The effect twisted petung bamboo variations as reinforcement on concrete beam

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Abstract. Reinforced Concrete is a composite material consisting of concrete and steel-reinforced concrete. Steel is used as reinforcement because it has high yield strength. However, the price of steel reinforcement is higher due to high demand. Besides having a relatively high price, steel is a non-renewable material, which makes the amount of course very limited as for other alternatives as a substitute for the concrete reinforcement, called bamboo. Bamboo is a renewable natural product with high tensile strength. With the many advantages of bamboo, especially petung bamboo as a construction material, therefore, necessary to research the flexural strength of bamboo petung reinforced beams. Reinforced bamboo used is twisted petung bamboo with a variation of three strands, five strands, and seven strands. The method used in this study is a numerical analysis based on standard concrete flexural strength test with two loading points. Analysis shows that tensile strength of bamboo strands for three strands amounted to 222.93 MPa, five strands of 230.04 MPa, and seven strands of 237.14 MPa. For the maximum load, The highest load produced for concrete beams with reinforcement three strands, five strands, and seven strands are 11.87 kN, 35.62 kN and 52.21 kN respectively. Meanwhile, The flexural strength produced for each scheme is 6.73 Mpa, 8.23 Mpa and 9.86 Mpa.

1. Introduction

Concrete has a relatively higher compressive strength than the tensile strength. The compressive strength of 28-day-old concrete is approximately 10 + 65 MPa, and the value of concrete tensile strength is only around 9% to 15% of the compressive strength [18]. The type of concrete commonly used in the construction process is reinforced concrete. Reinforced Concrete is a composite material consisting of concrete and steel-reinforced concrete. Reinforcing steel in concrete serves to withstand the pulling forces that work and as a compressive force, so the need for the addition of tensile reinforcement that helps to withstand the tensile forces that bear the loads acting on the concrete. Steel is used as a reinforcement because it has a high yield strength. However, the price of steel reinforcement is higher due to high demand will be very burdensome for the community, especially people in economically vulnerable groups, in their efforts to meet their primary needs. In addition to having a relatively high price, steel is a non-renewable material, which makes the amount of course very limited, so innovation is needed to replace steel reinforcement. And for other alternatives as a substitute for the concrete reinforcement, Bamboo is a choice.

Bamboo is a renewable natural product that can be obtained easily, cheaply, easily planted, grows fast, can reduce the effects of global warming, and has a high tensile strength [20]. Also, based on the results of research conducted by Morisso [17], the selection of Bamboo as a building material can be based on such a relatively low price, fast growth, easy to plant, and easy to do. On the other hand, Bamboo has a relatively high tensile strength, between 100-400 MPa, where the tensile strength is equivalent to \( \frac{1}{4} \) of the ultimate steel stress. According to Morisso [16], the tensile strength of
Bamboo reaches 1280 kg/cm². According to Ogunbiyi et al. [22], the tensile strength of Bamboo can reach 94.60 MPa and yield strength 50.19 MPa. Based on the results of previous studies indicate that Bamboo can be used as a substitute for reinforcement in reinforced concrete beams.

2. Research method

The research was conducted in the form of testing the constituent materials of concrete (coarse aggregate and fine aggregate), manufacturing of specimens, testing the characteristics (compressive strength, slump, and bulk weight) [1,2,3,4,5,6,7,8,9]. The tests were carried out at the Concrete Laboratory of the Civil Engineering Department, Institut Teknologi Kalimantan. For the tensile strength of the strands of petung bamboo, it was obtained from secondary data related to the tensile strength for bamboo reinforcement without strands and 3 strands. Predictions were made for 5 strands and 7 strands using a simple linear regression method. For the flexural strength of concrete using strands of bamboo, it was obtained from Numerical analysis using secondary data related to the tensile strength of bamboo strands along with the prediction results which refer to the single reinforcing concept of beam structure.

For more detail, concrete flexural strength testing is carried out to determine the maximum load value generated and also to determine the cracks that occur based on the type of collapse in the beam based on SNI 4431: 2011 [10]. Whereas, in this study, to determine the flexural strength and maximum load that can be held by a bamboo reinforced concrete beam, the data used is secondary data that is processed in such a way as to obtain the required value is the maximum load value using specific static structure methods and the value of bending stress by referring to the concept of single reinforcement [13] which can be seen in figure 1.

