SANDWICH COMPOSITE STRUCTURE MADE OF DIFFERENT SYNTHETIC SKIN MATERIAL ON MECHANICAL AND PHYSICAL PROPERTIES FOR DECKING APPLICATION - A REVIEW

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ABSTRACT: Nowadays, sandwich composite has become one of the widely reliable material due to its high tensile strength, excellent flexural strength and incredible energy absorber yet lightweight and durable. The use of synthetic fiber as skin has proved to be superior since the hydrophilic behavior of natural fiber affects the composite structural integrity when exposed to water or moisture. Synthetic fiber also highly utilized due to its mechanical properties stronger than natural fiber. In this study, the manufacturing of sandwich composite structure made of synthetic fiber as skin will be fabricated by straightforward hand lay-up and vacuum bagging method to determine the best combination of synthetic fiber which are Kevlar, Carbon and Fiberglass with Polypropylene (PP) honeycomb core and Epoxy resin as matrix. Through comprehensive literature review will be anticipated that this research will produce strong yet lightweight sandwich composite with synthetic fiber as skin that will be specifically employed as construction material such as decking material.

KEYWORDS: *Sandwich Composite; Synthetic Fiber; PP Honeycomb Core; Hand-Lay Up; Vacuum Bagging.*

1.0 INTRODUCTION

The spreading of the composite material has had a world-changing effect. In this centuries, scientist discover new composite material that is lightweight yet durable. The material is also known as sandwich composite. Sandwich composite is as a combination of material structure consists mainly of the core material and the fiber-reinforced polymer (FRP) face sheets that excel as structural purposes such as roofing panels, house partitioning, decking, and cladding. Many Building composite structures from rigid outer skin with non-rigid and low-density elastic core materials are favourable to design structural components with high performance mechanical properties outer-layer skin, simultaneously, able to handle high impact and vibration tolerances within the core layer, making them good options for aerospace, marine and wind power industries.

Natural and synthetic fiber made into fabric can be used as reinforced face-sheet in sandwich composite. Natural fibers are plant-based material that are known to be renewable and biodegradable materials. Hence fiber made of material such as flax, sisal, banana, hemp and jute have advantages over economic, environmental, and ecological compares to synthetic fibers. Synthetic fibers on the other hand are nonbiodegradability and causes great emission of greenhouse gasses into the environment. However, composite made with reinforcement material such as glass and carbon, Kevlar, Nomex fiber are more suitable for structural applications due to high mechanical properties. By adding glass fiber reinforced polymer

(GFRP) in ultra-high performance concrete (UHPC) sandwich panel has improved its flexural strength and able to be applied as wall panels.

The world faces energy crisis and deteriorating environment have encouraged the rapid development of sandwich structures such as Nomex honeycomb, kraft honeycomb, polyurethane (PU), geopolymer foam, polyvinyl chloride (PVC), Aluminium foams, balsa woods, PVC foam. The material failure of composite sandwich structures with a honeycomb core under low-velocity perforation impact and revealed that honeycomb (HC) sandwich structure, when reinforced with composite material panels, has outstanding in energy absorption, force resistance and massive weight reduction. Hence has been attraction to be used in the components of some mass transport tools. The core material has dynamic mechanical properties. Sandwich panel made of metal foams and carbon fiber exhibit lower density yet higher specific properties in stiffness, energy absorption, and mechanical and acoustical damping capacities.

The fabrication process of sandwich composites predominantly involves the hand lay-up technique. It provides versatility to design complex geometry of composite panel, cost effective and better quality control. Vacuum bagging is also one of the examples of commonly used method to manufacture composite. This method has been applied to produce sandwich composite that is void-free and consistent thickness. Therefore, this review papers will comprehensively discuss and highlight latest and relevant information for future application of decking using sandwich composite.

2.0 SANDWICH COMPOSITE

In recent studies, Sahib and Kovács [1] stated that sandwich structure is a multifunctional composite structure characterized by a low weightto-strength ratio. The study of sandwich composite aimed to obtain advanced composite structures with high structural stiffness, strength, and energy absorption potential. Sandwich core has space-filling properties which are also crucial in increasing the moment of inertia of the structure. Due to these properties, it provides high impact resistance, energy absorption, shear rigidity, and flexural stiffness. Additionally, sandwich composites are commonly used in movable constructions, sporting equipment, vehicles, automobiles, trains, and airplanes, among other places where weight reduction is a top need. Since the faces make up most of the panel's outside surfaces and bear the brunt of the weight, it must be strong and has high stiffness to withstand the conditions in which they function such as decking and paneling. While the core fills most of the volume at the center of the sandwich structures, it must be light, stiff and strong enough to carry the shear stresses to make the whole panel behave as a load bearing unit.

