NOVEL COMPOSITE CELLULAR MATERIALS SHOWING AUXETIC BEHAVIOR: PROCESSING AND PROPERTIES

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Introduction

The term auxetic [1-3] refers to a novel class of materials characterized by negative Poisson ratio, this means that these materials expand when stretched rather than contracting as traditional materials.
Scarpa et al [5] have recently reported a combined analytical, numerical and experimental analysis on the compressive strength of hexagonal chiral honeycombs due to elastic buckling of the unit cells under flatwise compressive loading. Hexagonal chiral honeycombs are cellular structures composed noncentresymmetric unit cells, with an in-plane negative Poisson's ratio equal to -1 the compressive strength for low-density ratios was showed to be higher compared to analogous density properties in conventional centresymmetric honeycombs.
In the present paper the development of a novel RTM methodology to produce a chiral auxetic structure is described. The material has been fully characterized in terms of mechanical properties and, the comparison with commercial cores will be discussed.

Manufacturing method

The key technology for the production of the novel cellular auxetic solid is based on the use of a proprietary resin transfer moulding technology [6] which has been awarded with the international award Polymer Challenge 2008.

Results and discussion

Fig. 1 shows some specimens obtained with the proprietary manufacturing method with glass fibers as reinforcement and polyester resin as matrix. The cell geometry of our sample is the hexachiral antisymmetric (Fig.2) reported by Scarpa et al [5]. The cell is characterized by a cylinder of radius r and six ligaments of length L.

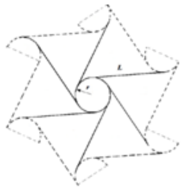


Fig.2 Cell geometry

All the materials (ie. glass fiber and vinylester) used were from commercial sources. The specimens were 2.5cm thick and 40*40cm wide. The specimens were tested according in terms of compression flatwise (ASTM C 365-00) and edgewise (ASTM C364-94), three point bending (ASTM C 393-00) and shear (ASTM C273-00).

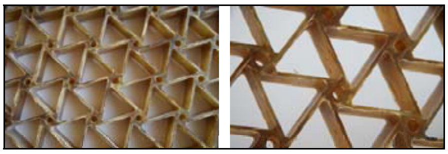


Fig.1 Examples of cellular solids with chiral geometry obtained by RTM.

The properties of the materials developed were compared to commercial cores Dynicell from DIAB [7]. The results of the comparison are reported in the following graph in terms of nondimensional properties calculated according to the following formula (1):

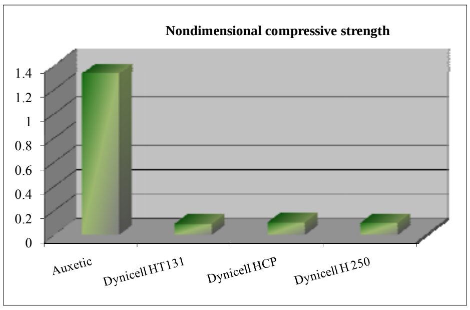
$$P_A = \frac{P}{\rho_S} \quad (1)$$

Where P_A is the adimensional mechanical property; P is the mechanical property (ie. compressive strength, compressive modulus etc.) and ρ_S is the surface density. The surface density is calculated according to the formula (2):

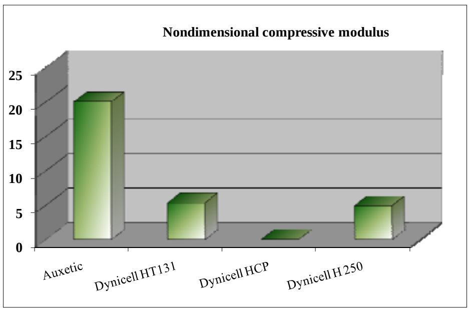
$$\rho_S = \rho_V * t * g \quad (2)$$

Where ρ_S is the surface density, ρ_V is the volumetric density, t the sample thickness and g the constant of gravity.

Fig.2 reports the comparison of the auxetic cellular composite with some commercial cores from DIAB in terms of the non dimensional compressive strength and modulus.



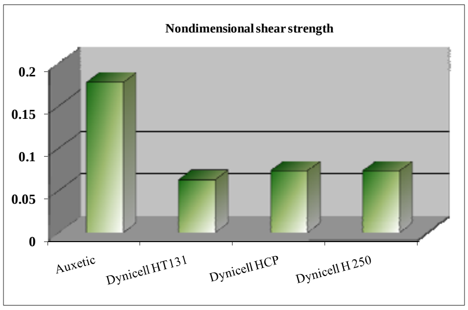
(a)



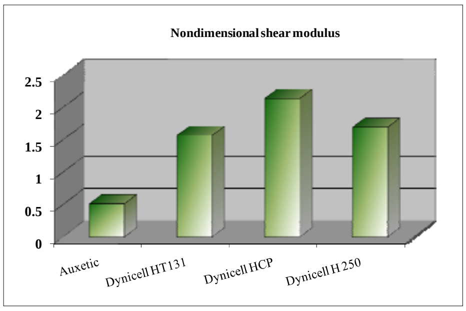
(b)

Fig.2 Non dimensional compressive strength (a) and modulus (b)

The comparison (Fig.2) shows that the auxetic materials outperform the commercial products both in terms of strength and modulus when compression is considered. This result is largely due to the cell topology of the auxetic that, being characterized by cylinders stabilized by tangential ligaments, is quite resistant to buckling loads. The following Fig.3 reports the comparison of the mechanical properties in term of the non dimensional shear strength and modulus.



(a)



The shear strength is still considerably higher for the auxetic compared to the commercial core materials. The shear modulus was lower even thought comparable. This result seems to be largely due to the use of short fibers for the specimens used in the present study.

The auxetic materials were also evaluated in terms of the economics compared to a laminate construction. The use of the auxetic materials developed lead to a total cost saving of about 50% largely due to the reduction of the labour costs.

Conclusions

The properties of some novel cellular composites with auxetic properties were investigated. The materials manufactured by RTM were compared to standard commercial cores. The comparison proved the increased performances of the auxetic materials which do not act only as spacers but can have structural properties.

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