The Compressive Strength of Post-Fire Concrete Prepared with Bamboo Fiber

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Abstract. The purpose of this research was to identify the compressive strength of the concrete post-fire with the addition of bamboo fiber length variation. This research used quantitative experimental method. The independent variables were bamboo fiber length variation (2 cm, 3 cm and 4 cm by 1.5% proportion of cement weight, and the combustion temperature variation (200 °C, 300 °C and 400 °C). The dependent variable was compressive strength of concrete. The result showed that the addition of bamboo fiber length variation and combustion temperature variation producing the maximum unit of concrete compressive strength was found in bamboo fiber with length of 2 cm and burned at 200 °C. The value decreased with the increase of combustion temperature. The length of 4 cm bamboo fiber produced the highest compressive strength with the maximum compressive strength 20.93 MPa.

1. Introduction
The need for high-quality materials for construction is increasing every day. This is due to the increasing demands for development growth. These have made the architectural engineers look for different material that can be used as an alternate material in construction [1]. Fiber Reinforced Concrete (FRC) is one of the technology developments of concrete by adding fiber in the concrete mix. This type of concrete is one of the solutions for improving concrete quality [2]. The interest of using fiber in terms of composite strengthening has raised over the last few years [3]. The structural characteristics of concrete can be improved by the addition of natural or artificial fibers [4]. One of the natural fibers [5] which can be used as a material in a concrete mix is bamboo fiber [6]. Bamboo is low-cost material, fast-growing [7], and widely distributed in many zones [8].

One of the failures on the structure of concrete construction is when there is a fire on the construction. In the burned concrete structure, concrete’s strength is influenced by temperature change, heating level, and period [9]. The changes in the mechanical properties of concrete with high temperature are also related to the level of heating [10]. Concrete can also undergo significant physicochemical changes and loss of durability, through the appearing of cracks, spalling and a gradual deterioration of the hardened cement paste [11]. The decrease in concrete resistance and the expansion generated in reinforced...
concrete structures by direct exposure to fire at 400 °C maximum temperature serves as the basis for the present research [12].

The fire causes structures in a building to collapse. Even though the structure is intact, the strength remaining from this building is necessary to investigate so that it can be seen whether the building needs to be renovated or otherwise. When the fire is in structures made of fiber-reinforced concrete, uncertainty in the remaining strength would be higher due to lack of knowledge about the performance of FRC steel reinforcement at high temperatures [13]. In this study, bamboo fiber addition in a concrete mix was done by the existing optimum percentage and the concrete was combusted at the specific temperatures. It aimed to identify the strength produced by bamboo fibrous concrete after the combustion process.

2. Experimental

The research method used is quantitative experiments, by conducting laboratory investigations of specimens prepared with various fiber lengths for concrete compressive strength test.

2.1 Material

The main constituent of concrete is fine aggregate, coarse aggregate and cement. Natural fine aggregates were taken from the Mount Merapi mine, which had been tested by gradation tests and the results are shown in Figure 1. Meanwhile, the physical properties of fine aggregates are listed in Table 1. The test results are in accordance with SNI (Indonesian National Standards) S 04-1989-F criteria. Coarse aggregates were also taken from the destroyed Merapi volcano mine with a maximum size of 20 mm. The physical properties of coarse aggregates are presented in Table 2. Portland Cement Composites (PCC) used in this study is produced by Semen Gresik and in accordance with Indonesian specifications of SNI 7064-2004 [14].

![Figure 1. The gradation of fine aggregates.](image-url)
Table 1. The Physical Properties of Fine Aggregates

| Characteristic     | Point    | Standard from SNI | No. of SNI               |
|--------------------|----------|-------------------|--------------------------|
| Water content      | 0.2%     | 1-3%              | SNI 03-1970-1990         |
| Absorption         | 1.09%    | <2%               | SNI 1970:2008 [15]       |
| Specific gravity   | 2.54     | 2.5-2.7           | SNI 1970:2008[15]        |
| Fineness modulus   | 2.48     | 2.5-3.8           | SNI 03-1968-1990         |

Table 2. The Physical Properties of Coarse Aggregate

| Property           | Point    | SNI Criteria | No. of SNI               |
|--------------------|----------|--------------|--------------------------|
| Specific gravity   | 2.62     | 2.5 – 2.7    | SNI 1969:2008            |
| Absorption         | 0.94     | >3%          | SNI 1969:2008            |
| Abrasion           | 46.47    | <50%         | SNI 2417:2008            |
| Fineness modulus   | 3.58     | 2.5-3.8      | SNI 03-1968-1990         |

The bamboo fiber used has a diameter of 0.2 mm with three variations in length of 20 mm, 30 mm and 40 mm as shown in Figure 2.

Figure 2. Bamboo Fiber

2.2 Test specimens preparation

Specimen dimensions for compressive strength test according to SNI 1974: 2011 [16] are cylindrical in shape with a diameter of 150 mm and a height of 300 mm. The design of the concrete mix was in accordance with SNI 7656: 2012 [17]. Table 3 summarizes the results of the concrete mix design.

