

HiPerDuCT Programme Grant

Final report: Wavy-ply sandwich with crushable core

This workpackage focused on the design, simulation and testing of a sandwich structure (Figure 1) which exhibits large deformations (through unfolding of the wavy composite skins) and high energy-absorption (through crushing of the foam core cells) under tensile loading [1,2].

The wave geometry, foam material and shape of epoxy fillet were optimised through a combination of analytical modelling and Finite Element (FE) simulations. Abaqus' plasticity model for crushable foam with volumetric hardening was used to simulate the response of the core material; the initial yield surface of the foam was calibrated using the values of strength under uniaxial tension, uniaxial compression and shear loading provided by the manufacturer, and the assumed strain hardening behaviour was found to influence significantly the response and failure mode of the wavy-ply sandwich structure. Cohesive elements were used to account for the possibility of debonding near the bridging region, between the skin and the foam core / epoxy fillet.

Wavy-ply composite specimens were manufactured using machined foam cores and aluminium moulds. Experimental testing of the wavy-ply specimens demonstrated high strength, large deformations and high energy absorption (Table 1), as predicted by the FE simulations (Figure 2). Envisaged applications of the *wavy-ply sandwich with crushable core* concept include blast protection structures and casings.

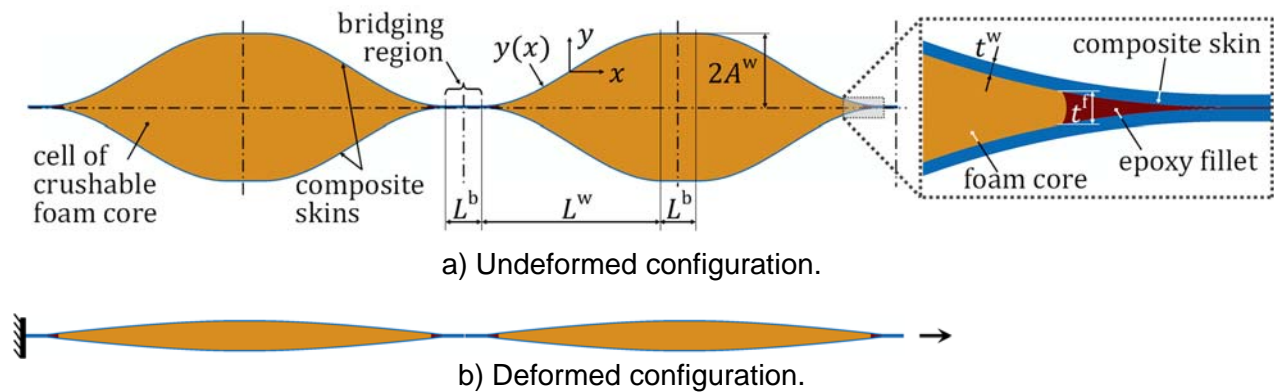
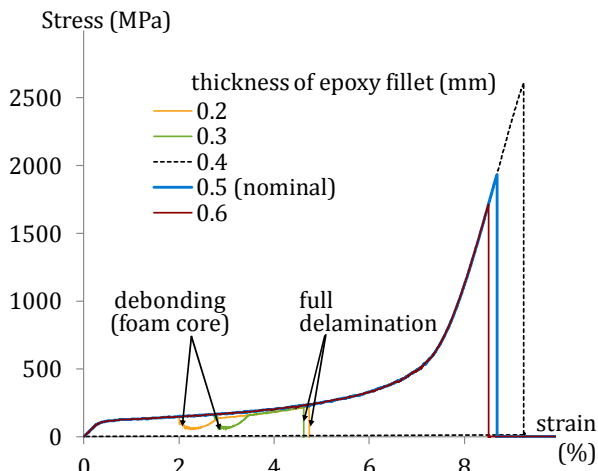


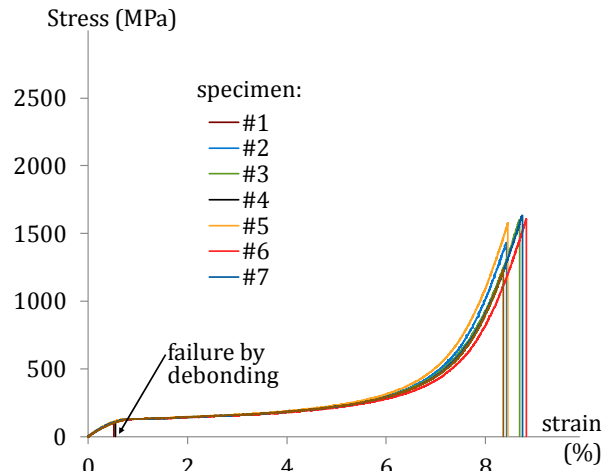
Figure 1. Wavy-ply sandwich concept.

Table 1: Mechanical properties measured for wavy-ply composites (from six successful tests).

	Initial stiffness, E_0	Ultimate strength, X_∞	Failure strain, e_∞	Energy dissipated, U
Average	28.4 GPa	1570 MPa	8.62%	9.35 kJ/kg
Coefficient of Variation	2.9%	5.0%	2.1%	9.6%



a) FE stress-strain curves for different resin fillet thicknesses.



b) Experimental stress-strain curves.



c) Original configuration in the FE (tessellated).



d) Untested wavy-ply sandwich specimen.



e) Predicted deformed shape before failure (tessellated).



f) Wavy-ply sandwich specimen immediately before final failure.

Figure 2: Comparison between FE (left) and experimental (right) results.

References

- [1] Pimenta S, Robinson P, "[Wavy-ply sandwich with composite skins and crushable core for ductility and energy absorption](#)", *Composite Structures* 116 (2014), 364-376.
- [2] Imperial Innovations Limited, "**Structural composite material**". UK Patent: application 1405824.2; 1 April 2014.