Effect of Cyclic Compression Loading on Crushing Response of Polymer Based Composites Sandwich Panels

M Sripathy, K V Sharma, M Krishna

Abstract - The objective of work was focused to investigate microstructure of polyurethane foam and cyclic crushing strength of its sandwich structure which made of sisal / coir / bamboo / glass fabrics as reinforcement with polyester resin to form composites skin. The tested sandwich panels were constructed four type of FRP faceplates made of sisal / coir / bamboo / glass fiber reinforcements impregnated in polyester resin in four different material combinations. Each specimen subjected ten cyclic compression loading upto 40% maximum strain. The results indicate that the foams initially harden after the first cycle and then soften in subsequent cyclic loading. The hysteresis loops tend to shrink and approach asymptotically to a steady state before failure both the foam and the skin. The considered damage is in a form of through-width zone of crushed foam core accompanied by a residual crushing in the foam. It is shown that such damage causes a significant reduction of compressive strength. Glass/polyester and bamboo/polyester skin based sandwich structures have superior compressive strength. Coir /polyester based sandwich structure shows next to glass/polyester sandwich structures.

Keywords- glass fabrics as reinforcement with polyester resin to form composites skin.

I. INTRODUCTION

Sandwich panels show an outstanding performance in structures that require a light weight and a high bending stiffness. Consequently, sandwich materials are extensively used by the aircraft and aerospace industries [1-2]. Since a high bending stiffness at low weight is also desirable in modern vehicles, sandwich panels are considered as potential structural element for automotive applications [3]. In other hand, presently, increasing demand for environmentally friendly materials and the desire to reduce the usage of conventional fibers such as carbon, glass and aramid fiber. Few authors [3-5] have explored various natural fibers, where good mechanical strength was achieved. Natural fibers are a low-density material, yielding relatively lightweight composites with high specific properties. It also offer significant cost advantages and benefits associated with processing, as compared to synthetic fibers. Natural fibers have been used to reinforce traditional thermoplastic polymers in automotive applications [6].

The influence of surface treatments of natural fibers on the interfacial characteristics was also studied [7]. Natural fiber reinforced composites However presently natural fiber limited only for fiber reinforced plastics laminates and for sandwich structure's skin construction the conventional glass fiber and carbon fiber are used. This study aimed at developing sandwich structural skin members made from natural fiber like sisal, coir and bamboo reinforced with polyester and tested for crushing behavior. Mean time glass fiber reinforced polyester composites tested and compared with crushing behavior. The objective of this work is therefore to conduct face-wise cyclic compression tests to investigate into the crushing behaviour of polyurethane foam cored composite sandwich structures.

II. EXPERIMENTAL STUDIES

2.1 Materials used

The materials used in making the beams were polyester resin, natural fibers (jute, Bamboo and coir), E-glass fiber and polyurethane foam. The natural fibers and the coupling agents are characterized as follows

1. Natural fiber, mechanically separated, industrially purified and alkalized at less than 5% NaOH, carding strip
2. Treated fiber separated by steam explosion

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

2.2 Fabrication of sandwich specimen

The procedure followed for fabricating the sandwich specimens:

1. Calculated amount of MDI and PP liquids were taken in separate clean and dry glass cups to produce PU foam of density 0.8 gm/cc.
2. Inner surface of the wooden die fabricated to suit the impact specimens (63.5mm x 12.5mm x 3 mm) was covered with teflon sheet.
3. MDI and PP were mixed by vigorous mechanical stirring
4. The mixture was poured into the die.
5. The die was covered with a teflon coated metal plate and a pressure of 0.5 MPa was applied.
6. PU rigid foam was taken out of the die after curing for 20 minutes.
7. Woven fabric was laid-up on the polyurethane foam core

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Table 1 Material Composition of skin.		
Material Composition	Weight Fraction (in %)	
	Fiber	Polyester Resin
Glass /polyester composites	65	35
Jute /polyester composites	50	50
Bamboo/polyester composite	50	50
Coir / polyester composites	50	50

8. Polyester resin was laid up on each face of the fabric (the specification is given in Table 1)
9. The specimens were cured in hot press at a pressure of 0.5 MPa and 120 °C for 3 hours

2.3 Crushing (Lateral compression) tests

Experimental study was initially conducted to investigate the physical phenomena of local damage and crushing in sandwich beams. The specimen for crushing tests 100 mm x 100mm x 50 mm. Crushing tests were conducted in an Instron Universal testing machine at cross-head displacement rate of 2 mm / min. to limit the overall bending the sandwich beams were entirely rested on a steel plate. Load was applied through a steel plate as shown in Fig. 1. The load is applied for all the specimen is upto 300 kg (uniform cross head) the deformation of the sandwich is noted. Repeating crushing cycles are applied upto 10 cycles for all the specimens. In result and discussion only two cycles of compression are given for clarity purpose. The following four types of specimens were used for crushing test for ten cycles: Polyester / e-glass, Polyester / bamboo, polyester / coir mat and polyester / sisal

Fig. 1 Crushing of sandwich structures

III.RESULTS AND DISCUSSION

3.1 Foam microstructure

The SEM photograph of undeformed PU foam material is given in Fig. 2 (a). Unlike slender edges in regular closed cell foam, anomalous sheet edges were found. Fig. 2(b) gives SEM photographs of dynamically compressed specimen. There is evidence that the PU foam is crushed in a spatially uniform manner both at quasi-static rate. It indicates that the foam deformation is uniform with no crush band formation.

