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Effect of varying geometrical parameters of trapezoidal corrugated-core sandwich structure

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Abstract. Sandwich structure is an attractive alternative that increasingly used in the transportation and aerospace industry. Corrugated-core with trapezoidal shape allows enhancing the damage resistance to the sandwich structure, but on the other hand, it changes the structural response of the sandwich structure. The aim of this paper is to study the effect of varying geometrical parameters of trapezoidal corrugated-core sandwich structure under compression loading. The corrugated-core specimen was fabricated using press technique, following the shape of trapezoidal shape. Two different materials were used in the study, glass fibre reinforced plastic (GFRP) and carbon fibre reinforced plastic (CFRP). The result shows that the mechanical properties of the core in compression loading are sensitive to the variation of a number of unit cells and the core thickness.

1 Introduction

Composite laminate with single skin, made from carbon, glass and other fibres may be strong but lack of stiffness due to their relatively low thickness[1]. Sandwich structures comprising of face-sheets and cores are broadly used in transportation vehicles and civil infrastructure due to their high stiffness/strength-to-weight ratio [2–10]. Sandwich structures have numerous topologies in different material- e.g composite corrugated-core, metallic core, or metallic textile core [10–14]. Sandwich structures have different core material including the shape. The foam cores are preferably used when the waterproof, sound and heat insulation qualities of cores are required. Moreover, the foam cores are the cheaper among core materials and can offer some advantages in sandwich construction. Furthermore, the honeycomb core sandwich structure comprise of a thick layer core separate with thin stiff layers (skins) and they are describe as cellular cell because of the shape like bee honeycomb. Honeycomb is lightweight, high flexural stiffness and can support classical loadings like tension and bending. Applications of corrugated-core sandwich structure have been used in aerospace and automotive industries, marine ship and civil due to their high strength to weight ratio[6][9][15]. Previously, Mohammadi et al. [16] proposed analytical formulation for trapezoidal corrugated panels. The formulation was based on energy approach and castigliano's theorem. The analytical was compared with FEM results. Investigation of large displacement behaviour of aramid/epoxy trapezoidal

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corrugated laminates under tensile loading transverse to the corrugation direction was conducted by Thill et al. [7]. Rejab and Cantwell [9] studied compressive properties of triangular corrugated-core sandwich structures based on three dissimilar material both experimental and numerically. From the study, indicate that thick CFRP corrugations offer properties that are similar to those exhibited by aluminium honeycombs. In this paper, sandwich structure with trapezoidal corrugated-core is loaded in compression direction and the effects of geometrical parameters are discussed. The trapezoidal corrugated specimens are made of carbon fibre reinforced plastic (CFRP) and glass fibre reinforced plastic (GFRP).

2 Experimental setup

2.1 Core fabrication

The corrugated-core specimens were fabricated using a trapezoidal machined mild steel mould. By using epoxy resin carbon fibre plain weave fabrics were hand-layup and cured for 24 hours in room temperature. Ply of the carbon fibre are count to obtained desired thickness. Figure 1 shows the trapezoidal corrugated-cores mild steel mould. The cores were cut to test specimen size using electrical saw.

Fig. 1. Trapezoidal corrugated-core mould.

2.2 Core geometry

The length of the trapezoidal corrugated-core investigated in this paper is 40 mm, 120 mm and 200 mm. Which is 40 mm is for 1 unit cell, 120 mm is for 3 unit cell and 200 mm is for 5 unit cell. The width of compression test and tensile test specimen are 25 mm, respectively. Furthermore, thickness of tensile test specimen and thickness of compression test specimen is tabulated in Table 1.

2.3 Core material characterization

The corrugated-core is made of different plies of plain weave carbon fibres with epoxy resin. To evaluate the mechanical properties of the carbon fibre reinforce polymer, a total of five specimens were manufactured and were end tabbed using aluminium and Araldite 420AB adhesive for tensile test. The length, width and thickness of the tabbed sections are 250 mm, 25 mm and 2 mm individually.

3 Experimental works

3.1 Static compression test

A compression test tested on each specimen by using a testing machine, Instron series 3369, load capacity 50 kN as shown in Figure 2. The specimen was placed and a uniform compression was then applied at rate of 2 mm/min. Each specimen have core ID, for example CF1U3P (CF is stand for carbon fibre, 1U stand for one unit cell and 3P is stand for three plies). Table 1 below shows material used, core ID, number of unit cell, number of plies, average core width, average core length and average core height. Tests were repeated three specimens for one core ID. The data of load-displacement was recorded until the specimen fully crushed by compression.

Table 1. Compression test parameter for corrugated composite core.

