

Comparative Computational Analysis of Diverse Cell Geometries for Honeycomb Aircraft Floor Beds

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Abstract

This project presents computational analysis of honeycomb core and sandwich structures designed for aircraft floor bed applications. The study investigates three distinct core geometries—an axis-symmetrical irregular (ASI) hexagonal cell, an axis-symmetrical irregular (ASI) hexagon with a circular cutout and rhombus with a circular cutout—each modeled with an iso-areal cell to ensure a fair comparison. The sandwich panel configuration consists of a Polyethylene Terephthalate Glycol (PETG) core bonded between Carbon Fiber Reinforced Polymer (CFRP) face sheets. Using finite element modeling, the structures are subjected to simulated mechanical tests to evaluate their flatwise compression and 3 point bending performance. This work addresses the limited understanding of how variations in honeycomb geometry influence the structural efficiency of sandwich composites. The objective is to identify the most structurally efficient configuration capable of offering optimal strength-to-weight ratio, stiffness and durability under different load conditions. The results are expected to contribute valuable insights for the aerospace industry by promoting weight reduction, enhanced performance and improved material utilization in aircraft floor structures.

Keywords: Axis-Symmetrical Irregular (ASI) Hexagon; Iso-Areal Cell; Honeycomb Structure.

1. Introduction

Aircraft structures are fundamentally designed to maximize structural efficiency while minimizing weight, which is essential for fuel economy, safety and performance. This trade-off has led to the extensive use of sandwich structures with honeycomb cores due to their exceptional strength-to-weight and stiffness-to-weight ratios (Jhaver & Tippur, 2010; Urbahs et al., 2019). In such configurations, thin face sheets resist bending stresses, while the lightweight core resists shear loads and prevents local buckling. Various studies have experimentally and numerically examined the load-bearing and buckling behavior of honeycomb sandwich panels to enhance their performance in aerospace and automotive applications (Kaman et al.,

2010; Reddy & Reddy, 2019). Conventional hexagonal cores are widely used because of their uniform load distribution and manufacturability; however, they may not provide optimal structural responses under complex or localized stresses. Several experimental and computational analyses have demonstrated that modifications in cell geometry, such as the addition of cutouts or asymmetric designs, can significantly improve structural efficiency (Sanchaniya et al., 2022; Riyaz & Reddy, 2022). The advent of additive manufacturing has further enabled the fabrication of complex cellular topologies such as spiderweb or irregular lattice cores with customizable mechanical properties (Bari & Bollenbach, 2022). Recent

research emphasizes that the geometry of the honeycomb unit cell plays a crucial role in determining its deformation and energy absorption behavior (Matam et al., 2024; Sekizawa & Ishida, 2025). Comparative investigations on different cell shapes and materials show that core optimization can lead to substantial weight reduction without compromising stiffness or load capacity, providing valuable insights for high-performance structural components. However, there remains a gap in understanding how iso-areal constraints—where all geometries have the same cell area—affect the structural efficiency among varied core designs. This project presents a comprehensive computational investigation into the structural efficiency of next-generation honeycomb cores and sandwich panels. We meticulously designed and analyzed structures based on three core configurations:

- Axis-symmetrical irregular hexagonal cell
- Axis symmetrical irregular hexagonal with circular cutout [1]
- Rhombus with circular cutout

The core material was modelled as Polyethylene Terephthalate Glycol (PETG) combined with Carbon Fiber Reinforced Polymer (CFRP) face sheets. The initial phase of the study involved drafting all core geometries using Fusion 360 CAD software to strictly maintain the isoareal constraint, ensuring that any observed difference in performance is solely attributable to the change in cell geometry. Subsequent analysis was performed via the Finite Element Method (FEM), conducted specifically in Ansys R2 2025. This computational approach was used to predict the behavior of both the isolated core structures and the complete integrated sandwich structures under critical loads, including Flatwise compression and 3-point bending. Three core geometries were modeled and analyzed: ASI Hexagon, ASI Hexagon with a circular cutout and Rhombus with a circular cutout. Each was precisely dimensioned in CAD with uniform cell height and wall thickness to study how internal shape and orientation influence the strength and performance of the honeycomb sandwich structure Shown in Figure 1 Methodology.