![Figure 1. The concept of a single reinforcement.](image)

3. Results and discussion

3.1. Compressive test result

Concrete compressive strength testing refers to SNI 1974: 2011 [9] and using cylindrical specimens with a diameter of 10 cm and a height of 20 cm. This compressive strength test is carried out when the concrete sample is seven days, with a total of 3 concrete specimens. Those results are used to get the prediction of concrete compressive strength of 28 days. The purpose of this compressive strength test is to determine the compressive strength of concrete from the results of a mixed design or mixture that has been made in accordance with what has been planned. The results of concrete compressive strength are presented in table 1.

| Concrete Specimens | Age (Day) | Surface Area (mm) | $P$ (kN) | Correction Factor | $f'_c$ (MPa) |
|---------------------|-----------|------------------|----------|------------------|---------------|
| Concrete 1          | 7         | 7.85             | 110      | 0.65             | 21.56         |
| Concrete 2          | 7         | 7.85             | 110      | 0.65             | 21.56         |
Concrete Specimens | Age (Day) | Surface Area (mm) | P (kN) | Corecction Factor | $f'_c$ (MPa) |
---|---|---|---|---|---|
Concrete 3 | 7 | 7.85 | 100 | 0.65 | 19.60 |

Based on the table 1, the average compressive strength of the concrete is 20.91 MPa, and it exceeds the planned compressive strength of 20 MPa [11]. So, it can be concluded that the results of the mixed design calculations can be used as a reference for making concrete beam test specimens.

### 3.2. Tensile Strength of twisted bamboo

This test aims to determine the tensile strength of the bamboo petung and its resistance when the breaking limit occurs. Commonly, the method used is a tensile test, which refers to SNI 2052: 2017 [12]. In this study, the data of bamboo's tensile strength is secondary data obtained from several previous studies. This data is used to make predictions related to the tensile strength of the twisted bamboo (five strands and seven strands). The secondary data used are research conducted by Lasino [14] and Marsudi et al. [15]. The results of tensile strength testing of petung bamboo are presented in table 2.

**Table 2.** Results of testing the tensile strength of petung bamboo by lasino. [14]

| P (length) | Ø | Weight (gr) | Area (mm$^2$) | Breaking Load (kN) | Tensile Strength (MPa) |
|---|---|---|---|---|---|
| 600 | 10 | 72.5 | 78.50 | 13.210 | 168.2 |
| 600 | 10 | 71.9 | 78.50 | 12.930 | 164.8 |
| 600 | 10 | 73.1 | 78.50 | 13.510 | 172.1 |
| 600 | 10 | 72.3 | 78.50 | 12.450 | 158.6 |
| 600 | 10 | 71.8 | 78.50 | 13.200 | 168.2 |
| 600 | 10 | 72.7 | 78.50 | 13.590 | 173.1 |

On the other hand, in a study conducted by Marsudi et al. [15], where the tensile test specimens used were steel reinforcement and twisted bamboo petung (3 strands of 5 mm each and 5 mm thick). The results of the tensile test are presented in table 3.

**Table 3.** Results of testing the tensile strength of petung bamboo by Marsudi et al. [15]

| type of test object | Area (mm$^2$) | Load (kN) | Tensile Strength (MPa) |
|---|---|---|---|
| Steel Bar | 78.50 | 33.5 | 426.75 |
| Twisted Petung Bamboo | 78.50 | 17.5 | 222.93 |

Based on research conducted by Marsudi et al. and Lasino [14,15], it can be seen that the number of strands greatly influences the maximum load value and tensile strength of the Petung bamboo. The tensile strength of a strand petung bamboo (a diameter of 10 mm) is around 167.5 MPa. Whereas, the tensile strength produced from three strands of petung bamboo was 222.93 MPa. Based on those researches, it can be concluded that the more the number of strand of the petung bamboo, the higher the tensile strength.

