Influence of Length Variation in Bamboo Fiber on Tensile Strength and Compressive Strength of Concrete

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Abstract. Concrete is one of the most commonly used building construction materials since concrete has advantages such as high compressive strength, can be molded to any desired shape and easy to find material for a relatively cheap price. However, concrete also has disadvantages such as brittle and has low tensile strength. Tensile strength of concrete is only about 8-10% of its compressive strength. From previous researches, the use of fibers is effective to increase the tensile strength of concrete. Types of fiber that commonly use in concrete mixtures are natural fibers from animals and plants, also artificial fibers such as steel, glass fibers, and synthetic fibers. Natural fiber concrete such as bamboo has low manufacturing cost than the other types of fiber. The aim of this research is to investigate the influence of fiber size in bamboo fiber on tensile strength and compressive strength of concrete. The percentage of bamboo fiber addition in concrete mixtures was 2% with variation of fiber 2 cm, 3 cm and 4 cm in length. The optimum tensile strength and compressive strength of the concrete is obtained from bamboo fiber concrete with 2 cm variation in length, which is 107,41 kg/cm² and 230,03 kg/cm² respectively at 28 days.

Keywords: Fiber Concrete, Bamboo Fiber, Tensile Strength, Compressive Strength

1. Introduction

Concrete is construction materials that have been used widely almost in every country. The advantages of using concrete as construction material are it can be molded to any desired shape, easy to find material for relatively low price and has high compressive strength. However, concrete has a low tensile strength. Concrete is brittle material and has tensile strength for about 8-10% from its compressive strength. Brittle material usually has limited ductility and low resistance to crack. Cracks in concrete must be controlled because cracks caused the entrance of water and another aggressive mineral into concrete structure and caused corrosion to the steel reinforcement. From previous research, the use of fibers is effective to increase the tensile strength of concrete.

Fiber concrete is concrete containing fiber which is uniformly distributed and randomly oriented in the cement matrix. Fiber concrete is being investigated to enhance the tensile
strength of concrete and to inhibit the growth of tensile cracks in concrete [1]. In recent years, the concept of fiber reinforced concrete is a great development to enhance the performance of concrete such as high strength and durability of concrete [2]. There is numerous type of fibers, such as synthetic fiber like steel, glass, and carbon also natural fiber materials from plants and animals that have been examined to make fiber concrete. The manufacture of synthetic fiber is quite expensive and consume considerable energy [3]. Therefore, natural fiber like bamboo becomes a solution.

For a long period, bamboo has been known as one of the oldest building material because it characterized by high strength and low weight, and is easily worked using simple tools [4]. Bamboo as building material has been used for the construction of scaffolding, bridges, and house. Bamboo plant growth well and fast also has minimum energy to harvest and transport. Therefore bamboo has low manufacturing cost compared with synthetic fiber such as glass or steel fibers [5].

The aim of this research is to investigate the influence of fiber size in bamboo fiber on fresh and hardened state of concrete, such as workability, tensile strength, and compressive strength of concrete.

2. Method

2.1 Materials

Cement This research use Portland cement type I from PT. Semen Gresik, Indonesia.

2.2 Fine Aggregates

Fine aggregates were from natural rivers and from East Java, Indonesia. From the sieve analysis result, this research using fine aggregate with grading zone 2.
2.3 Coarse Aggregates

Coarse aggregates were crushed gravel with 40-mm maximum diameter. The sieve analysis result from coarse aggregates is shown in Fig. 3.

Physical properties of fine and coarse aggregates are reported in Table 1.

### Table 1. Physical properties of fine and coarse aggregates

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>San</th>
<th>Crushed Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content</td>
<td>2.72%</td>
<td>0.42</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>1.43%</td>
<td>2.43</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>1490 kg/m³</td>
<td>1230 kg/m³</td>
</tr>
</tbody>
</table>

2.4 Bamboo Fiber

This research uses original bamboo from East Java, Indonesia.
2.5 Experimental Procedure

Mixtureproportions:
There were 4 mixtures prepared for this research. One mixture as controlled specimen which has 0% of bamboo fiber. The other mixtures contain bamboo fiber for about 2% weight of cement with a variation of fiber 2 cm, 3 cm, and 4 cm in length.

Mixtures proportions were calculated using the DOE method with 200 kg/cm² compressive strength. Mixtures proportions of concrete are shown in Table 2.

