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Bamboo as a Building Materials

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Abstract: Bamboo is one of the natural resources that get high demand in timber materials because it has high tensile strength, flexural strength and modulus of elasticity. Since concrete is a quasi-brittle material which is very weak in tension and undergo very little deformation, reinforcement is very indispensable. Widespread use of steel as concrete reinforcement has a greatest impact on energy and environment. Therefore, an evaluation has been made to develop the reinforcement material. The aim of this paper is to study the ultimate tensile strength of bamboo strips, flexural strength, flexural modulus and load capacity of concrete beam reinforced with bamboo. There were two sample of bamboo strips (BS1 and BS2) and three sample consist of unreinforced concrete beam (UCB), 10 x 10 mm bamboo reinforced concrete beam (BRC10) and 10 x 16 mm bamboo reinforced concrete beam (BRC16) were constructed and tested under tensile test and three-point bending test respectively. The ultimate tensile force for sample BS1 and BS2 is 22.11 kN and 26.78 kN respectively. The ultimate tensile strength of sample BS1 is 138.21 N/mm^2, while sample BS2 is 167.40 N/mm^2. Experimental three-point bending indicate ultimate load capacity, flexural strength and flexural modulus of sample UCB is 35.60 kN, 7.56 N/mm^2and 1323.30 N/mm^2 respectively. For sample BRC10, the ultimate load capacity is 42.87 kN, 9.11 N/mm^2 of flexural strength and 208.56 N/mm^2 of flexural modulus, while sample BRC16 had 37.72 kN, 8.01 N/mm^2, 653.66 N/mm^2 of ultimate load capacity, flexural strength, and flexural modulus. The bamboo material has very poor in tension where it breaks sharply without undergo plastic deformation. The presence of bamboo reinforcement affects the increment of concrete beam capacity where it improved about 7% to 17% of load capacity, flexural strength and allows the beam to deflect more than unreinforced beam.

Keywords: Bamboo Reinforced Concrete Beam (BRC Beam), Tensile Strength, Flexural Strength.

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1. Introduction

A structure can be developed with the result of particular method of assembling and constructing structural elements so that they support and transmit applied loads safely to the ground. The required elements are columns, beams, slabs, wall and foundation. In the construction of concrete structure, all of these elements are made of concrete, which is a mixture of paste, aggregates and reinforcement. According to Li Gu [1] in the construction industry, the standard materials to be use as reinforcement in concrete is steel bars. From P. R. Mali [2], the reinforced concrete in the 19th century is reformed and reinforced concrete become one of the most world common building construction methods. The expansion of construction sector predicted to become a key driver for the growth of steel bar market size. As mentioned by Steel Rebar Market 2020: Global Market Report "Global steel bar market is expected to rise from its initial estimated value in 2018 (USD 132.15 billion) to USD 198.99 billion in 2026". In Malaysia, the consumption of steel value has reached 9.5 million tons in 2019 and Vincent Choong, National Committee Secretary of Malaysia Iron and Steel Industry said "Malaysia has reached 9.5 million tons of steel bar consumption in 2019" at SEAISI e-Conference on 2 July 2020. Reinforcement in any concrete element is very important to act in resisting forces and strengthens the concrete. The ability to absorb tensile, shear and compressive stresses makes the concrete structure become sturdier to withstand the external forces such as wind, vibration and earthquake or access load.

Nowadays bamboo is being addressed as a building material that can contribute to sustainable development. It is uniquely qualified because of its environmental, social and economic benefits. Bamboo has been used as a construction material due to its easy availability, ease of workability and its strength. Bamboo is stronger as a tensile member and it is recommended for use as horizontal members less than 3–3.6 m long without middle support. According to Paudel [3], bamboo has the potential to withstanding up to 3656 kg/cm2 of pressure 358.53 MPa.

The aim of this research is to evaluate the capability of bamboo strip in term of the tensile strength through an understanding of tensile test curve. The results obtained are compared with data from previous study.