Table 3. Mix design result

| Material         | Amount  | Unit   |
|------------------|---------|--------|
| Cement           | 297.101 | Kg/ m³ |
| Fine Aggregate   | 868     | Kg/ m³ |
| Coarse Aggregate | 984.639 | Kg/ m³ |
| Water            | 273.588 | Kg/ m³ |

Three length variations of bamboo fiber, 20 mm, 30 mm, and 40 mm, were added to the concrete mixture as much as 1.5% of the weight of cement. Specimens were prepared to be burned in three temperature variations namely 200 °C, 300 °C, and 400 °C. Normal concrete without additional fiber and combustion is also prepared as a control variable. Each variation consisted of four specimens.
2.3. Casting of test specimens
Concrete cylinder specimens were prepared to determine the compressive strength of FRC. The process of mixing the ingredients began by inserting half the sand into a cement mixer, inserting half the cement and waiting for them to mix. Then half of the bamboo fiber was put in consistently bit by bit and waited until evenly distributed. Half the cricket was put into the mixture. The next step was putting the remaining of sand, cement, bamboo fiber, and gravel in the same way. After everything was mixed well, then the water was poured bit by bit. The mixing process was performed so that bamboo fiber could be mixed consistently in the concrete mixture. Fresh concrete mixture was poured into the mold and compacted using a vibrator table. Based on SNI 2493-2011, maintenance of concrete fiber test objects was performed by opening the mold after 24 hours ± 8 hours after printing. Concrete would be tested after the concrete reached 28 days. Soaking in concrete was done as a concrete treatment. Specimens were soaked in water for 26 days then placed at room temperature for a day before the specimens were burned in 200 °C, 300 °C, and 400 °C.

2.4. Testing
Four normal concrete specimens and 60 FRC bamboo fiber specimens were used to determine compressive strength at high temperature exposure. All tests were executed at room temperature after the specimen was cooled from the temperature specified for each specimen. Testing of concrete compressive strength was carried out in accordance with SNI 1974: 2011 testing procedures [17]

3. Results and Discussion

![Compressive Strength vs Combustion Temperature](image)

**Figure 3.** Compressive strength in length fiber variations and combustion temperature

Based on Figure 3, it could be seen that the addition of bamboo fiber increased the compressive strength of concrete. It was directly proportional to the increase in fiber length. The highest increase in compressive strength was 21.31% in the addition of 4 cm bamboo fiber length.
The compressive strength of concrete with increasing length of bamboo fiber had increased. Nevertheless, the combustion process at a temperature of 200 °C, 300 °C, and 400 °C made the strength of the concrete change. At combustion temperature of 200 °C, the value of concrete compressive strength could reach the maximum value with an increase of 23.30% in the addition of 2 cm bamboo fiber. The process was supported by an opinion which states that if the cement paste is heated in room temperature to about 200 °C, its strength appears to increase slightly.

Combustion of concrete at a temperature of 300 °C and 400 °C did not meet the maximum value on the compressive strength of concrete. The greatest decrease in compressive strength was 24.41% at the addition of bamboo fiber length of 2 cm and temperature of 300 °C. At the temperature of 400 °C, the greatest decrease in strength occurred at 57.89% at the addition of 3 cm fiber length.

In short, based on the research results and discussion concerning bamboo fiber length toward the value of post-combustion concrete compressive strength, it can be concluded that:

1. The variation of bamboo fiber length by a diameter of 0.2 cm and a length of 2 cm, 3 cm, and 4 cm resulted in a decrease of the compressive strength at 300 °C and 400 °C. At a temperature of 300 °C, the reduction percentage was 24.41%, 16.90%, and 11.27%. At a temperature of 400 °C, the reduction percentage was 41.23%, 57.89%, and 16.67%

2. The variation of the length of the bamboo fiber and the variation in combustion temperature producing maximum value of concrete compressive strength occurred on the bamboo fiber by a diameter of 0.2 cm and a length of 2 cm combusted at 200 °C. The compressive strength produced was 20.46 MPa.

4. Conclusion
Based on the research results and discussion concerning bamboo fiber length toward the value of post-combustion concrete compressive strength, it can be concluded that:

- The variation of bamboo fiber length by a diameter of 0.2 cm and a length of 2 cm, 3 cm, and 4 cm resulted in a decrease of the compressive strength at 300 °C and 400 °C. At a temperature of 300 °C, the reduction percentage was 24.41%, 16.90%, and 11.27%. At a temperature of 400 °C, the reduction percentage was 41.23%, 57.89%, and 16.67%.

- The variation of the length of the bamboo fiber and the variation in combustion temperature producing maximum value of concrete compressive strength occurred on the bamboo fiber by a diameter of 0.2 cm and a length of 2 cm combusted at 200 °C. The compressive strength produced was 20.46 MPa.

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