

FILLED HONEYCOMB CORE STRUCTURE WITH DIFFERENT SIZE OF KENAF CORE ON MECHANICAL AND ACOUSTICAL PROPERTIES FOR PANELING APPLICATION – A REVIEW

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Article History: Received xxxxx; Revised xxx; Accepted xxxx

ABSTRACT: This study investigates the development and analysis of honeycomb core structures filled with different sizes of kenaf cores, focusing on their mechanical and acoustical properties for paneling applications. The research aims to identify the need for innovative and sustainable materials in construction, particularly for paneling application. Kenaf, a natural fiber, offers potential as a green and locally available material, aligning with environmental and economic considerations. The study evaluates the manufacturability, cost-effectiveness, strength, and durability of kenaf-filled honeycomb cores. Comprehensive testing includes mechanical properties and acoustic performance according to ASTM standard. The findings aim to predict the potential of kenaf core structures as an alternative material for paneling, contributing to sustainable environmentally friendly construction.

KEYWORDS: *Sandwich composite, Kenaf core, Mechanical properties, Acoustical properties, Paneling applications.*

1.0 INTRODUCTION

Sandwich composites are a type of material that is widely used in a variety of industries, including aviation, aerospace, marine engineering, and shipbuilding, due to their outstanding properties. Composite materials generally comprise face sheets on either side of a core fabric. The core composition may vary, including auxetic honeycomb, M-formed core, lattice cores, and foam cores. Face sheets are often fabricated of carbon fiber, glass fiber, or fabric-bolstered graphite. The combination of various core and face sheet materials allows for adjusting the mechanical properties of the sandwich composite to meet specific requirements.

The honeycomb core structures have found vast application in many different industries because of their high ratio of strength-to-weight and superior mechanical properties. The addition of different materials to the core can also result in improved performance of sandwich panels, and thus, they are applied in different areas, starting from paneling. Kenaf is one such material, which has shown potential in improving some of the characteristics of honeycomb core structures.

Kenaf, a robust fiber plant from the Malvaceae family, finds applications in automotive, construction, and packaging industries due to its mechanical properties and sustainability. The scale of kenaf core used affects mechanical properties like rigidity and strength. Combining kenaf core with materials like rubberwood enhances internal bonding strength in composite panels, suggesting benefits for mechanical and acoustic performance in sandwich structures.

Advances in core designs and manufacturing methods, including hand lay-up and vacuum bagging, further enhance performance. These composites also offer excellent mechanical properties and acoustical performance for paneling applications.

2.0 SANDWICH COMPOSITE

Bühring et al. [1] stated, the usage of sandwich structures offers advantages in many ways. Particularly in terms of bending and buckling behaviour sandwich structures show outstanding mechanical properties and high weight efficiency. Sandwich structures, as emphasized by Shahbazi et al. [2], have garnered considerable popularity among various design concepts in composite structures due to its superior performance, impressive stiffness-to-weight ratio, and enhanced energy efficiency. Moreover, Castanie et al. [3] describe the defining aspect of sandwich construction involving employing a multi-layered skin composed of high-strength outer layers (faces) and low-density inner layers (core). Figure 1 shows the component in the sandwich structure consist of upper skin, lower skin, adhesive film and core.

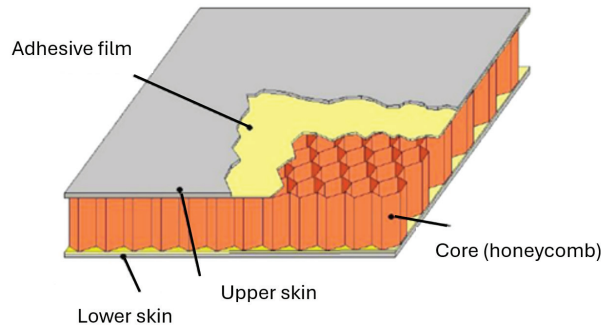


Figure 1: Sandwich construction [3]

