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# Investigation of Static Flexural Strength of Aluminium Honeycomb Panels with Varying Cell Sizes

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**ABSTRACT**

In this paper, the static flexural strength of aluminium honeycombs with varying cell sizes were tested experimentally using three-point bending method. Three different cell sizes, namely 2 mm, 4 mm and 6 mm, which were produced in a local workshop in the city of Medan, were used for this study. The main focus is to observe the maximum load and permanent deflection under static loads. The results show that the fracture mode that occurs after reaching the maximum load is core fracture followed by rupture of the adhesive between the core and the skin sheet. It is found that cell size has a significant influence on the maximum flexural strength of honeycomb panels which can be approximated by a regression curve with the results $a_1$ = 0.3475 and $a_0$ = 1.51.
**Keyword:** Aluminium Honeycombs, Static Flexural Strength, Cell Size

**ABSTRAK**

Dalam tulisan ini, kekuatan lentur statis sarang lebah aluminium dengan berbagai ukuran sel diuji secara eksperimental menggunakan metode three-point bending. Dengan tiga ukuran sel yang berbeda yaitu 2 mm, 4 mm dan 6 mm yang diproduksi di bengkel lokal di kota Medan, digunakan untuk penelitian ini. Fokus utamanya adalah mengamati beban maksimum dan defleksi permanen pada beban statis. Hasil penelitian menunjukkan bahwa modus patahan yang terjadi setelah mencapai beban maksimal adalah patahan inti yang diikuti dengan pecahnya perekat antara inti dengan lembaran kulit. Diketahui bahwa ukuran sel mempunyai pengaruh yang signifikan terhadap kuat lentur maksimum panel sarang lebah yang dapat didekati dengan kurva regresi dengan hasil $a_1$ = 0.3475 dan $a_0$ = 1.51.
**Keyword:** Sarang Lebah Aluminium, Kekuatan Lentur Statis, Ukuran Sel

## 1. Introduction

Aluminium honeycomb panels are used in a variety of industrial applications. The industry with the earliest application was the aircraft industry, but currently other fields of transportation also use aluminium panels as energy absorbers to reduce the risk of injury to occupant [1-3]. Safety criteria are increasingly tightening as manufacturing technology and vehicle speeds improve significantly. Which if ignored can cause damage due to accidents. In high-speed trains, a type of energy damper was developed to eliminate the impact of large kinetic energy in a collision situation.

Aluminium panels consist of two aluminium covering sheets together with an aluminium honeycomb core. The sandwich panel can be a solution for a lightweight and highly rigid material. Recently, various types of microarchitectural materials have been developed as cores in sandwich structures. The panel cores other than honeycomb can be wood or metal foam [4], prismatic truss [5] and lattice truss [6]. Investigation of the honeycomb sandwich structure is still of interest to many researchers due to various factors [7-15]. Honeycomb panels are typically used for weight and damping sensitive structures where high flexural strength is a top priority. Honeycomb panels are formed by gluing two high-strength thin face sheets with a low-density honeycomb core that has high strength and stiffness. To improve the desired mechanical properties, the panel composition can be varied such as by varying the core thickness, hexagonal cell size, face sheet size and material. The main goal of varying the honeycomb structure is to increase the strength-to-weight ratio.

This research was conducted to enrich the current experimental results of the flexural behavior of aluminium sandwich panel and also to support the small industry in making aluminium sandwich panels. The aluminium sandwich panels used were made by a local workshop in the city of Medan. The main focus is to observe to flexural strength and maximum permanent deflection.

Figure 1. Aluminium Honeycomb Cell Size Variations

**2. Method**

The aluminium honeycomb panel is developed at local workshop in Medan, Sumatera Utara. Forming honeycomb polygons from aluminium sheets using a simple method, that is by applying rack gears as the base plate and gears as the shaper. The aluminium plate is placed between them so that the top gear presses the aluminium sheet until the rack gear plate forms a polygon aluminium sheet. By using cyandacrylate adhesive, a honeycomb panel core can be formed which is then sandwiched between the top and bottom skins. Variations in the size of aluminium honeycomb cell cores are shown in Figure 1. All cores and skins are made using aluminium sheet with the same thickness of 0.4 mm. The mechanical properties of the aluminium sheet are shown in Tabel 2.1.

