Compression Characteristics of Honeycomb Sandwich Panels to Improve Their Impact Resistances

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Abstract. Honeycomb sandwich panels are kind of composite panels constructed by bonding core material of honeycomb structures with thin plate surfaces together. Since honeycomb sandwich panels (Briefly called composite panels) have the light-weight and high strength performances, they are widely utilized in many fields, especially light-weight required aerospace field. However, data on impact resistant properties of such composite panels are not widely publicized, and the testing method is not clearly specified. Therefore, in this study, the local buckling tendency of composite panels was experimentally evaluated with respect to various design variables, such as the foil thickness, cell size and specimen dimension of honeycomb structures. As conclusion, under local compressive loading for honeycomb sandwich panels, honeycomb cores are buckled before reaching yielded points and cause the danger of panels being degraded from their original levels.

1. Introduction

Honeycomb sandwich panels are kind of composite panels constructed by adhering thin surface plates such as CFRP (Carbon Fiber Reinforced Plastic) laminates or metal sheets with honeycomb cores made of aluminum or aramid materials. Figure 1 shows the image of the honeycomb core structure with different design variables. Honeycomb sandwich panels have light-weight and high strength performances. So they are widely used in many fields such as the transportation equipment field, especially for light-weight mainly required aerospace field. On the other hand, the merit of the honeycomb sandwich panels is effective only in the limited environment. For example, it is strong only when uniform loads are applied on the surfaces of the panels, while honeycomb cores show vulnerability with local concentrated loads applied. Under concentrated loads, it is possible that the strength of whole panel should be reduced due to local buckling failure inside the honeycomb core. However, no data on local buckling properties of honeycomb structures are widely publicized and testing methods are not clearly stipulated.

![Figure 1. Design variables of honeycomb structure model.](image-url)
Therefore, the purpose of this study is to grasp the local buckling tendency of honeycomb structures affected by design variables like foil thickness, cell size and specimen size (length, width, height dimension) of honeycomb structures. Compression tests on honeycomb sandwich panels having different design variables are executed to examine buckling performance under local loading.

2. Compression tests of composite panels with different design variables
Sample composite panel specimens with different design variables were fabricated by bonding aluminum honeycomb cores and 1.0 mm thick CFRP laminate faces. As shown in table 1, 12 kinds of panel specimens were introduced having honeycomb cores having three different cell sizes and four kinds of specimen sizes. 10 specimens were prepared for each kind of panel specimens indicated by the numbers as shown in table 1. The foil thickness of specimens is 0.003 inch for specimen number ⑤ and ⑦, and 0.001 inch for the other specimens. In the compression tests, a circular indenter with diameter of 100.0 mm was utilized to the tensile/compression tester. The test speed of compression loading was set at 1.0 mm/min for composite panel specimens. Figure 2 shows the photo images of the compression test and composite panel specimen.

Table 1. Dimensions of honeycomb cores for composite panels.

| Cell size [inch] | 1/8 | 3/16 | 1/4 |
|------------------|-----|------|-----|
| Dimensions [mm]  |     |      |     |
| (Length × width × height) | 30×30×30 | ① | ⑤ | ⑨ |
| 30×30×20 | ② | ⑥ | ⑩ |
| 20×20×30 | ③ | ⑦ | ⑪ |
| 20×20×20 | ④ | ⑧ | ⑫ |

Figure 2. Photo image of compression test and composite panel specimen.

3. Compression characteristics of composite panels

3.1. Compression test results of composite panels
Typical compressive load-displacement diagrams obtained from the compression tests of composite panel specimens are shown in figure 3 to figure 5. These results represent three patterns of compression characteristics for different composite panel specimen groups. Figure 3 shows the type results of specimen number ⑧, ⑨, ⑩, ⑪ and ⑫. Figure 4 shows the type results of specimen number ③ and ⑥. Figure 5 shows the type results of specimen number ①, ②, ⑤ and ⑦. Specimen number ④ shows different compression characteristic with all trends of these three patterns appeared.

It can be seen from figure 3 first that the honeycomb structures buckled starting at the unstable yield loads. Figure 4 and figure 5 show the honeycomb structures buckling after stable yield points, and also
different behaviors can be observed from these two type results. Regarding the overall results, the buckling behaviors due to compressive load-displacement curves tends to be more stable with the cell size of honeycomb structure is smaller. When considering the local compression effects of honeycomb sandwich panels, compression strength of honeycomb structure will become lower than usual when buckling started at yielding loads as shown in figure 3. So, it is important to pay attention to the cell size of honeycomb structures as applied for composite panels under local compression loading.

**Figure 3.** Typical compresion test results (specimen number ⑩).

**Figure 4.** Typical compresion test results (specimen number ⑥).
3.2. Compression characteristics of honeycomb structures

Average yield loads derived from the compressive load-displacement diagrams are shown in figure 6. In addition, yield stresses calculated from the average yield load results shown in figure 6 divided by the exact cross-sectional area of honeycomb cores are shown in figure 7.

Figure 5. Typical compression test results (specimen number ②).

Figure 6. Average yield loads of different composite panel specimens.
Figure 7. Average yield stresses of different composite panel specimens.

From figure 6, it can be seen that the yield loads tends to increase as the height of honeycomb core is decreased, regardless of the compression area of composite panel specimens of ①, ②, ③ and ④ with 1/8 inch cell size. However, from the yield stress results which take into account of the cross-sectional area of the honeycomb core, it can be seen that the stress level becomes larger with smaller compressive area and lower height of specimen. From the results of specimen number ⑤ and ⑦, one can see that the yield stresses become smaller with respect to the yield load results. This is just because of the 0.003 inch foil thickness which is thicker than the others.

Comparing the test results of specimen number ⑨, ⑩, ⑪ and ⑫ with honeycomb cell size of 1/4 inch, one can see that the yield loads become proportional to the panel specimen area and not affected by specimen height. However, the yield stress results of such composite panels show different behaviours. This is considered that buckling of 1/4 inch panel specimens occurred at yielding point, which is different from other two type composite panel specimens.

4. Summary
Local buckling tendency of composite panels was experimentally evaluated with respect to various design variables, such as the foil thickness, cell size and specimen dimension of honeycomb structures. From experimental results, the following conclusions are obtained.

(1) Buckling behavior of the honeycomb structure due to compressive load stabilized with smaller cell size. Composite panels with large cell size honeycomb cores will be caused unstable buckling behavior under compression loading no matter with the local impact sizes.

(2) When the cell size of honeycomb core is large and unstable buckling occurred at yield point, yield loads become proportional to the panel specimen area and hardly affected by specimen height. However, the yield stress results of such composite panels show smaller differences due to different design variables.

(3) For composite panels under local compression loads or impacts, honeycomb structures having different design variables will be selected due to local size of compression loads or impacts.

5. References
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