The Influence of Bamboo Fibers as Additive on the Mechanical Properties of High Strength Concrete

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Abstract. The aim of this research is to investigate the influence of bamboo fiber on the mechanical properties of high strength concrete. The fiber was taken 0%, 0.5%, 1% and 1.5% against the weight of cement. The mix design conducted using weight comparison method. The test carried out at 28 and 56 days. The compressive and tensile strength test 28 days showed concrete obtained an average value of 62.47 MPa and 3.444 MPa for 0%, 59.83 MPa and 4.246 MPa for 0.5%, 59.07 MPa and 4.907 MPa for 1%, 54.92 MPa and 5.379 MPa for 1.5% bamboo fiber. The test at 56 days obtained 62.56 MPa and 4.907 MPa results with 0%, 60.77 MPa and 5.143 MPa at 0.5%, 59.82 MPa and 5.331 MPa at 1%, 55.11 MPa and 5.426 MPa with 1.5% use of bamboo fiber. The decrease in compressive strength on test 28 days occurred, which was close to the strength design, and there was an increase in the 56-day test. Tensile strength test of 28 and 56 days show an increase in each percentage of bamboo fiber added, where the optimal value obtained from the addition of 1.5% bamboo fiber.

Keywords: Bamboo Fiber, High Strength Concrete, Mechanical Properties

1. Introduction
The fiber concrete is a mixture made from cement, fine aggregate, coarse aggregate and a small amount of fiber [1]. Various types of fiber materials used to improve the mechanical properties of concrete such as steel fiber, fiber glass, polypropylene fiber (high-quality plastic), carbon (carbon) and natural fiber derived from natural materials, such as palm fiber, coconut fiber, jute fiber, bamboo fiber, and others [1]. Bamboo fiber obtained from bamboo stems which grow in various regions of Indonesia and easy to find. Based on multiple studies, the structure of bamboo has many advantages. The toughness and elastic fiber are good at holding loads (compressive/tensile, sliding, and bending). The tensile strength of bamboo without books is between 151-29 MPa while bamboo with books has a tensile strength between 55-128 MPa [2]. The fibers include natural fiber whose raw materials are easy to obtain, and the process is relatively easy by splitting bamboo sticks. One of the main factors in adding fiber to concrete is to increase the tensile strength of concrete. Very low tensile strength results in concrete cracking easily and reducing the durability of concrete. The existence of fiber turns concrete becomes more resistant to cracking. The addition of fiber to concrete does not greatly increase the compressive strength of concrete, but only add elasticity [3]. Ductility is one of the important properties in concrete. Ductility is the ability of the structure or its components to carry out repeated inelastic deformation back and forth beyond the limit of the first melting point while maintaining a large amount of load-carrying capacity (SNI 2847-2013).
In this study using FAS 0.25 with a concrete compressive strength plan of \( f'_{c} \) 60 MPa and the number of test specimens was 48 cylindrical test specimens. The variation of bamboo fiber addition is 0%, 0.5%, 1% and 1.5% of the weight of cement. Concrete mixture added substances such as fly ash, 15% palm shell ash and 2% superplasticizer by weight of cement. The coarse aggregate used is crushed stone with a maximum aggregate diameter of 12 mm. Concrete tensile strength and concrete compressive strength tests were carried out at 28 and 56 days of concrete using 15/30 cm cylindrical specimens.

2. Experimental/Methods

2.1 Materials
The materials used in this study are Portland Cement type I, palm shell ash is used as an additive, and viscocrete N-10 is used to improve the workability of fresh concrete. In this study, the aggregates originated from the Krueng Meureubo river in West Aceh. Oil palm ash comes from a CPO mill in West Aceh. The addition of fillers expected to cover the cavity or pore between aggregate particles, with the filled cavity increasing the area of the concrete so that the concrete's ability to withstand the load can be perfect. The material used as filler is coconut shell ash shown in Figure 1. This fiber used because of the high silica content (SiO2) so that it can become a pozzolan material in a concrete mixture. Coconut shell ash with requirements to pass the sieve no. 200 used as a filler for porosity cavities. The results also show that the optimal compressive strength using oil palm shell ash is at an additional value of 15% (Yusra, 2014). concrete is low in tensile strength, so the test performed is a tensile test to determine the tensile strength of high strength concrete. The concrete strength \( f'_{c} = 60 \) MPa with cylindrical diameter 150 mm and height 300 mm.