Another study conducted by Santos et al. [2] examined the sandwich composite reinforced with sisal and coir fibers in the egg-box shaped core, significantly improving strength and stiffness of the sandwich structure. Scientists have explored alternatives of core shape and geometrical structure such as foam, hexagonal honeycomb, pyramidal truss, and triangular corrugated cells. These are commonly used due to their low weight and strength. However, nowadays, the design of novel derivative structures has appeared, including the Y-shape, auxetic, egg-box shape and truncated dome [2]. Sandwich composite shown in Figure 1 are widely used for their resistance to buckles and their bending stiffness. According to Li and Ma [3], sandwiches are mainly composed of at least one ply of face sheets, a bonding layer, and a core.

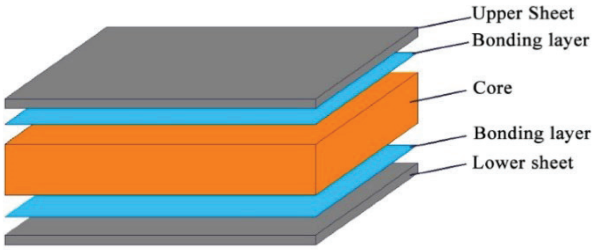

Figure 1: Symmetrical sandwich composite [3]

2.1 Honeycomb Core

Honeycombs are also known as the core of the sandwich composite structure. It plays a crucial role in absorbing energy from an impact. He et al. [4] mentioned that honeycomb sandwich structural parameters are based on its geometry which are thickness of cell wall, side length of honeycomb cell, height of honeycomb core and thickness of the face sheets. Investigation by Zhang et al. [5] revealed that honeycomb core structure has the ability to increase the compressive strength by approximately 50 % and double the energy absorption capacity of honeycomb plates with the same material costs. Furthermore, experiment by Alí et al. [6] also proved that the higher number of layers of sandwich core, the higher energy absorption. Generally, honeycomb structure consists of multiple, fixed size tubulars, arranged closely to each other. The designers and researchers have been studying the geometrical of honeycomb, that is not only limited to hexagon shape but also pentagon, octagon, 12-sided and 16-sided star [7]. Hollow columns, usually circular, can also exist within the design such as attached to the wall, junction or both. Figure 2 shows a honeycomb structure without any hollow column that is commonly used in aerospace industries.

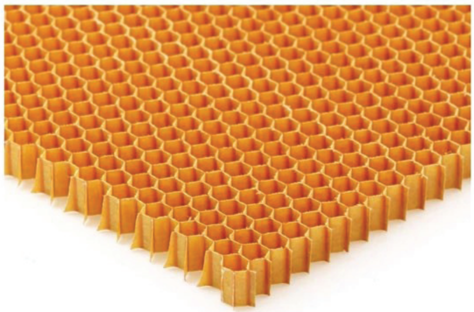

Figure 2: Honeycomb core [3]

2.2 Synthetic Skin

Face sheet is also famously known as skin. Face sheets can be made of synthetic fiber and natural fiber. The fabric-like fibers are layered up on the front and back surfaces of sandwich core to increase strength, toughness and flexural of the final material. Mahmoudabadi and Sadighi [8] studied the effect of energy absorption on different face sheet thickness and the number of plies. In their findings, it revealed that the sandwich panel with 2 plies of face sheets can withstand maximum load of 3765 kN while with 1 ply, maximum load it able to handle is 3193 kN. However, increasement of thickness face sheet shows huge difference with 0.9 mm of aluminium face sheet able to reach 6309 kN maximum load while 0.5 mm only 3261 kN, more than 50 % increasement on face sheet in-plane stiffness [8]. The deformation of composite with higher thickness of face sheet are more significant than thinner face sheet which appeared more severe and obvious. Table 1 shows the specification of honeycomb sandwich panels with aluminium face sheet specimens and Table 2 shows the result of the honeycomb sandwich panel subjected to quasi-static punch loading by flat nose projectiles.

Table 1: Specifications of honeycomb sandwich panels [8]

Sample Index	Wall Thickness (mm)	Core Thickness (mm)	Number of facesheets	Facesheet thickness (mm)
SMF2	0.0254	20.0	1	0.5
SMF7	0.0254	20.0	1	0.9
SMF5	0.0254	6.7	1	0.5
SMF11	0.0254	6.7	2	0.5

Table 2: Quasi-static experiment results of specimens [8]

Sample Index	Absorbed energy (J)	Specific energy (J/kg)	Densification strain (%)	Maximum load (N)	Strain at peak load (%)
SMF2	36.7	1920	85	3261	35
SMF7	53.3	1857	71	6309	22
SMF5	10.1	713	63	3193	63
SMF11	10.4	405	58	3765	58

3.0 FABRICATION METHODS

The process of hand lay-up is a conventional process used for sandwich composite structures. The first step of this process is to set up the mold with antiadhesive to prevent polymer from sticking to the surface. Next, a thin plastic sheet is applied at the top and bottom of the mold plate so a smoother surface of the product can be produced. Figure 3 shows the hand lay-up method by using roller to spread matrix on woven reinforcement. Zainuddin et al. [9] formed a sandwich composite structure from floral foam core and aluminium sheets that firstly cut into 30 cm x 3 cm square, by using hand lay-up method. On each layer between aluminum sheets and foam cores, epoxy resin as adhesive was spread using a flat blade. The face sheets were slightly pressed into the core to the surface to make sure the layers were sticking evenly. The sandwich composite was cured for 2 days.

