Development and Comparative Studies of Bio-based and Synthetic Fiber Based Sandwich Structures

Sripathy Mallaiah, Krishna Vinayak Sharma, M Krishna

Abstract-The present work was to focus on the investigation of the flexural and fatigue behaviour of flatwise, edgewise compression and water absorption of E-glass/ epoxy, jute/ epoxy, bamboo/epoxy, glass-jute/epoxy, glass-bamboo, Jute/bamboo /Polyurethane foam sandwich composites. Both natural and synthetic based sandwich composites were synthesized with different fabric and polyurethane foam. The fiber/ resin ration for glass/epoxy is 65:35 and all other natural fibers composites are 50:50 ratio of fibre to resin weight fraction. The sandwich specimens were prepared by hand adopting the lay-up method. This was followed by compression at room temperature. Bamboo/glass hybrid structure yields higher value of core shear stress and facing bending stress. This is higher than both pure glass, bamboo. This shows how effectively hybridization can be used to tailor materials for our specific use.

Index Terms- Natural fiber, polyurethane foam, sandwih structure, synthatic fiber,

I. INTRODUCTION

Recently, the increase in environmental awareness has impacted the materials design and manufacturing. Many products and structures made by non-renewable resources require substantial amount of energy for production that would generate excessive amounts of carbon dioxide. The introduction of natural fibres from renewable resources for structural composites can provide benefits to the environment with respect to their bio-degradability, costs and natural availability [1,2]. Research has been conducted with natural fibres such as jute, flax, hemp, coir and sisal as reinforcements for thermoset and thermoplastics since the last decade. The attractive features of these fibres are their abundant availability in the nature, low cost, light weight and high specific modulus in contrast to the synthetic fibres [3].

As a result of the increasing demand for environmentally friendly materials and the desire to reduce the cost of traditional fiber i.e. carbon, glass, and aramid fiber reinforced petroleum-based composites, new bio-based composites have been developed [4]. The authors have explored different natural composite materials made of soybean based resin and natural fibers, where good mechanical strength was achieved. It was shown that the flexural modulus increased from 1 GPa for the neat resin to about 6 GPa when the same resin was reinforced with recycled paper made from old cardboard boxes. The work reported here is based on work related to the development of bio-based thermosetting resins from plant oils such as soybean[5-6]. Natural fibers exhibit many advantageous properties as reinforcement for composites. They are low-density material, yielding relatively lightweight composites with high specific properties. Natural fibers also offer significant cost advantages and benefits associated with processing, as compared to synthetic fibers. Finally, they are a highly renewable resource, which reduces the dependency on foreign and domestic petroleum oil.

Recently, natural fibers have been used to reinforce traditional thermoplastic polymers in automotive applications [7]. Polypropylene has often been used as the matrix material. The influence of surface treatments of natural fibers on the interfacial characteristics was also studied [8,9] and reviewed by Mohanty et al. [10]. The micromechanics [11] and the thermo-elastic anisotropy [12] of natural fiber composites were also examined. Life cycle assessment of bio-fibers replacing glass fiber was also studied [13]. The objective of the research was to focus on the development and testing of: PU foam cored FRP sandwich structures using epoxy / e-glass, epoxy / jute and epoxy/bamboo as skin materials. Proprietary instrumented impact, bending, damping, buckling, crushing tests were conducted along with the interfacial studies to investigate into the static and dynamic mechanical behaviour of the PU foam cored composite sandwich structures.

II. EXPERIMENTAL STUIDES

The sandwich specimens were fabricated according to standard specifications. The specimen consist laminates of glass fiber/epoxy, jute /epoxy, bamboo/epoxy and PUF as core. The primary chemicals used to produce the PUF were methylene di-isocyanate (MDI) and polyether polyol (PP).

The procedure for preparation of rigid polyurethane foam can be summarized as follows:

- Amount of MDI and PEP liquids were taken in separate clean and dry glass cups.
- Inner surface of wooden die (250mm x 250mm x 25mm) was covered with a Teflon sheet.
- MDI and PEP were mixed using a stirring rod in a separate glass vessel.
- The mixture was poured into the die.

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- The die was covered with a wooden plate and a pressure of 5 tons was applied using hot press.
- PU rigid foam was taken out of the die after curing for 30 min.
- A Glass /Jute/Bamboo fiber mat was laid-up on PUF core.
- A resin and hardener was laid up on each face of the Glass/Jute/Bamboo fiber mat.
- Reinforcement fibers on each side of the rigid foam were laid-up.
- The specimens were cured at ambient temperature for 24 hours while applying pressure using hot press.

