PERFORMANCE OF HONEYCOMB SANDWICH STRUCTURE WITH NATURAL FIBRES FABRIC REINFORCED FACESHEETS

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To my beloved family.

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ABSTRACT

The purpose of this study is to investigate the mechanical behaviour and failure mechanisms of sandwich structures with polypropylene (PP) based honeycomb core and natural fibre reinforced polymer (NFRP) facesheets as a function of facesheets. Flax fibre/epoxy facesheets with PP honeycomb core was fabricated by vacuum bagging hand lay-up technique. The properties of sandwich constitution is investigate by using tensile and flexural test for facesheet and flatwise test for core. Three-point bending (3PB) tests were performed to evaluate the mechanical behaviour of the composite sandwich structures. For the sandwich structures, three point bending test results showed that core shear stress, sandwich beam deflection and panel bending stiffness increased with the facesheet thickness increment. The increment of facesheet thickness show significant increase of bending stiffness but also increase the density of the whole sandwich.

ABSTRAK

Kajian ini dilakukan bertujuan mengkaji kelakuan mekanikal dan mekanisma kegagalan bagi struktur sandwich dengan teras sarang lebah berasaskan polypropylene (PP) dan kepingan muka serat semula jadi diperkukuh polimer (FRP) berfungsikan kepingan muka. Kepingan muka serat flax/epoksi dengan teras sarang lebah PP dihasilkan melalui teknik *vacuum bagging hand lay-up*. Sifat-sifat penjuzukan sandwic disiasat dengan menggunakan ujian tegangan dan lentur untuk kepingan muka dan ujian tekanan leper untuk teras. Bagi struktur sandwich, ujian tiga titik lenturan (3PBT) menunjukkan teras tegasan ricih teras, pesongan rasuk sandwich dan lenturan kekakuan panel meningkat dengan peningkatan ketebalan kepingan muka. Ujian tiga titik lenturan (3PB) dijalankan untuk menilai sifat mekanikal bagi struktur sandwich komposit. Berdasarkan ujian 3PB, peningkatan tekanan kepingan muka, tegasan ricih teras, pesongan rasuk sandwich dan lenturan kekakuan panel adalah diperhatikan dengan kenaikan dalam ketebalan kepingan muka. Mekanisma kegagalan sandwich diperhatikan dengan perbezaan ketebalan kepingan muka. Peningkatan ketebalan kepingan muka menunjukkan peningkatan yang ketara lenturan kekakuan tetapi juga telah meningkatkan ketumpatan keseluruhan sandwic.

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LIST OF SYMBOLS

σ	-	Stress
P	-	Force
A	-	Cross Section Area
E	-	Modulus
ε	-	Strain
R	-	Rate of crosshead motion
Z	-	Rate of straining of the outer fibre (0.01mm/mm/min)
L	-	Support Span
d	-	Thickness
b	-	Width
m	-	slope of the tangent
E_b	-	flexural modulus
S	-	slope of the initial linear portion of load-deflection curve
c	-	Core thickness
τ	-	Shear stress
Δ	-	Total beam midspan deflection
U	-	panel bending rigidity
D	-	Panel bending stiffness
G	-	Core shear modulus

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, composite sandwich structure have attracted considerable interest as advances composite materials that satisfy high performance requirement of machine design, lightweight structure, aerospace, civil, marine and automobile industries [1-2]. These materials have high structural crashworthiness that are capable of absorbing large amounts of energy under impact loads [3].

In general, sandwich structure composed of two high-rigidity thin stiff facesheets (or skin) and a thick lightweight core bonded possessing less strength and stiffness between them. The role of the core is to transmit the shear between the face sheets and the face sheets provide the flexural stiffness. A sandwich structure will offer different mechanical properties with the use of different types of materials because the overall performance of sandwich structures depends on the properties of the constituents [4]. A core with poor mechanical properties will reduce the performance of the panel but a strong core can contribute to the flexural stiffness and to the out of plane shear and compressive strength of the panel [1, 5].

Generally in a sandwich structure, the bending loads are carried by the force couple formed by the facesheets and the shear loads are carried by the lightweight core material [6]. The core material is low in density that primarily is to maintain a high moment of inertia compared to the facesheets that are strong and stiff both in tension and compression. The low density of the core material results in low panel density, therefore under flexural loading sandwich panels have high specific mechanical properties whereby loads are supported through facesheets known as the monocoque structures. Therefore, sandwich panels are highly efficient in carrying bending loads. Under flexural loading, one laminate is under compression and the other one under tension which forming a force couple as facesheets act together.