By utilizing 3 pairs of rack gear and pinion gear, three hexagon sizes have been created with dimensions of 2 mm, 4 mm and 6 mm. Each cell size is made referring to the dimensions shown in Table 2.2. Photos of specimens for each cell size are shown in Figure 2. A total of 18 specimens have been made and are ready to be tested. In order to examine the flexural strength of locally produced honeycomb, a three-point bending test was chosen. The experimental setup is shown in Figure 3(a), while Figure 3(b) shows the specimen under static load. The crosshead speed was set to 0.5 mm/min with a specimen span of 160 mm.

Table 2.1. Mechanical properties of aluminium sheet.

| No. | Properties | Value |
|---|---|---|
| 1. | Tensile strength | 81 MPa |
| 2. | Elastic Modulus | 69 GPa |
| 3. | Poisson Ratio’s | 0.35 |
| 4. | Density | 2800 kg/m$^3$ |

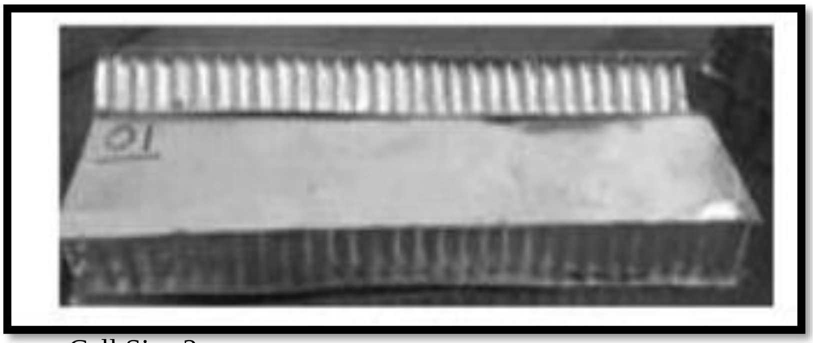
Table 2.2. The size of specimen after the skin and core are assembled.

| Length (*l*) [mm] | Width (*b*) [mm] | Depth (*d*) [mm] | Core Thickness (*tc*) [mm] | Skin Thickness (*ts*) [mm] |
|---|---|---|---|---|
| 210 | 55 | 20 | 0,4 | 0,4 |

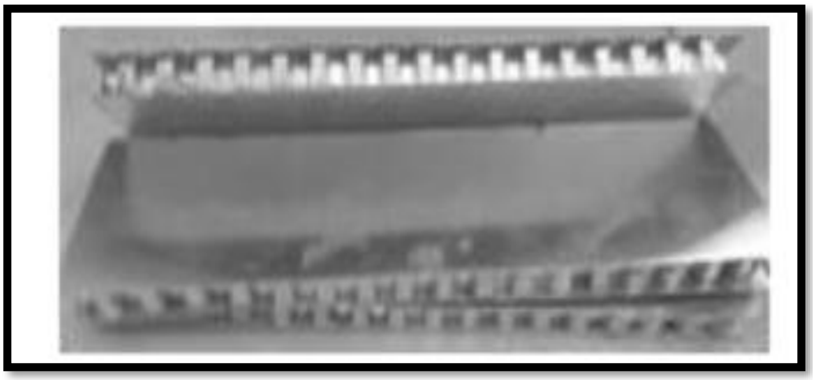
The test setup is powered by a hydraulic cylinder. Hydraulic cylinders can be displacement driven or force controlled. The maximum stroke on the Universal Testing Machine (UTM) is not set, but is maintained manually until the specimen downs to approximately half the height of the jig. The test method is carried out at room temperature with the specimen size determined, the maximum load, and the flexural strength of the specimen calculated and analyzed. To induce uniform failure i.e. failure at the core indentation, the load is applied with a small diameter around 20 mm. The maximum flexural stress is approximated by the following equation,

