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Strengthening of RCC Beams Using Bamboo Sticks

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Abstract

Because of quite high tensile strength, economical and locally available; bamboo can be used as a natural retrofitting material for the strengthening of RCC beam. The performance of bamboo sticks are investigated in this paper as retrofitted material. Three set of RCC beams of same dimension (width 4", thickness 6" and span 5.5') are tested up to ultimate load by one point loading system as a simply supported beam. These beams are addressed as S-1(a), S-1(b), S-1(c), S-2(a), S-2(b), S-2(c), S-3(a), S-3(b) and S-3(c) according to their set. Beams S-1(a), S-1(b) and S-1(c) are made without strengthening. The Beams S-2(a), S-2(b), S-2(c) is subjected to one layer of bamboo sticks only the bottom surface of beam. And another three beams of S-3(a), S-3(b), and S-3 (c) are strengthened by one layer of bamboo sticks on three sides of beams. After that they are tested and a comparison has been made on cracking load, ultimate load and deflection between the beams of with and without bamboo. Also a graphical representation indicates difference between the sets of two strengthening system. From this paper we can understand that the beams of three side bamboo layer (repairing) give comparatively good performance.

Keywords: *Bamboo stick, beam, strengthening, cracking load, ultimate load and deflection*

1. Introduction

In a developing country the cost of building retrofitting is a major consideration. Due to modernization of buildings, it is sometimes desirable to remove supporting walls or individual supports, leading to the need for local strengthening. Retrofitting is the process of introducing specific elements or features into an existing structure so as to improve its resistance against natural disasters like earthquakes and cyclones. And in another word repairs are taken up on damaged buildings to restore loss of strength after a disaster. The various retrofitting techniques are exist include steel plate bonding, polymer injection followed by concrete jacketing, use of advanced composite materials like FRP, Ferro cement *etc*. [6] External bonding of steel plates to damaged reinforced concrete structures is one of these methods and has been shown to be quite an efficient and a well- known repair or strengthening technique. It has been largely studied in France (L. Hemite, 1967), (Bresson, 1971) and intensive research performed in the beginning of the eighties (Theillout, 1983) results in French rules concerning the design of those structures (SOCOTEC, 1986).

The use of composite materials represents an alternative to steel as it can avoid the corrosion of the plate. FRP materials are also very lightweight, have a high strength to weight ratio and are generally resistant to chemicals. The price of these materials, especially of Carbon Fiber Reinforced Plastics (CFRP), could represents a drawback but the ease in handling the material on construction sites, due to the light weight, helps to reduce labor costs. This technique has been largely investigated especially in Switzerland

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(Meier, 1995) where existing structures have been retrofitted using epoxy-bonded composite materials.

A new natural retrofitting material bamboo which grows in many parts of the developing country and now a days it is planted artificially because of various purposes. There are various retrofitting materials in the world but the cost effective materials like bamboo may use structural purpose as well as aesthetical purpose. The bamboo sticks have been used in beam reinforcement because of their good load deformation, crack control and tensile strength.

RCC beam is the most important integral part of a structure. If the strength of the beam built as designed, could be predicted accurately and if the loads and their effects were known accurately, safely could be measured by providing a carrying capacity just barely in excess of the known loads. However, there are a number of sources of uncertainty in the analysis, design and construction of the reinforced concrete beam. In a developing country it is not possible to replace all the older structures which were failed by new ones. But experimental investigation shows that it is more feasible to rehabilitate them of load carrying capacity of beam. From both the economical and strength point of view in a developing country, it can be designed such a beam which will be less in cost, strong enough to resist the failure resulting from the external, internal load *etc*.[6] Considering this condition the reinforcement concrete beam can be needed to be repair by using bamboo sticks.

2. Objective with Specific Aims

Beam is that part of a building which may produce important effect on that structure. The objective of this study is to make a comparison on strengthening of reinforcement concrete beam using bamboo sticks. The following objectives of this investigation are as follows:

1) To compare the strength, first cracking load, ultimate load, deflection between the beam before and after repair with bamboo sticks.

2) To investigate the performance on strength of two types strengthening system by bamboo sticks.

3) Give a reasonable strength to the cracked beam.

3. History of Bamboo

The word bamboo comes from Kannada term bamboo, which was introduced to English through Malay. [2] Bamboos are some of the fastest-growing plants in the world, [3] due to a unique rhizome-dependent system. Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia, being used for building materials, as a food source, and as a versatile raw product. Bamboo has a higher compressive strength than wood, brick or concrete and a tensile strength that rivals steel [4, 5].

