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# Numerical and experimental analyses of the effect of different geometrical modelings on predicting compressive strength of honeycomb core

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ABSTRACT

In this article, behavior of honeycomb core against compressive force along cell axis was investigated. The samples were laterally compressed quasi-statically between rigid platens under displacement control. First, for some samples with different cell wall thicknesses and sizes, compressive strength was made by finite element using LSDYNA 971 program. It was determined that decreased cell size and increased cell wall thickness resulted in the increased compressive strength of the honeycomb. Afterwards, homogeneous and non-homogeneous methods were used for modeling the whole honeycomb and the relationship of sample modeling from smaller size to the original ones was stated.


## 1. Introduction

Sandwich structures are composed of a thick lightweight core bonded by adhesion to two thin but stiff skins. These cores have a variety of types, one of which is honeycomb cores.

Fig. 1 illustrates a sandwich panel with honeycomb core. Honeycomb structures are natural or human-made structures with the geometry of a honeycomb which allow for the minimization of the amount of used material in order to reach minimal weight and minimal cost. Strength of the honeycomb core against compressive force is an effective factor in many applications of sandwich panels. Accordingly, effects of the geometrical parameters of honeycomb on its weight and compressive strength have an important role in designing.

One of the first theoretical studies in this field was performed by McFarland [1,2] and Wierzbicki [3–5]. In his analysis, Wierzbicki introduced angle element to make calculations easier. Then, by calculating the rate of energy dissipation in one honeycomb cell and equalizing it with the performed external work, he calculated the required mean crushing force for one-hexagonal cell of honeycomb which yielded good results. One of the latest modifications on this force was performed by Mahmoudabadi and Sedighi [6]. Afterward, most of the studies have been experimental and numerical. Goldsmith and Sackman [7] investigated properties of energy absorption of honeycombs and sandwich panels under contact on the experimental basis and stated that these properties were mostly dependent on the density of honeycomb. Alavi Nia and Sadeghi [8] experimentally investigated compressive strength of five types of aluminum honeycomb with different cell sizes, cell wall thicknesses, and cell height filled with polyurethane foam as well as empty ones. Zhang and Cheng [9,10] compared energy absorption capability in square columns filled with foam and empty honeycomb structure with square cells and pointed out the capability of honeycomb structures compared with square columns. Various laboratory and numerical studies related to the out-of-plan properties of honeycombs as the absorbers of energy and compressive strength of single-cell columns have been also conducted [11–19].

In this article, first, using a smaller model and application boundary conditions, effect of geometrical parameters like thickness of honeycomb and cell size were studied and, afterwards, the relationship between modeling with different domain sizes was investigated. Finally, the effect of initial defect on compressive strength of the honeycomb was examined.

## 2. Theory

Wierzbicki presented theoretical relationships for determining mean crushing strength of honeycombs with hexagonal cells under axial compressive loading based on plasticity principles

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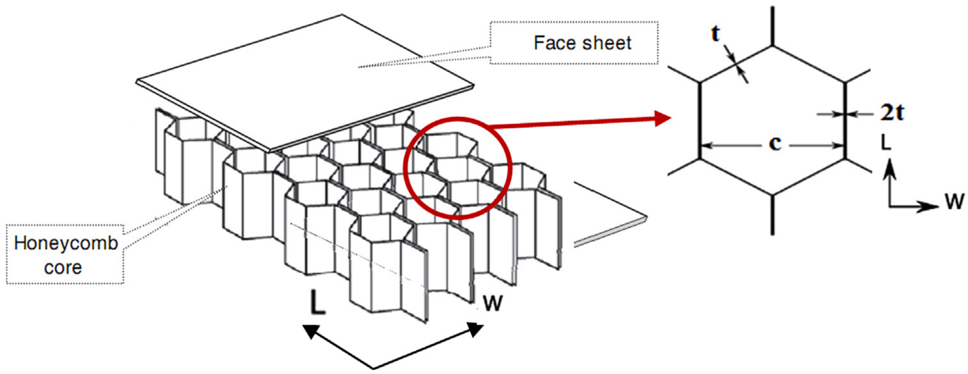


**Fig. 1.** Components of the sandwich plate.

**Table 1**
Mechanical properties of Al 3105-H25.

| $E$ (GPa) | $G$ (GPa) | $\sigma_u$ (MPa) | $\sigma_y$ (MPa) | $\tau_y$ (MPa) | $\varepsilon_u$ |
|---|---|---|---|---|---|
| 69 | 25 | 180 | 160 | 105 | 0.08 |

and energy. First, he studied a Y-shaped element with a desirable angle and then simplified the relationships for 120°.