![Bamboo Fiber](image_url)

**Figure 1. Bamboo Fiber**

2.2 Mixed design, samples and test
The high strength concrete mix design has a compressive strength design of 60 MPa for cylindrical specimens, using a cement water ratio of 0.25. Use plasticizer with a percentage of 2% by weight of cement. Aggregates use crushed stones with a maximum aggregate diameter of 12 mm, and oil palm shell ash 15% by weight of cement. The percentages of bamboo fiber are 0%, 0.5%, 1%, 1.5%, by weight of cement. For this study, the quantity of cylindrical specimens with Ø size 15 cm and height 30 cm are 48 pieces. which is shows in Figure 2.
The compressive strength test and splitting tensile strength test were carried out on days 28 and 56. The compressive test was carried out with a compressive strength test machine. The design of concrete mixtures for all variations of bamboo fiber shows in Table 1.

| Materials          | 0% (kg) | 0.5% (kg) | 1% (kg) | 1.5% (kg) |
|--------------------|---------|-----------|---------|-----------|
| Portland cement    | 3.18    | 3.18      | 3.18    | 3.18      |
| Water              | 0.80    | 0.80      | 0.80    | 0.80      |
| Coarse aggregate   | 4.68    | 4.65      | 4.60    | 4.56      |
| Fine aggregate     | 3.12    | 3.09      | 3.07    | 3.04      |
| Palm shell ash (15%) | 0.48    | 0.48      | 0.48    | 0.48      |
| Viscocrete N-10 (2%) | 0.06   | 0.06      | 0.06    | 0.06      |
| Bamboo Fiber       | 0       | 0.02      | 0.03    | 0.05      |

The production of high-strength concrete starts with mixing concrete forming material (coarse aggregate, fine aggregate, cement and water) and superplasticizer. Then the material is put into a mixer and placed in a concrete mold for 24 hours. The making of bamboo fiber concrete is as follows: cement mixed with, coarse aggregate and fine aggregate, water and superplasticizer and bamboo fibers added so that it becomes a mixture of concrete material. Testing the compressive strength and tensile strength of concrete cylinders is carried out after the concrete reaches the planned age, i.e. at the period of 28 and 56 days. Cylinder test is carried out by giving a vertical direction or slowly parallel to the cylinder until the specimen is crushed. The number of samples is 48 cylinders (Ø15 cm, T = 30 cm) with various variations in the aggregate percentage, can be seen in Table 2.
Table 2. Test Specimens Design (cylinder Ø15 cm, T = 30 cm)

| Type of Specimens | The Percentage of Bamboo Fiber | Total of Specimens |
|-------------------|-------------------------------|--------------------|
|                   | 0%                            | 0.5%               | 1% | 1.5% |                      |
| Cylinder for      | 3 pcs                         | 3 pcs              | 3 pcs | 3 pcs | 12 pcs               |
| Compressive       |                               |                    |     |      |                      |
| strength (28 days)|                               |                    |     |      |                      |
| Cylinder for      | 3 pcs                         | 3 pcs              | 3 pcs | 3 pcs | 12 pcs               |
| Compressive       |                               |                    |     |      |                      |
| strength (56 days)|                               |                    |     |      |                      |
| Cylinder for      | 3 pcs                         | 3 pcs              | 3 pcs | 3 pcs | 12 pcs               |
| Split tensile     |                               |                    |     |      |                      |
| strength (28 days)|                               |                    |     |      |                      |
| Cylinder for      | 3 pcs                         | 3 pcs              | 3 pcs | 3 pcs | 12 pcs               |
| Split tensile     |                               |                    |     |      |                      |
| strength (56 days)|                               |                    |     |      |                      |

3. Result and discussion
The testing of concrete compressive strength aims to obtain load data that can be carried by concrete cylindrical specimens until destruction occurs. The compressive strength is obtained from the ratio of the maximum load to the cylinder cross-sectional area. Compressive test concrete was conducted when the test object was at the age of 28 and 56 days. Result in Table 3am shows decrease in concrete strength for the test in age 28 days. The highest value of strength is 59.83 MPa with 0.50% bamboo fiber which is the closest strength compare to the 62.47 MPa for 0% fiber. In age 56 days, the test result shows increasing value of concrete strength which is obtain 60.77 MPa for 0.50% addition of bamboo fiber and reach the mix design strength of 60 MPa.

