Finite Element Analysis of Skate Board Made of Bamboo Composite

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Abstract - *Although synthetic fibre based composite material became popular because of their high strength and low weight however energy required for fibre extraction is very high, they are non-degradable and costly. Because of these demerits there is need of development of biodegradable and cost efficient composite materials. In the recent past natural fibre reinforced composite material has gained significant attention because of their high specific properties bio degradability and low cost. In this paper bamboo based composite material has been fabricated by hand layup method. Flexural strength of composite for different volume fraction is determined by three point bend test .Maximum flexural strength of 195.5Mpa was observed for 50% bamboo volume in composite. The Finite element analysis of skate board made up of bamboo composite is carried out by using HyperMesh and Optistruc. The maximum stress in skate board is within the permissible range of bamboo composite. The cost efficient bamboo composite with comparable mechanical properties indicates the possibilities to use it as a promising alternative to synthetic fiber based composites.*

Key Words: **Bamboo Composite, Strips, flexural strength Volume fraction, Elastic constants**.

1. INTRODUCTION:

Now a day the use of synthetic fibre based composite materials is increasing continuously. Total amount of glass fibre reinforced composite consumed in India was 25 thousand tons in year 2000[1]. Synthetic fibres are non-degradable and ten times costlier than natural fibre [1]. In the recent past natural fibre have gained popularity in industries due to their low density and high strength. A significant amount of research has been carried out on the development of natural fibers based composite materials. Bamboo is one of the most popular natural fibre. India contributes to 34% of world bamboo resources [2]. Bamboo is one of the fastest growing plants in world and achieves its complete mechanical properties within 3-4 years [2]. Bamboo has the highest mechanical strength in all natural fibre and lowest density, of 0.9 g/cm^3, compared with 1.45 g/ cm^3 of jute and 2.5 g cm^3 of fiberglass [3]. Though properties are inferior to fiber glass, but specific properties are comparable.

There number of researchers worked on bamboo composite. Shah Huda et al prepared light-weight composite with bamboo strip. He conducted three point bend test by varying bamboo strip thickness and width to determine its effect on flexural modulus and strength [3]. C.S.Verma investigated tensile, compressive and flexural strength of bamboo strips selected from different regions of culm [4]. V.M Charair developed a bamboo composite from bamboo strips. He determined strength and stiffness experimentally and compared it with analytical values[5]. José Jaime García et al adopted a simple test method in his study to determine the circumferential Young's modulus, the radial-circumferential Poisson's ratio and the circumferential-axial shear modulus of bamboo culm using ring specimens[6].

In this work bamboo strips were used in composites instead of extracted bamboo fibers .Unidirectional bamboo composite was fabricated by hand layup technique .Flexural strength and modulus was determined by flexural test. Results obtained from testing were used to find four elastic constant of composite .By taking these elastic constants FEA skate board made of bamboo composite was carried out in HyperMesh. and Optistruct.

2. MATERIALS AND METHOD

Mature Bamboo was purchased from local markets in Maharashtra, India. The bamboo culm had an average length of 7 m, diameter at bottom and at top was 89 mm and 35 mm respectively. The thickness of the wall was 25mm at the bottom and 8 mm at the top. Bamboo strip was cut circumferentially because fine strip can be cut in this direction. Average dimensions of intermodal strip are 300mm X 11mm X 0.5mm.After cutting bamboo strip they were dried in sun light for one week. Density of bamboo culm is 0.8 g/cm^3 is taken from literature. [7]

The epoxy (520 F) with curing agent/hardener (EH 408) was used as matrix for preparation of composites. Mechanical and physical properties of epoxy provided by manufacturer are shown in table 1. Curing time at room temperature was 24 hours. Suggested mixing ratio of epoxy and hardener is 100:50 by weight

Table 1: Properties of epoxy

Young's modulus	3700 Mpa
Ultimate tensile strength	58 Mpa
Poisson's ratio	0.33
Density	1.1g/cm^3

2.1 Test specimen

Bamboo composite of volume fraction 30%, 38%, 50% were cut using cross cutting and grinding machine. Two specimens for flexural testing from each plate were cut as per ASTM standard D790. The specimens were in the form of constant rectangular cross section of 120 mm overall length, 65mm span length and 16 mm wide with a thickness of 4.2–4.8mm as shown in figure 1 .