4. Properties of Used Materials

Here bamboo is used as retrofitting material which is collected from local market. For RCC beam steel (40 G), Cement (Ordinary Portland, and confirm to ASTM C-150), sand (Collected from Tista river, Rangpur which is locally called Domer sand) and Khoa (Brick chips) are used.

The basic properties of used materials are presented by Table 1.

Table 1. Basic Properties of used Materials

SL No.	Properties of Materials	Test Results	Figure
Steel			
1	Bar type	Deformed bar	
2	Bar diameter	1/2 ″	
3	Average yield strength	39.47 ksi	
4	Bending	ok	
Bamboo Sticks			
1	Average size	1/2"	
2	Tension strength	17.78 ksi	
3	compressive strength	10.24 ksi	
Cement			
1	Compressive strength	23.5 ksi (28 days)	
Sand			
1	Fineness Modulus	2.98	
2	Water content	0.5%	
3	Density	101.50 pcf	
4	Specific gravity	2.59	
Water			
Ordinary potable drinking water free from organic matter, silt, oil, sugar, chloride and acidic material was used for mixing.			

5. Methodology

5.1. Test Specimen

In the investigation, there are three set beams of length 6ft-8in, width 4in and thickness 6in, reinforced with two bars of #4 in tension and two bars of #3 in compression. Among these three set of beams one set (three beams which are addressed as S-1(a), S-1(b) and S-1(c)) was tested without strengthening, another one set (three beams which are addressed asS-2(a), S-2(b) and S-2(c)) was subjected to strengthen by four no bamboo sticks (size ½ ") at the bottom surface of beam @1" C/C and they were tested. Rest one set (three beams which are addressed as S-3(a), S-3(b) and S-3(c)) was subjected to strengthen by four no bamboo sticks (size ½ ") at the bottom surface of beam @1" C/C and five no bamboo sticks (size 1/2") at two sides of beam @ 1.25" C/C and they were tested again.

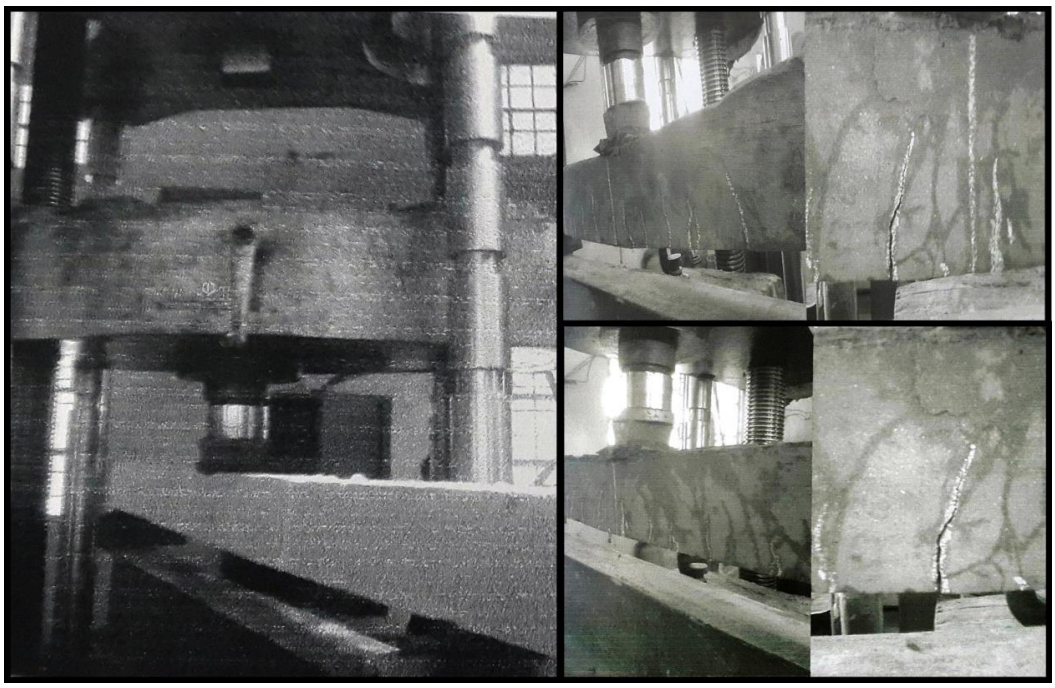

Figure 1. Experimental Setup and Testing Arrangement of Specimens

5.2 Test Setup

After painting and coating period, all the three set beams were tested as simply supported with an effective span of 5.5ft; deflectometer was fixed at mid-point of the beam of its tension face of each specimen. A universal testing machine was used to load the specimen. For all the beams deflection at different loads were measured. The beams were subjected to one point loading. The loading is gradually increased from zero until the beams were near to fail. Deflectometer reading was record with a specific time interval for each loading. Increments of load were decided so that a representative load-deflection curve could be realized.