As stated before, the tensile strength of twisted petung bamboo is directly proportional to the amount of strand. Using the data presented in table 1 and table 2, the tensile strength of twisted petung bamboo - five strands and seven strands - can be predicted by applying simple linear regression method [21]. Table 4 shows the result of this method.
Tabel 4. Prediction Results of Maximum Load of Twisted Petung Bamboo.

| Twisted Petung Bamboo | Area (mm²) | Maximum Load (kN) | Tensile Strength (MPa) |
|-----------------------|------------|--------------------|------------------------|
| One strand            | 78.50      | 13.15              | 167.50                 |
| Three strand          | 78.50      | 17.50              | 222.93                 |
| Five strand           | 94.99      | 21.85              | 230.04                 |
| Seven strand          | 113.04     | 26.80              | 237.14                 |

The change in tensile strength can also be seen in the figure 2.

Figure 2. Prediction of tensile strength of bamboo petung reinforcement.

As can be seen in table 4 and figure 2, the amount of bamboo strands affects the maximum load that can be held by petung bamboo—the greater the number of strands, the greater the tensile strength. Figure 2 shows that the tensile strength of one strand is 150 Mpa. Meanwhile, three strands can improve tensile stress up to 222 Mpa. On the other hand, although seven strands show the highest tensile strength (237 Mpa), this change is not significant if it is compared with five strands (230 Mpa).

Meantime, comparison with steel bar which has 426 Mpa of tensile strength, twisted bamboo petung shows half of the steel strength. Based on this fact, the twisted bamboo petung has the potential to be used as a substitute for reinforcement in concrete, especially for reinforcement with seven strands of petung bamboo.

3.3. Flexural analysis of single reinforced concrete beam

By using a specific static structure method and the concept of a single reinforcement [13], the value of the flexural stress and the maximum load that can be held by bamboo reinforced concrete beam with variation of 3 strands, five strands, and seven strands can be known. The flexural stress values of the concrete beams without reinforcement can be known based on research conducted by Fanto Pardomuan P., H. Tanudjaja, and RS Windah [19]. Recapitulation of concrete beam flexural strength and its maximum load can be seen in table 5.

Table 5 explains that The maximum breaking load that can be resisted by a regular concrete (without reinforcement obtained) is about 11.87 kN. Meanwhile, using three strand as reinforcement
can enhance the maximum load up to 33.64 kN and seven strands shows the highest value of maximum load (49.19 Mpa).

Table 5. Recapitulation of concrete beam flexural strength.

| Type of Concrete Beam | Maximum Load (N) | Flexural Strength (N/mm²) |
|-----------------------|------------------|--------------------------|
| Without Reinforcement | 11877.63         | 3.56                     |
| 3 Strands Reinforcement | 33645.22       | 6.35                     |
| 5 Strands Reinforcement | 41101.79       | 7.76                     |
| 7 Strands Reinforcement | 49191.26       | 9.29                     |

Figure 3. Flexural strength of bamboo reinforced concrete beam.

Based on figure 3, it can be seen that concrete beam will only has flexural strength of 3.56 Mpa if it do not apply reinforcement in it. However if it uses 3 strand reinforcement, it will rise it’s flexural strength up to 6.35 Mpa. In addition, concrete beams with seven strands reinforcement of bamboo petung can reach 9.29 Mpa. this finding can be used as a consideration for using petung bamboo as a substitute reinforcement.

4. Conclusion

Based on this research, it can be concluded that:

1. The tensile strength of three strands bamboo petung obtained from previous studies amounted to 222.93 Mpa. On the other hand, although seven strands show the highest tensile strength (237 Mpa), this change is not significant if it is compared with five strands (230 Mpa).
2. The maximum breaking load that can be resisted by a regular concrete (without reinforcement obtained) is about 11.87 kN. Meanwhile, using three strand as reinforcement can enhance the maximum load up to 33.64 kN and seven strands shows the highest value of maximum load (49.19 Mpa).
3. concrete beam will only has flexural strength of 3.56 Mpa if it do not apply reinforcement in it. However if it uses 3 strand reinforcement, it will rise it’s flexural strength up to 6.35 Mpa. In
addition, concrete beams with seven strands reinforcement of bamboo petung can reach 9.29 Mpa. this finding can be used as a consideration for using petung bamboo as a substitute reinforcement.

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