2. Method

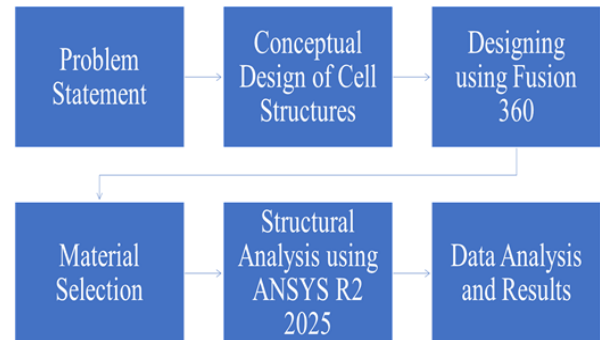


Figure 1 Methodology

2.1. Area Calculation

2.1.1. ASI Hexagon

Area of 1 Hexagon cell:

$$\begin{aligned} \text{Area of Outer Hexagon} &= 2 \times \text{area of Trapezium} \\ &= 2 \times \left(\frac{a+b}{2} \right) h \\ &= 102.27 \text{mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Area of Inner Hexagon} &= 2 \times \text{area of Trapezium} \\ &= 2 \times \left(\frac{a+b}{2} \right) h \\ &= 63.611 \text{mm}^2 \end{aligned}$$

Therefore,

$$\begin{aligned} \text{Remaining area of cell} &= 102.27 - 63.611 \\ &= 38.659 \text{mm}^2 \end{aligned}$$

Total number of cells = 88

$$\begin{aligned} \text{Therefore, Total Area of Core} &= 88 \times 38.66 \\ &= 3402.08 \text{mm}^2 \end{aligned}$$

2.1.2. Circular Cored ASI Hexagon

Area of 1 Circular Cored Hexagon cell [2]:

$$\begin{aligned} \text{Area of Outer Hexagon} &= 2 \times \text{area of Trapezium} \\ &= 2 \times \left(\frac{a+b}{2} \right) h \\ &= 102.27 \text{mm}^2 \end{aligned}$$

$$\text{Area of Circle} = \frac{\pi d^2}{4} = \frac{\pi(9)^2}{4} = 63.617 \text{mm}^2$$

$$\begin{aligned} \text{Remaining area of 1 cell} &= 102.27 - 63.617 \\ &= 38.653 \text{mm}^2 \end{aligned}$$

Total number of cells = 88

Therefore,

$$\begin{aligned} \text{Total Area of Core} &= 88 \times 38.66 \\ &= 3402.08 \text{mm}^2 \end{aligned}$$

2.1.3. Circular Cored Rhombus:

Area of 1 Circular Cored Rhombus cell:

$$\text{Area of Rhombus} = \frac{15 \times 13.636}{2} = 102.27 \text{mm}^2$$

$$\text{Area of Circle} = \frac{\pi d^2}{4} = \frac{\pi (9)^2}{4} = 63.617 \text{mm}^2$$

$$\text{Remaining area of cell} = 102.27 - 63.61 = 38.66 \text{mm}^2$$

Total number of cells = 88

Therefore,

$$\text{Total Area of Core} = 88 \times 38.66 = 3402.08 \text{mm}^2$$

2.2. Material Selection

2.2.1. Core Material: PETG (Polyethylene Terephthalate Glycol)

PETG is a thermoplastic polyester known for its excellent balance of strength, flexibility and ease of 3D printing. PETG was chosen as the core material due to its compatibility with additive manufacturing, which allowed precise fabrication of complex honeycomb geometries [3].

