Bamboo Slit Segment Laminate and Strip Truss Core Sandwich - Efficient Structural Elements

RAMESH KUMAR. R[1], SREELAL. S[2], VISHNU P[3]
Department of Mechanical Engineering, Government Engineering College Barton Hill, Thrivananthapuram

Abstract -- The most attractive properties of bamboo as its specific stiffness is quite comparable to that of steel is utilized as a structural element following a simple joinery technique of split bamboo segment including Culm nodes with wood powder as an additive to resin system is brought out based on the test data. The fabrication methodology for bamboo strip truss core is described and aluminum skinned truss core sandwich design of unit cell size as an impact resistant structure is analyzed to ensure no failure prior to the buckling.

Index Terms – bamboo- laminate, Culm, impact analysis, interlaminar shear, truss core sandwich

I. INTRODUCTION

It is well – known that bamboo is considered as one of the most environment friendly renewable source of material**.** Bamboo is an unidirectional fibrous material, having very high specific stiffness comparable to steel more suitable for a frequency based design. However, top part of the bamboo is not considered for structural application. With the increasing demand, techniques should emerge to enable the left out top part of bamboo that has low strength but with normal stiffness as an efficient structural element. Aluminum skinned bamboo truss core is one of the suitable options for providing impact resistance to automobiles, besides load bearing structures under bending. Fabrication, testing and comparison with analysis are discussed.

II LITERATURE

A compendium on various structural application of bamboo and data on mechanical properties was reported by Suresh [1]. Verma and Chariar tested four layered bamboo epoxy laminated out of thin plane laminates processed from dry bamboo Culms of Dendrocalamus strictus (without Culm nodes) and observed that mechanical behavior was similar to fibre reinforced composites [2]. Kimiyoshi *et. al.* based on their studies on the effect adhesive layer thickness in bonded joints concluded that adhesive thickness did not seem to affect the shear strength of single lap joints [3].

As Culm nodes become a hurdle for lamination of bamboo segments, no study was reported on the joinery techniques of bamboo slit segment- epoxy laminates Similarly, studies on truss core were confined to discrete bamboo columns that are good for providing bending rigidity and not suitable for impact resisting structure as buckling prior to compression failure is required.

III OBJECTIVES

1) A new lamination technique of bamboo slits segments with wood powder as additives to the adhesive system to enhance section modulus and interlinear shears strength for a stiffness based design and discussion on bond integrity based on test data [5].

2) Development of bamboo strip truss core sandwich and comparison of test data with analysis results covered [6].

IV FINDINGS ON THE NEW TECHNIQUES

A. Bamboo Slit- Epoxy Laminate

Steel welded tubular (40 x 40 x 2mm) framed structure for transport vehicle shown as an inverted U in Fig.1t was designed based on a frequency constraint [4]. For a cost effective and environmental friendly material like bamboo is a suitable replacement for the steel structure.

Fig. 1 Inverted U shape welded steel frame structure of a transport bus [4]

Various bamboo species have high ratio of Young's modulus (along fibre direction) to density. It may be noted from the Table 1 that steel has a specific stiffness of 2690km while Dendrocalamus strictus

Table-1 Fibre direction modulus of elasticity various species of bamboos that is available in plenty has a value of 1672km.

No.	Name Length of the specimen L = 150mm P- applied load	W & t (mm)	I (mm^4)	Elastic Mod. E (GPa)	Specific stiffness [1] (km)
1	Dendrocalamus brandisii	29.0 7.25	921	13.45	1921
2	Dendrocalamus strictus	20.9 11.44	2610	11.71	1672
3	Bambusa bambos	23.5 15.2	6877	4.86	694
4	Bambusa balcooa	19.8 11.1	2284	8.51	1216
5	Thyrsostachys siamensis	20.4 6.52	471	14.23	2028
6	Oxytenanthera stocksii	19.6 7.52	710	7.22	1031

W – width, t-thickness, I – Moment of inertia and
E – Young modulus = $P L^3/48 \delta I$,
δ – deflection under three point bending
Specific stiffness of steel = E/ρ = 2690 km
ρ is the density.