$$\sigma_f = \frac{3FL}{2bd^2} \quad (1)$$

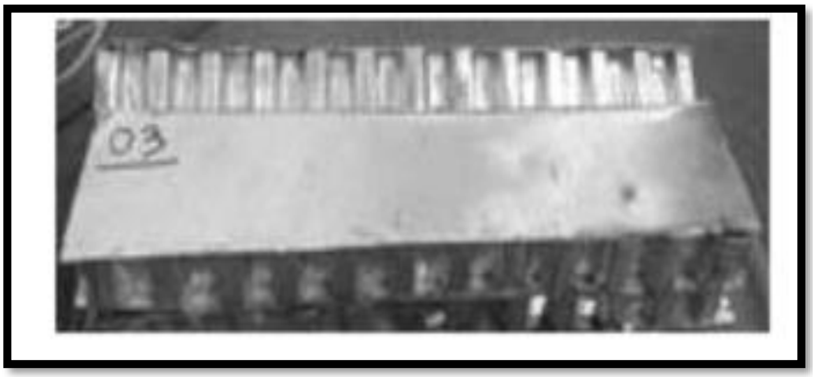
where *F* is load at a given point, *L* is support span, *b* is width and *d* is depth of the specimen. In this test, the bending strain was not measured.



Cell Size 2 mm



Cell Size 4 mm



Cell Size 6 mm

Figure 2. Aluminium Honeycomb With Varying Cell Size.

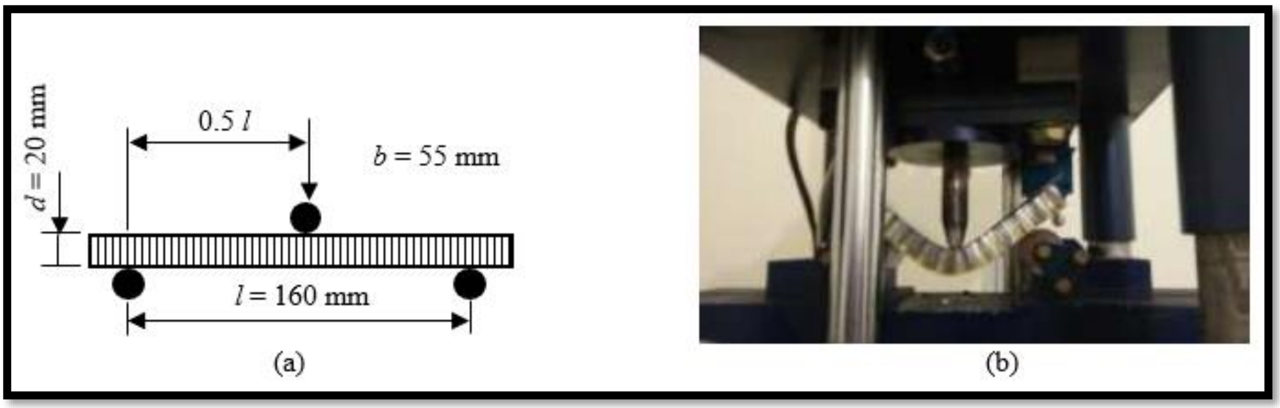



Figure 3. Three Point Bending Experimental Setup (A) Test Fixture (B) Specimen Under Static Load.