For each type of rigid polyurethane foam and sandwich structures, flatwise compression specimens are made in accordance with ASTM C 365. The length, width, depth of sandwich structure is 30 x 25.4 x 25.4mm respectively. The experiments were carried out on a computerized universal testing machine; in order to obtain the load versus deflection data. The test procedure for flatwise compressive properties was according to ASTM C 365 standards. Flatwise compression specimens were loaded in universal tensile testing machine. Edgewise compressive test for different proportions of rigid polyurethane foam and different types of sandwich structures are conducted in accordance with ASTM C 365 standards. The length, width, depth of sandwich structure is 75mm, 60mm and 30 mm respectively. Three point bending test for varied proportion of rigid polyurethane foam and different types of sandwich structures are done in accordance with ASTM C 393 standards. The length, width and depth of the sandwich structure are 100mm, 60mm and 30mm respectively. From each type of rigid polyurethane foam and sandwich structures water absorption specimens are made in accordance with ASTM C 272 standards. The length, width, depth of sandwich construction and core is 7.2mm, 7.2mm and 12.77 mm respectively. Flammability test of rigid polyurethane is done in accordance with ASTM D 3014 standards. The length, width, depth of core is 254 mm, 19.05mm, 19.05mm respectively.

III. RESULT AND DISCUSSION

A. *Microstructure of interface of core and skin*

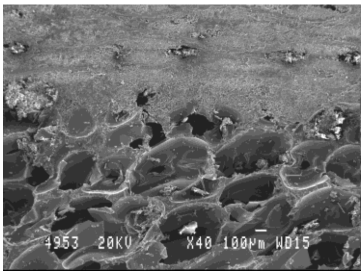
Fig. 1 refers to the interface between the core and facing (skin) of the sandwich structures. In Fig. 1 A, B, C refers to interface of rigid PUF with glass, jute, and bamboo respectively. From the micrographs shown below, it clearly observed that the hydrophilic nature of natural fibers leads to poor interface.

B. *Flatwise compression*

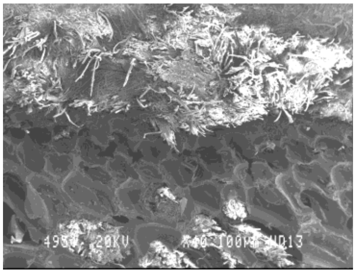
From Fig. 2, it is observed that facing material combination influenced the flatwise compressive strength of sandwich structure. Flatwise compressive strength is found to be high for glass/jute hybrid sandwich structure, which is higher than the glass sandwich structure. The flatwise compressive strength of hybrid sandwich structure, glass/bamboo is found to be satisfactory. The glass/jute hybrid sandwich structure possess flatwise compressive strength of nearly 1.07, 1.17, 2.05, 1.11, 2.06 times higher than glass, jute, bamboo, glass/bamboo, jute/bamboo sandwich structures respectively.

C. *Edgewise compression*

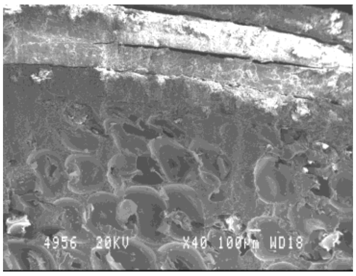
From Fig. 3, it is observed that the facing material combination influenced the facing bending stress in edgewise compression of sandwich structure. Glass/jute hybrid sandwich structure possess high facing bending stress, whereas for Jute/bamboo hybrid sandwich structure facing bending stress is found to be least. Facing bending stress of glass/ jute sandwich structure is 1.74, 2.77, 5.18, 1.40, 2.89 times higher than glass, jute, bamboo, glass/bamboo, Jute/bamboo sandwich structures respectively.



A. Glass/PUF



B. Jute/PUF



C. Bamboo/PUF

Fig 1 Scanning electron

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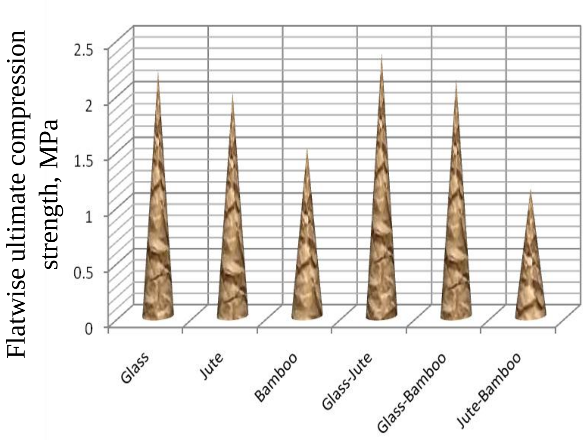

Fig. 2 Flat wise ultimate compression strength for different sandwich structure

D. *Edgewise compression*

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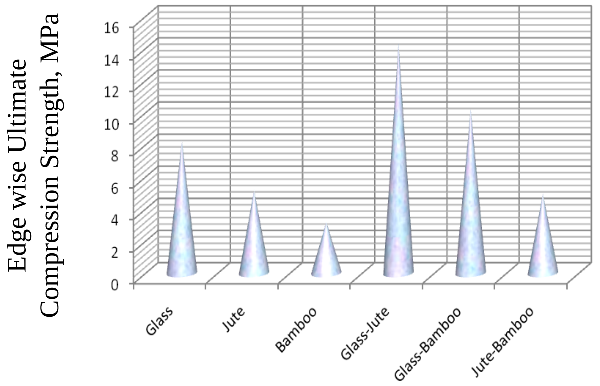

Fig 3: Edge wise ultimate compression strength for different sandwich structure.

