SANDWICH COMPOSITE STRUCTURE MADE FROM DIFFERENT SKIN MATERIALS ON MECHANICAL AND PHYSICAL PROPERTIES FOR ROOFING APPLICATION - AREVIEW

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ABSTRACT: In this era of globalization, natural fibers have become one of the most widely utilized materials due to its abundance, cheaper cost, sustainability, and environmental friendliness in contrast to artificial fibers. Natural fibers are increasingly being substituted in sandwich composite manufacturing for roofing applications due to its mechanical and physical properties that are more superior compared to synthetic fibers. In this study, the manufacturing of roofing panel will be done to determine the best stacking sequence by using natural fiber like Hemp, Jute and Kenaf as face sheet and Polypropylene honeycomb as core material and epoxy as resin. The effectiveness of using hand lay – up and vacuum bagging technique to fabricate these materials need to be studied. Additionally, this study will to be put through testing in line with ASTM standard to test its properties. Finally, it is anticipated that this research will produce natural fiber of sandwich composite that will specifically be applied for future engineering growth in roofing applications.

KEYWORDS: *Sandwich Composite; Natural Fiber; Roofing Material; Manufacturability; Malaysia Weather.*

1.0 INTRODUCTION

Nowadays, construction industry facing growing demand for cost and eco-friendly material used for roofing due to the depletion of traditional raw materials and increasing environmental concerns. Conventional roofing materials, such as concrete, clay tiles, and asbestos, pose a significant environmental challenge to disposal, high- cost manufacturing, and resources availability [1]. Based on the current challenge, a new alternative material is needed so that the current lack of roofing material can be reduced.

Jute, hemp, sisal, and flax are examples of natural fibers that have emerged as viable substitutes due to their minimal environmental effect, biodegradability, and renewability [2]. Sandwich composites provide a possible answer by fusing the advantages of natural fibres with improved mechanical and thermal qualities. A lightweight core material is sandwiched between two robust outer face sheets with epoxy resin act as matrix. Studies on natural fiber to be use as sandwichcomposite' face sheet should be conduct to investigate its mechanical and physical properties to provide a superior performance material for roofing applications.

All products that are exposed to the real environment at prolonged willexperience deterioration in the value of mechanical and physical properties. Country that has quite extreme weather changes which contributes to content of humidity, heat and UV exposure that will accelerate the decline in product performance [3]. Based on the statementof this problem, it shows that this review study is important and relevant to find and understand the potential of sandwich composite made of natural fiber for future roofing material that can be use in Malaysia one day.

2.0 SANDWICH COMPOSITE

Sandwich composite structures have been around since the middle of the 20th century, and over the years, many notable developments and uses have emerged. Gibson [4] explains that in the 1950s and 1960s, sandwich structures became more and more popular in aerospace engineering. When aircraft panels started using honeycomb core materials it brought about lightweight solutions in composite industry. Advances, in material science like foam cores and advanced resin

systems have further enhanced the performance and versatility ofsandwich composites. This has solidified the position of sandwich structures as useful technology development for high performance andlightweight applications in various industries from automotive, tomarine and construction.

Sandwich structures are engineered materials that consist of a core material sandwiched between two face sheets. These are also known assandwich panels or composite sandwich materials. The diverse applications of sandwich composites offer benefits in the construction industry, where they provide a combination of strength and lightness [5].The face sheets made of high strength materials provide protection andload bearing capacity while the lightweight core material contributes most of the thickness of the structure. Figure 1 illustrates how a sandwich composite structure is organized.

Figure 1: Composite sandwich panel with tetrahedral truss structure core [6].

3.0 HONEYCOMB CORE

One of the most important factors in sandwich structure design is thatthe core must have a high enough shear stiffness to avoid buckling prone to high force or heat [7]. Research by Feng [8] Polypropylene honeycomb core have a structure of hollow hexagonal pattern. There are various pattern of honeycomb core but study by Shi [9] found that when compared to alternative structures of hybrid FRC, which had 0.1% micro polypropylene fibres (12–25 mm) and 0.3–1% macro polypropylene fibres (60 mm), the auxetic-honeycomb structures have that were designed have a higher compressive strength and can absorbmore energy as shown in Figure 2. To study the dynamic response of sandwich panels with auxetic cores, creating a cellular auxetic structure that was submerged in a filler material with a specificPoisson's ratio and contrasted with rotating squares or re-entrant honeycomb would actually produce stiff and high durability sandwichcore.