2. Assessment of bamboo strips and concrete beam

The construction material that has almost the same behavior as steel bar will be discuss. The investigate for an elective fiber has been there since 1960. Many actually accessible strands have been utilized together with concrete. The purpose of such materials is to upgrade the mechanical properties of the plain concrete. One such normally accessible fiber is bamboo.

Past study on the performance evaluation of bamboo was done by J. K. Sevalia [4]. The three bamboo strips samples with length of 520 mm and thickness of 10 mm were used to take the tensile load. The result of tensile test shows that the bamboo has the ultimate tensile forces of 34 kN and the ultimate tensile strength reaching the value of 161.137 N/mm^2. From the observation, the failure of the samples was occurred looks like splitting of the fibers. The flexural strength test was conducted on bamboo reinforced concrete beam having a dimension of 130 mm × 130 mm × 750 mm beam specimens were reinforced with bamboo strips of length 730 mm. This test involved a plain cement concrete beam, singly reinforced cement concrete beam with two bamboo strips at the tension area without any stirrup and double reinforced cement concrete beam with two bamboo strips at top and bottom. The ultimate load of this sample is 11.65 kN then complete failure take place. For singly and doubly bamboo reinforced cement concrete beam has reaching 11.6 kN and 15 kN of ultimate load respectively.

3. Materials and Methods

The laboratory includes tensile test and three-point bending test had been conducted to find physical and mechanical properties of bamboo strips and concrete beam reinforced with bamboo. The data was analyzed to determine the tensile strength and capacity of bamboo strip, flexural strength and flexural modulus of bamboo reinforced concrete beam.

3.1 Materials

The material used in this study are coarse and fine aggregates, Portland cement, water, concrete mold, and bamboo strips.

3.2 Methods

Figure 1: Preparation of bamboo strips

For this study, the usage of the bamboo's strips was shaped in rectangle and square with dimension 10 mm × 10mm and 10 mm × 16 mm respectively to be used in tensile test and act as a reinforcement in concrete beam. Three sample of beam consist one unreinforced concrete beam and two BRC beam were designed and cast. All the concrete beam samples having same dimension which is 120×200×730 mm. The curing process has been done for 28 days.

3.3 Equations

The tensile stress, tensile strain, flexural modulus, flexural stress and flexural strain of rectangular beam were calculated using following equation:

$$Tensile\ stress, \sigma = \frac{F}{A} \qquad \text{Eq. 1}$$

$$Tensile\ strain, \varepsilon = \frac{displacement}{L} \qquad \text{Eq. 2}$$

$$Young's\ modulus = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \qquad \text{Eq.3}$$

$$Flexural\ strength, \sigma_1 = \frac{3PL}{2bd^2} \qquad \text{Eq. 4}$$

$$Flexural\ strain, \varepsilon_f = \frac{6Dd}{L^2} \qquad \text{Eq. 5}$$

$$Experimental\ flexural\ modulus, E_f = \frac{\sigma_f}{\varepsilon_f} \qquad \text{Eq. 6}$$

$$Theoritecal\ flexural\ modulus, E_f = \frac{L^3 F}{4bd^3 D} = \frac{L^3 m}{4bd^3} \qquad \text{Eq. 7}$$

4. Results and Discussion

In this study, the capability of bamboo strips and BRC beam was determined by observing the load-deflection and stress-strain curves. To obtain this result, the data was calculated and plotted from the raw data gained from the tensile test and three-point bending test. Then, the results were analyzed to achieve the objective.

4.1 Tensile test

From the figure 2. The result indicates the amount of load capacity and displacement for both specimens. The graph shows load acted on sample BS1 increasing linearly reaching 22.1 kN. Then, sudden drop of 18.87 kN load at extension of 4.69 mm before it starts to rise again. The second test was conducted on the BS2, the graph displays a sudden drop of load after it is reaching 9.63 kN at 2.98 extension before it shows the load increase directly proportional to displacement until it reaches 26.78 kN. From the observation, there is only a slight difference of ultimate load and extension between both specimens which is 17% increment.