Material	Core ID	No of unit cell	No of plies	Average core width (w)	Average of core length (l)	Average core height (mm)
CFRP	CF1U3P	1	3	25	40	13
	CF2U3P	2	3	25	80	13
	CF3U3P	3	3	25	120	13
	CF1U4P	1	4	25	40	14
	CF2U4P	2	4	25	80	14
	CF3U4P	3	4	25	120	14
	CF1U5P	1	5	25	40	16
	CF2U5P	2	5	25	80	16
	CF3U5P	3	5	25	120	16
GFRP	GF1U2P	1	2	25	40	14
	GF2U2P	2	2	25	80	14
	GF3U2P	3	2	25	120	14
	GF1U3P	1	3	25	40	17
	GF2U3P	2	3	25	80	17
	GF3U3P	3	3	25	120	17
	GF1U4P	1	4	25	40	18.5
	GF2U4P	2	4	25	80	18.5
	GF3U4P	3	4	25	120	18.5

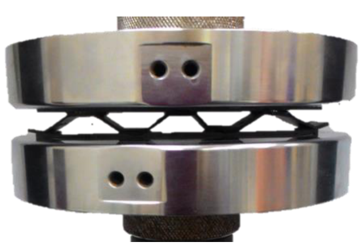

Fig. 2. Static compression test setup on CFRP specimen.

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4 Results and discussion

4.1 Compression test

Compression testing on the trapezoidal corrugated-cores displayed that the behaviour of different core were significantly difference.

4.2 Mechanical bBehaviour of corrugated-core

The failure processes in CFRP trapezoidal corrugated-core are shown in Figure 3, the early failure start with debonding at the end of right and left specimen. Following failure include delamination, fibre breaking and debonding (III-VI).

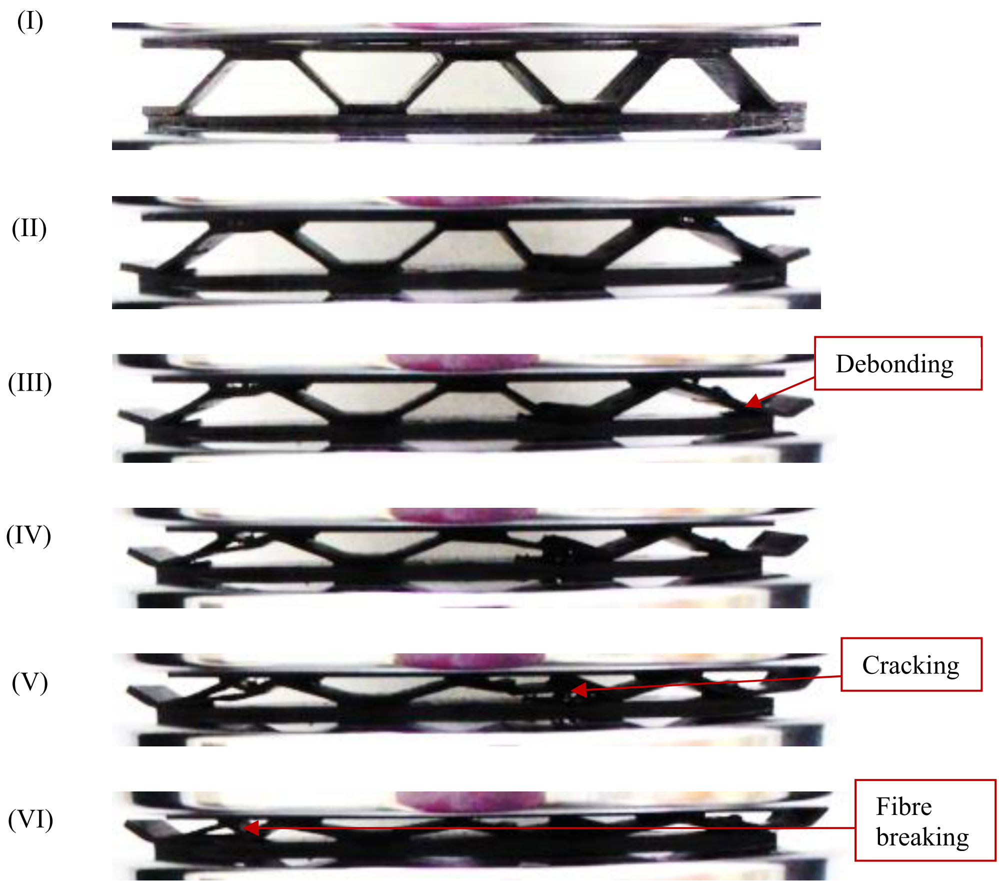

Fig. 3. Compression behaviour of CFRP trapezoidal corrugated-core.

