PRELIMINARY INVESTIGATION OF SUITABILITY OF BAMBOO STRIPS AS AN ALTERNATIVE FOR STEEL REINFORCEMENT IN BEAMS

G.V.J. Mendis[1], B.P. Perera[1], P.K. Attygalle [1], W.R.T.D.De Silva [1], R.S.Mallawaarachchi[2*], K.K.Wijesundara[3]

[1] Department of Civil & Infrastructure Engineering, Faculty of Engineering, South Asian Institute of Technology and Medicine (SAITM), Sri Lanka.

[2*] Corresponding Author, enior Lecturer, Department of Civil & Infrastructure Engineering, Faculty of Engineering, South Asian Institute of Technology and Medicine (SAITM), Sri Lanka, Email: rajeev.m@saitm.edu.lk

[3] Senior Lecturer, Department of Civil & Infrastructure Engineering, Faculty of Engineering, South Asian Institute of Technology and Medicine (SAITM), Sri Lanka.

ABSTRACT

Bamboo is popular among the general public in Sri Lanka since ancient times due to its fascinating properties like wider availability, strength, light weight, flexibility and durability. Evidences for the applications of bamboo poles and strips can still be found in the skeletons of conventional adobe walls in low rise buildings and in false work constructions. However, this has not been used as a structural element except in load bearing adobe walls. Nowadays, bamboo is being proposed as a low cost reinforcing method for small scale building projects such as single story or two story houses in many parts of the world mainly because of its high tensile strengths. The properties of bamboo and their applications have been investigated in countries like India and some states in the USA. However, the applications of these findings have not been used effectively in Sri Lanka. Therefore, the main objective of this study is to investigate the performance of bamboo reinforced concrete beams.

For this purpose, a simply supported bamboo reinforced concrete beam is analysed experimentally to obtain the force-deformation relationship under a point load applied at the mid length of the beam and subsequently, it is compared with the experimental force-deformation curve. Furthermore, a sectional analysis is performed to obtain the bending capacity.

***Key words*:** Bamboo strips, Shear strength, Bending capacity

1. INTRODUCTION

The suitability of low cost building materials and long lasting methods for the building constructions are greatly benefitted to the poor people in the third world countries in significantly reducing the cost of small scale house constructions. Apart from the different methods in reducing the cost of building construction, bamboo is being proposed to be used as a low cost reinforcing method for small scale building constructions. In other words, bamboo could be used as a substitute for steel reinforcement bars in concrete beam and column constructions. Another advantage of using bamboo instead of reinforcing bars is the weight. It is considerably lighter. The declination of the self-weight of the beam reduces bending moment and shear force acting on the beam.

The properties of bamboo and their applications have been investigated in countries like India and some states in the USA [1, 2 and 3]. However, the applications of these findings have not been used effectively in Sri Lanka.

Therefore, the main objective of this study is to investigate preliminarily the performance of a bamboo reinforced concrete beam under the combined actions of shear and bending deformations.

For this purpose, a simply supported bamboo reinforced beam is tested under a point load applied at the mid length of the beam to obtain the experimental force-deformation curve and subsequently, it is compared to the numerical curve. Furthermore, sectional analysis is also performed to obtain the bending capacity. It is important to note that tensile properties are extracted from the experimental programme reported in the literature [1].

2. EXPERIMENTAL PROGRAMME

Figure 1 illustrates geometric characteristics of the bamboo reinforced concrete beam section before the test. There are two layers of bamboo

reinforcements at the bottom of the beam.

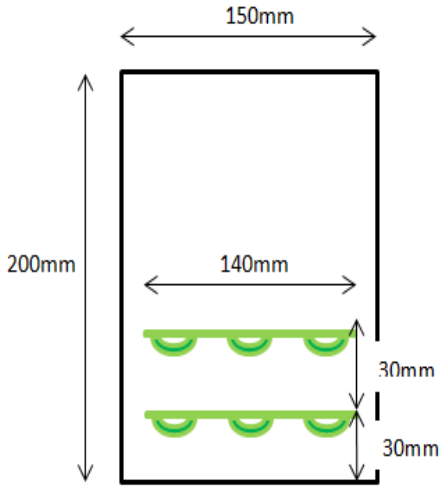


Figure 1: Geometric characteristics of the bamboo reinforcing beam.

The bamboo type which was chosen to be used in this beam was "green bamboo". This was selected because it is the most common type of bamboo available in Sri Lanka.

A typical bamboo reinforcement layer is shown in Figure 2. This was arranged using bamboo strips which were obtained by dividing one bamboo pole into 8 parts, and connecting those strips using steel connectors. Subsequently, three of these strips were connected together using short connecting bamboo pieces as shown in the figure 2 to form a single layer of bamboo reinforcement. These pieces were approximately 6 cm apart from each other. Average thickness of a bamboo strip was 0.4 - 0.6 cm.

