Performance Evaluation Of Bamboo Twig As A Potential Reinforcement In Concrete Considering Tensile Property

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ABSTRACT

This research was undertaken to evaluate the aptness of bamboo twig as reinforcement in concrete to compensate the low tensile property of the concrete. Even though steel reinforcement is a very suitable material for complementing concrete's low tensile strength, considering the high cost and general shortage of reinforcing steel in many parts of the world has led to increasing interest in the possible use of alternative locally available materials for the reinforcement of concrete. Since bamboo twig is a natural, cheap and also readily available material, it can be a substitute of steel in reinforcing of concrete. To assess this, tensile strength test of bamboo twig specimen having minimum three knots were performed. From this test, the tensile strength, proof strength and modulus of elasticity were determined from stress-strain curve for bamboo twig reinforcement and satisfactory results were obtained in terms of tensile strength and stress-strain characteristics of bamboo twig for using as reinforcement in the concrete.

***Keywords* - Bamboo twig, Potential Reinforcement, Stress-Strain, Tension test.**

1. INTRODUCTION

In today's society, most buildings are built using such materials as steel reinforced concrete and structural steel. Specifically, concrete is a high quality and economical material with its ability to support fire and earthquake defense in buildings constructed in developed and developing countries. Unfortunately, structural steel is not easy to find in many countries due to limited natural resources and lack of skilled labor. For the same reasons, use of steel reinforcement in concrete is not widespread. Some buildings in the world have been built of just plain concrete or bricks without steel reinforcement. These buildings typically cannot withstand the effects of natural disasters such as earthquakes, hurricanes and storms. Thus a suitable substitute of this with a low cost, environmental friendly and also a less energy consuming one, is a global concern; especially for developing country. Addressing all these problems, bamboo twig is one of the suitable replacements of reinforcing bar in concrete as it is available in almost every tropical and subtropical regions, this lowers the cost of construction and increases the strength of the buildings that would otherwise be unreinforced. Tension test is the most basic type of mechanical test and the stress strain characteristics of bamboo twig have been derived from the results of this tension test as a check of the feasibility to use bamboo twig as a reinforcement agent in concrete.

2. PREVIOUS RESEARCHES

Whereas the mechanical properties and behavior of steel reinforcement have been thoroughly studied and well documented, there exists no comprehensive data describing bamboo twig reinforcement. Some of the previous researches are mentioned on bamboo in connection with bamboo twig as bamboo twig is simple the branches of bamboo. The mechanical properties vary with height and age of the bamboo culm. Research findings indicate that the strength of bamboo increases with age. The optimum strength value occurs between 2.5 and 4 years. The strength decreases at a later age [1]. Amada et al. [2] investigated the mechanical and physical properties of bamboo. They conducted a thorough investigation into the structure and purposes of the nodes, which they found to strengthen the bamboo culm. Lo et al. [3] gave a detailed description of the mechanical properties of bamboo in their study. They found that the physical, as well as mechanical attributes vary with respect to diameter, length, age, type, position along culms and moisture content of bamboo. Different bamboo species perform differently for the same set of test [4]. Amada and Untao [1] studied the fracture properties of bamboo. In contradiction to other studies, this study states that the tensile strength of bamboo fibers almost corresponds to that of steel. Ghavami [5] discussed the mechanical properties of bamboo, specifically pertaining to bamboo in concrete. This study showed that the ultimate strength of a concrete beam reinforced with bamboo is approximately 4 times when compared with un-reinforced concrete. Further Ghavami [6] studied the mechanical properties of six different types of bamboo and their behaviour in concrete. The study concluded that bamboo can substitute steel satisfactorily.

3. PREPARATIONS OF BAMBOO TWIG SPECIMENS

Bamboo twig is naturally round in shape. Therefore, it was used directly in its natural shape as shown in Fig.1. But bamboo twig is relatively soft materials than the materials used for gripping purpose in UTM. At the time of tension tests, early failure was observed at the gripping end as shown in the Fig. 2, possibly due to high stress developed from lateral compression. Moreover, the surface of the bamboo twig specimen is very slippery and therefore the samples in some case experienced slip at the time of tension test and proper gripping is an important factor for tensile test. To solve these gripping problem GI wires (2mm diameter) were wringed spirally at both ends of the specimen as shown in Fig. 3. Finally 3 samples of bamboo twig of natural condition and 3 samples of bamboo twig with GI spiral were taken for tensile test each having the following criteria-

i. Each specimen enclosed at least 3 knots.
ii. Any form of imperfection (fracture, void, decay, etc) was avoided.
iii. Any undulation (side branches) was trimmed off.
iv. Outer diameter and inner diameter were measured at two different locations and then the average area was calculated.