The sample of BS2 has sligthly higher in tensile strength value which is 167.40 MPa compared to sample BS1, 138.21 MPa. From the result, it can be seen that there is no point where the data shows the bamboo strip is yielding. Further analysis was observing the range in which the stress is proportional to strain before the samples were deform. At this range, the young's modulus can be obtained by using theoretical calculation of linear gradient, as shown in Eq.3.

4.2 Three-point bending test

From the graph and table above, it shows the UCB sample has 35.60 kN of ultimate load at 2.20 mm deformation. Up to this point, the beam has shown major flexure crack at the middle and behave in a linear elastic manner. After this phase, a sudden failure of beam take place. For the sample BRC10 and BRC16 of bamboo reinforced concrete beam indicates the first crack load is about 32.01 kN and 34.27 kN respectively after it has surpassed the proportional limit. At the first crack, the BRC beam deflect up to 2.15 mm for BRC10 and 1.65 mm for sample BRC16. From the graph indicator for BRC10, it displays the load increasing linearly and constant about 40 kN to 41.5 kN until it is having increment about 7% reaching the ultimate load and complete failure at 16.83 mm deflection. The amount of load capacity of sample BRC16 reaching 6% increment compared to un-reinforced concrete beam with deflection at 4.31 mm before it shows the decreasing trend of load-deflection and total failure at 7.86 mm deformation.

The stress versus strain graph has been plotted as shown in figure 5 to observe the characteristic stages of stress and strain of the concrete beam. The stress-strain graph of concrete beam indicates the maximum flexural strength of sample BRC10 has the highest value which is 9.11 N/mm^2 compared with sample UCB and BRC16 which is about 17% of differences.

4.3 Discussions

The tensile test provides the average value of ultimate tensile strength of bamboo strips. The result shows bamboo material has very poor in tension giving average ultimate tensile strength of 152.81 N/mm^2 and average maximum tensile forces 24.45 kN without any yielding point. It can be seen that sample BS1 and sample BS2 start a simple deformation at different point, may be due to the low strength of fibers at the bamboo node. It can be seen that BS1 and BS2 start a simple deflection at different point, may be due to the low strength of fibers at the bamboo node. Both specimens have the same failure mode which is splitting at node. High value of young's modulus indicates that bamboo is a stiff material and change its shape only slightly under elastic loads.

From the analysis of result of three-point bending test, it can be seen that as the load increase, the stress will increase consequently. Failure of unreinforced concrete beam occurs at the early time of testing and low deflection. The experimental result shows the presence of bamboo reinforcement affects the increment of concrete beam capacity where it improved about 7% to 17% of load capacity and allows the beam to deflect more than control beam. The graph of sample of BRC beam undergoes an increase in strain without much increase in stress. BRC Beam clearly shows a point where this starts to occur and the stress at which this happens was taken as the yield strength which is 6.57 MPa and 7.09 MPa for sample BRC10 and BRC16 respectively. From the flexural strength analysis, it shows that strength of BRC beam improved significantly about 7% to 17% and proved that the presence of bamboo reinforcement in concrete beam can enhance the ability of beam to withstand higher impact load. The comparison between both bamboos reinforced concrete beam shows that sample BRC16 has low ductility than sample BRC10, this may be caused by the arrangement of longitudinal reinforcement and less bonding with the concrete. The calculation of flexural modulus displays the sample UCB has the highest value followed by sample BRC16 and sample BRC10. This analysis proved that the sample UCB is stiffer and has low ability to bend during the load action.

4.4 Tables

All tables below show the calculated and analyzed data of tensile test and three-point bending test.

Table 1: Statistical results of standard mechanical properties of tensile specimens.