On the other hand, the core resists transverse forces and stabilizes the laminates against global buckling and local buckling [7]. Additionally, the core provides increased resistance to buckling and crippling of shear panels and compression members [8]. Sandwich panels are also costs saving other than it's advantageous as light weight material and structural performance [9]. Especially for sandwich structures for civil applications that's need large cell size of (typically in the range from 500 mm to 1500 mm) allows the fabrication of cores using fibre reinforced polymers [10]. For example, Ji et al. introduced a glass-fibre reinforced-polymer corrugated-core which is fabricated via the assembly of pultruded and thermoformed shapes [10, 11].

Recent technological developments have expanded the use of composites in industrial, automotive, construction, sports and leisure, and mass production industries which focusing on sustainability and renewable reinforced natural fibres composite [12]. Thus, creating an interest toward substituting glass and carbon fibres by natural fibres [13]. In some research, the use of natural fibres reinforced have been found use in several application, ranging from simple design to complex engineering uses such as building material and automobiles parts [15–17].

The advantageous of natural fibres compared with the synthetic fibres; natural fibres are cheaper, lower mass per unit area, eco-friendly, recyclable and biodegradable by nature, do not produce skin irritation and provide good acoustic insulating properties [17, 18]. On the other hand, natural fibre reinforced composites exhibit inferior mechanical performance and water resistance properties than conventional glass fibre reinforced composites [17–21]. Due to these problems, many research programmes have been undertaken in an attempt to better understand the impact response of these materials [22–24].

Stocchi et al [25] introduced a novel honeycomb core made of a natural fibre reinforced composite that consists of a thermoset-polymer (vinylester) reinforced with jute fabrics. 6 mm and 10 mm cell honeycombs are manufactured using two compression moulding techniques which the best results are obtained for the mould with lateral compression. Experimental tests are conducted to characterize the elastic response of the composite and the core response under flatwise compression. The result of the test show that the core failure mechanisms are yarn pull out and fibre breaking. The large wall thickness relative to the cell size of the jute–vinylester cores, which inhibits buckling, and the heterogeneities in the composite, which are preferential damage initiation sites, explain the observed behaviour. When compared in terms of the specific strengths, the jute/vinylester cores introduced in this work show similar performances to those of their commercially available counterparts. The results from this study suggest that jute-reinforced cores have the potential to be an alternative to standard cores in applications that sustain compressive static loads.

Evaluations are needed for different properties or characteristics of sandwich panels depending on sandwich structure of area application [26]. Thus, it can be concluded that sandwich structure critical properties are depending on area of application. For example, out of plane compressive properties are more critical for automotive industry, whereas in plane compressive properties are more important in wind turbines.

1.2 Problem Statement

Green technologies is a part of the larger process of technological change that comprises invention, innovation and diffusion that reduce the production of waste [27]. Therefore, replacing synthetic fibre for natural fibre are significant due to its lightweight, nonabrasive, non-irritating, combustible, non-toxic, biodegradable properties [28], low energy consumption for production and renewable. It is known that natural fibre reinforced composites exhibit inferior mechanical performance than conventional glass fibre reinforced composites. Hence, this study will determine the mechanical properties of natural fibre as facesheet reinforcing material. The incompatibility and poor interfacial adhesion of natural fibre reinforced composite with matrix compare to the synthetic fibre (glass, carbon, aramid, ets.) should be investigate in order to replace the synthetic fibre. There are less research regarding the effect of facesheet natural fibre composite on performance sandwich structure, thus making the research an advantage for further development.

1.3 Objective

The objective of this study is to determine the mechanical behaviour and failure mechanisms of sandwich structures with polypropylene (PP) based honeycomb core and natural fibre reinforced polymer (NFRP) facesheets as a function of facesheets thickness. For this purpose, tensile test, flexural test, flatwise test and three point bending tests will be conducted on composite sandwich specimens with various of facesheets thickness. Constituents of the sandwich structures are also tested mechanically.

1.4 Research Scopes

The research project is a study and development of honeycomb sandwich structure with natural fibres fabric reinforced facesheets suitable of mechanical applications. In this research, few sample of honeycomb sandwich structure with NFRP facesheets are fabricated using flax fabrics as the reinforcement phase and epoxy are use as matrix phase. The performance of facesheets are then determine by tensile and flextural test for strength and modulus. The performance of core are then determine by flatwise test for strength and modulus. The performance of sandwiches are then determine by three point bending tests for core shear stress, facesheet bending stress and panel bending stiffness that will be conducted on composite sandwich specimens with 10 mm core thicknesses.

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