PERFORMANCE EVALUATION OF BAMBOO AS REINFORCEMENT IN CONCRETE

M. R. Awall*, M. H. Ali, M. A. Rahman, M. A. Hossain & S. U. Khan

Department of Civil Engineering, Rajshahi University of Engineering & Technology, Rajshashi, Bangladesh
**Corresponding Author: robi95@gmail.com*

ABSTRACT
Bamboo is a low cost construction material and is available in Bangladesh. So, it is more effective and economic in rural construction. Usually steel is used as reinforcement in concrete, but it is costly than any other materials. If bamboo is used as the replacement of steel, then the rural people can build bamboo reinforced concrete building. In this study, performance of bamboo as reinforcement in concrete has been investigated. Strength property of bamboo is observed by tensile test of bamboo sticks and suitability of bamboo as reinforcement in concrete has been evaluated by testing of slab and beam. Three types of sample having without node, middle node and node at a distance L/4 of single and double seasoned are used for tensile test. Also, three types of beam are used for flexural test, namely plain concrete beam, single reinforced beam and doubly reinforced beam having same dimensions 750 mm length, 200 mm width and 250 mm depth. Again, two identical two way slabs of 750 mm width, 1200 mm length and 150 mm depth are used for slab test. In singly reinforced concrete beam the load carrying capacity is found about 2.2 times and for doubly reinforced beam about 3.0 times more than plain concrete beam. The ultimate load carried by slab is 78 kN and corresponding deflection is 2.17 mm. The doubly seasoned stick can increase the tensile and flexural stresses than single seasoned.

Keywords: Bamboo; reinforcement; seasoned stick; concrete beam; slab; flexural stress.

INTRODUCTION
As Bangladesh is a developing country, the cost of housing is a major consideration. Although most of the houses in rural areas are made of wood, bamboo, brick which are easily available. Concrete is widely used construction material for its various advantages such as low cost, availability, fire resistance etc. But it cannot be used alone everywhere because of its low tensile strength. Therefore, generally steel is used in reinforce concrete. Though steel has a high tensile strength to complement the low tensile strength of concrete, use of steel should be limited since it is very costly and so much energy consuming in manufacturing process. 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 is one of the suitable replacements of reinforcing bar in concrete for low cost constructions. Bamboo is natural, cheap, widely available and most importantly strong in both tension and compression. 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 and the strength decreases at a later age (Amada and Untao, 2001). The function of the nodes is to prevent buckling and they play a role of axial crack arresters. The tensile strength of bamboo can reach up to 370 MPa, which makes bamboo an attractive substitute to steel in tensile loading applications (Rahman et al., 2011).
Janseen (2000) conducted her study on Bamboo reinforced building and discusses the joints and building with pure Bamboo. Listed in her book are several things that are more of a hassle than steel reinforcement. Of those, the bonding between the Bamboo and concrete is considered the biggest problem due to absorption of water and smooth wall of the Bamboo culm. Vengala et al. (2004) constructed a prototype Bamboo reinforced concrete house and used an earthquake simulator to find that the house stood sound during a 7.8 (on the Richter scale) earthquake. They found no cracking in the concrete, the Bamboo to be extremely resilient to earthquakes, and the cost to be split in half compared to mud and brick construction. Lo et al. (2004) and Amada et al. (1997) 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. They also commented on the advantage of Bamboo has over other natural building materials with its fast growth rate. Amada and Untao (2001) 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. The main discovery is that the fracture properties of Bamboo depend upon the origin of fracture. Ghavami (1995, 2004) discussed the mechanical properties of Bamboo, specifically pertaining to Bamboo in concrete. This study showed that the ultimate load of a concrete beam reinforced with Bamboo increased about 400% as compared to un-reinforced concrete. It was found that, compared to steel, there was lower bonding between the Bamboo and concrete, and the Bamboo had a Modulus of elasticity 1/15 of steel. This study concluded that Bamboo can substitute steel satisfactorily, and that there is a need to establish the characteristic strength of Bamboo for design purposes. In the current study, tensile property of bamboo is observed and performance of bamboo as reinforcement in concrete with replace of steel has been thoroughly investigated.

METHODOLOGY

Bamboo

Bamboo is a composite material, consisting of long and parallel cellulose fibres embedded in a ligneous matrix. The density of the fibres in the cross-section of a bamboo shell varies along its thickness. In this study, bamboo was given consideration for using as reinforcement for the construction of low-cost houses in Bangladesh. As a high demand of occupy houses in Bangladesh is highly increasing. Therefore, urgent and effective action is required to secure the demand in sustainable basis. Most bamboos are hollow. In the hollow inner area, some horizontal partitions called diaphragms. On the outside, these partitions are denote by a ring around the culm. A diaphragm and the ring on the outside together form a “node”. Branches grow from these nodes. The part between two nodes is called an inter-node. The internodes of most bamboos are hollow. They have a cavity. The wall of the culm is called simply the culm wall as shown in Fig. 1.