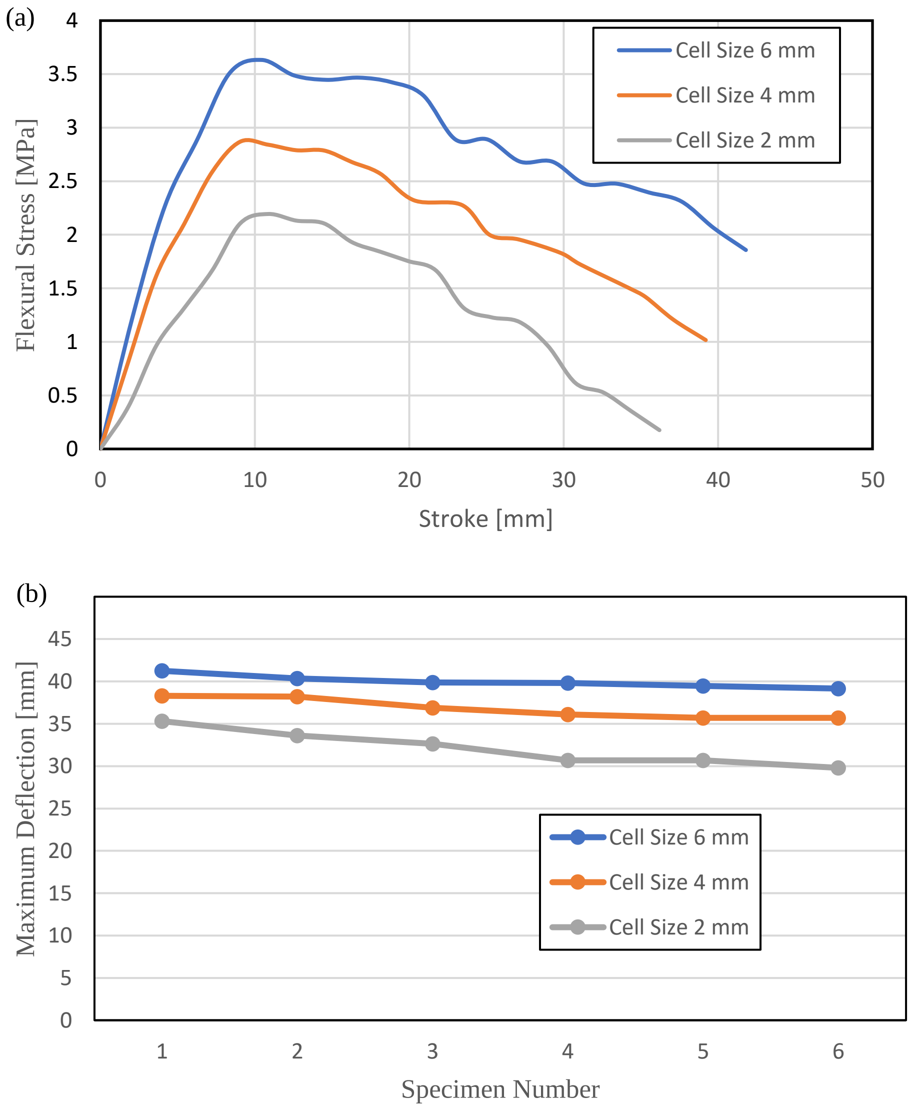



Figure 4. Experimental of three-point bending results (a) Flexural stress versus stroke; (b) maximum deflection of all specimens