The failure processes in GFRP trapezoidal corrugated-core are shown in Figure 4, the initial failure start with debonding at the end of right and left specimen. Following failure include delamination, fibre breaking and debonding (III-VI). The stress strain curve in Figure 5 for GFRP trapezoidal corrugated-core shows that the compressive stress increases to 3.36 MPa at 0.0589 mm of displacement and drop to 1.38 MPa at 0.6 mm. When the cell wall buckled or debonding at left and right, the force dropped progressively in image (I-II). Following failure include delamination, fibre cracking and debonding (III-V).

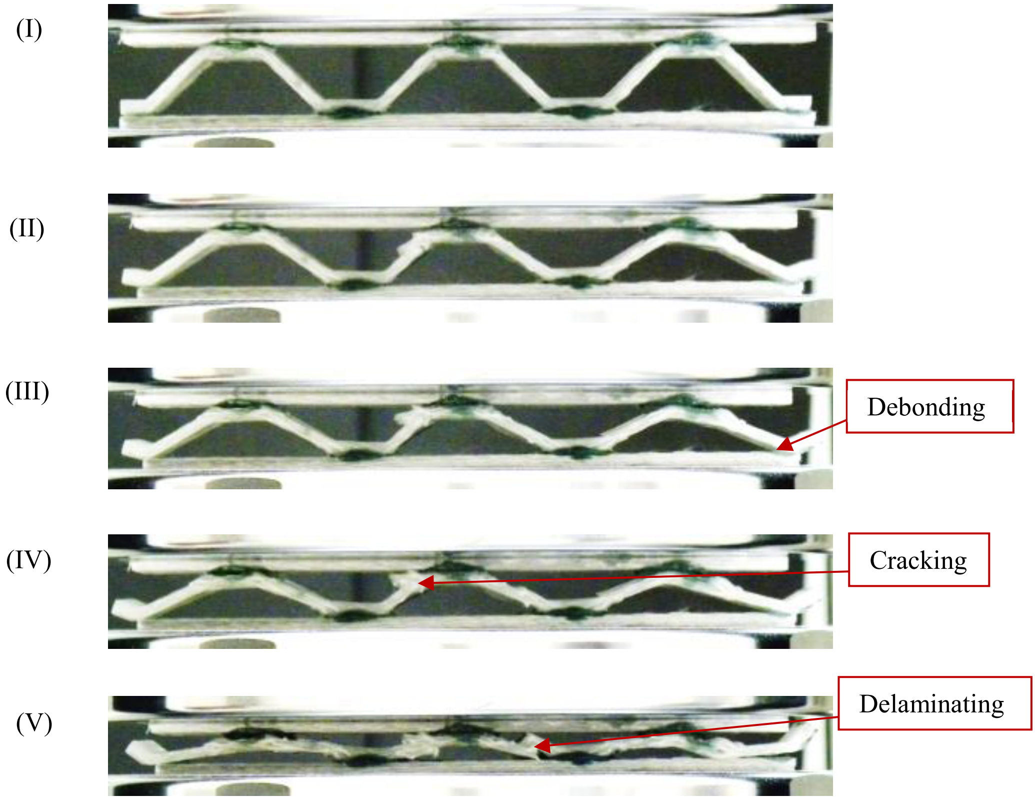

Fig. 4. Compression behaviour of GFRP trapezoidal corrugated-core.

4.3 Effect of varying no of plies and varying no. of unit cell

In an attempt to validate more precisely, test were taken on three specimens for GFRP and CFRP. The effect of varying number of unit cell and varying wall thickness on compression strength of GFRP and CFRP trapezoidal corrugated-core sandwich structure is shown in Figure 6 and Figure 7. Obviously, the compression strength of (CFRP) is much higher than GFRP structure due to the fact that carbon fibres have higher mechanical properties than GFRP. Figure 6 and 7 shows effect of varying the number of unit cell for GFRP and CFRP from one to three unit cells. It shows that the higher number of unit cell, it influences the composite strength. For the effect of cell wall thickness, Figure 7 shows the higher the wall thickness, the higher the compression strength.

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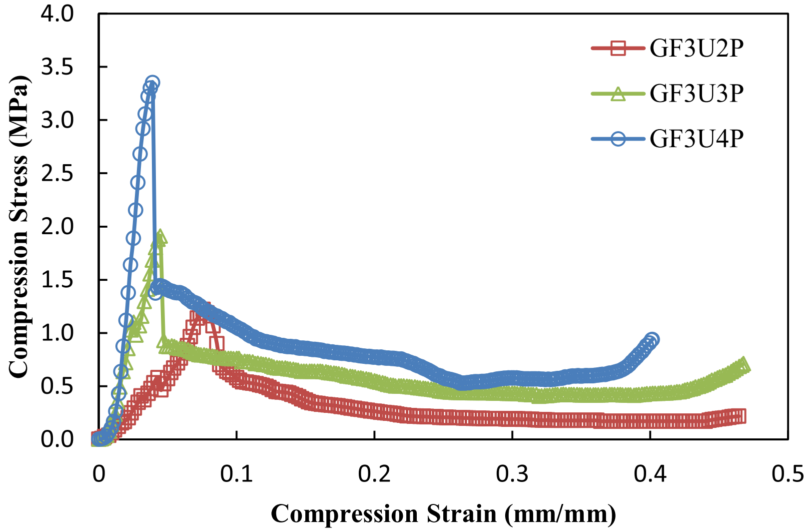

Fig. 5. Compression Stress Strain Curve for a GFRP trapezoidal corrugated-core.