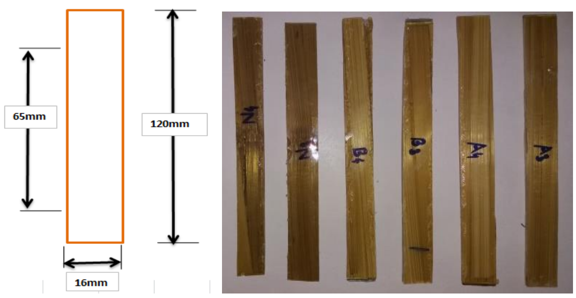

Fig -1: flexure test specimen

2.2. Experimental setup

The experiments were performed on universal testing machine. The stress–strain curves were obtained for each specimen from the automatic computerized recorder with the help of software inbuilt in machine. Composite specimens were simply supported at two points and load at the centre was applied. Flexural test was conducted at a test speed of 5 mm/min. Standard laboratory atmosphere (temperature:26±3°C; relative humidity: 50±10%) is maintained according to ASTM D790. Setup for flexure test is shown in figure 2.

Fig -2: Flexure test setup

3. RESULTS AND DISCUSSION

Typical stress-strain diagram is as shown in chart 1. Stress increases with increase in load and reaches to maximum value. At this point, sudden drop in stress is observed this is because of tensile failure of bamboo strips at outer most portions. Fluctuation in stress-strain curve after peak stress is observed due to successive failure of bamboo strips.

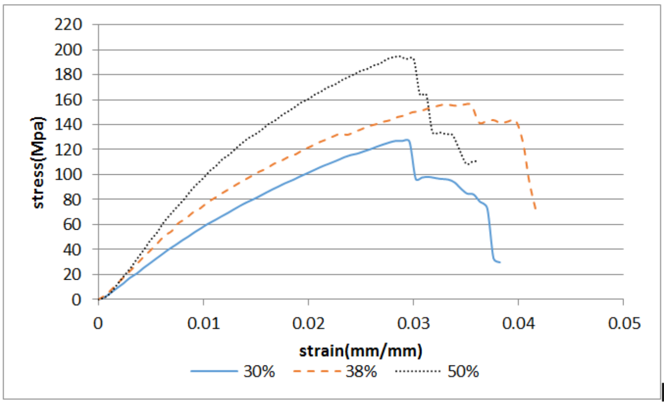

Chart -1: Stress-strain curve of flexure test

It is noted that increasing bamboo volume also increases flexural strength and modulus. Initially stress-strain curve is straight line but as load increases its slop decreases, hence flexural modulus is calculated using initial portion of curve. Flexural test results are indicated in table 2.

Table 2: Flexural properties of bamboo composite

	Specimen Number	Maximum flexural stress(Mpa)	Experimental. Flexural. modulus (Mpa)
30%	1	127	6060
	2	142.39	5860
38%	1	156	8360
	2	185	7300
50%	1	160.23	9218
	2	195.29	10400

4. ELASTIC CONSTANTS OF COMPOSITE

Bamboo composite prepared in this study is transversely isotropic which has four elastic constant E_1, E_2 ,ν_{12} and G_{12}. E_1 ,E_2 has been determined experimentally in our previous work.

ν_{12} ,G_{12} can be evaluated by strength of material approach equation (1) and (2) respectively. For evaluation of these constants, properties of bamboo are listed in table 3.

Table 3: Properties of bamboo strip

Modulus along fibre (E_1)	21104 Mpa (test result)
Modulus across fibre (E_2)	398Mpa (available data)
Shear modulus (G_{12})	582Mpa (available data)
Major poisson ratio(ν_{12})	0.3 (available data)
Maximum tensile strength	350.8 Mpa (test result)

$$v_{12} = v_{ft} * V_f + v_m * V_m \quad (1)$$

$$G_{12} = \frac{1}{\frac{V_f}{G_{ft}} + \frac{V_m}{G_m}} \quad (2)$$

G_{ft} is in-plane shear modulus fibre, in the plane perpendicular to the plane of isotropy and V_{ft} is Poisson's ratio characterizing the contraction in the plane of isotropy when longitudinal tension is applied. Average values were considered for analysis.

Table 4: Elastic constant of bamboo composites

	Exp. E_1Mpa)	Exp. E_2(Mpa)	Evaluated v_{12}	Evaluated G_{12}(Mpa)
30%	7550.5	720	0.321	981
38%	9805	560	0.318	910
50%	10821	500	0.315	820

5. FINITE ELEMENT ANALYSIS

Flexural test of bamboo composite specimen was simulated in HyperMesh to confirm that it shows similar results as experiments. Bamboo composite of 50% fibre volume was considered in this analysis .Elastic constants are available in table 4 .

Specimen is simply supported between two points only translation in Z-axis was restricted; distance between supports is 65 mm. A point load of 220 N is acting at the centre.