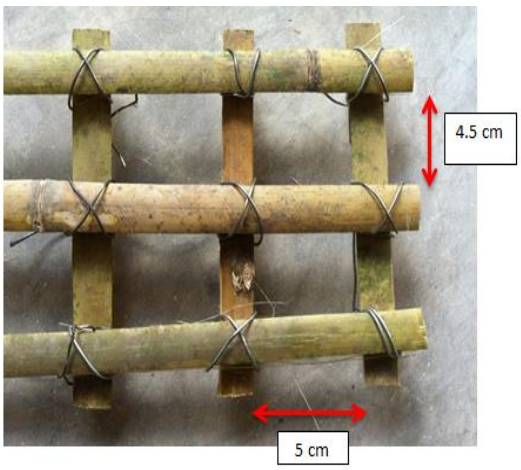
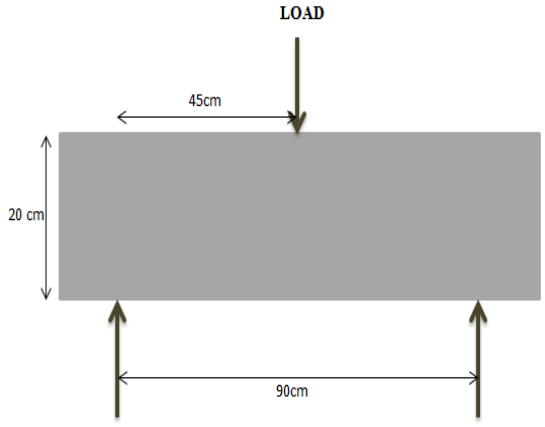


Figure 2: Arrangement of the bamboo reinforcement layer

Furthermore, it is important to note that the bamboo strips used in the beams were treated with burnt oil or wood preservatives to prevent termite infestations.

All the bamboo strips were sun-dried to remove the moisture and then soaked in a mixture of burnt oil and wood preservatives for 2 to 3 hours. Finally, they were sun-dried again for few hours before using them in the concrete beams.



$$\frac{Span}{Height} = \frac{45}{20} = 2.25$$

Figure 3: Testing arrangement

Figure 3 shows the testing arrangement. The length of the simply supported beam is 1000 mm with support length of 900 mm and the cross section of 150 x 200 mm. Incremental point load of 0.98 kN is applied exactly at the mid point of the beam until the failure is observed. Deflection at the mid span was measured using a dial guage. The design grade of the concrete is 30.

3. TEST RESULTS

Figure 4 illustrates the tri-linear vertical force deformation curve obtained from the test. The first branch of the curve indicates the linear elastic behaviour with the highest stiffness while the second branch indicates that the stiffness is significantly reduced after the first bending crack appeared at the bottom of the mid region of the beam. Third branch shows the force-deformation response after yielding of the bamboo reinforcement.

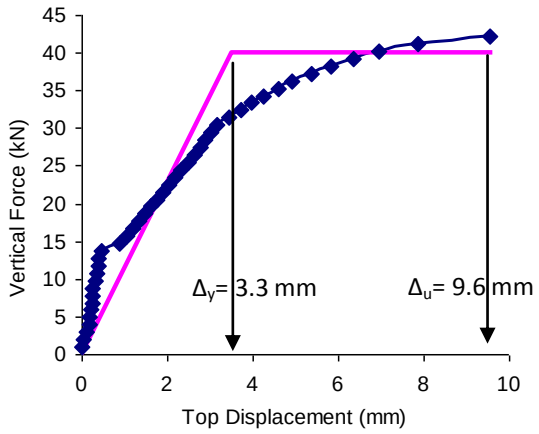
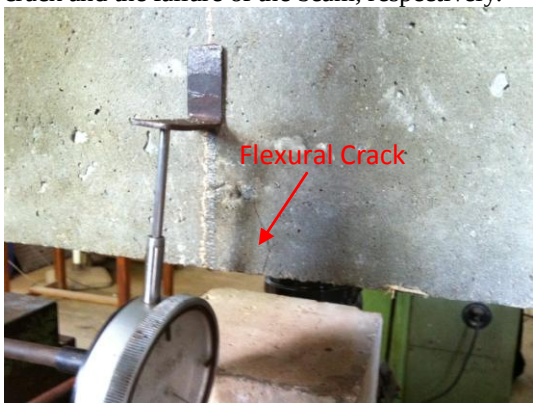


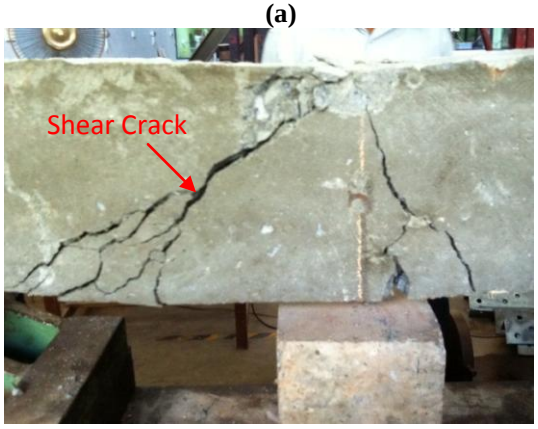
Figure 4: Vertical force-deformation curve obtained from the experiment

Figure 4 also shows the idealized bi-linear curve for the experimental vertical force-deformation curve. This idealization is based on the equal energy concept that the areas under the two curves are equal. As shown in Figure 4, the yield displacement and ultimate displacement are 3.3 and 9.6 mm, respectively. Therefore, the ductility that is defined as the ratio of ultimate displacement to yield displacement is approximately equal to 3. Furthermore, it is important to note that the failure occurs due to propagation of shear crack before the compression crushing of concrete due to bending action.