Preparation of bamboo sticks

Bamboo preparation is essential for increasing its durability, long life and to prevent it from insects. After cutting the bamboo plant, it should be allowed to dry and season involves immersing the culms in stagnant or running water for four to six weeks to leach out the sugars. After that the wet bamboos are air-dried under shade. Air drying is necessary before using the bamboo as reinforcement for preventing

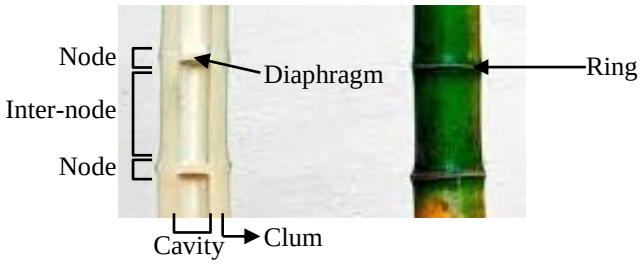

Fig. 1: Various parts of Bamboo culm

contraction and shrinkage because it may contain 50-60% moisture content depending on the season, area of growth and species. Usually, one or two weak is used for full air drying (Janseen, 2000). During cutting great care should be taken not to split the specimen, because splitting will result in continuous tearing of fiber. Bamboo sticks are cut according to the size of the specimen and allowed to dry and again season for 30 days. When seasoned bamboo either split or whole is used as reinforcement, it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking and the member may be damaged. A dip coat of asphalt emulsion is used in this study shown in Fig. 2.

Tensile test of bamboo sticks

Bamboo sticks are generally more popular than whole culms in construction works. In order to conduct the tensile strength test, bamboo stick samples are cut of 750 mm length and around 25 mm width shown in Fig. 3. The first set of tensile tests was conducted on bamboo samples having without node, second set of tensile test was conducted on bamboo sticks having single node at middle and third set of tensile test was conducted having node at L/4 distance. These all three sets are taken as single seasoned; also another set is taken doubly seasoned. Specimen was placed in Universal Testing Machine (UTM) and tensile load was being applied until failure. During these tensile tests, all tensile specimens were failed at node point. The maximum tensile strength is obtained for the sample having node at L/4 distance and tensile stress is increasing 6.4% in double seasoned stick than single seasoning shown in Table 1.

Fig. 2: Preparation of bamboo sticks (a) Seasoning (b) Air drying (c) Asphalt emulsion coating

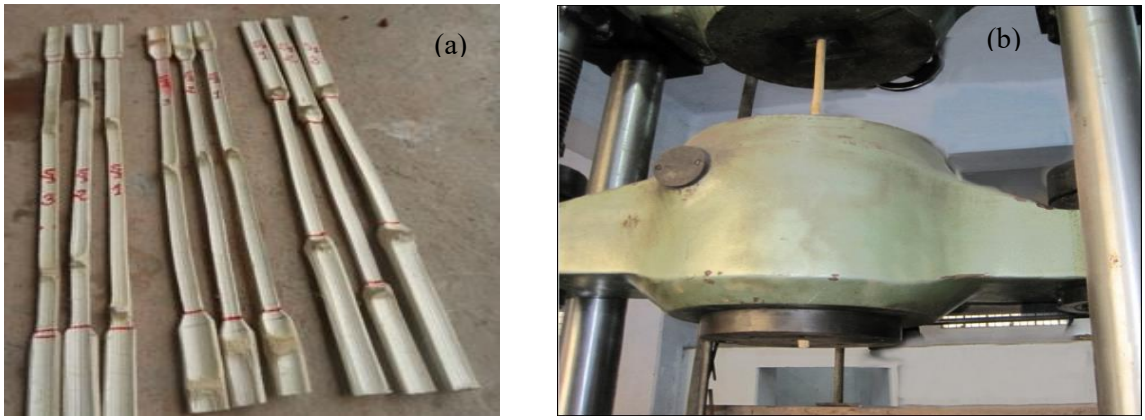

Fig. 3: Tensile strength test of bamboo sticks (a) bamboo sticks (b) testing under UTM machine