Key properties:

- Good impact resistance and durability
- Lightweight and cost effective
- Easily printable with FDM 3D
- Sufficient stiffness and energy absorption for structural core applications

2.2.2. Face Sheet material: CFRP (Carbon Fiber Reinforced Polymer)

CFRP is a high-performance composite material consisting of carbon fiber embedded in a polymer matrix. It was selected for the face sheets due to its superior mechanical properties, including high tensile strength, stiffness and fatigue resistance, which are critical for load-bearing aerospace components Shown in Table 1.

Key properties:

- Extremely high strength-to-weight ratio
- Excellent stiffness and rigidity
- Corrosion and fatigue resistant [4]
- Commonly used in Aircraft interiors, wings and fuselage panels Shown in Figure 2 – 5.

2.3. Table

Table 1 Sandwich Structure Dimensions

Total Length	150mm
Total Breadth	60mm
Total Height	44mm
Face sheet Height	2mm
Core Height	40mm
Number of Cells	88

2.4. Figures

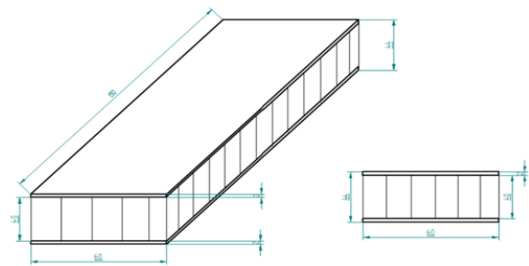


Figure 2 Preliminary Design

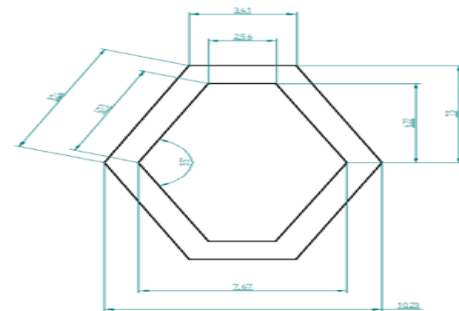


Figure 3 ASI Hexagon Cell

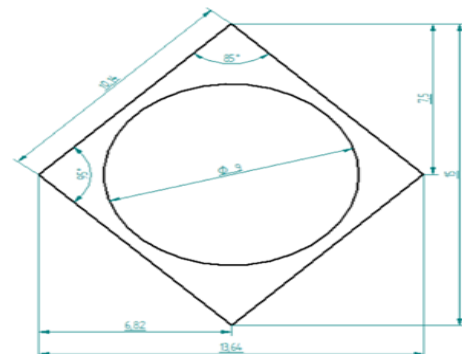


Figure 4 Circular cored ASI Hexagon Cell

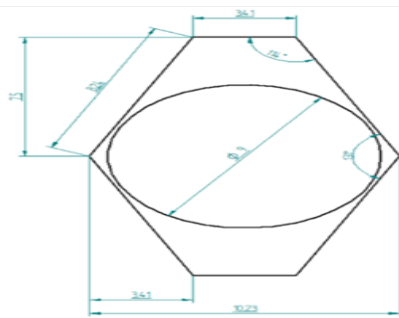


Figure 5 Circular cored Rhombus Cell

3. Results and Discussions

3.1. Results

- Analysis of Sandwich Structure [5]
- Flatwise Compression Test Results Shown in Figure 6 – 8.

