performance.

The findings support the potential of using natural, sustainable materials like bamboo in construction, particularly in regions where bamboo is abundant. This approach not only enhances the mechanical properties of concrete but also contributes to more eco-friendly and cost-effective construction practices.

Further studies are recommended to explore the long-term durability of bamboo-reinforced concrete and investigate other mechanical properties such as flexural and tensile strength, as well as the potential treatment of bamboo fibers to improve their performance in concrete.

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