Table 1: Tensile stress of bamboo specimens

Seasoned type	Specimen type	Sample no.	Average Area (mm^2)	Ultimate load (kN)	Stress (MPa)	Average Stress (MPa)
Single seasoned	Without node (S_1)	1	177	22	124.30	118.5
		2	174.33	22	126.20	
		3	200	21	105.00	
	Middle node (S_2)	1	185	19	102.70	116.72
		2	197	23	116.75	
		3	153	20	130.71	
	Node at L/4 (S_3)	1	148.33	20	134.83	132.84
		2	162	21	129.60	
		3	141.67	19	134.11	
Doubly seasoned	Node at L/4 (S_3)	1	154.5	22	142.39	141.31
		2	147	21	142.86	
		3	137	19	138.67	

Preparation and testing of beam and slab

In this research, three types of beam were used namely plain concrete beam, singly reinforced beam and doubly reinforced beam having same dimensions. In plain concrete beam, no bamboo stick was used. Three bamboo sticks were placed at the bottom with 25 mm clear cover in singly reinforced beams. Similarly, three bamboo sticks were placed at the top and bottom with 25 mm clear cover in the case of doubly reinforced beams shown in Fig. 4. When placing the bamboo, the top and bottom of the stems were altered in every row and the nodes were staggered. This ensured a fairly uniform cross-section of the bamboo reinforcement throughout the length of the member, and the wedging effect was obtained at nodes increased the bond between concrete and bamboo. After 28 days curing, beam was carefully placed under the testing machine (UTM) and supports were placed at the measured location of 100 mm inside from each end. Dial gauges were also provided at mid-span to calculate the deflection. After placing the beam, one point loading at the mid-span of the beam was applied gradually by controlled pumping unit. The deflection of the beam at mid-span was measured at regular interval of loading shown in Fig. 5.

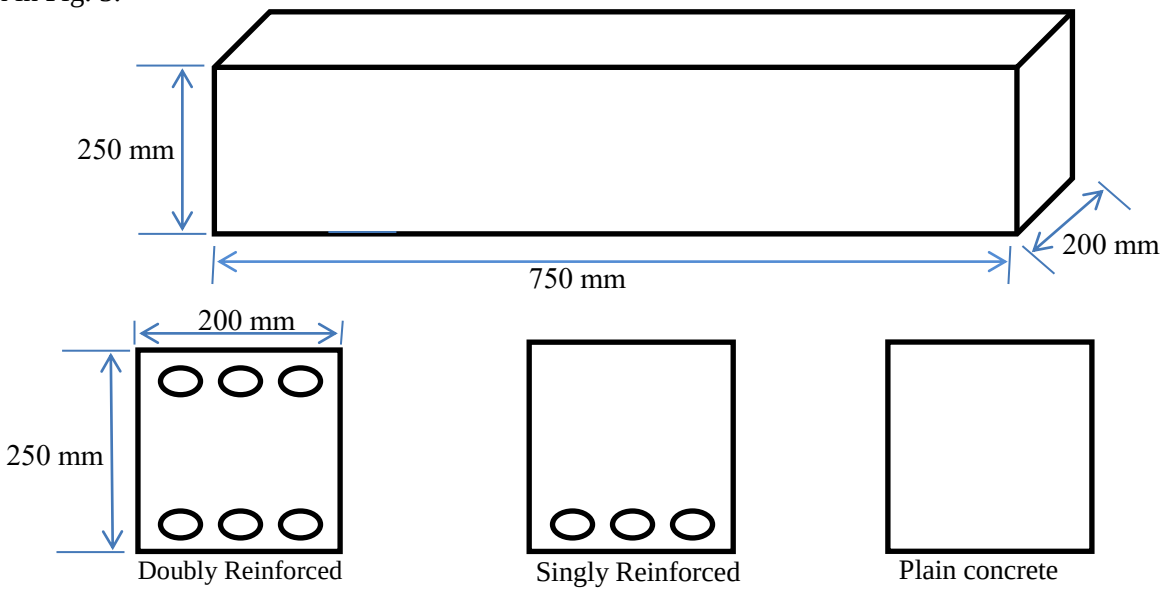

Fig. 4: Dimensions and cross-section of sample concrete beam

Fig. 5: Flexural test of beam

Fig. 6: Flexural test of slab

Also two identical two way slabs were used in dimension 1200 mm length, 750 mm width and 150 mm depth. Clear cover 25 mm is provided and bamboo reinforcements having uniformly spaced from center to center are ensured. After 28 days curing, slabs are tested under the universal testing machine (UTM). Dial gauges were also provided at mid-span to calculate the deflection. After placing the slab, line loading along length at the mid-span of the beam using I-beam was applied gradually by controlled pumping unit shown in Fig. 6.