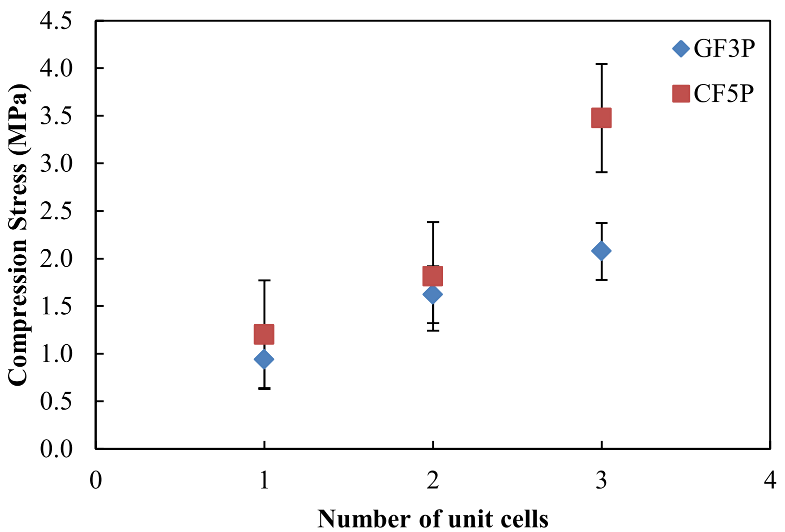

Fig. 6. Comparison between glass fibre four plies (GF3P) with carbon fibre 5 plies (CF5P).

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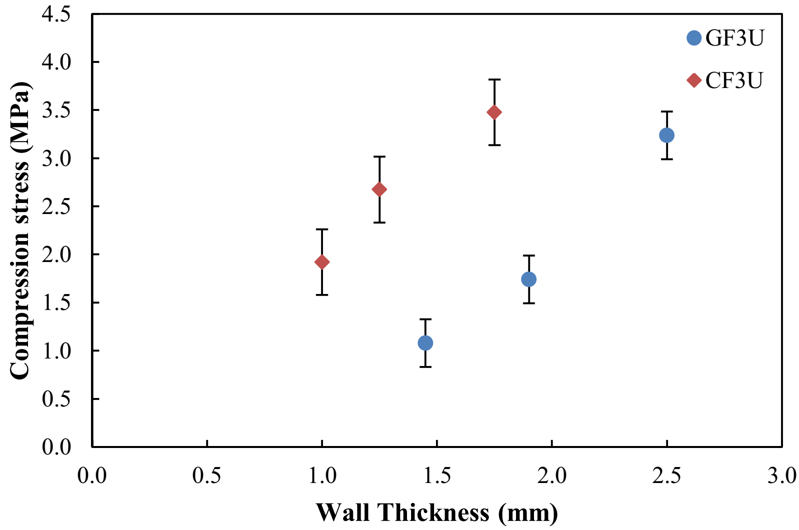

Fig. 7. Comparison between glass fiber three unit cells (GF3U) with carbon fiber three unit cell (CF3U)

5 Conclusions

Trapezoidal corrugated-core was fabricated using a 45˚ profiled mould, was used to manufacture range of lightweight sandwich structures. A 45˚ corrugation angle was designated since it represents an optimal configuration for all combinations of bending, shear and stretching stiffness. The compressive behaviour and resulting failure mechanism in structures based on two different materials have been investigated experimentally. An investigation of corrugation during testing indicated that initial failure was dominated by instabilities as the cell walls begin to buckle. In contrast, the composite fibre exhibited fibre fracture, delamination and debonding. From the finding the effects of varying the number of unit cell dominate by CFRP is 3.48 MPa higher than GFRP that 2.08 Mpa at three unit cell. It shows that the higher number of unit cell, it influences the composite strength. For the effect of cell wall thickness, shows the higher the wall thickness, the higher the compression strength. Compression strength CFRP and GFRP are 3.48 MPa and 1.74 MPa at thickness 1.75 mm and 1.90 mm respectively. For future work, the testing will be extended to correlation under bi-axial loading.

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