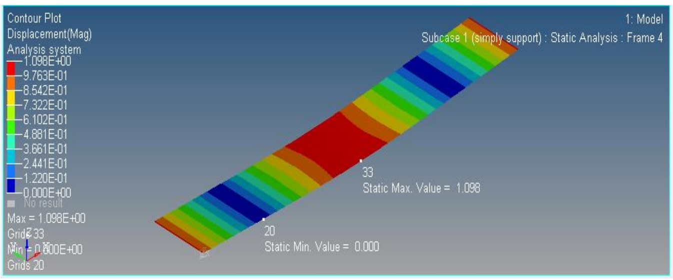

Fig-3. Displacement in flexure specimen

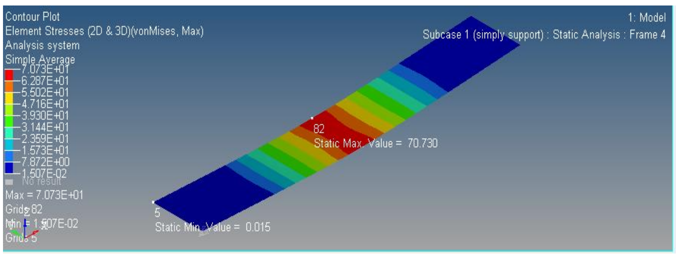

Fig-4. Stress in flexure specimen

Comparison between experimental and FEA. Results are shown in table 5.

Table 5: Comparision of results

	Experimental	FEA	% Error
Displacement	1.2 mm	1.098	8.5
Stress	67.512 Mpa	70.730 Mpa	4.7
Strain	0.006	0.005	15

Simulation results are close to experimental; this validates FEA. Model of bamboo composite. Most of the previous work on bamboo composite is related to experiment only .Limited amount of work is done in application based commercial use of bamboo composite .In this study Finite Element Analysis of bamboo composite skate board is carried out to check whether this material is suitable for this application or not.

5.1 Meshing

CAD. model was created in Catia and imported in HyperMesh for meshing . Component was meshed using 2D quad element having size 6 .. There are about 3816 2-D elements and 8 RBE2 (rigid elements).Total number of nodes are 4004. Meshed details are shown in figure 5.

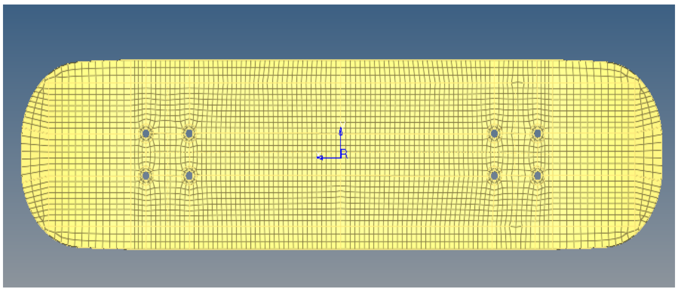

Fig-5 : meshing of skateboard

5.2 Composite modeling

Before proceeding to composite modeling it is necessary to ensure that normal of all elements are in one direction only. Because ply stacking sequence is along the normal direction to particular element. Planar orthotropic material MAT8 was assigned to skate board and elastic constant were taken from table 4 for 50% fibre volume. Here in this study ply based modeling approach was used, hence PCOMPP property card was assigned.

Six pies were generated having equal thickness of 2 mm and their orientation was also defined. Details of plies are shown in figure 6.

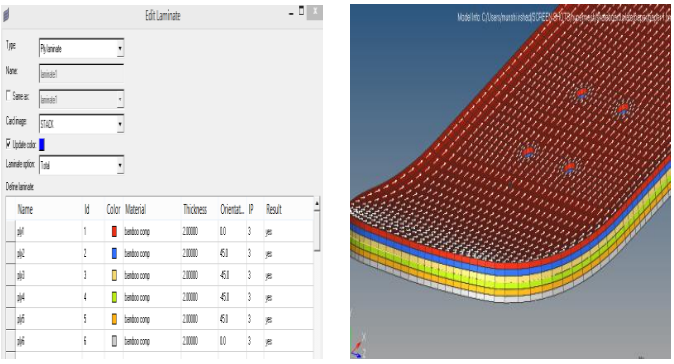

Fig-6 : Details of plies

Stacking sequence in this study is [0/45/-45/-45/45/0].figure 6 shows laminate and stacking sequence of plies and their fibre directions.

5.3 Load and boundary condition

Assume the skateboarder weighs 70 kilograms, to make it safer 145 kg (1420 N) load is applied at the centre of skate board .

A node was created at centre of each hole .Nodes around the hole were connected by central node by using rigid element RBE2 to simulate bolted joint .All degree freedom of central nodes were fixed except rotation about transvers axis of skateboard (Z-axis) .

5.4 **FEA results**

Optistruct was used as solver in this study. As laminate is symmetric results for three plies are shown here.