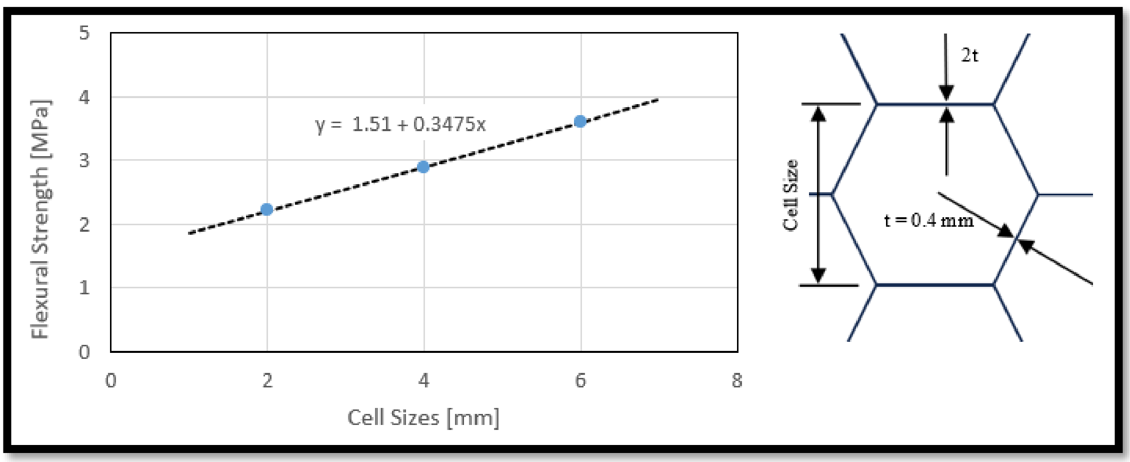



Figure 5. The effect of cell sizes to flexural strength.

## 3. Result and discussion

The static flexural strength results are shown in Table 3.1. For each cell size, 6 test specimens with successful results were selected. The 2 mm cell has an average maximum load of 10.12 N, while the 4 mm cell has an average load of 13.23 N and the highest average maximum load is the 6 mm cell, which is around 16.45 N. By utilizing the Eq. (1), then the maximum flexural stress is calculated. The average bending stresses are 2.20 MPa, 2.89 MPa and 3.60 MPa for cell sizes of 2 mm, 4 mm and 6 mm, respectively.

Table 3.1. The result of flexural strength of aluminium honeycomb with varying cell sizes.

| No. | Cell size [mm] | Maximum Load [N] | Maximum Flexural Stress $\sigma_f$ [MPa] |
|---|---|---|---|
| 1 | 2 | 10.59 | 2.31 |
| | | 10.18 | 2.22 |
| | | 9.63 | 2.10 |
| | | 11.09 | 2.42 |
| | | 8.85 | 1.93 |
| | | 10.40 | 2.27 |
| 2 | 4 | 12.42 | 2.71 |
| | | 13.29 | 2.90 |
| | | 14.21 | 3.10 |
| | | 14.76 | 3.22 |
| | | 11.55 | 2.52 |
| | | 13.20 | 2.88 |
| 3 | 6 | 16.27 | 3.55 |
| | | 15.72 | 3.43 |
| | | 16.55 | 3.61 |
| | | 16.45 | 3.59 |
| | | 16.59 | 3.62 |
| | | 17.33 | 3.78 |

The typical stress vs. stroke for each cell size is shown in Figure 4(a). Most of the specimens experienced core fracture after reaching the maximum load and gradually bent along with the breakdown of the adhesive between the core and the skin sheet. The breakdown of adhesive can be identified by the wavy lines in Figure 4(a).

The maximum deflection of each specimen is measured again after the test is completed in the form of permanent deflection. The results are shown in Figure 4(b). A cell size of 6 mm has a higher bending strength compared to other hexagonal cell sizes. The maximum loads recognize the hexagonal honeycomb cell size contribution has a significant impact on increasing flexural strength. When comparing the hexagonal cell size of 2 mm and 4 mm there is an increase of 30.76%, while when compared with 6 mm, there is an average increase of double, namely 62.89%. The relationship between flexural strength to cell sizes, that presented in Figure 5, is approached using fitting technique such as linear regression [16] that yield at $a_1 = 0.3475$ and $a_0 = 1.51$, therefore, the least-squares fit is

$$y = 1.51 + 0.3475x \tag{2}$$

Based on the current fitting results, the maximum flexural strength for other cell size can be predicted.

## 4. Conclusions

To investigate the static flexural strength of aluminium honeycomb with varying cell sizes, a three-point bending test was carried out using a universal testing machine (UTM). The fracture mode that occurs after reaching the maximum load is core fracture followed by rupture of the adhesive between the core and the skin sheet which can be identified as a wavy line on the load versus stroke curve. The cell size has a significant influence on the maximum flexural strength of honeycomb panels under static loads that is approached using linear regression that yield at $a_1 = 0.3475$ and $a_0 = 1.51$. By comparing the hexagonal cell sizes of 2 mm and 4 mm, there is an increase of 30.76%, whereas when compared with 6 mm, the average increase is twofold, namely 62.89%.

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