Bamboo strip sample (10mm×16mm×280mm)	**BS1**	**BS2**	**Average**
Max. Tensile Force (kN)	22.11	26.78	24.45
Ultimate tensile strength (N/mm^2)	138.21	167.40	152.81
Young Modulus (N/mm^2)	11453.02	11623.70	11538.36
Breaking force (kN)	22.09	26.78	24.44

Table 2: Mechanical properties of each concrete beam samples

Sample	Maximum Load (kN)	Deflection (mm)	Flexural strength (N/mm^2)	Flexural strain	Flexural modulus (N/mm^2)	
					Theo.	Exp.
UCB	35.60	2.20	7.56	0.005713	1325.02	1323.30
BRC10	42.87	16.83	9.11	0.043680	208.58	208.56
BRC16	37.72	4.31	8.01	0.012254	716.62	653.66

4.5 Figures

Figures consist of load-deflection and stress-strain curve of tensile test and three-point bending test

Tensile test:

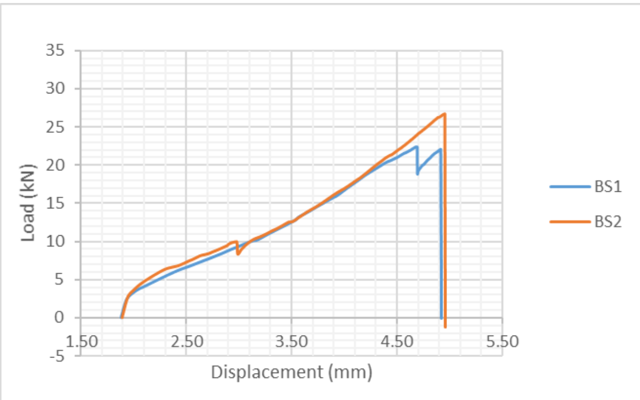

Figure 2: Load-displacement graph for both specimens.

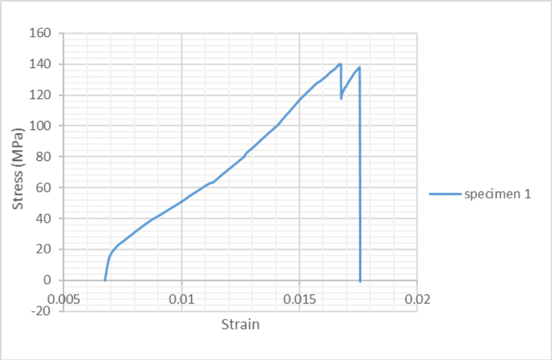

Figure 3: Result of stress-strain curve of BS1

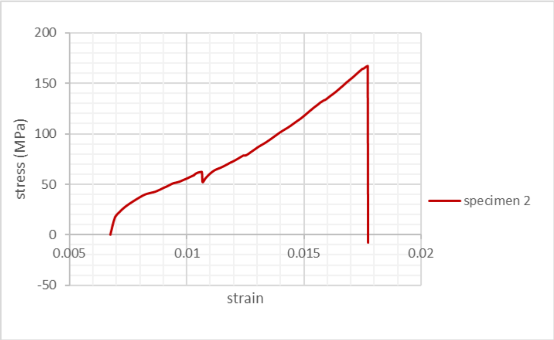

Figure 4: Result of stress-strain curve of BS2

Three-point bending test:

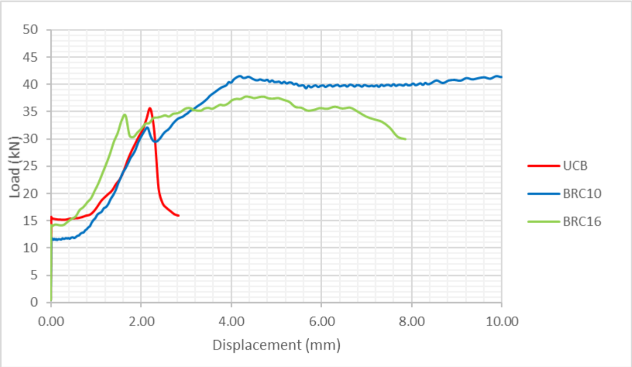

Figure 5: Load-deflection result

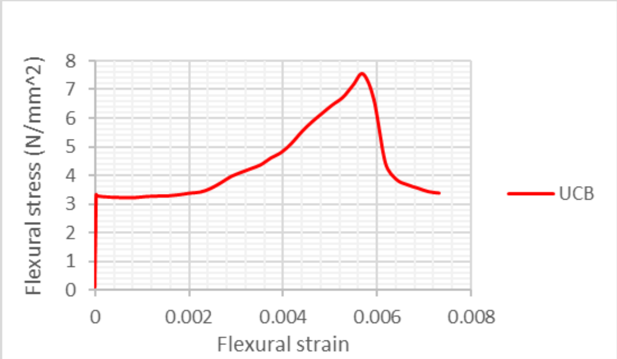

Figure 6: Stress-strain graph for sample UCB

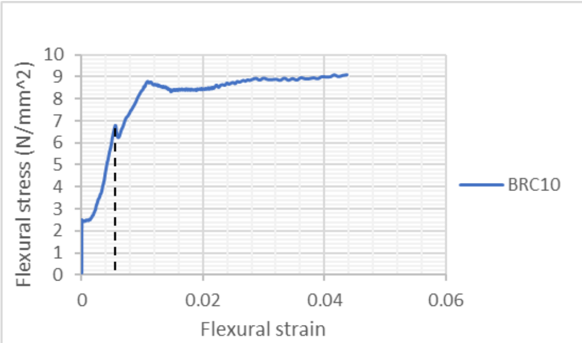

Figure 7: Stress-strain graph for sample BRC10

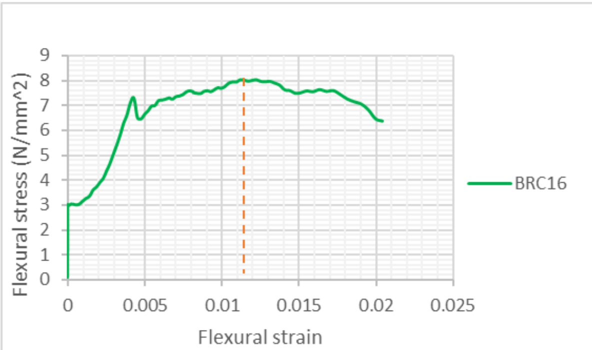

Figure 8: Stress-strain graph for sample BRC16

5. Conclusion

The result of tensile test was analyzed and compared with Ogunbiyi [5] research to examine their tensile properties. The tensile test result indicates that bamboo unlike steel has a very poor tensile property and undergoes brittle failure when loaded. This is a huge disadvantage of using bamboo as a structural member in building construction. Therefore, the study concludes that due to the minimal braking force (FB) of bamboo, it can be employed as a main structural member in buildings and lightweight engineering works.

The experimental result of three-point bending shows the presence of bamboo reinforcement could append the capacity of concrete beam where it improved about 7% to 20% of load capacity and allows the beam to deflect more than control beam. From the flexural strength analysis, it shows that strength of BRC beam improved significantly about 7% to 17% and proved that the present of bamboo reinforcement in concrete beam can enhance the ability of beam to withstand higher impact load. The flexural modulus result comparison shows that unreinforced concrete beam has high flexural modulus which is 1323.30 N/mm^2 while bamboo reinforced concrete beam has 208.56 to 653.66 N/mm^2. This result proved that concrete beam is characterized as a brittle material with low tensile strength and low strain capacity. Problems related to concrete brittleness and poor resistance to cracking can be improved by reinforcing plain concrete with bamboo strips as a reinforcement.

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