6. Test Result

Different cracking loads with three corresponding deflection were recorded during testing. We also recorded the ultimate load of the beams and their corresponding deflection. To know the comparison between the normal beam and repaired beam first we have to make a table showing the loads and corresponding deflection. The tables are showed below:

Table 2. Results of Cracking Loads and Ultimate Loads with Deflections of Beam Set 1

Beam Set 1						Average	
S-1(a)		S-1(b)		S-1(c)		Ultimate Loads (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0		
2.45	0.034	2.50	0.035	2.55	0.033		
4.10	0.090	4.00	0.089	3.89	0.087	**5.00**	**0.679**
4.88	0.240	4.90	0.236	4.92	0.240		
5.00	0.700	5.00	0.667	5.01	0.670		

Table 3. Results of Cracking Loads and Ultimate Loads with Corresponding Deflections of Beam Set 2

Beam Set 2						Average	
S-2(a)		S-2(b)		S-2(c)		Ultimate Loads (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0		
3.54	0.076	3.15	0.079	3.49	0.078		
4.89	0.343	5.15	0.333	6.57	0.466	**8.230**	**1.150**
6.42	0.757	7.01	0.756	7.71	0.801		
7.29	1.213	8.52	1.206	8.88	1.031		

Table 4. Results of Cracking Loads and Ultimate Loads with corresponding Deflections of Beam Set 3

Beam Set 3						Average	
S-3(a)		S-3(b)		S-3(c)		Ultimate Loads (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0		
3.97	0.079	4.23	0.097	3.74	0.1		
6.25	0.449	6.75	0.379	6.59	0.458	**9.220**	**1.162**
8.23	0.785	7.98	0.814	8.11	0.754		
8.99	1.225	9.15	0.997	9.52	1.263		

7. Graphical Representation

The load Vs deflection curves indicated by the graphical representation which provides the strength performance of the beams. These graphs are very important to know the rate of increasing strength before and after strengthening with bamboo layer. By our experimental data we made the graph for three set beam with and without bamboo sticks.

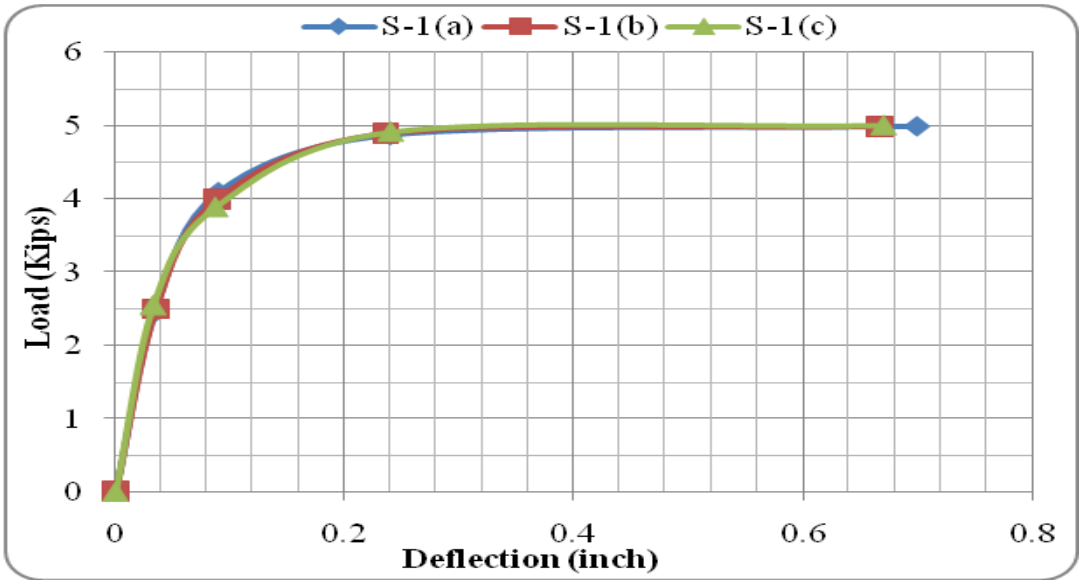

Figure 2. Load (Kips) Vs Deflection Curve of S-1(a), S-1(b) & S-1(c)