E. Core-shear strength and 3-point impact strength

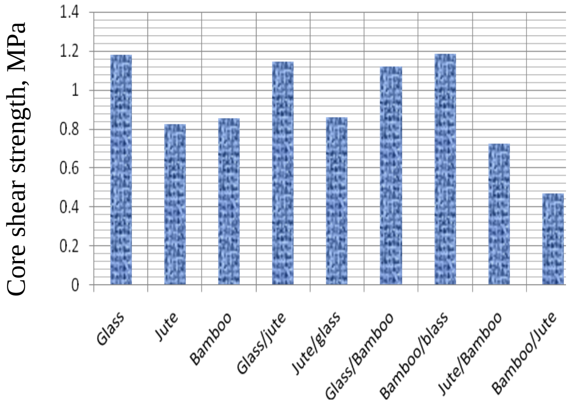

Fig. 4 Core shear strength for different sandwich structure.

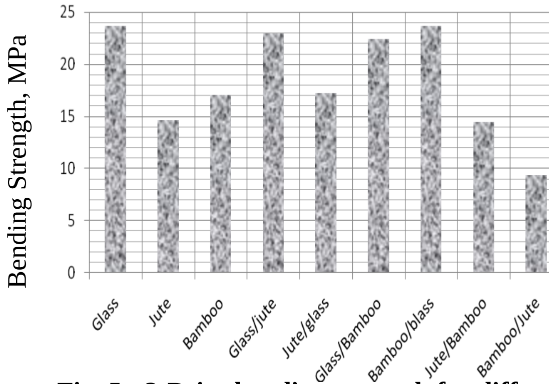

Fig. 5: 3-Point bending strength for different sandwich structure

The variation of core shear stress (CSS) v/s type of sandwich structure and facing bending stress v/s type of sandwich structure in three point bending is depicted as shown in Fig. 4 and Fig. 5 respectively. Bamboo/glass sandwich structure possesses higher CSS and facing bending stress, whereas bamboo/ jute possess lower value. In the figure, for table for example, glass/bamboo means upper/lower facing in sandwich structures respectively. The facing bending stress and core shear stress of bamboo/ glass sandwich structure is 1.01, 1.44, 1.39, 1.032, 1.63 and 2.53 times higher than glass, jute, bamboo, glass/jute, jute/glass, jute/bamboo, bamboo/jute sandwich structures respectively.

F. Water absorption

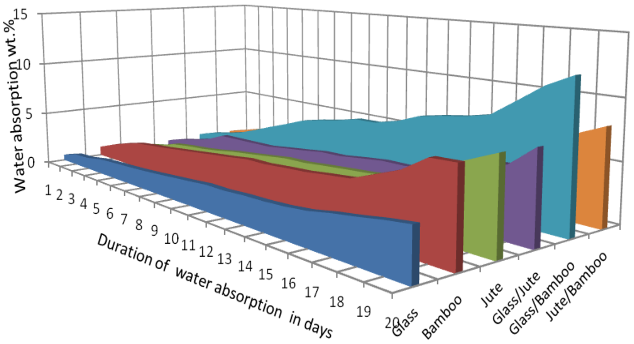

Fig 6 : Water absorption of different sandwich structures

From Fig. 6, it is noticed that the percentage of water absorption is found to be high for glass/ bamboo hybrid sandwich structure, whereas it is low for glass sandwich structure at the end of 20 days of immersion in water. The water absorption of glass sandwich structure is 0.55, 0.54, 0.55, 0.33; 0.51 times lower than bamboo, jute, glass / jute, glass / bamboo, and jute / bamboo structures respectively. Since bio-fibers are hydrophilic they are capable of absorbing more water than artificial fibers

IV. CONCLUSIONS

1. CONCLUSIONS

Based on the results of the experimental analysis the following conclusions are derived.

- In the flatwise compression test of sandwich structures, glass/jute hybrid sandwich structures possess higher value of flatwise compressive strength compared to other types of sandwich structure.
- In edgewise compression test of sandwich structure, glass/jute hybrid sandwich structure possess higher value of facing compressive stress compared to other types of sandwich structure.
- In the three-point bending test of sandwich structure, bamboo/glass hybrid structure yield higher value of core shear stress and facing bending stress, which is higher than both pure glass and bamboo.
- In water absorption test, the percentage of water absorption is found to be the maximum in case of glass/bamboo hybrid sandwich structures. This is higher than pure jute or bamboo sandwich structures.

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