Figure 5(a) and (b) illustrate the crack patterns observed at the first appearance of the flexural crack and the failure of the beam, respectively.



(a)



(b)

Figure 5: Crack pattern (a) at the first appearance of bending crack (b) at the failure of the beam

The failure of the beam in shear rather than in flexure highlights the importance of estimating the shear capacity of the beam in the design stage. The shear links are provided in typical reinforced concrete beams to prevent the premature failure in shear. Since there is no shear reinforcement provided in the bamboo reinforced beam, the shear strength is limited to the shear strength of concrete which depends on the interface shear stress, often called aggregate interlocking.

4. MOMENT-CURVATURE ANALYSIS

Sectional analysis is performed using OpenSees computer programme [4]. Beam section is defined using a fibre section which is constructed using a patch and two bamboo reinforcement layers. The material nonlinearity of the concrete represents a uniaxial Kent-Scott-Park concrete material model with degraded linear unloading/reloading stiffness according to the work of Karsan-Jirsa. This material model also consider the tensile strength of the concrete. Since there are no adequate shear reinforcements provided in the beam, the confinement effect of the core concrete is minimized. The strain components ε_c at the peak compressive strength and ε_u at the concrete crushing are estimated using Eq. (1) and (2), respectively as specified in uniaxial Kent-Scott-Park concrete material model.

$$\varepsilon_c = 0.002k$$
$$k = 1 + \frac{\rho_s f_{yh}}{f_c^{'}} \quad (1)$$

$$\varepsilon_u = \frac{0.8}{z_m} + 0.002k$$
$$z_m = \frac{0.5}{\frac{3 + 0.29 f_c^{'}}{145 f_c^{'} - 1000} + \frac{3}{4}\rho_s \sqrt{\frac{h}{S_h}} - 0.002k} \quad (2)$$

The material nonlinearity of the bamboo represents a uniaxial bilinear material model. The properties of the bamboo strips are taken from the research reports [1]

Figure 6 shows the moment-curvature plot obtained from the sectional analysis. The moment capacity obtained from the section analysis is 12 kNm while it is 11 kNm obtained from the experiment.

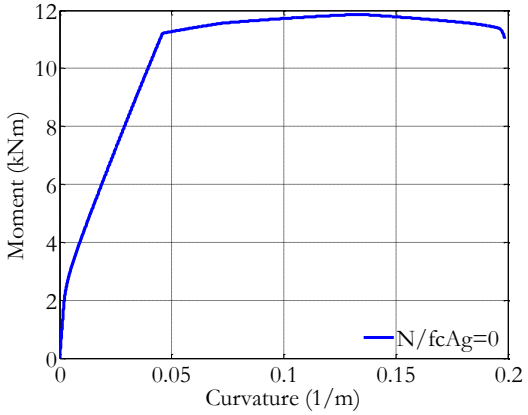


Figure 6: Moment-curvature response

5. CONCLUSION

In this study, our main objective was to preliminary investigate the use of bamboo strips as an

alternative for typical steel reinforcement in the construction of single or two story buildings. Based on the analytical and experimental investigations, following conclusions can be drawn.

By replacing the steel reinforcement with bamboo strips, adequate ductility can be achieved before the failure. However, premature shear failure of the beam can be expected as observed in the experiment since there is no shear reinforcement provided in the bamboo reinforced concrete beam. Therefore, beam design is mainly governed by the shear forces.

Further experimental and numerical investigations are required to propose an alternative solution to prevent the premature of shear failure of the beam and hence optimize the design.

6. REFERENCES

[1]. Iyer S., "Guidelines for Building Bamboo Reinforced Masonry in Earthquake-Prone Areas in India" *Faculty of the School of Architecture, University of Southern California*, (2002).

[2]. Kakkad M.D., Sanghvi C.S. "Comparative Study of Bamboo (Ikra) Housing System with Modern Construction Practices" *National Conference on Recent Trends in Engineering & Technology*, (2011).

[3]. Lissel S.L., Moroz J.G., "Tonkin Cane Bamboo as Reinforcement in Masonry Shear Walls" *11th Canadian Masonry Symposium*, Toronto, Ontario, May 31- June 3, (2009).

[4]. PEER OpenSees: Open System for Earthquake Engineering Simulation. Pacific Earthquake Engineering Research Centre, University of California, Berkeley, (2006).