Fig. 1: Bamboo Twig Specimen

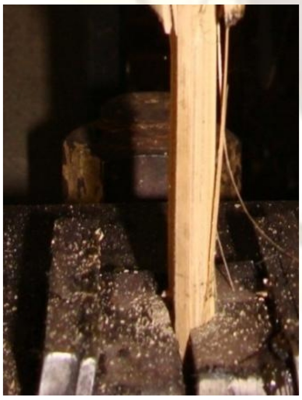

Fig. 2. Failure of the sample at Grip During Tension Test

Fig. 3. Bamboo Twig Specimen with GI Spiral

4. TEST SETUP

The purpose of tensile tests was to determine the tensile capacity of the selected bamboo twig specimens. The tensile strength test was performed using Universal Testing Machine (UTM) as shown in Fig. 4. Specimen (Bamboo twig) was placed in UTM and tensile load was being applied until rupture. To derive the stress-strain characteristics, the bamboo twig specimen was placed in such a way that strain measurement and the corresponding load can be taken by using a compressometer (Gage constant 0.01) with a constant gage length . The use of compressometer in taking strain is shown in Fig.5.

Fig. 4 Bamboo Twig Under Tension Test

Fig. 5 Use of Compressometer in Tension Test of Finished Bamboo Twig

5. RESULTS OF TENSION TEST

The first set of tensile tests was conducted on bamboo twig specimen having normal surface at grip area and second set of tensile tests was conducted on bamboo specimens having GI wire at grip area. Their failure pattern, ultimate and yield strength will be discussed in the following section.

5.1. RESULTS OF TENSION TESTS FOR BAMBOO TWIG SPECIMENS WITH NORMAL SURFACE AT GRIP AREA

According to the tensile test, the grip failure due to slippage of the smooth surface of the bamboo twig was observed for sample-1(Fig.6). The bamboo twig is also smashed at the grip. Therefore, it can be opined that if failure at grip would have been avoided, the specimen would take more load. The second and third sample experienced failure similar to sample-1 (Fig.7 and Fig.8). The failure loads of these samples are shown in Table 1.

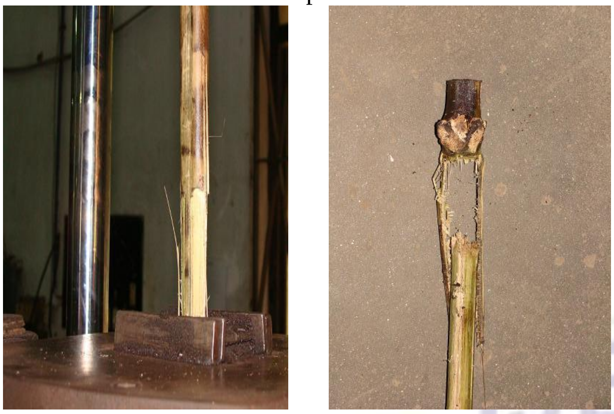

Fig. 6 Smashing and Slip Failure at the Grip (Sample-1)

Fig. 7 Smashing and Slip Failure at the Grip (Sample-2)

Fig. 8 Slip Failure at the Grip (Sample-3)

Table 1: Results of Tension Test for Bamboo Twig Specimens

Specimen no.	Area (mm^2)	Failure Load (kN)	Stress at Failure (MPa)	Failure type
1	181	15.8	82.3	Grip failure
2	181	20.7	114.4	Grip failure
3	207	18.5	89.4	Grip failure

5.2. **RESULTS OF TENSION TESTS FOR BAMBOO TWIG SPECIMENS WITH GI WIRE AT GRIP AREA**

During tension tests of bamboo twig specimen, an attempt was made to avoid failure at the grip by wrapping the ends by GI wire as shown in Fig.9. According to the test, the failure pattern of bamboo twig specimen was typical splitting without any slip at the grip location as shown in the Fig.9. The split is parallel to the grain and propagates through the knot and finally failure occurs at the knot location. The failure patterns of other two samples are similar to sample no-1 as shown in the Fig. 10 and Fig. 11. The failure loads of these samples are shown in Table 2.