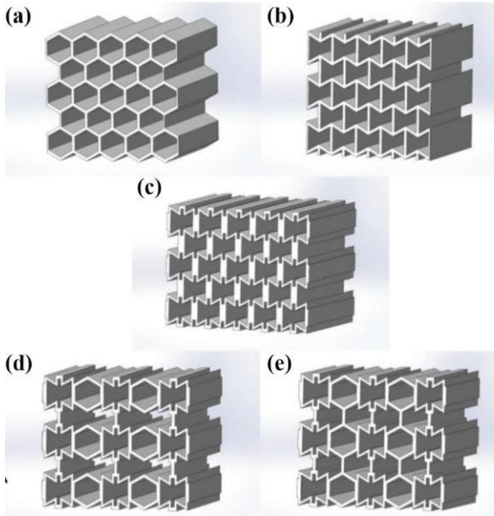

Figure 2: Honeycomb core structures (a) honeycomb, (b) reentrant auxetic, (c) auxetic-strut, (d) auxetic-honeycomb, (e) auxetic-honeycomb [7].

According to Kabir [10] sandwich structures are suitable for a wide range of applications, from lightweight composite bridges and high- performance sporting equipment to aircraft fuselages and wind turbine blades. Sandwich structures can be engineered to withstand various loading conditions, including bending, torsion, and compression. Yu [11] states that sandwich structures are more effectiveat insulating against heat and sound than solid materials, whichmakes them appropriate for applications that call for sound attenuation or temperature control.

3.0 NATURAL FIBER

Plant fiber crops are among the first known cultivated plants, and overmillennia, humans have continued to domesticate these crops. Varieties of fiber crop have been created via breeding and selection in response to the values and needs of the respective societies. Kausar [12]refers that the history of natural fiber composite began when fragmentsof hemp and linen dating were introduced in 10,000 – 8,000 years ago that havebeen found in Neolithic sites in Syria, Turkey, Mesopotamia (modern-day Iraq), and Persia (modern-day Iran). Keya [13] states in their research that any type of hair-like raw material that is directly obtainedfrom plant, animal, or mineral sources is referred to as natural fiber.

These raw materials are then processed into nonwoven fabrics, which can subsequently be made into filaments, thread, or rope, which can then be utilized as a component of composite materials. There are thousands of different types of natural fibers found in the environment and they use natural fibers to develop new applications and work to enhance the qualities of composite materials that contain natural fibers. Figure 3 show the classifications of natural fiber resources.

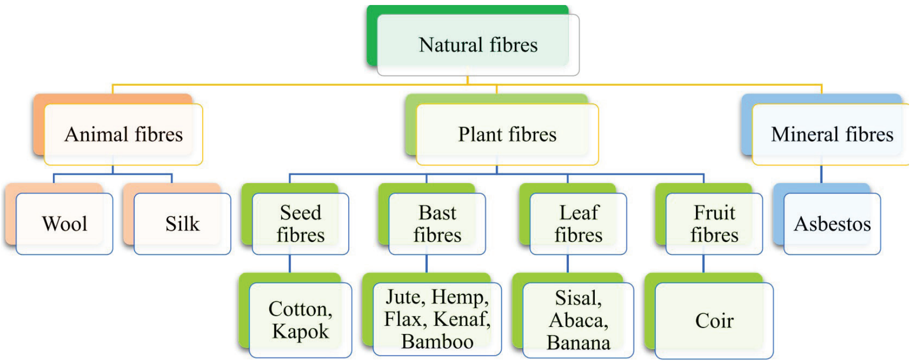

Figure 3: The classifications of natural fibers [13].

The favorable mechanical qualities and eco-friendliness are making naturalfibers widely used in composite materials at an increasing rate. Hemp, kenaf, and jute are three common natural fiber sources used in composites.Jute fibers are inexpensive and have a high tensile strength, which makes them perfect for reinforcing composite materials. They are derived from the Corchorus plant. Research by Islam [14] highlights the use of jute fibers in polymer composites to enhance mechanical properties such as tensile strength and modulus. Jute fibers also have the benefit of biodegradability that is safe to the environment, whichis also in line with the expanding need for sustainable materials across a range of industries nowadays.

The Hibiscus cannabinus L. plant also known as kenaf fibers, which are suitable for reinforcing polymer matrices in composites due to their high tensile strength and modulus, among other desirable mechanical properties [15]. Through the exploration of natural fiber treatments and theoptimization of processing methods, researchers have recently concentrated on improving the properties of natural fiber composites. Forexample, Koohestani [16] investigated how two types of fiber treatment, which are silane coupling agent and alkali treatment can affected the mechanical characteristics of composites reinforced with kenaf fiber. They discovered that the interfacial adhesion between the fibers and the polymermatrix was greatly improved when it undergoes alkali treatment, improving its mechanical properties of the composites. Hemp fibers are derived from the Cannabis sativa plant that originated in Central Asia. Hemp fiber is ideal for variety of composite applications due to their exceptional strength, stiffness, and resistance to moisture absorption [17]. Figure 4 is the example of a few commonly used natural fibers in various industry.

