FABRICATION AND ANALYSIS OF LAMINATED BAMBOO COMPOSITES

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ABSTRACT: Production of laminated bamboo composites (LBCs) are done by using epoxy resins of laminas and laminates of dendrocalamus strictus bamboo culms. Under different loading conditions mechanical properties of bamboo laminae have been examined. Bamboo laminas are comparable with hard woods and indicate that average strength of bamboo laminae obtained under different loading conditions is better than softwoods.

Key words: laminated bamboo,composites ,Mechanical property , LBC

1. INTRODUCTION

There are over 1000 species of bamboo and for certain varieties; a tensile strength of 370 MPa was reported [3]. This bamboo pole can be converted into bamboo timber by engineering. Woods can be substituted by bamboo timber. With the help of adhesive, when slivers and lamins are arranged suitably, bamboo timber is formed. For structural purpose, Mousou bamboo can be used due to its tensile strength. As the moisture contents increases, Compressive strength, buckling capacity and elastic modulus of Mao Jue bamboo decreases. Compressive strength is about one third the tensile strength [6] and tensile strength is around 100MPa. bending strength , compressive and tensile of bamboo clums for different species are 86-229MPa , 53-100MPa and 111-219 MPa respectively[7]. Bamboo culms for different species were in the range of 111-219 MPa, 53-100MPa, and 86-229MPa respectively [7]. These properties are proportional to volume fraction of fibers of bamboo where volume fraction of fibers is dense in the outer region (60~65%), sparse (15~20%) in the inner region and increases linearly with height by about 20~ 40% .Volume fraction of fibres were measured by counting the dots that represent the fibers on image (taken by CCD Video Camera) of a cross section of bamboo culm [8]. a report has been prepared on some mechanical properties such as tensile, compressive and flexural of bamboo laminates with other bamboo composites. Therefore we have selected bamboo culms and their laminates with other composites from different region, to prepare a report on tensile, compressive and flexural of bamboo laminates.

2. FABRICATION OF LAMINA AND THEIR *LBCS*

We have taken Green bamboo culms(Fig.1) from TERI, district Gurgaon (Haryana), India, aged four years. Bamboo slivers (Fig.2) and specimen of lamina were prepared (Fig.3A, 3B and 3C for tensile, compressive and flexural testing respectively)

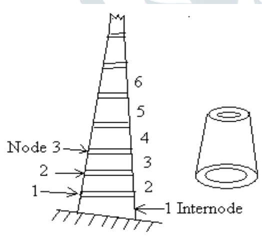


Fig. 1.1. Bamboo culms with labels

Fig. 1.2. Bamboo Laminae

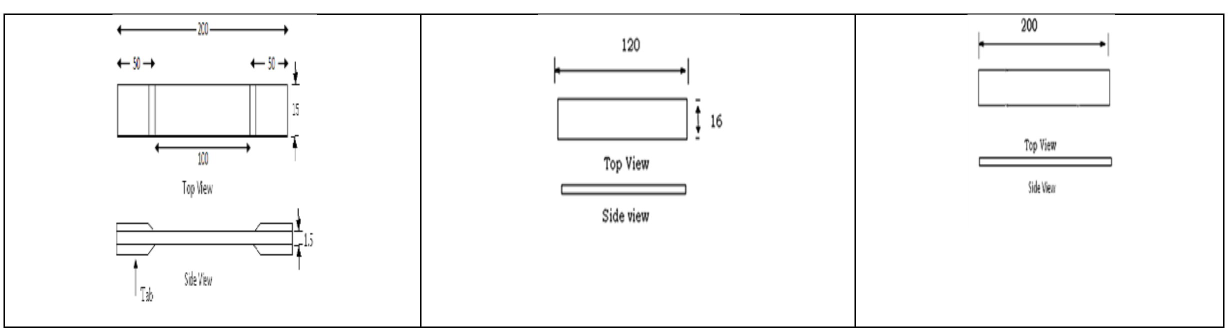


Fig 1.3. Lamina for tensile test
(b). Lamina for compressive tests (c). Lamina for flexural tests

It has been observed during LBCs preparation that width of laminae from bamboo culms are less in amount due to circular cross section. Therefore to make laminae with larger width adhesive were used to butt joined laminae. Keeping the ratio of araldite and hardener 100:23 by weight, epoxy araldite (LY 556)with curing agent/hardener (HY 951) was used as adhesive. Using adhesive, first laminae with larger width is butted against another, the size of one laminae is 250mm x 16-20mm x2mm. this process is followed to prepare first lamina with larger width of 100mm. one sample of unidirectional LBCs i.e. Type A [0°/0°/0°/0°/0°]. Similarly, Type B [0°/45°/0°/45°/0°] and Type C [0°/90°/0°/90°/0°] samples and their specimens with different lamina configurations/ angles(as shown in Fig.5) were stacked together to form one sample using die (Die cavity: length x width x thickness as shown in Fig.4). all types of LBCs sample are used to prepare five test specimens using cross cutting and grinding for tensile, compressive and flexural testing respectively ,as per ASTM standards. The standards and machines for evaluating mechanical properties of LBCs are listed in Table 1.

