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Experimental Investigation of Energy Absorption in Aluminum Sandwich Panels by Drop Hammer Test

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ABSTRACT. This paper is aimed to study the behavior of sandwich panels made of Aluminum face sheet and Aluminum corrugated core under impact loading. Sandwich panels with square and triangular honeycombs of two different heights are constructed and the effect of honeycomb geometry on the level of absorbed energy as well as the panel strength are investigated. Drop Hammer apparatus by a cylindrical impactor with the weight of 25 kg is applied for exerting the impact. Acceleration, velocity, and displacement of impactor as well as the absorbed energy are evaluated throughout the test. The damage mechanisms include the buckling of core walls, separation of core from surface sheets, and formation of plastic hinges in the core plate. The results show that panel height and the geometry of its core play an important role on the impact strength, as the panels with more height have higher energy absorbability and panels with square core have higher impact strength than ones with triangular core.

Introduction. In recent years, sandwich panels have been widely used for constructing bridge decks, temporary landing mats and thermal insulation wall boards due to better performance in comparison to other structural materials in terms of enhanced stability, higher strength to weight ratios, better energy absorbing capacity and ease of manufacture and repair. In sandwich panels, low density material, known as core, is usually adopted in combination with high stiffness face sheets to increase the moment of inertia and to resist high loads. The main functions of core materials are to absorb energy and provide resistance to face sheets to avoid local buckling [1]. The most applicable core materials include Aluminum honeycomb structure and Aluminum/polymeric foams. Foam core materials are applied to improve acoustical, thermal and moisture insulation properties. In addition, polymeric foams have an important role in reducing the panel production costs. Aluminum foam is preferred where the ballistic properties are of important significance. Although foam core sandwich panels have a high strength-to-weight ratio the main drawback of such structures is the low area of common surfaces between foam cells and facesheets. This problem results in low core-to-facesheets adhesion that, besides the production defects and extreme service conditions, will finally cause panel delamination and its rupture.

Since honeycomb panels are frequently applied as energy absorbers against impact loads, predicting their dynamic behavior is of important consideration for their optimum utilization.

Numerous studies made on the sandwich panels with foam or honeycomb cores under high velocity impact or explosive loading have revealed excellent energy absorption of such structures in comparison with integrated solid structures [1-6]. Zhu et al. assessed the effect of various parameters on the behavior of honeycomb sandwich panels under the air blast loading. Their study signified dependency of deformation and failure mechanism on the facesheets thickness as well as core characteristics such as pores size and wall thickness. By experimenting on the honeycomb sandwich panels subjected to underwater blast loading, Fan et al. [8] studied the influence of design parameters on the structure stiffness and its failure mechanism. Li et al. [9] investigated failure modes of
honeycomb sandwich panels, including core compression, progressive buckling, shear deformation, and fracture. They found that by closing the explosive to the specimen the maximum pressure on the panel facesheet gets increased, while taking away the explosive from the specimen will increase the plastic deformation.

Dharmasena et al. [6] showed that honeycomb sandwich panels have less deflection in comparison with solid panels with the same mass. Nurick et al. [10] studied the effect of core height, facesheet thickness and the interaction of panel components on its failure modes. Theobald et al. [11] found that the facesheet thickness has the most impressive factor on the impact loading of sandwich panels. Wadley et al. [12] studied the deformation and fracture in sandwich panels with triangular corrugated core under the impact of accelerated sand grains.

Yahaya et al. [13] evaluated the effect of core configuration on the panel deformation behavior under the impact of aluminum projectile with various velocities. Mohammad et al. [14, 15, 25] studied the deformation and fracture of foam-filled corrugated core sandwich panels under low velocity impact; also, they studied the energy absorption in aluminum foam sandwich panels by drop hammer test. In addition, they studied about the comparison of static and dynamic buckling critical force in the homogeneous and composite columns (Pillars).

In this paper, drop hammer tests are carried out to investigate the effect of core geometry on the mechanical behavior and energy absorption of aluminum corrugated core sandwich panels.

1. Materials and experiments. 1200 aluminum sheets with thickness of 0.3 mm and 0.8 mm were used to make core and facesheets, respectively. Tow triangular configurations and two square configurations were considered as core geometry with 10 cm width and dimensions according to Fig. 1.

![Fig. 1. Core geometries of sandwich panels: (a) sample 1, (b) sample 2, (c) sample 3, (d) sample 4.](image)

Spot welding machine was used to attach the panel components together [16-20]. Figs. 2-5 illustrate the prepared specimens of sandwich panel. Drop hammer apparatus was applied to exert the impact by releasing a cylindrical weight of mass 25 kg from the height of 11 cm.
Fig. 2. Picture of sample 1.

Fig. 3. Picture of sample 2.

Fig. 4. Picture of sample 3.

Fig. 5. Picture of sample 4.
Fig. 6. Picture of drop hammer apparatus.

Fig. 7. Deformed configuration of sample 1.

Fig. 8. Deformed configuration of sample 2.

Fig. 9. Deformed configuration of sample 3.
2. Experimental results. Pictures of deformed specimens are shown in Figs. 7-10. Extracted data from the test apparatus are used to obtain time variations of displacement, velocity and acceleration of panel facesheet as well as absorbed energy [21-26]. Fig. 11 shows the variation of impactor acceleration against its displacement for various core geometries [14, 15, 25]. The variation of impactor velocity in terms of its displacement for different core geometries is shown in Fig. 12. Time variation of impactor displacement for different core geometries is illustrated in Fig. 13. The curves of absorbed energy over time is plotted in Fig. 14. Regarding to Fig. 11 it can be seen that samples with square core possess higher values of average acceleration and thus more impact strength [25-28]. Also, according to Fig. 12 the compression speed of all samples is rather the same except for sample 1. As shown in Fig. 15 the samples 1, 3 absorb less energy in comparison with the others because of their less height.

Fig. 11. Effect of core geometry on the acceleration-displacement curve of sandwich panels
Fig. 12. Effect of core geometry on the velocity-displacement curve of sandwich panels

Fig. 13. Effect of core geometry on the displacement-time curve of sandwich panels

Fig. 14. Effect of core geometry on the energy-displacement curve of sandwich panels

Summary. In this paper, the impact behavior of sandwich panels made of aluminum facesheets and aluminum corrugated core with different geometries is investigated using drop hammer apparatus. It
is concluded from the absorbed energy that increasing panel height will cause increasing of absorbed energy and triangular core with the height of 30 mm absorbs the most energy [14, 15, 25]. Deformed configuration of panels implies that initial deformation is due to the core wall buckling. After buckling, the core will undergo the plastic deformation and plastic hinges occur. On the other hand, separation of core from the facesheet signifies the existence of high shear stress between them. Regarding to high value of average acceleration in panels with square core, it is concluded that they possess higher impact strength.

References