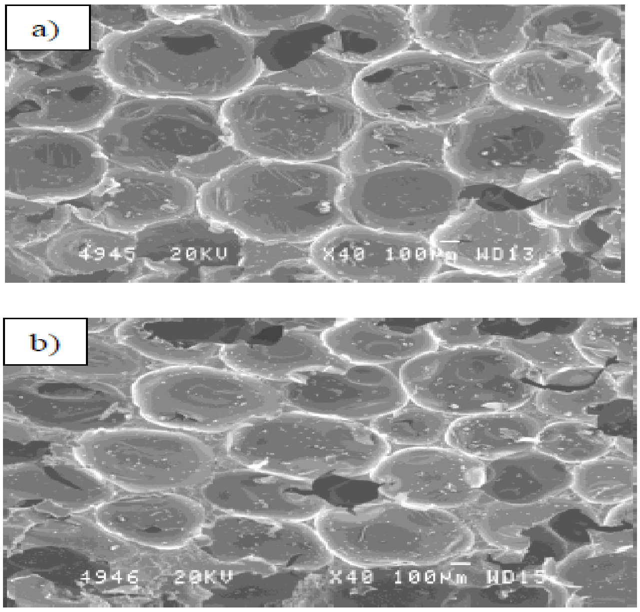

Fig. 2 Microstructure of PU foam a) before crushing and b) after crushing

3.2 Cyclic crushing

Typical load–displacement curve sampled during the tests for e-glass/polyester, bamboo/polyester, coir/polyester and sisal /polyester is shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5 respectively. Only two cycles of crushing data as given these figures for clarity purpose. But the overall performance i.e maximum deflection of these sandwich structures are given in the Fig. 6. The load-displacement curve shows pure elastic response of a specimen at first cycles, the onset of core crushing occurs, and the following cycles a progressive growth of a crushed core zone as shown in Fig. 6. Undergoing relatively high deflection 20-30 mm for sisal /polyester sandwich structures, the faces emitted popping sound, presumably indicating microscopic failure of individual fibers in the vicinity of the contact with a steel plate.

The crushed core zone was clearly observed during and after the crushing tests, since it had specific appearance and colour. Increasing the damage area caused substantial change in the crushing compression properties, namely the local squeeze buckling in the damaged zone followed by an instantaneous drop in the overall stiffness.