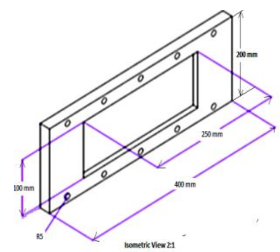


Fig. 1.4 Die made using MS plate

Fig.1.5 Side views of LBCs for Type A, B and C

Table 1: Standard and Machines

Mechanical Property	**Standards**	**Machine (Capacity)**	**Cross head speed (mm/min)**
Tensile	ASTM-D3039	Instron UTM (5T) for lamina, Zwick UTM (25T) for LBCs	2
Compressive	ASTM-D3410	Instron UTM (10T) for both laminae and LBCs	2
Flexural	ASTM-D7264	Instron UTM (5T) for both laminae and LBCS	2

3. TESTING OF BAMBOO LAMINAE AND LBCS SPECIMENS

Average failure strength and young's modulus of bamboo laminae under tensile, compressive and flexural tests are given in following Tables (3A-3B, 3C-3D and 3E-3F). Similarly, the summarized tests results for tensile, compressive and flexural properties of LBCs with different laminae angles are presented in Table 3.

The specimen no 1,4,8,11,14 named as specimen A, B ,C ,D, E respectively

Table 3A : Average Tensile Failure Stress (MPa)

Specimen	Internodal number				
	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
Outer region	237.5	255.2	271.9	282.5	301
Middle region	170.9	171.9	200.86	233.2	229.1
Inner Region	98.2	102.5	164.9	174.1	218.9
Avg.	**168.86**	**176.53**	**212.53**	**229.93**	**249.6**

Table 3 (b): Average Tensile Young Modulus **(GPa)**

Specimen	Internodal number				
	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
Outer region	15.21	15.1	17.12	15.12	14.94
Middle region	13.9	14.9	14.9	16.91	18.24
Inner Region	8.1	7.9	11.9	10.01	12.9
Avg.	12.403	12.63	14.64	14.013	15.36

Table 3(c): Average Compressive Failure Stress (MPa)

Specimen	Internodal number				
	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
Outer region	24.89	31.1	34.1	36.02	43.9
Middle region	22.78	28.69	30.69	34.9	44.7
Inner Region	22.9	20.9	27.23	32.9	37.89
Avg.	23.523	26.896	30.673	34.606	42.163

Table 3D: Average Compressive Young Modulus (GPa)

Specimen	Internodal number				
	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
Outer region	4.9	11.1	15.23	15.6	15.9
Middle region	5.6	10.0	15.4	12.6	17.1
Inner Region	4.1	8.43	12.2	11.2	12.5
Avg.	4.86	9.843	14.276	13.13	15.16

Table 3(e): Average Flexural Failure Stress (MPa)

Specimen	Internodal number				
	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
Outer region	105.9	128.2	139.9	154.12	163.6
Middle region	109.2	114.2	115.62	119.6	134.59
Inner Region	92.66	100.9	111.3	111.1	112.9
Avg.	102.586	112.76	122.273	128.273	137.03

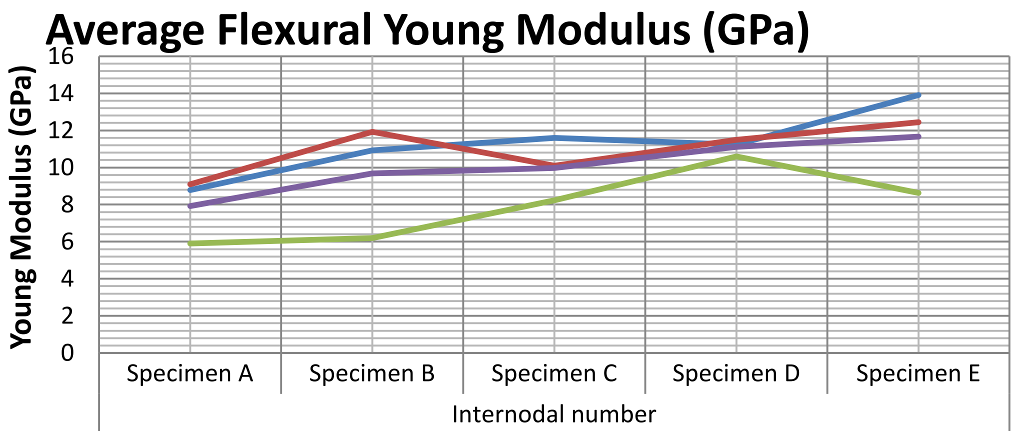
Table 2(f): Average Flexural Young Modulus (GPa)

Specimen No.	Internodal number				
	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
Outer region	8.78	10.93	11.6	11.23	13.9
Middle region	9.1	11.93	10.1	11.5	12.45
Inner Region	5.9	6.2	8.23	10.6	8.63
Avg.	7.926	9.686	9.976	11.11	11.66

4. RESULTS AND COMPARISONS

4.1 Bamboo laminae/culms vs woods

Table 3 shows the comparative analysis of mechanical strength properties of bamboo laminae are better than softwood and comparable to hard woods and variation in nature of mechanical properties of wood species are similar to that of bamboo laminae. These results indicate that bamboo can be utilized for fabrication of LBCs



	Specimen A	Specimen B	Specimen C	Specimen D	Specimen E
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Inner Region	5.9	6.2	8.23	10.6	8.63
Avg.	7.926	9.686	9.976	11.11	11.66

Fig 3.1 Average Flexural Young Modulus (GPa)

Table 3 shows the strength properties of proposed LBCs which range of mean strength values of Type A, Type B and Type C LBCs are reproduced in Table 6. composite material and teak wood from literature is also given in Table6, for comparison. Comparative analysis indicates that tensile, compressive and flexural strength of LBCs is better than other composite materials and even at par of teak wood, which is one of the strongest woods Table 3

5. CONCLUSIONS

1. With increase in height of bamboo culms, there is a increase of mechanical properties bamboo increases from inner to outer regions.
2. Mechanical strength properties of bamboo laminae are better than softwood and comparable to hard woods and variation in nature of mechanical properties of wood species are similar to that of bamboo laminae.
3. Mechanical properties of LBCs are better than other composite materials and even at par of teak wood, which is one of the strongest woods.

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