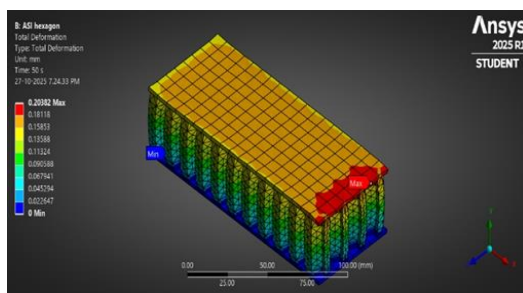


Figure 6 ASI Hexagon Cell

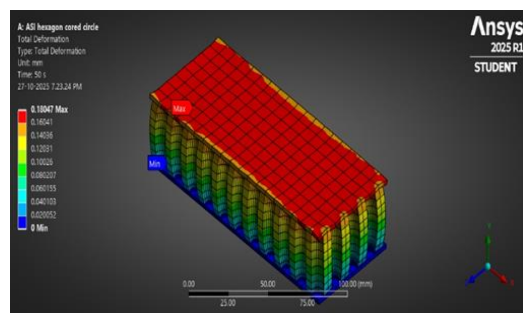


Figure 7 Circular cored ASI Hexagon Cell

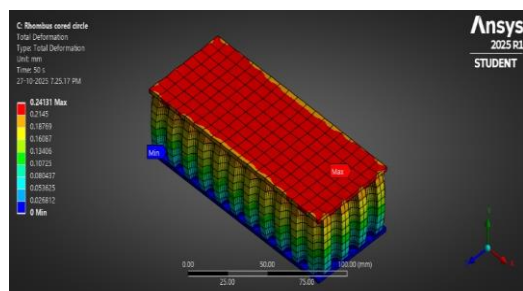


Figure 8 Circular cored Rhombus Cell

- Point Bending Test Result Shown in Figure 9 - 11

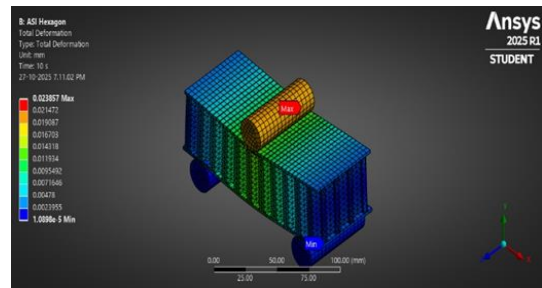


Figure 9 ASI Hexagon Cell

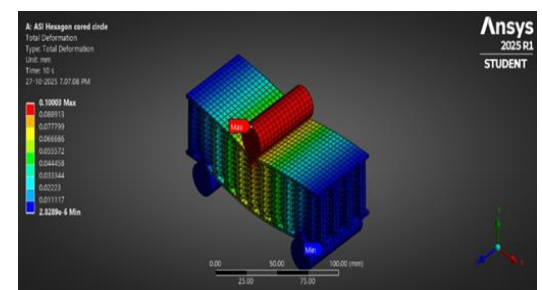


Figure 10 Circular cored ASI Hexagon Cell

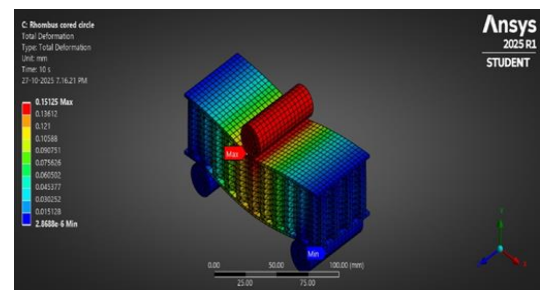


Figure 11 Circular cored Rhombus Cell

- Analysis of Core Structures [6]
- Flatwise Compression Test Results Shown in Figure 12 – 14.