(a) (b) (c)

Figure 4: Actual images of natural fibers; (a) jute, (b) hemp (c) kenaf [13].

Natural skin fibers also possess an ability to endure environmental conditions such, as high humidity, and extreme temperature variations. Byregulating their moisture levels these fibers reduce the risk of moisture induced deterioration in materials. The organic composition of leather fibers contributes to their biodegradability aligning with the sustainability goals of construction. A study conducted by Musthaq [18] has emphasized the potential of leather-based composites as eco alternatives, to reinforcement materials showcasing their positive environmental impact. Figure 5 depicts a graph illustrating the percentage of water absorbed by fiber reinforced composites.

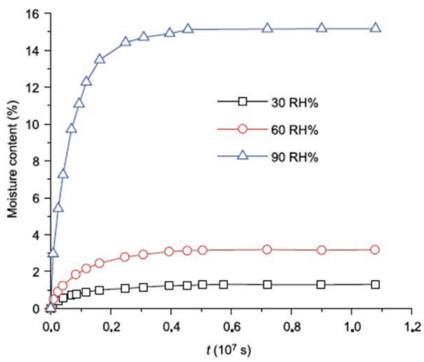

Figure 5: The experimental results on moisture absorption with different relative humidities of sisal-fiber-reinforced composites [18].

5.0 ROOFING APPLICATION

Throughout the history of construction roofing has played a role, in shielding buildings from weather conditions like rain, snow, wind and sunlight. Over time there have been advancements in roofing materials and techniques. In the days roofs were constructed using resources such as thatch, wood, and stone. Thatch roofs made from vegetation like straw or reeds were particularly popular in areas for their insulation properties and easy construction process. In line with this advances the house design also have been through some development, where each country has embedded their own culture when design and building the houses without disregard the climate of the country or places [19]. There are clear differences in the design of the house and the material that was used as a roof. As for example, the continent which has hot climate such as Asia, Australia, America, and Africa they adopted green roof in the constructions elements in building their houses [20].

In addition, to offers the advantages of contemporary building materials, composite roofing materials can be engineered to resemble natural materials like slate, wood, or clay tiles [21]. Due to its adaptability, a broad variety of architectural designs and styles can be implemented, giving architects and homeowners the freedom to realize their desired aesthetic vision without compromising roof durability or its performance. Additionally, composite materials can be produced in a variety of sizes, and shapes, allowing for customization to match particular roofing geometries and designs. This reduces material waste and increases installation efficiency [22]. Figure 6 show the schematic view of hypothetical house using composite materials.

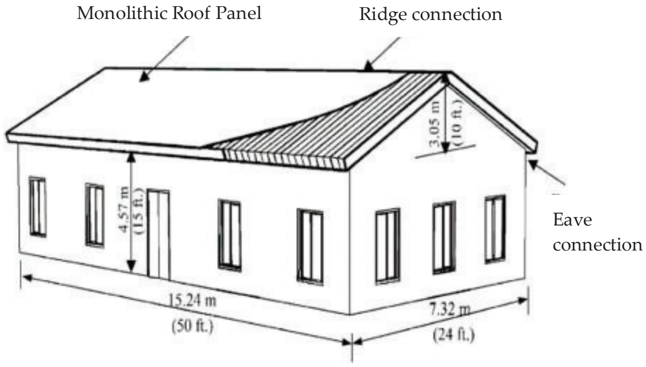

Figure 6: An illustration of the hypothetical house [22].

6.0 FUTURE POTENTIAL AND CONCLUSION

The unique honeycomb design enhances the inherent advantages of natural fibers, offering a combination of lightweight properties, high strength-to-weight ratio, and excellent thermal and acoustic insulation. This configuration can significantly reduce the structural load on buildings while improving energy efficiency.

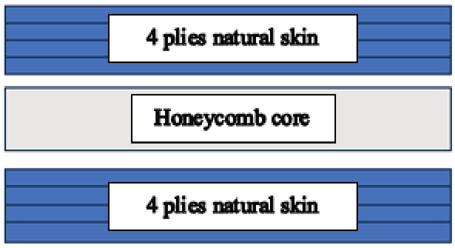

Figure 7: Proposed future prototype using natural fiber

The research, on creating and studying sandwich structures using natural skin materials for roofing purposes provides valuable insights into the physical and mechanical characteristics of these materials. Through an assessment of natural skin the study emphasizes the potential of these composites in improving the strength, durability and overall performance of roofing systems. The results indicate that natural materials offer a sustainable option compared to traditional roofing materials with mechanical properties that are just as good, if not better while also supporting environmental preservation efforts. The successful incorporation of skins into sandwich composites for roofing shows promising prospects, for construction practices promoting ecological advantages and structural reliability.

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