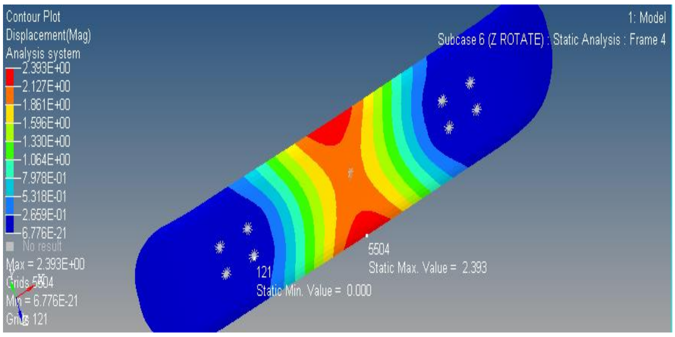

Fig-7 : Displacement

It is obvious that displacement at the centre of skate board is highest. As bamboo composite has comparatively less young modulus than other synthetic fibre, somewhat high displacement of 2.33mm is obtained.

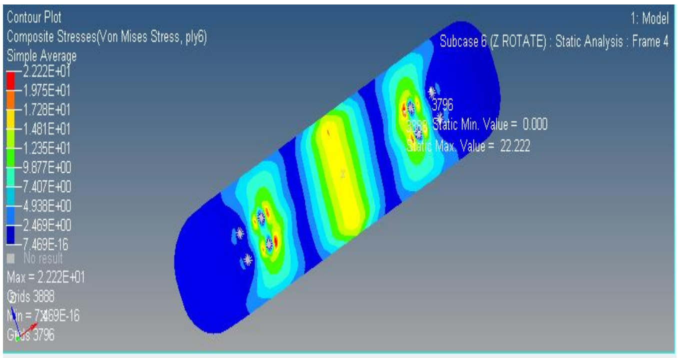

Fig-8 : stress in 0^0 ply

The highest stress is noticed at ply having fibre along x-axis (0^0) because this is outermost ply of laminate and stiffness of ply along x-direction (0^0) is highest.

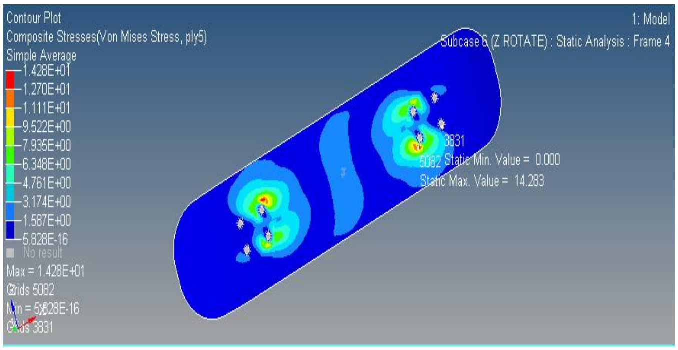

Fig-9 : stress in 45^0 ply

Highest stress in 45^0 and -45^0 ply is noticed around the holes which are diagonally opposite to each other, this is because of fibre orientation in that ply.

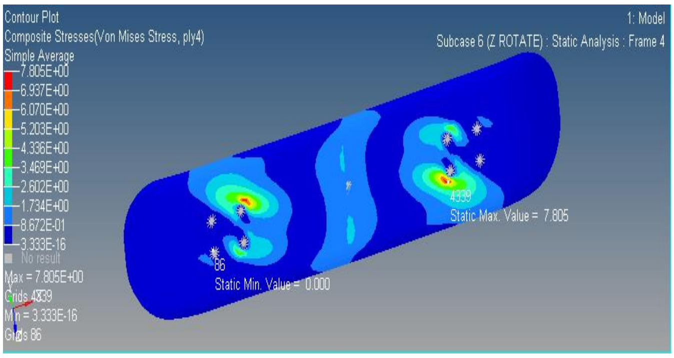

Fig-10 : stress in -45^0 ply

Maximum stress at each ply is tabulated in table 6.

Table 6: Maximum stress in each ply

Ply angle	Maximum stress
0^0 ply	22.22 Mpa
45^0	14.23 Mpa
-45^0	7.85 Mpa

Composite having 50% bamboo volume has highest flexural strength of 195.29Mpa.Taking factor of safety of 2.5, allowable stress is 78Mpa.Though maximum stress in skate board is 22.22Mpa which is far less than allowable stress but displacement at the centre of skateboard is 2.39mm which is considerably high .Here we are considering displacement as limiting value for design.

This study found that, skate board can be manufactured by using bamboo composite instead of glass fibre or conventional material.

6. CONCLUSIONS

1. Experimental investigation shows that bamboo composite has flexural strength 195.25Mpa and flexural modulus 10821Mpa for 50% bamboo volume fraction.

2. Deviation in FEA and experimental results of flexure specimen are within 15%; this validates bamboo composite FEA model.

3. Maximum displacement is 2.39mm which is at the centre of skate board

4. Maximum stress is 22.22Mpa is acting in outer ply (0^0 ply) around the holes, which is within the maximum allowable stress.

5 .Bamboo composite can be a cost effective alternate material of glass fibre for skate board manufacturing.

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