He decreased analysis complexities by considering the behavior of elastic–perfect plastic as well as fixed wavelength and buckling during the test.

According to Wierzbicki's theory [6], the fold wavelength of Y-shaped element and radius of the plastic pivot are calculated by

$$H = 0.821\sqrt[3]{tS^2} \tag{1}$$

$$b = 0.683\sqrt[3]{h^2 D} \tag{2}$$

Mean crushing force of one Y-shaped element is calculated by

$$F_m = 8.61\sigma_0 t^{5/3} S^{1/3} \tag{3}$$

With dividing this force into element area $\left(\sqrt{3}/4\right)S^2$, mean crushing strength is calculated by

$$\sigma_m = 16.5\sigma_0\left(\frac{t}{S}\right)^{5/3} \tag{4}$$

where $S$ is width of the cell wall, $t$ is the cell wall thickness, as indicated in Fig. 1, and $\sigma_0$ is the flow stress of the foil material.

The model presented by Wierzbicki benefited from good predictability for calculating the mean crushing force of honeycomb, which was widely used afterwards.

## 3. Experimental

The applied honeycomb in the experiments was made of Al3105-H25 with the cell size of 17.32 mm, sheet thickness of 0.074 mm, and height of 26 mm. The mechanical properties of the aluminum are illustrated in Table 1.

Two kinds of specimen were used: the first kind was a 25-cell specimen (5 × 5 upon ASTM C365-05 [20]) and the second was a complete cell taken from a 5 × 5 specimen to investigate the influence of defect on the compressive resistance of honeycomb.

Compression test was performed using a ZWICK 100 machine registering load–displacement variation. The tests were carried out by displacement control. Compression speed was 2 mm/min.

Regarding high sensibility of honeycomb, two smoothed iron plates were put on the top and bottom of the honeycomb to

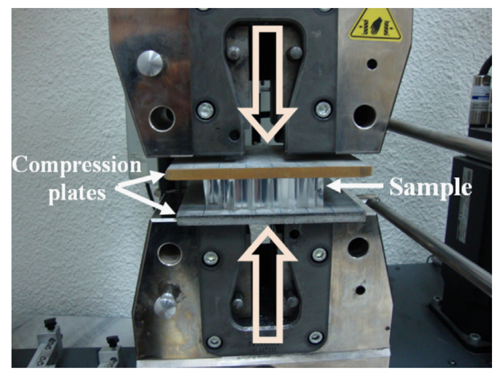


**Fig. 2.** Zwick apparatus.

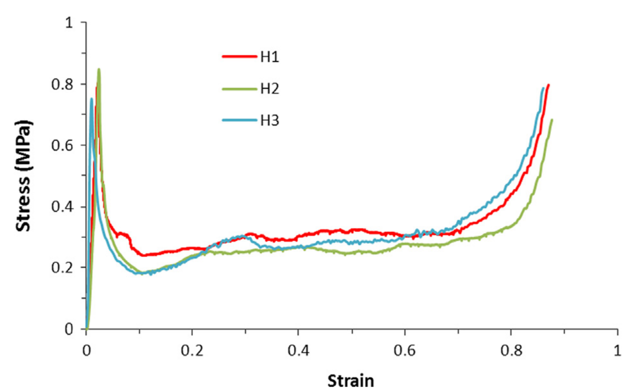


**Fig. 3.** Stress–strain curve of 5 × 5 honeycomb specimen from experiment.

ensure a homogeneous application of the applied load in the whole area (Fig. 2).

Due to the sensitivity of honeycomb and in order to ensure reliability of the tests, multiple tests with similar conditions were performed and the mean diagram was used as the main diagram. For this purpose, in order to obtain accurate results, 3 samples of complete 5 × 5 honeycombs and 3 samples with initial defect were chosen and tested and means of their curve were used as the main results. Their strain–stress and force–displacement curves are illustrated in Figs. 3 and 4, respectively. In Fig. 3, H1, H2, and H3 correspond to 5 × 5 honeycomb specimen and, in Fig. 4, HI1, HI2, and HI3 correspond to the samples with initial defect. Discussion of the results is reported in Section 5.

## 4. Numerical

The problem complexity was reduced by neglecting changes on mechanical properties and residual stresses. Furthermore, the