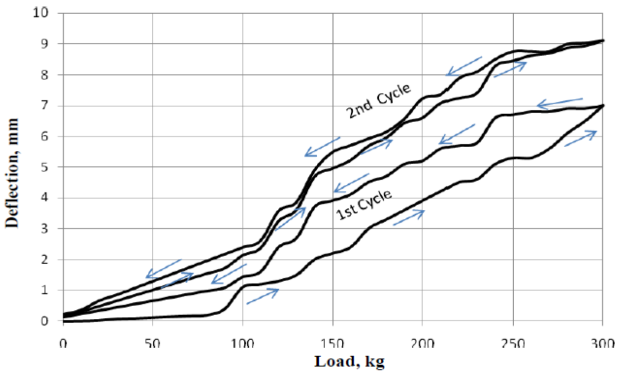

Fig. 2 Cyclic compressive loading – Polyester / e-glass with double woven

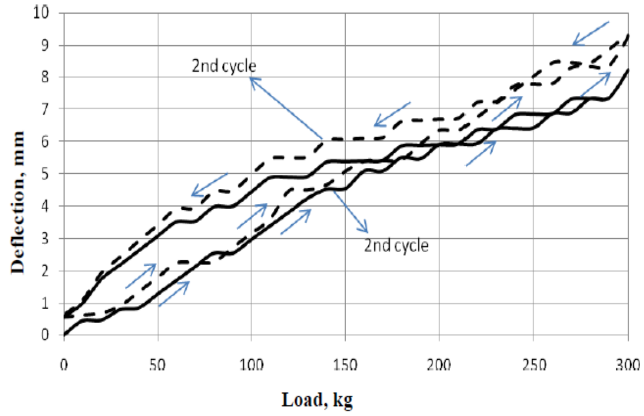

Fig. 3 Cyclic compressive loading – Polyester / Bamboo with double woven

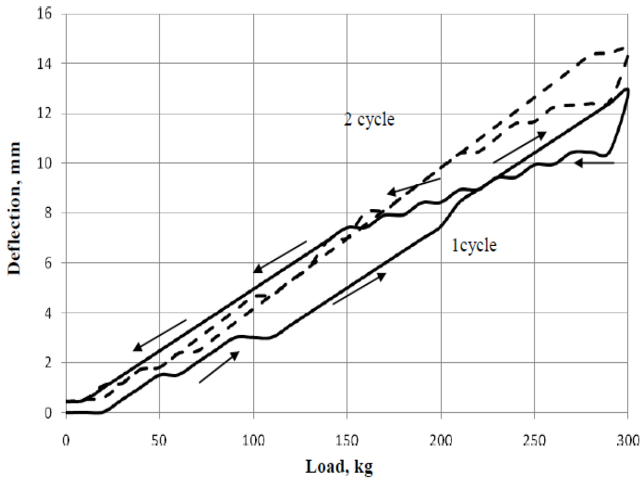

Fig. 4 Cyclic compressive loading – Polyester / Coir with double woven

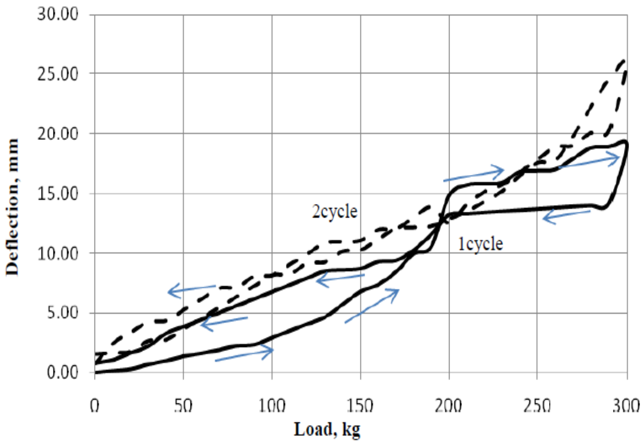

Fig. 5 Cyclic compressive loading – Polyester / Sisal with double woven

The specimens were subjected to compressive loads up to 0.56% of their compressive strength. The compressive behaviour was similar irrespective of the skin material, which shows that in lateral compression the specimens behave similar to that of parallel springs. The skin transfer full load on to the foam. Hence, the lateral crushing strength of the sandwich structures depends on only the strength of the foam. A very little difference in results was observed in lateral compression, amongst the samples, which means, only interfacial strength contributes to the crushing resistance of the sandwich structures.

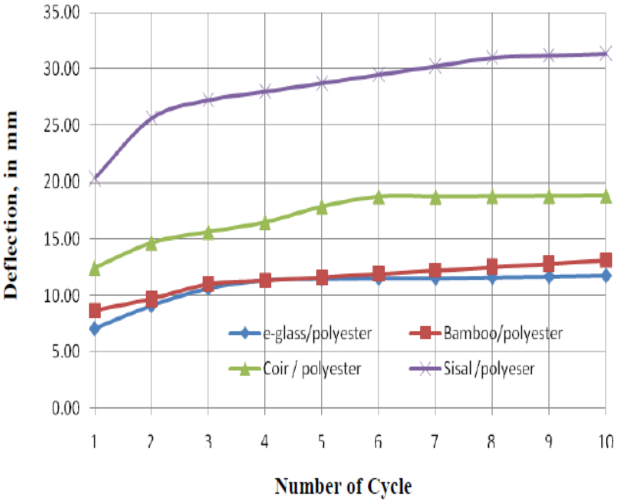

Fig. 6 Effect of number of cycles on deflection of sandwich structures at 300 kg force.

In cyclic compression the structures absorb energy when compressive loads are applied and release energy when the loads are removed with a very small deformation. The experiments showed a small deformation in the initial cycles (upto 6 cycles) and no deformation in the subsequent cycles. The very large foam cells get fully damaged in the initial cycles of compression due to high air compression ratio and in the subsequent cycles, there will not be any effect of these large cells. The smaller cells act as dampers because of low air compression ratio. In compression the circular holes of PU foam become elliptical perpendicular to the axis of load. The compressive strain signature is non-linear due to the stiffening of the sandwich with increase in compressive load. The deformation mechanism of foam are localized under-static compression conditions they become even more localized and propagate through the material as crushing wave fronts which have some of the character tics waves[8].

IV. CONCLUSIONS

The results of an extensive test program on crushing compression for the four types of sandwich structure specimens namely e-glass/polyester, bamboo/polyester, coir/polyester and sisal / polyester based sandwich structure are discussed. The particular focus was posed on the stability of the face sheets within the damaged zone. The main results can be outlined as the following

- The experimental study revealed that a typical damage consists of sub-interface zone of crushed core and bend in the face sheet without delamination between foam and face sheets.
- For one sandwich configuration subject to crushing loading, the only core damage can be seen this effect reduced considerably in face sheet.
- The crushing occurred in the damage zone and was proved by the residual square in the core. This failure mode caused substantial increase in the compression deformation i.e reduction in the compression load capacity and overall stiffness.
- Of the four types of sandwich specimens glass/polyester and bamboo/polyester exhibited highest crushing resistance and sisal /polyester exhibited the lowest crushing strength.

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