Fig. 9 Typical Tensile Failure at Knot between Grips (Sample-1)

Fig.10 Typical Tensile Failure at Knot between Grips

(Sample-2)

Fig. 11 Typical Tensile Failure at Knot between Grips (Sample-3)

Table 2: Results of Tension Test of Bamboo Twig Specimen With GI Wire at Grips

Sample no.	Area (mm^2)	Failure Load (kN)	Stress at Failure (MPa)	Failure type
1	173	27.2	157	Tensile failure at node
2	101	15	149	Tensile failure at node
3	113	20	177	Tensile failure at node

From these results it can be said that the tensile strength is nearly uniform and failure pattern is very similar for bamboo twig specimens where failure at grip was avoided. The tensile strength of bamboo twig specimens with prepared ends (to avoid grip failure) is always higher than the corresponding bamboo twig specimens without prepared ends (failure at grip).

6. STRESS STRAIN RELATIONS

Stress-strain data are shown for sample-1 and sample-2 in the Table 3 and Table 4. The gage length was taken between 203 mm and 254 mm for all the samples. The stress-strain curve for sample-1 and sample-2 is shown in Fig. 12. From this curve the yield strength has been calculated by offset method. The offset is the horizontal distance between the initial tangent line and any line running parallel to it. The value of the offset for a given material is usually expressed this way: Yield Strength, 0.1% Offset. "0.1% Offset" means 0.1% of the fundamental extension units of inches per inch, or 0.001in./in. along the X-axis. Now using that as the origin, a line (C-D) parallel to the initial tangent line was drawn. It is be noted that the line C-D intersects the stress- strain curve at a certain point Y shown in the Fig. 13. The ordinate of this point (the amount of stress in psi) is the yield strength at 0.1% Offset.

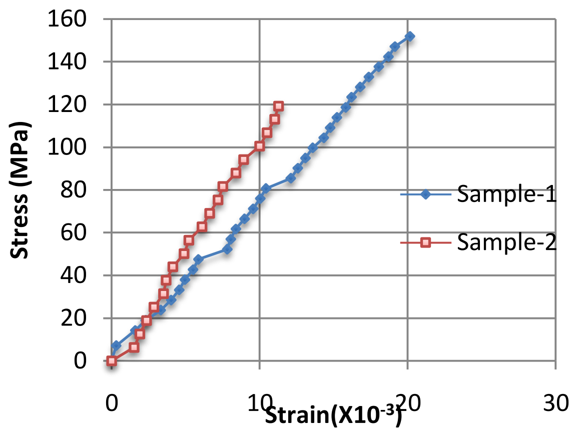

Fig. 12 Stress-Strain Curve for Bamboo Twig Samples

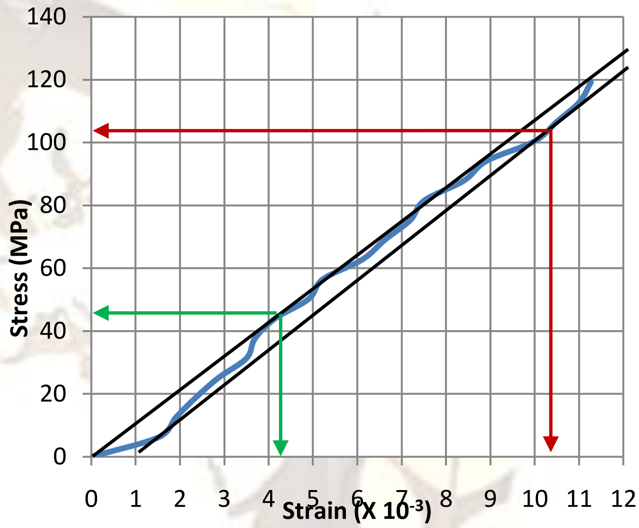

Fig. 13 Stress-Strain Curve for Bamboo Twig Sample

Table 3: Stress-Strain Data for Bamboo Twig Sample-1

Load	Area (mm^2)	Stress (MPa)	Displacement (mm)	Strain(X 10^{-3}) (mm/mm)
0.0	185	0.0	0	0
1.3	185	7.1	0.08	0.31
2.6	185	14.2	0.41	1.6
3.5	185	19.0	0.59	2.3
4.4	185	23.7	0.85	3.32
5.3	185	28.5	1.03	4.02
6.2	185	33.2	1.17	4.57
7.0	185	38.0	1.27	4.96
7.9	185	42.7	1.41	5.51
8.8	185	47.5	1.5	5.86
9.7	185	52.2	2	7.81
10.6	185	56.9	2.06	8.05
11.4	185	61.7	2.15	8.4
12.3	185	66.4	2.3	8.98