Table 3. Result of compressive strength concrete cylinder (Ø 15, T30 cm)

| No | Percentage of Bamboo Fiber | Average of compressive strength concrete (MPa) |
|----|----------------------------|-----------------------------------------------|
|    |                            | 28 days | 56 days       |
| 1  | 0.00%                      | 62.47   | 62.56          |
| 2  | 0.50%                      | 59.83   | 60.77          |
| 3  | 1.00%                      | 59.07   | 59.82          |
| 4  | 1.50%                      | 54.92   | 55.11          |

Table 4 shows the testing of the concrete tensile strength aims to obtain load data that can be carried by concrete cylindrical specimens until destruction occurs. The size of the split tensile strength is obtained from a ratio of twice the maximum load with the multiplication area between the diameter and height of the cylinder. The results of the tensile strength in Table 4 shows test 28 days concrete with 0%, 0.5%, 1%, and 1.5% bamboo fiber obtained an average value of 3.444 MPa for 0% bamboo fiber, 4.246 MPa for 0.5% bamboo fiber, 4.907 MPa for 1% bamboo fiber and 5.379 MPa for 1.5% bamboo fiber. Tensile strength with 56 days obtained 4.907 MPa results with 0% bamboo fiber, 5.143 MPa at 0.5% bamboo fiber, 5.331 MPa at 1% bamboo fiber and 5.426 MPa with 1.5% use of bamboo fiber.
### Table 4. Result of Tensile strength concrete cylinder (Ø 15, T30 cm)

| Percentage of Bamboo Fibre | w/c  | Cylinder Specimens | Weight of Specimens (kg) | Area of Specimens (mm$^2$) | Penetration Load (kN) | Tensile Strength (fct) (28 days) (N/mm$^2$) | Tensile Strength (fct) (56 days) (N/mm$^2$) |
|----------------------------|------|--------------------|--------------------------|-----------------------------|----------------------|------------------------------------------|------------------------------------------|
| 0%                         | 0.25 | 1                  | 12.84                    | 176625                      | 35                   | 3.397                                    | 4.954                                    |
|                            | 0.25 | 2                  | 13.12                    | 176625                      | 37                   | 3.114                                    | 5.237                                    |
|                            | 0.25 | 3                  | 12.91                    | 176625                      | 32                   | 3.822                                    | 4.529                                    |
| Average Value              |      |                    |                          |                             |                      | 3.444                                    | 4.907                                    |
| 0.5%                       | 0.25 | 1                  | 12.84                    | 176625                      | 37                   | 3.114                                    | 5.237                                    |
|                            | 0.25 | 2                  | 12.87                    | 176625                      | 37                   | 3.963                                    | 5.237                                    |
|                            | 0.25 | 3                  | 12.89                    | 176625                      | 35                   | 5.662                                    | 4.954                                    |
| Average Value              |      |                    |                          |                             |                      | 4.246                                    | 5.143                                    |
| 1%                         | 0.25 | 1                  | 13.04                    | 176625                      | 38                   | 4.954                                    | 5.379                                    |
|                            | 0.25 | 2                  | 13.14                    | 176625                      | 38                   | 4.812                                    | 5.379                                    |
|                            | 0.25 | 3                  | 13.05                    | 176625                      | 37                   | 4.954                                    | 5.237                                    |
| Average Value              |      |                    |                          |                             |                      | 4.907                                    | 5.332                                    |
| 1.5%                       | 0.25 | 1                  | 12.96                    | 176625                      | 39                   | 6.086                                    | 5.520                                    |
|                            | 0.25 | 2                  | 13.08                    | 176625                      | 38                   | 5.237                                    | 5.379                                    |
|                            | 0.25 | 3                  | 12.86                    | 176625                      | 38                   | 4.812                                    | 5.379                                    |
| Average Value              |      |                    |                          |                             |                      | 5.378                                    | 5.426                                    |

**Figure 3. Diagram Split Tensile Strength of HSC**

Diagram Split Tensile Strength of HSC in figure 3 shows the results of the tensile strength test of 28 and 56 days showed a significant increase in each percentage of bamboo fiber added, where the optimal value obtained at the addition of 1.5% bamboo fiber.
Figure 4 shows the stress – strain behavior, where is concrete with bamboo fiber more ductile than concrete without bamboo fiber. We can see in value of the strain that occurs that is different between concrete with bamboo fiber and concrete without bamboo fiber.

4. Conclusions
Based on the results of research and data processing that has been done, several conclusions can be taken as the final results of this study:

a) From the results of the study, the use of bamboo fiber in the concrete mixture caused a decrease in the compressive strength of high-strength concrete; on the contrary there was an increase in the quality of the concrete tensile strength due to the addition of fiber bamboo.

b) The value of Compressive Strength indicates a decrease that is not significant in the 28-day test but is still close to the compressive strength of the plan and an increase in the value of the results in the 56-day test at 0.5% use of bamboo fiber. The results of the tensile strength test of 28 and 56 days showed a significant increase in each percentage of bamboo fiber added, where the optimal value obtained at the addition of 1.5% bamboo fiber. It shows that bamboo fiber has potential as an additives material that can increase the tensile strength of high strength concrete.

c) Concrete with variations in the addition of fiber bamboo is still classified as high-quality concrete because it has a compressive strength greater than 50 MPa [4].

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