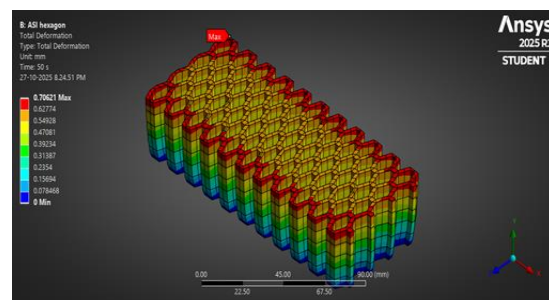


Figure 12 ASI Hexagon Cell

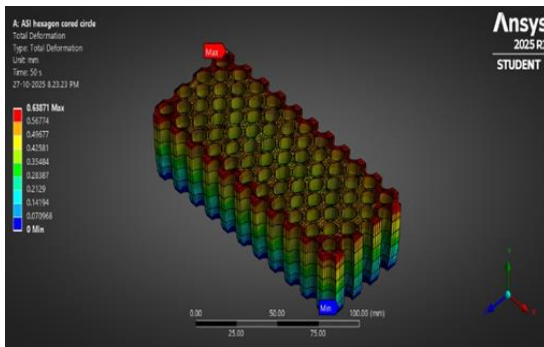


Figure 13 Circular cored ASI Hexagon Cell

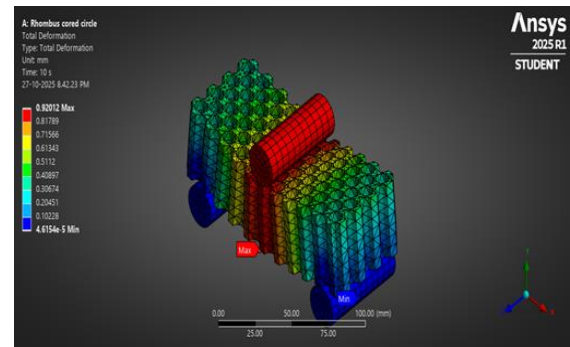


Figure 17 Circular cored Rhombus Cell

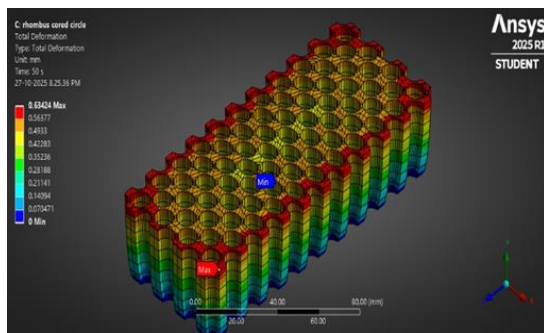


Figure 14 Circular cored Rhombus Cell

- 3 Point Bending Test Result Shown in Figure 15 - 17

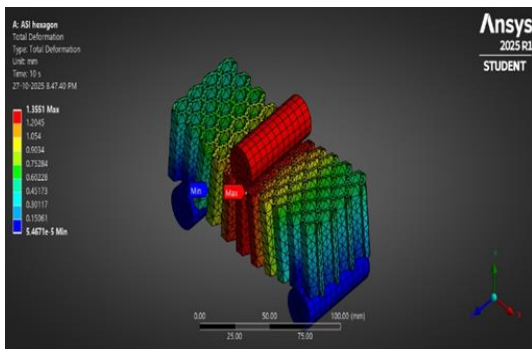


Figure 15 ASI Hexagon Cell

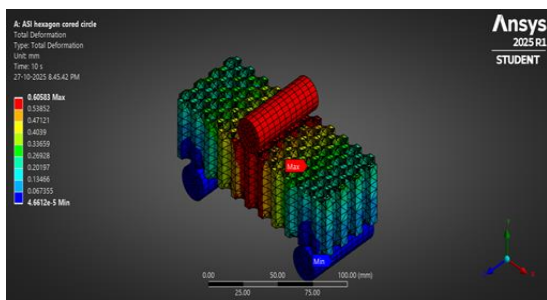


Figure 16 ASI hexagon circular cored cell

3.2. Discussions

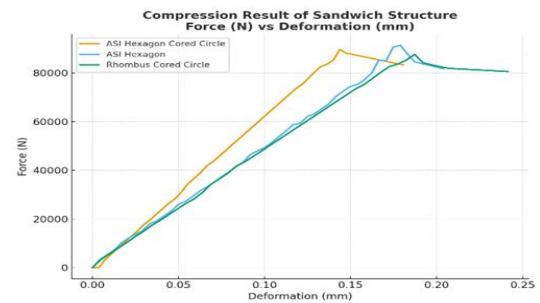


Figure 18 Compression result: sandwich structure

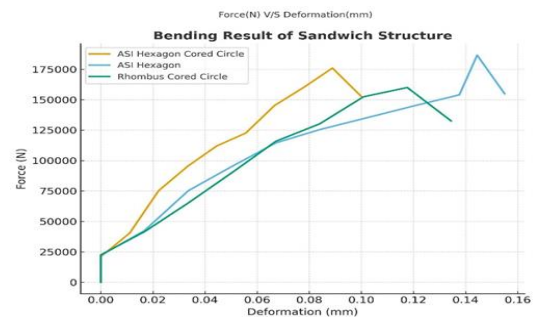


Figure 19 Bending result: sandwich structure

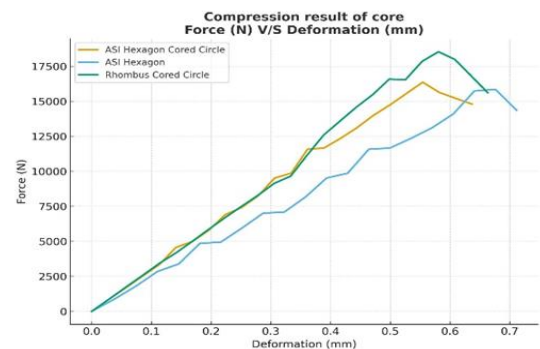


Figure 20 Compression result: Core

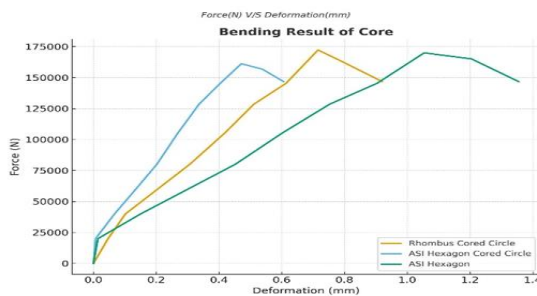


Figure 21 Bending result: Core

4. Compression Analysis

The results revealed that the ASI Hexagon with Circular Cutout structure demonstrated the highest compressive strength of 58.59 MPa, indicating superior load-bearing capacity under axial stress. This improvement can be attributed to the stress distribution enhancement provided by the circular cutout, which reduces localized stress concentration. The Rhombus with Circular Cutout and ASI Hexagon structures recorded compressive stresses of 56.10 MPa and 54.63 MPa, respectively. Although slightly lower, these values still indicate significant structural integrity and stability under compression Shown in Figure 18 – 21 [7 - 9].

5. Bending Analysis