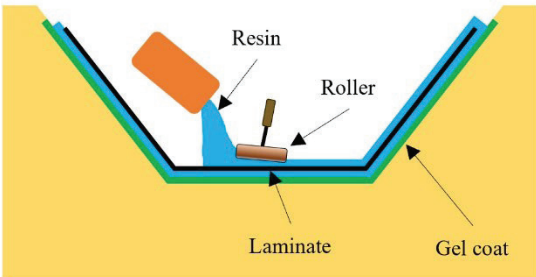

Figure 3: Hand lay-up process [10]

Vacuum bagging is one of the most famous methods to fabricate a sandwich composite. According to Kausar et al. [11], vacuum bagging technique creates pressure on sandwich composite which will result in smoother surface finish. Valenza and Fiore [12] stated that void contents in sandwich composite have negative effects on its structural response such as lower fatigue resistance and higher water absorption. Hence, voids that formed due to air trapped in resin formulation can be considered as defects in laminated composite. In the same study, Valenza and Fiore [12] fabricate glass fiber reinforced polymer with PVC foam as core. The sandwich structure was wrapped in vacuum bagging and left to cure for 24 hours at room temperature before being heated at 60 °C for an estimated 16 hours. The scientists successfully fabricated sandwich composites that not only appeared as void free and reduced in porosity but also have more consistent laminate thickness and fiber fraction. Zebrine et al. [13] mentioned that sandwich panels for aerospace applications require smooth surfaces for better aerodynamic and aesthetic purposes. Spoiler is one of aircraft component built with sandwich structure made of resin preimpregnated carbon fiber material and an aramid honeycomb core, cured with vacuum bagging technique in an autoclave. Hence, they formed a sandwich composite made of carbon fiber with Nomex honeycomb that has been cured in vacuum condition with pressure below 5 kPa. Figure 4 shows chamfered honeycomb sandwiched in a vacuum bag with one ply on fiber on each side and epoxy as adhesive.

Figure 4: Schematic of sandwich panel layup [13]

4.0 DECKING APPLICATION

Decking application of composite material has been explored more and more due to its eco-friendliness and cheaper other than providing mechanical performance as good as steel. In an experiment by Wasti et al. [14], they build a Polypropylene-Bamboo Fiber (PP-BP) sandwich composite truck/trailer decking. Truck/trailer decking material properties must be high strength and stiffness to weight ratio, excellent corrosion resistance, high fatigue, impact resistance, easy installation, and excellent durability [14]. Trailer decking sandwich panels were prepared by overmolding process which includes PP-BF as skin and Bamboo Strip (BS) as the core as shown in Figure 5.

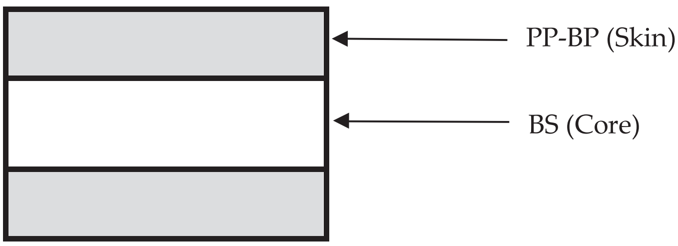

Figure 5: Cross Section of PP-BF-BS sandwich composite [14]

According to Wasti et al. [14] the core performs well as heat insulator, sound and vibration. The tensile test was performed on Test Resources universal testing machine Model 313 series frame, MN with 50 kN load cell capacity, resulted in tensile strength and modulus of PP increased by 10 and 45 % respectively with 5 wt.% addition of BF. However, with the addition of 10 %, 15 % and 20 wt.% of BFs, the tensile strength decreased. It revealed at the end of the experiment, prototype of PPBF-BS trailer decks with dimension 1.21 m × 0.355 m x 0.0635 m performed excellently under aggressive loading conditions. PP-BF-BS decks also survived 400 cycles of load with minimum damage.

5.0 CONCLUSION

Findings from this comprehensive literature review have been made by going deep in the knowledge of composite material, introduction of sandwich composite, mechanical and physical properties of sandwich composite, manufacturing of sandwich composite and applications of sandwich composite from the past researcher. It has been found that mechanical properties of sandwich composites such as hardness, tensile and flexural strength heavily impacted by thickness and layer of face sheets. In addition, the core of sandwich composite presents excellent energy absorption and stiffness depending on core size, thickness and material. Selection of matrices for better bonding is also carefully made to prevent delamination, peeling and to make the composite structure behave as brittle or ductile material. Most of the research or experiment that has been reviewed are found to be using carbon fiber and fiber glass as face sheets in their sandwich composites. In conclusion, this research will focus on optimizing the layer of face sheets, thickness of core and face sheets to consider desired mechanical and physical performance using synthetic skin and honeycomb core.

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