Table 2. Concrete Mixtures for compressive strength 200 kg/cm² per each m³

<table>
<thead>
<tr>
<th>Mixtures</th>
<th>Cement (kg)</th>
<th>Water (kg)</th>
<th>Fine Aggregate (kg)</th>
<th>Coarse Aggregate (kg)</th>
<th>Fiber (2% weight of cement) (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 cm</td>
</tr>
<tr>
<td>NC</td>
<td>308.33</td>
<td>199.39</td>
<td>747.28</td>
<td>1130.01</td>
<td>-</td>
</tr>
<tr>
<td>FC-2</td>
<td>308.33</td>
<td>199.39</td>
<td>747.28</td>
<td>1130.01</td>
<td>6.17</td>
</tr>
<tr>
<td>FC-3</td>
<td>308.33</td>
<td>199.39</td>
<td>747.28</td>
<td>1130.01</td>
<td>-</td>
</tr>
<tr>
<td>FC-4</td>
<td>308.33</td>
<td>199.39</td>
<td>747.28</td>
<td>1130.01</td>
<td>-</td>
</tr>
</tbody>
</table>

Name of mixture explanation:
NC = Normal concrete (controlled specimen) FC-X, defines:
FC = Fiber concrete
X = Length of fiber in cm

Some testing methods used in this research were slump test according to ASTM C143 [6], compressive strength test according to ASTM C39 [7] and splitting tensile strength test according to ASTM C496 [8]. Both, compressive strength test and splitting test using specimen of concrete that were cylindrical with 15 cm diameter and 30 cm in height and were cured by submerged into the water in room temperature as shown in Fig. 4. Those specimens were tested at the age of 7 and 28 days.

![Fig 4 Concrete curing](image-url)
1 Result and Discussion

Slump test result. This test result defines the workability of fresh concrete. Fig 5 shows the influence of bamboo fiber length variation on slump test result.

Fig 5: Effect of bamboo fiber length on the workability of fresh concrete

Slump test measurement determines the workability of concrete. Concrete mixtures that have a lower value of slump measurement mean lower workability. The result shown in Fig 5 concluded that the presence of bamboo fiber also affects the workability of concrete. Normal concrete (NC) which has 0% of bamboo fiber has the highest slump test result for about 10 cm, however, concrete mixtures containing bamboo fiber have lower values of slump measurement because bamboo fiber tends to absorb the free water content in the mixture.

Fig 5 also shows that longer size of fiber results in lower slump test which because longer size of fiber tends to have a larger surface area that means more water being absorbed by the bamboo fiber.

Compressive strength test result. Fig 6 shows the difference of crack failure from normal concrete and fiber concrete.

(a) (b)
It is shown that normal concrete has severe crack failure than fiber concrete, that is because the presence of fiber makes concrete has larger crack resistance due to binding of fiber [9]. Therefore, concrete with fiber has better crack control.

Fig. 7 shows a relation of bamboo fiber length variation in the mixture and compressive strength of concrete.

The result showed that there is a slight increase in the compressive strength in concrete with bamboo fiber. The compressive strength of concrete which has 2 cm length of bamboo fiber (FC-2) is 159.33 kg/cm² at 7 days and 230.03 kg/cm² at 28 days, increases about 3% and 5% respectively compared with normal concrete (NC). FC-3 and FC-4, which have longer bamboo fibers, show lower compressive strength value. The compressive strength of concrete decreases for about 19% - 34% than normal concrete. It is because the mixtures have less workability which made the compaction process of concrete harder and increases the volume pores of concrete.

Splitting tensile strength test result. Fig. 8 shows the effect of bamboo length fiber on splitting strength test result.
It is shown that there is an increase in the tensile strength of concrete with 2 cm of bamboo fiber length (FC-2). The splitting tensile strength at 28 days increases by about 18% and 3% at 7 days, respectively, compared to normal concrete. It is because the fibers make the concrete less resistant to cracks. So the concrete able to receive higher tensile force. Fiber concrete which has longer bamboo fiber (FC-3 and FC-4) shows lower tensile strength value. That is because of the decrease in workability of concrete, which makes the compaction process harder, so that the increase in the volume pores in concrete and decreases the bond between the concrete constituent materials.

2 Conclusion

Length of concrete fiber influences the workability of concrete, the compressive strength, and the splitting tensile strength. Concrete with fibers has reduced workability than ordinary Portland cement concrete. Longer size of bamboo fibers has a lower slump value test. It is because bamboo fiber absorbs the free water content in the mixture. A mixture with 2 cm length of fiber concrete has the optimum compressive strength test and splitting tensile strength test. It is because fiber concrete tends to have higher tensile strength due to the fiber bonding. Therefore, the specimen able to receive higher axial and tensile force than normal concrete. Both compressive strength and splitting tensile strength decrease in mixtures that have 3 cm and 4 cm of fiber length. Because the mixture has less workability, which makes the compaction process of concrete harder and increases the volume of pores in concrete.

References