2.1 Honeycomb

Honeycomb structures are lightweight and versatile, making them popular in aerospace, aircraft, trains, cars, marine industries, and more [4]. A noise reduction composite with a honeycomb sandwich structure filled with various fibers and micro-perforated plates has been proposed by Liu et al. [5]. Honeycomb structures, widely used as core materials in sandwich composites, have elastic properties defined by foil thickness and cell size, significantly impacting mechanical characteristics [6]. Aluminium honeycomb sandwich panels are noted for being sustainable, lightweight alternatives offering strength, stiffness, and energy absorption [7]. Honeycombs represent common cellular materials characterized by two-dimensional arrays of unit cells in the in-plane direction and arranged in parallel stacks in the out-of-plane direction, as shown in Figure 2.

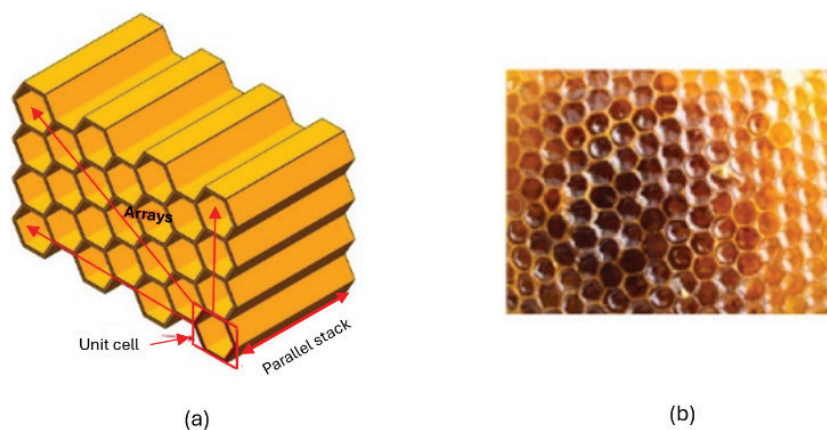


Figure 2: Honeycomb (a) hexagonal configuration, (b) natural beehive [8]

The modern manufacturing of honeycomb structures began in the late 1930s, typically involving an expansion and corrugation process to create thin-walled, cellular hexagonal structures. These structures are effective for energy absorption and economical material use [9]. Increasing the cell wall thickness leads to higher tensile load capacity and stress within the wall [10].

2.2 Kenaf

Kenaf also known as *Hibiscus cannabinus* L. is originates from Africa and has spread to Asia and the USA over the past century [11]. As a resilient annual crop in the Malvaceae family, kenaf grows rapidly, reaching up to 10 cm/day and maturing in three months to an average height of 3 meters. The plant's dry weight consists of 30-40% bark and 60-70% core fibers, from which fibers and wood are extracted as show in Figure 3 [12].



Figure 3: kenaf (a) chip, (b) powder, (c) fiber, (d) stem [13]

An experiment studied the impact energy absorption of kenaf core (KC) reinforced composites with 3 mm, 20 mesh, and 40 mesh sizes using soft epoxy (SE) and polyurethane (PU) matrices. This involved 27 layup sequences with a cold press process. Results showed that the ACA layup sequence with PU had the highest energy absorption, 208.5% more than pure PU foam. The ACC layup sequence with SE absorbed 9.90 J of energy. Overall, smaller KC mesh sizes led to better impact energy absorption [14]. Kenaf's value as a renewable resource comes from its bast and core parts. Bast fibers, comprising 35% of the stem, are found in the outer bark and are used in textiles and paper for their strength and flexibility. Core fibers, constituting 65 % of the stem, are shorter and less flexible, suitable for insulation and bedding [15]. These fibers differ in chemical composition and structure, with the pith featuring polygonal parenchymatous cells.

