Modelling structural response of flax-based composite interlocking structures

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Recently, an increasing interest in designing an environmentally-friendly materials and lightweight structures has growth rapidly. Composite based on natural fibre has shown its offer great specific properties that comparable with those traditional composite materials. In this paper, the structural behaviour of the sandwich structures made from flax-based composite was studied experimentally and numerically. Flax reinforced polypropylene (flax/PP) and flax reinforced polylactide (flax/PLA) were selected to manufacture the skin and core of square and triangular interlocking structures. These structures were tested in quasi-static and dynamic loading conditions. Finite element models were then developed to simulate response of the structures subjected to static and dynamic compression. Here, modelling covers strength, energy absorption, buckling behaviour and failure modes. Reasonably good correlation was obtained between the experimental results and the finite element simulations.

Keywords: Natural fibre, Environmentally-friendly, Flax, finite element, impact

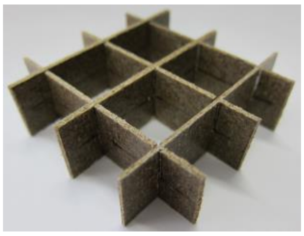
Introduction

To date, large amount of work on natural fibre composite materials has been conducted. Many researches have reported that natural fibres are good in specific properties and biodegradable materials. Natural fibres such as flax, hemp, oil palm and more can be a potential replacement to those glass fibres with a careful designation. In addition, natural fibres can offer low density, high specific properties, low cost and biodegradable [Mohanty et al. (2005); Saheb et al. (1999)]. In this study, interlocking core structures manufactured from flax-based composites were investigated. The square and triangular core interlocking structures were considered and compared. Subsequently, the finite element models were developed to predict the properties and compare with the experimental data.

Experimental and Numerical Procedures

The flax/PP and flax/PLA composites were manufactured using a Meyer hot press under a pressure of 1.5 bar and temperature of 190ºC and 180ºC, respectively, with three plies each. Following this, the core interlocking structures were produced using the simple slotting technique from a strip with 20 mm height. Then, it was bonded to the two skins using the same materials made for core with an epoxy resin. Figure 1 show the photograph of square and triangular interlocking of flax/PP composite.

Later, the square interlocking structures were modelled using the ABAQUS/Standard to simulate response of the structures subjected to static and dynamic compression. The flax-based composite was modelled as an isotropic material with hardening prior to the core buckling. A geometrical imperfection was introduced by using the *IMPERFECTION function in the linear perturbation step in order to develop an accurate result with the experimental data.


(a)

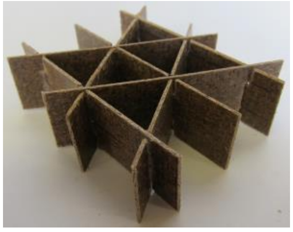

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Figure 1. Photograph of (a) square core interlocking and (b) triangular core interlocking of flax/PP composite.

Result and Discussions

Results from the quasi-static and dynamic tests for the flax-based composite interlocking structures are shown in Table 1 and 2. Here, the maximum strength and SEA values for square interlocking core structure of flax/PP were 1.87 MPa and 3.07 kJ/kg, respectively. The difference in strength between the triangular to that square interlocking of flax/PP was approximately 25% higher. It is clear that both interlocking structures of flax/PP composite have outperformed the flax/PLA composite in terms of the strength and SEA values. There were no significant differences between the two structures of the flax/PP and flax/PLA composites.

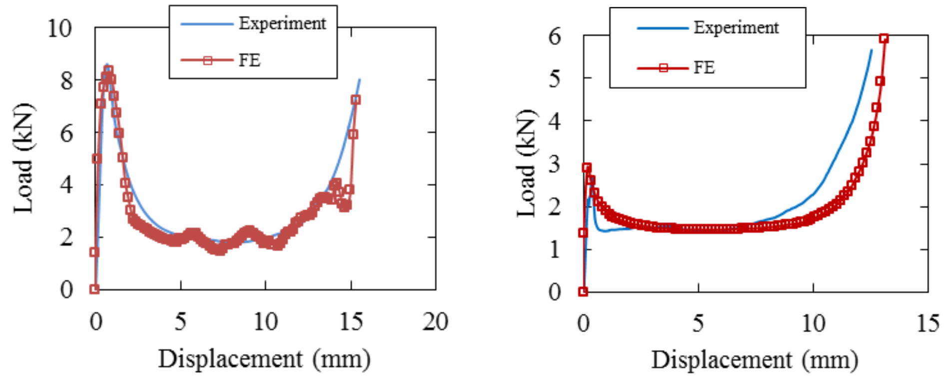
Table 1. Quasi-static properties of flax-based interlocking core structures.

Interlocking Structure	Material	Max. Strength (MPa)	SEA (kJ/kg)
Square	Flax/PP	1.87	3.07
	Flax/PLA	0.52	0.82
Triangular	Flax/PP	2.51	2.62
	Flax/PLA	0.54	0.81

Table 2. Dynamic properties of square interlocking core structures.

Material	Max. Strength (MPa)	SEA (kJ/kg)
Flax/PP	2.63	5.26
Flax/PLA	0.41	1.13

The square and triangular core structures has been modelled to predict the load-displacement curves and compared with the experimental results. A very good agreement was observed between the experimental and finite element data, from the beginning until the densification stages, for the quasi-static and dynamic tests of flax/PP composite. Similarly, the quasi-static loading of flax/PLA composite modelling has also shown a good correlation with the experimental result. However, the dynamic loading for flax/PLA composite modelling showing a late densification stage compared to the experimental result but the trends was similar.



(a) (b)

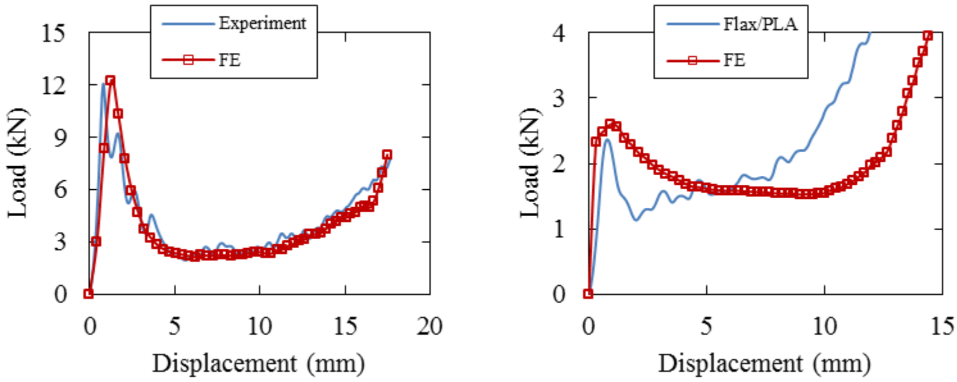


Figure 2. Results of square interlocking through quasi-static tests of (a) flax/PP and (b) flax/PLA composite, and dynamic tests of (c) flax/PP and (d) flax/PLA composite.

Conclusions

The interlocking structures have shown that the mechanical properties of flax/PP composite were better than the flax/PLA composite. Both core structures show no significant differences, hence, it was assumed that both can provide a similar mechanical properties. The finite element modelling show a good relationship of the load-displacement traces with the experimental result. However, the flax/PLA composite model needs a further investigation due to the late densification stage on the finite element result.

References

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