IV. METHODOLOGY

A Lamination of split bamboo with Culm nodes

Bamboo can be easily split into six splits using iron splitter having six blunt knife edges that are kept at an angle of sixty degree each. It is possible to cut down the Culm projections. There two major issues to be resolved in bonding any two split bamboo to form a thick section over a desired length. Being a curved element and with nodes (at nearly regular intervals) makes the bonding very difficult. The gap when two split bamboo of 60 degree each are kept one over the other is about 2 to 3mm in middle region and around 0.5 mm at the edges. The adhesive thickness should neither be too low nor be too thick to obtain maximum shear strength. Five percent of wood powder by mass is added to the adhesive. Two types of specimens are prepared.

a) Lap shear test:- Lap joint of 35mm overlap (width of one segment is 35mm) to determine lap shear strength

b) Three point bend test:- Two 60 degree bonded segments of bamboo slit of minimum 500 mm length are bonded together.

Both types of specimens were kept for curing for 24 hrs under dead weight pressure of 0.3 to 0.4bar. Specimens are then made by joining such two pieces for a four layered bamboo laminate to verify the bond integrity.

B. Test results

Test were carried out on the lap shear (25mm overlap) specimen of two 60 degree segments of bamboo slit with and without wood powder additive [5]. It was observed that the interlinear shear strength was 6.1 MPa which is 65% higher when compared to adhesive without wood powder. No separation between the layers did not occur. Fixture bond failure happened. In the case of the three point bend test on four layered (thickness of 35 mm) bonded joints of bamboo was loaded up to 11.2 kN (Fig.2). The laminate did not show any separation between each bamboo layer. The test was continued even up to a permanent deformation of 5mm of the bamboo (Fig. 3). A good bond integrity was ensured.

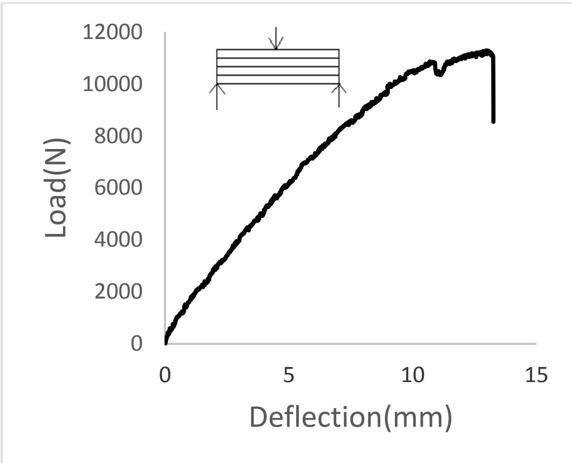


Fig. 2 Variation on Load –deflection of four layered laminate

Fig. 3 Three point bend test of four layered laminate

B Bamboo truss core using strips

Bamboo strip of 20 mm width, 1mm thickness is folded in required numbers and overall size of the truss core as shown in Fig. 4. Prepare one more similar set and position over them, orthogonal to the earlier one in an inverted way for a dry assembly (Fig 5a). It may be noted from the figure that the grains of bamboo folded strips are orthogonal to each other. Take two aluminum plate of same size equal to the size of the core. Follow convention procedure of etching, cleaning and drying. Apply resin uniformly over inner sides of top and bottom plate to form a sandwich plate. Follow vacuum bag curing at room temperature to obtain the product (Fig. 6).

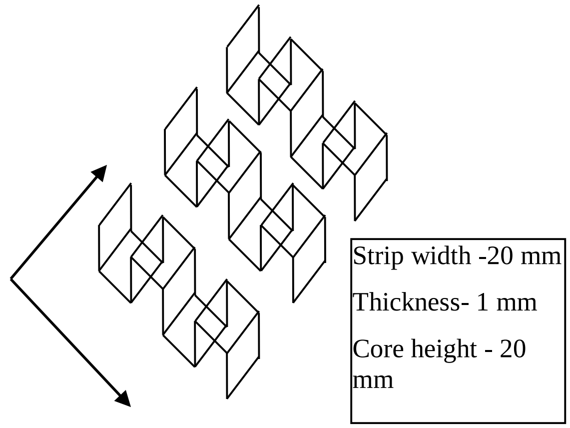
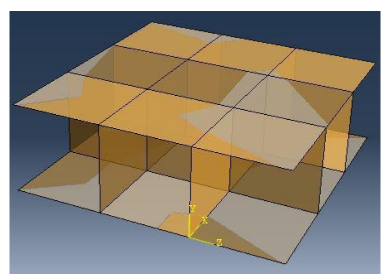
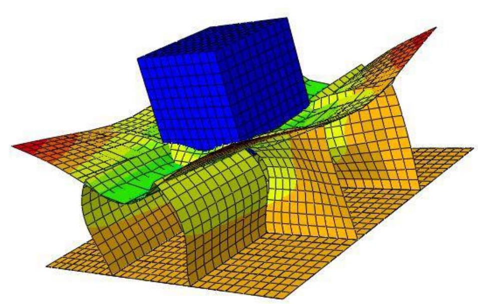