2.3 Acoustical Sandwich Panel

Wood, vital to forest ecosystems, serves diverse applications from construction to energy. Mixed forests with hardwoods and conifers have elevated wood as an environmentally friendly material that enhances room aesthetics and acoustic functionality [16]. In a 2020 study, Santoni et al. explored the use of wood in wood plastic composites (WPC) for automotive and construction applications [17]. They optimized the sound transmission loss of WPC panels using numerical methods, developing models for panel radiation efficiency and transmission loss through analytical and semi-analytical approaches, validated by simulations and experiments. Figure 4 show images of the experimental setup employed to examine the response of WPC to both mechanical and acoustic excitation.

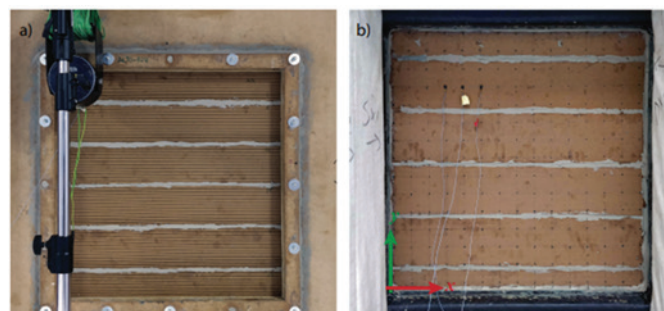


Figure 4: Panel for acoustic testing room (a) reverberant, (b) semi-anech [17]

The study emphasized the importance of properly designing junction systems in real plate-like WPC structures to enhance their vibro-acoustic performance. Analytical models tended to overestimate radiation efficiency compared to experimental results due to differences in real boundary conditions. Finite element (FE) analysis revealed that real boundary conditions deviated from the simply supported assumptions of the analytic models. Despite this, the analytical models were useful for preliminary evaluations. For greater accuracy, numerical approaches considering the actual fixing conditions of the plate's edges were recommended.

Sharma and Kumar [18] discuss the use of foams in engineering for their lightweight and effective energy absorption properties. These foams have a two-phase porous structure that deforms under load, dissipating impact energy through bending, torsion, and buckling. A composite of soft polyurethane and open-cell metallic foam improves sound absorption while maintaining high static stiffness. A lumped element model calculated the surface impedance and absorption coefficients for metal foam, polyurethane foam, and their composite, revealing absorption mechanisms [19]. Sandwich panels are widely used in civil engineering, particularly in non-structural or secondary structural roles within buildings. Proença et al. [20] reviewed of acoustic performance focused on sound transmission through idealized wave deformation. It emphasized the need for more research on FRP composite sandwich panels. Acoustic tests on a reassembled full-scale panel used Sikaforce 7710 L100 polyurethane adhesive, and a GFRP plate with the same fiber layup and resin was made to assess the mechanical properties of the GFRP face laminates. Double panel partitions with a foam core are commonly used in buildings for their lightweight design, offering high thermal insulation and sound transmission loss (STL) [21]. Despite their effectiveness, these panels exhibit a resonance issue that reduces Sound Transmission Loss (STL) at specific frequencies, influenced by the core material's stiffness. Resonant metamaterials can mitigate this by creating a stop band for bending waves at the resonance frequency. Adding resonators strategically to a double panel can predictably enhance STL, especially with varied resonator geometries. Figure 5 shows particleboard layer.

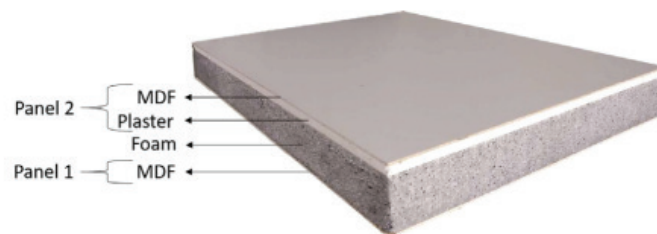


Figure 5: Double panel partition layer [21]