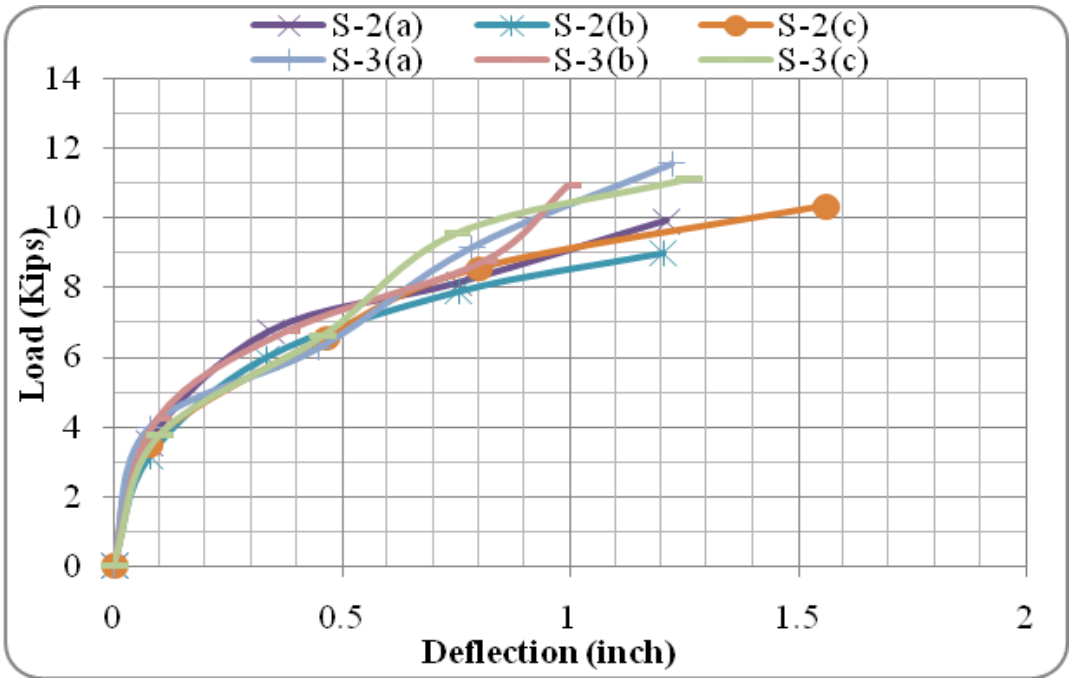

Figure 3. Load (Kips) Vs Deflection Curve of S-2(a), S-2(b), S-2(c) & S-3(a), S-3(b), S-3(c)