RESULTS AND DISCUSSIONS

Load-deflection curves of bamboo reinforced concrete beams are shown in Fig. 7. The ultimate load carrying capacity of plain concrete beam, singly reinforced with single seasoned (SB-SS), singly reinforced with double seasoned (SB-DS), doubly reinforced with single seasoned (DB-SS) and doubly reinforced with double seasoned (DB-DS) beam were found to be 32 kN, 66 kN, 67.5 kN, 88 kN and 89 kN respectively. Also the corresponding deflections were 0.69 mm, 2.94 mm, 3.11 mm, 3.90 mm and 3.92 mm respectively. From the test results, it can be observed that the maximum deflection of singly and doubly reinforcement beams are 4.5 and 6 times larger than the plain concrete beam respectively. Also in singly reinforced concrete beam (SB) the load carrying capacity is found about 2.2 times and in doubly reinforced beam (DB) about 3.0 times more than the plain concrete beam (PB). The doubly seasoned (DS) stick can increase 3% flexural stresses and 6% tensile stress than single seasoned (SS) stick. The ultimate load carried by slab is 78 kN with corresponding deflection 2.17 mm shown in Fig. 8. Flexure failure was occurred in each slab. From the test conditions, bamboo can potentially be used as substitute for steel reinforcement with treatment to control water absorption and to increase the bond. Steel reinforced concrete structures built in the past 30 years can reveal serious deterioration caused mainly by the corrosion of the steel reinforcement. Ghavami (2005) tested the bamboo reinforced beam, after that it has been exposed in open air climate. It can be observed that the

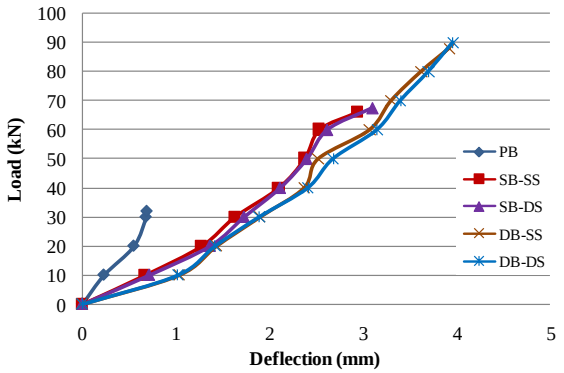

Fig. 7: Load-deflection curve of bamboo reinforced concrete beam

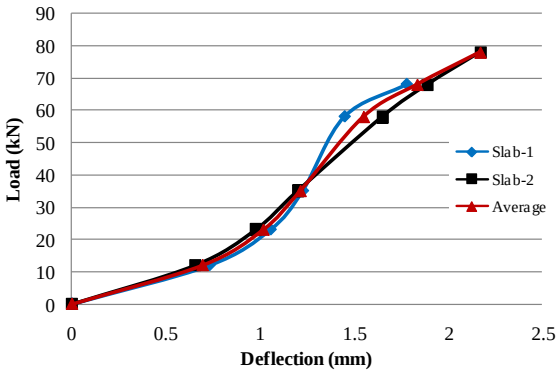

Fig. 8: Load-deflection curve of bamboo reinforced concrete slab

bamboo sticks of the beam reinforcement, treated against insects as well as for bonding with concrete, is steel satisfactory condition after 15 years. Therefore, the durability analysis shall be done before

employing it in important construction. Tensile strength of the bamboo shall be tested before designing structural members as it varies on soil condition, topography, water table, water absorption etc.

CONCLUSIONS

For developing country like Bangladesh, the cost of housing is a major concern to the poor or, low-income people. Steel is mainly used as reinforcement which is very costly. Scientists and engineers are seeking for new materials as substitute of steel, the idea of using bamboo as reinforcement has gain popularity due to cheap, natural and also readily available. From test results, the load carrying capacity of singly bamboo reinforced concrete beam is increased about 2.2 times and that for doubly bamboo reinforced beam about 3.0 times than plain concrete beam having same dimensions. The ultimate load carried by slab is 78 kN with corresponding deflection 2.17 mm.The doubly seasoned bamboo sticks are more effective than single seasoned bamboo sticks. Tensile strength of bamboo is good enough. Bamboo is week at node section and major failure occurs at node point. In the green material concept, the replacement of steel reinforcement can be possible by using bamboo for low cost construction. Moreover, there is a need to establish more characteristic strength of bamboo for design purpose based on experimental and rigorous statistical analysis.

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