Under bending conditions, the ASI Hexagon with Circular Cutout structure again exhibited the best performance with a maximum bending stress of 67.54 MPa, confirming its superior stiffness and resistance to deformation. The Rhombus with Circular Cutout followed closely with 66.63 MPa, while the ASI Hexagon recorded 65.30 MPa. The trend indicates that introducing circular cutouts within the cell geometry contributes positively to the flexural performance by enhancing stress dissipation and optimizing load transfer paths [10].

Conclusion

The consistent dominance of the ASI Hexagon with Circular Cutout configuration in both compression and bending tests confirms its structural superiority among the three designs. The circular cutout helps in reducing stress concentrations and enhances both compressive and flexural strength without a significant increase in mass, making it the most structurally efficient and lightweight design. These

findings demonstrate the importance of geometric optimization in honeycomb sandwich panels and provide a clear pathway for developing high-performance cores for aircraft floor bed structures. The results strongly support the use of customized, iso-areal, additive-manufactured cellular geometries to achieve a balance between weight reduction, mechanical robustness and long-term durability, thereby contributing to next-generation aerospace structural innovations.

Acknowledgements

The authors express sincere gratitude to the Department of Aeronautical Engineering and the project guide for their valuable guidance and support throughout the study. Appreciation is also extended to faculty members and peers for their helpful discussions during the computational analysis of sandwich structures and core designs. The authors thank ICRCESM-2025 organizers for providing the opportunity to present this research work.

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