2.4 Manufacturing of Sandwich Panel

According to Chen and Das [22], a sandwich structure comprises rigid skins like composite laminates or metal plates bonded to a lightweight core material such as foams, honeycombs, balsa wood, or corrugated materials. The skins can be fiber-reinforced composites, and the core, which is critical for energy absorption and stiffness, can be metal or polymer-based. Core sandwich panels often use two-dimensional honeycombs, cellular foams, or three-dimensional lattices [23]. Boccarusso et al. [24] emphasize the strong compression and energy absorption of metallic, polymeric, or natural cores, paired with the in-plane properties of composite skins. The hand lay-up technique, using epoxy and glass fiber, is typical for making and repairing sandwich composites, including epoxy resin with floral foam laminates and aluminum face sheets. Despite their high flexural strength, sandwich composites are prone to issues like cracks, delamination, and core failure. The press method effectively bonds the adhesive layer between core and face panels [25]. Figure 6 shows the hand lay-up method, a straightforward procedure. Foam injection molding (FIM), akin to plastic injection molding, incorporates foaming agents for cost efficiency and rapid cycle times. These agents generate foam cells in the polymer melt during mold filling. High-pressure FIM and additives improve

foam quality by managing void fraction and cell size. However, injection molded foams can develop unfoamed skin layers due to temperature variations during molding, potentially limiting their suitability as premium core materials for sandwich structures [26].

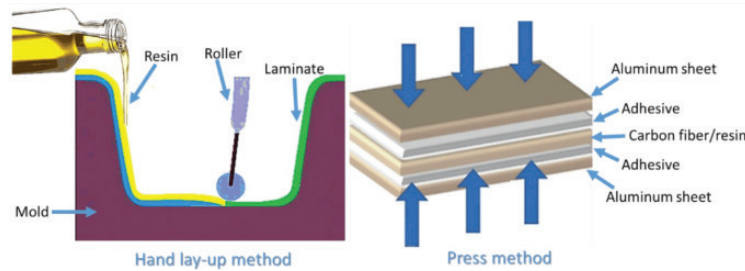


Figure 6: Hand lay-up and press methods for laminate composite structure [26]

New OOA preregs, discussed by Shaikh et al. (2021), can produce high-quality parts using the Vacuum Bag Only (VBO) process, eliminating costly autoclaves [27]. Advances in resin chemistry have improved mechanical properties and reduced porosity in VBO preregs, despite requiring slow ramp rates for air removal, offering potential cost savings compared to traditional autoclave methods.

2.5 The Potential

In summary, adjusting the size of the kenaf core within a honeycomb structure can offer a range of mechanical and acoustical properties. It's essential to conduct thorough testing and analysis to determine the most suitable configuration for specific paneling applications, considering factors such as load requirements, environmental conditions, and desired acoustic performance. Additionally, factors like manufacturing feasibility and cost-effectiveness should also be considered when designing panels with varying kenaf core sizes. This research will need to perform a mechanical and acoustical test according to the standard. Therefore, this research will focus on the development and Analysis of filled honeycomb core structure with different size of kenaf core on mechanical and acoustical properties for paneling application.

3.0 CONCLUSION

The review focus on developing and analyzing various composite structures, particularly honeycomb sandwich panels with kenaf reinforcement, kenaf-filled honeycomb structures with different size of kenaf core. These composites aim to leverage the high strength-to-weight ratio and energy absorption properties of honeycomb cores for paneling application, combined with the natural robustness and sustainability of kenaf fibers. Manufacturing techniques such as hand lay-up, vacuum bagging will be employed to enhance mechanical and acoustical performance. The research will emphasize optimizing these designs for paneling applications in aerospace, marine, automotive, and civil engineering, ensuring they meet specific load, environmental, and acoustic requirements while remaining cost-effective and environmentally friendly.

ACKNOWLEDGMENTS

The authors would like to thank Faculty of Industrial and Manufacturing Technology and Engineering, Universiti Teknikal Malaysia Melaka. This research was not funded by any grant or any institutions.

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