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# Experimental and numerical characterization of honeycomb sandwich composite panels

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ABSTRACT

In this paper, an experimental investigation, an analytical analysis and a numerical model of a typical four-point bending test on a honeycomb sandwich panel are proposed. The honeycomb core is modelled as a single solid layer of equivalent material properties. Analytical and numerical (finite element) homogenization approaches are used to compute the effective properties of the honeycomb core. A general kinematic model (unified formulation) has been adopted and used for the modelling of honeycomb sandwich panel submitted to the bending test. A comparative study of major classes of representative theories has been considered. Qualitative and quantitative assessments of displacement, stress have been presented and discussed.



## 1. Introduction

Honeycomb (HC) sandwich structures consist of a thick layer (core) intercalated between thin-stiff layers (skins) (Fig. 1). They are produced by bonding metal or composite laminate skins to a honeycomb core. These layered-like materials are characterized by lightweight, high flexural stiffness and can support classical loadings like tension and bending. The many advantages of honeycomb sandwich constructions, the development of new materials and the industrial needs for high performance and low-weight structures ensure that honeycomb sandwich construction will continue to be in demand. HC composites are increasingly being used to replace traditional materials in highly loaded applications [1,2]. Honeycomb cores are described as cellular solids [2,4], that make use of voids to decrease mass, whilst maintaining qualities of stiffness and energy absorption. This improvement, at relatively little expense, in terms of mass, is of great interest in aerospace, automotive and many other applications [2]. In order to use these materials in different applications, the knowledge of their mechanical behaviour is required. This calls for the development of rigorous mathematical and experimental methods capable of characterizing, modelling, designing and optimising of the composite under any given set of conditions. Numerical simulation of these structures requires, firstly, a proper experimental identification of the core and the skins material behaviors, and secondly an adequate kinematic model to obtain a reasonable computational cost. In the present paper, we propose to experimentally investigate and to identify the basic mechanical properties of the honeycomb sandwich panels and to analytically describe the response of HC sandwich panel submitted to a four-point bending test. The experimental investigations carried out consist in four-points bending static tests on two types of HC (Aramide Fibre, Aluminium) sandwich panels. The

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**Nomenclature**

| | |
|---|---|
| $M_x$ | bending moment, |
| $T_x$ | transversal force. |
| $D$ | indicates the bending stiffness |
| $E_{f_i}$ $(i = 1, 2)$ | Young modulus of the face $i$ |
| $t_{f_i}$ $(i = 1, 2)$ | thickness of face $i$ |
| $E_c$ | core Young modulus |
| $T_c$ | core thickness |
| $\sigma_x$ | stress inside the bottom skin |
| $\tau_{xz}$ | shear stress |
| $B(z)$ | the surface moment |
| $S$ | shear stiffness |
| $G$ | shear modulus |
| $h$ | thickness of the beam |
| $k$ | shear correction factor |
| $L$ | length of specimen |
| $L_1$ | distance between applied loads |
| $L_2$ = a | distance between the inner supports |
| $\sigma_f$ | tensile (or compressive) strength of the skins |
| $\tau_c$ | shear strength of the core |
| $x_1$, $x_2$ | displacement according to directions |
| $x_3$ | transversal displacement |
| $\sigma_{11}$, $\sigma_{22}$, $\sigma_{33}$, $\tau_{12}$ | stress components |
| $\tau_{13}$, $\tau_{23}$ | shear stress components |
| $U$ | displacement field |
| $u_\alpha$, $w$, $\gamma_\alpha$ | functions of $x_1$, $x_2$ |
| $f(z)$ | shear function |
| $W^*_{acc}$ | virtual work of acceleration quantities |
| $W^*_{int}$ | virtual work of interior forces |
| $W^*_{ext}$ | virtual work of exterior forces |
| $\varepsilon^*_{ij}$ | virtual deformations |
| $N_{\alpha\beta}, M_{\alpha\beta}, \widetilde{M}_{\alpha\beta}, \widetilde{Q}_\alpha$ | generalized efforts |
| $(P_{\alpha_3}, m_\alpha, \widetilde{m}_\alpha)$ | generalized vectors in the form |
| $B$, $\widetilde{B}$ | generalized constitution matrices |
| $q(x, y)$ | sinusoidal function |

additional outcome of the experimental study carried out is the analysis of the core density and the cell orientation ($L$ and $W$) effects on the maximum load as well as on damage processes.

The effective mechanical properties of the honeycomb have been estimated based on the work of Gibson and Ashby [4], Masters and Evans [5] and Grédiac [6]. For the modelling of the HC sandwich panel, an attempt has been made to propose a high order unified kinematical formulation able to describe the local (e.g. shear deformation) and global (e.g. deflection)

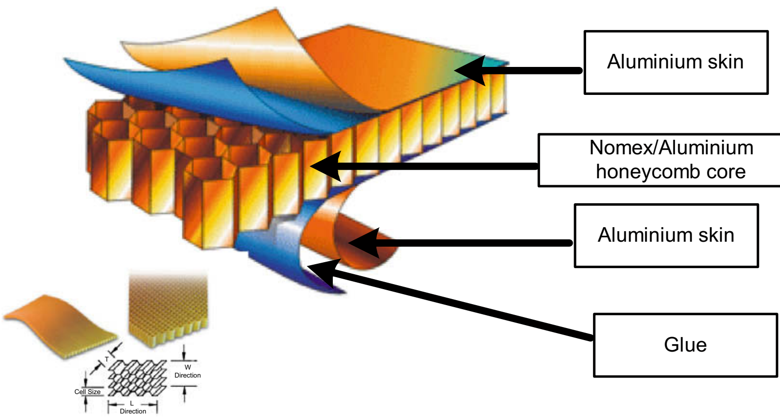


**Fig. 1.** Schematic detailed description of the honeycomb sandwich structure.