13.2	185	71.2	2.45	9.57
14.1	185	75.9	2.57	10.04
15.0	185	80.7	2.67	10.43
15.8	185	85.4	3.1	12.11
16.7	185	90.2	3.22	12.58
17.6	185	94.9	3.35	13.09
18.5	185	99.6	3.48	13.59
19.4	185	104.4	3.67	14.34
20.2	185	109.1	3.78	14.77
21.1	185	113.9	3.9	15.23
22.0	185	118.6	4.05	15.82
22.9	185	123.4	4.15	16.21
23.8	185	128.1	4.3	16.8
24.6	185	132.9	4.45	17.38
25.5	185	137.6	4.62	18.05
26.4	185	142.4	4.79	18.71
27.3	185	147.1	4.9	19.14
28.2	185	151.8	5.16	20.16

Table 4: Stress-Strain Data for Bamboo Twig Sample-2

Load (kN)	Area (mm^2)	Stress (MPa)	Displacement (mm)	Strain(X 10^{-3}) (mm/mm)
0.0	140	0.0	0	0.00
0.9	140	6.3	0.24	1.53
1.8	140	12.6	0.3	1.91
2.6	140	18.8	0.37	2.36
3.5	140	25.1	0.45	2.87
4.4	140	31.4	0.55	3.50
5.3	140	37.7	0.58	3.69
6.2	140	43.9	0.65	4.14
7.0	140	50.2	0.77	4.90
7.9	140	56.5	0.82	5.22
8.8	140	62.8	0.96	6.11
9.7	140	69.0	1.04	6.62
10.6	140	75.3	1.13	7.20
11.4	140	81.6	1.18	7.52
12.3	140	87.9	1.32	8.41
13.2	140	94.1	1.4	8.92
14.1	140	100.4	1.57	10.00
15.0	140	106.7	1.65	10.51
15.8	140	113.0	1.73	11.02
16.7	140	119.2	1.77	11.27

Therefore, from this method, the yield strength was found f_y = 112.5 MPa.
To be on the conservative side the value of f_y=105.7 MPa.
The modulus of elasticity was found to be 10000 MPa.

7. CONCLUSION

Based on the experimental studies presented in this paper, the following conclusions can be summarized:

(i) If tension tests were conducted without specimen end preparation, actual results may not be found due to smashing at the grip location but if the grip is prepared by using GI wire then no smashing and slippage occurs at that location. Without end preparation, the strength is considerably low because of premature failure at the grip.

(ii) In general, sample failure was accompanied by failure at knot.

(iii) In case of specimens (bamboo twig) with ends wounded by GI wire, the tensile strength failure was observed is nearly uniform and their failure pattern is also similar as splitting parallel to the grain. The average tensile strength of bamboo twig specimens with prepared ends (wounded with GI wire) has been found to be higher than the specimens without prepared ends.

(iv) The stress-strain relation of bamboo twig specimen is found to be almost linear up to its failure load.

(v) The modulus of elasticity, E of bamboo twig is found to be much lower than the steel reinforcement. Therefore, the deflection will be higher considering the steel reinforcement.

(vi) Knot has been found to be the weak point for bamboo twig specimen when subjected to tension.

REFERENCES

[1] S. Amada and S. Untao, Fracture Properties of Bamboo, *Composites Part B. Vol. 32, 2011*, 451-459.

[2] S. Amada, et al., Fiber Texture and Mechanical Graded Structure of Bamboo, *Composites Part B, Vol.288, 1997, 13*-20.

[3] Lo. Cuo, Leung, The Effect of Fiber Density on Strength Capacity of Bamboo, *Materials Letter, vol.58, 2004,* 2595-2598.

[4] U.S. Naval Civil Engineering Laboratory, *Bamboo Reinforced Concrete Construction*, (1766, 2000) (http://www.romanconcrete.com/docs/bamboo1966/ Bamboo Reinforced Concrete, Accessed 13/05/2000).

[5] K. Ghavam, Ultimate Load Behavior of Bamboo-Reinforced Lightweight Concrete Beams, Cement & Concrete Composites, *Vol.17, 1995,* 281-288.

[6] K. Ghavami, Bamboo as reinforcement in structural concrete elements, Cement and composites, *Vol.27, 2005*, 637-649.