Fig. 4. Schematic diagram of folded bamboo strips

(a)



(b)



(c)

Fig. 5 Bamboo truss core , Al skinned sandwich and corresponding FE model (unit cell)

Fig. 5a shows 60 x 60 x 20 mm truss core identified as unit cell without Al skin while .and Fig. 5b corresponds to FE model of Al skinned sandwich. The deformed configuration under impact load is given in Fig. 5c [6]. Critical buckling load obtained by finite element analysis is compared with ultimate compression failure load. It was noticed that buckling occurred before the compressive failure which is a required criterion for an energy absorption of the sandwich structure.

A bamboo core of size 300 x 300 x 20 mm sandwiched with Al skin of 0.5mm was carried out for a drop test (Fig.6) [6]. The energy absorption capacity was estimated as 3kJ/kg (= work done/ mass of the deformed volume). Permanent deformation of about 3mm on the aluminum skin clearly indicates that bamboo truss core has considerably sheared the impact load (Fi.g.7).

Fig. 6. Al skinned Bamboo truss core sandwich

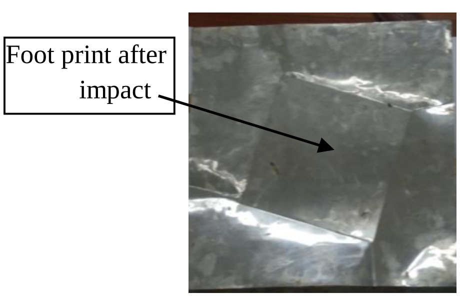


Fig. 7. Al skinned bamboo truss core sandwich

Based on a compression test, the stiffness of the Al bamboo sandwich core is obtained as 10N/mm and the density as $100 kg/m^3$[6].

V. CONCLUSIONS

A novel methodology of bamboo slit segment –epoxy laminate of with Culm nodes has been established with the use of wood powder as additive for bonding. About 65% increase in shear strength of the laminate when compared to pure adhesive joint has been observed. Three point bend test did not show separation of layers.. Development of bamboo strip truss core has been described. The ideal width of the bamboo strip to form a core height is identified as 20 mm and based on analysis it is concluded that for the thickness of 1 mm and width of 20 mm buckling prior to compression failure can be ensured for better energy absorption capacity of the bamboo metallic truss core sandwich structures.

REFERENCES

[1] Suresh Bhalla, Scientific design of bamboo structures, Dept. Civil Engg., IIT, Delhi. web.iitd.ac.in/~sbhalla/brg/pdf/Bamboo.pdf

[2] C.S. Verma, V.M. Chariar, Stiffness and strength analysis of four layered laminate bamboo composite at macroscopic scale", Composites: Part B, https:// doi.org/10.1016/j.compositesb.2012.07.048.

[3] Kimiyoshi Naito, Mutsumi Onta, Yasuo Kogo, The effect of adhesive thickness on tensile and shear strength of polyimide adhesive, International Journal of Adhesion & Adhesives, 2012. 34.

[4] Akhil G.S, Development and qualification of braided joints for mass minimization, M.tech thesis, August, 2017, Sree Chitra Thirunal College of Engg. Thiruvananthapuram, India.

[5] Sreelal S, Qualification of Bamboo Joints and Analysis of Framed Strucutres, M. Tech thesis, August, 2018, Dept. Mechanical Engg., GECBH, Thiruvananthapuram. India.

[6] Vishnu P, Impact analysis of aluminum skinned bamboo truss core sandwich structure, M. Tech., August, 2018, Dept. Mech.Engg., GECBH, Tvm 605035,India.