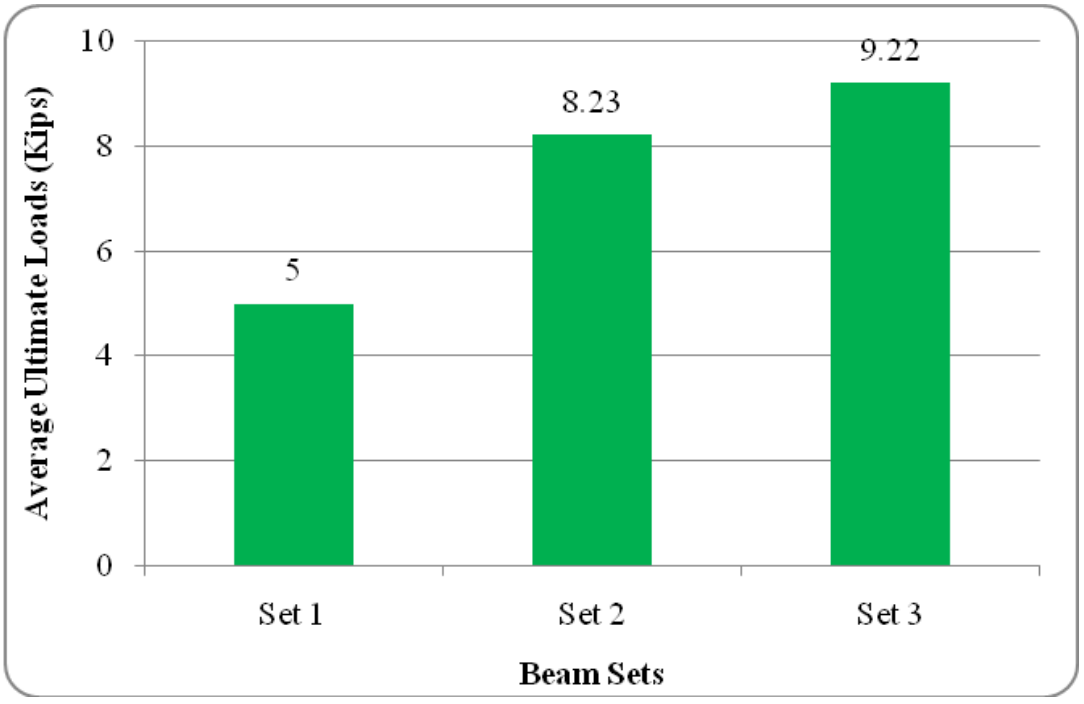

Figure 4. Ultimate Load Carrying Capacity of 3 Beam Sets

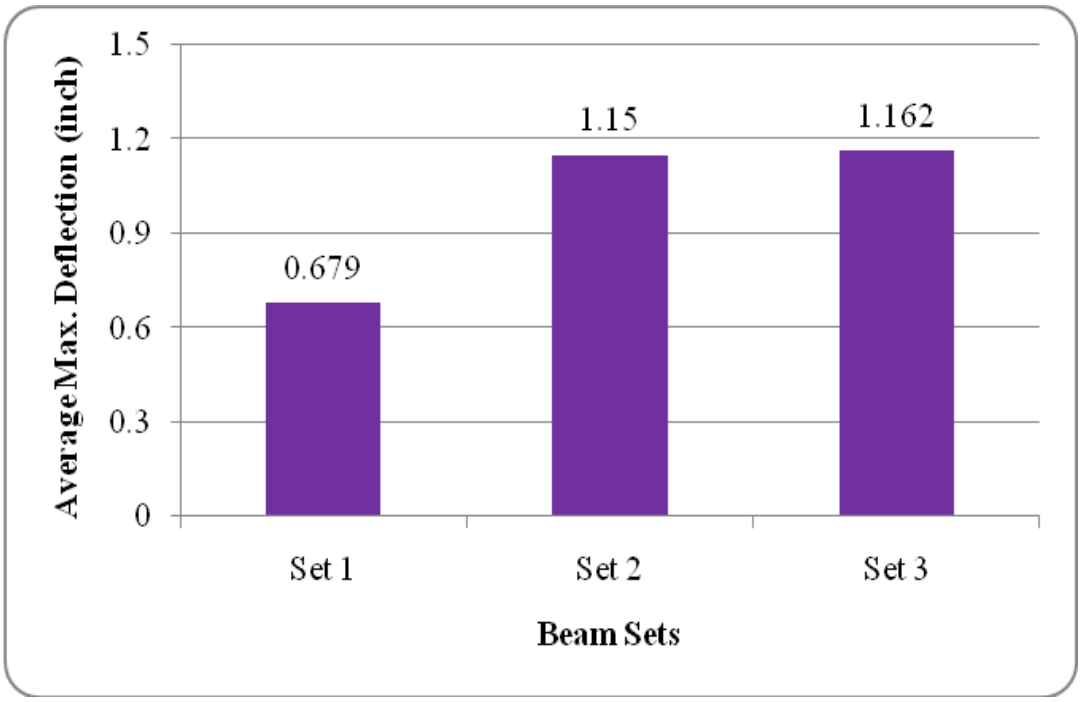

Figure 5. Maximum Deflection of 3 Beam Sets

Table 2, 3 and 4 represents the comparison of cracking load, ultimate load of three set beams before and after strengthening. Figure 2 shows that before repairing there is increase in deflection of beams with gradual increase in load. Figure 3 shows that after repairing with bamboo sticks there is increase in deflection but the load is not increasing by that rate. Figure 3 also indicates the one layered bamboo retrofitted beam in which the rate of load increasing pattern is not so gradual and at a specific point all retrofitted beams give same performance. But in ultimate point two type retrofitted beam give different performance. Figure 4 represents the average ultimate load and Figure 5 shows that the maximum deflection of three set beams. This focuses, the bamboo stick retrofitted beam gives a reasonable strength.

8. Conclusion

By this experimental investigation we can see the significant change in ultimate load, cracking load and deflection for retrofitted by the bamboo sticks. Therefore this method is advantageous for particular cases where the existing beam is strengthening for reusing.

The study on strengthening reinforced concrete beam by bamboo sticks has following utilization in future:

a) The under designed or overloaded reinforced concrete beam can be strengthening by bamboo sticks.

b) In case of beam set 2, 65% load carrying capacity increase in which bamboo sticks is used only at bottom of beam and another beam set 3, 84% load carrying capacity increase in which bamboo sticks is used at bottom and simultaneously at both sides of beam.

c) Improving structural behavior the reinforced concrete beam can be strengthening using bamboo sticks as a retrofitted material.

d) As the bamboo is locally available, cost effective material and gives good performance for strengthening so it can use as a retrofitted materials in RCC beam as well as in RCC structure.

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