THE FLEXURAL BEHAVIOR OF COMPOSITE SANDWICH STRUCTURE

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature

Name of Supervisor :

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Name of Panel :

Position :

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

I humbly dedicate this thesis to

my lovely mom and father, Che Jamilah Binti Hasan and Omar Bin Muhamad
my dearest sister, Nur Hanani Binti Omar, Qistina Binti Omar, Hafizah Binti Omar,
Izzati Binti Omar and Nur Bazla Binti Omar
my dearest cousin, Nik Norma Binti Nik Idris
and to all my friends.

who always trust me, love me and had been a great source of support and motivation.

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ABSTRACT

Sandwich construction is widely used because of its ability to provide high bending stiffness coupled with light weight. The main objective of this study is to investigate the effects of core under flexural test and to investigate performance of sandwich panels from the energy absorption point of view. The fibre used is woven roving glass fibre where the matrix used is based on saturated polyester resin. The composite skins of the sandwich panels were prepared by hand lay-up technique. Three point bending test was carried out to obtain flexural strength and flexural strain of the composite sandwich structures. Two different cores of sandwich panels were tested in this project. Sandwich panels with polyurethane core was found had higher flexural strength and higher energy absorption compared with sandwich panels with polyethylene core. From the observation, increasing the debonding strength of the core-face interface, the failure mode changed from debonding of the core-face interface to the failure of the face. The experimental results show that mechanical properties were improved when span decreased and also depends on core materials. Thus, the influence of core materials and span length of the sandwich panels has been evaluated.

ABSTRAK

Pembangunan struktur berlapis (sandwich structure) telah digunakan secara meluas kerana kemampuan untuk menyediakan kekuatan lenturan yang tinggi dan struktur yang lebih ringan. Objectif utama dalam kajian ini adalah untuk menyelidik kesan terhadap perbezaan teras di bawah ujian lenturan dan mengkaji kemampuan struktur berlapis dari sudut tenaga serapan. Bahan gentian yang digunakan adalah jenis gentian *woven roving* dan polyester tak tepu sebagai bahan matrik. Permukaan komposit disediakan dengan menggunakan teknik bengkalai tangan (Hand lay-up). Ujian 3 titik lenturan dijalankan untuk mendapatkan kekuatan lenturan dan ketegangan lenturan struktur berlapis. Struktur berlapis dengan menggunakan dua teras yang berbeza telah diujikaji dalan projek ini. Struktur berlapis dengan teras polyurethane didapati menunjukkan kekuatan lenturan dan penyerapan yang lebih tinggi dibandingkan dengan struktur berlapis yang menggunakan polyethylene sebagai teras. Daripada pemerhatian, kekuatan antara muka di antara teras dan permukaan meningkat, ragam kegagalan bertukar kepada kegagalan berlaku di permukaan struktur. Keputusan ujikaji menunjukkan bahawa sifat mekanikal dapat dipertingkatkan dengan mengurangkan panjang span dan juga bergantung kepada bahan teras yang digunakan. Dengan demikian, pengaruh bahan teras dan panjang span struktur berlapis telah dibuktikan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

ε	Strain
σ	Stress
σ_f	Flexural Strength
E_f	Modulus of Elasticity
P	Load
L	Support Span
b	Width of Test Beam
d	Depth of Test Beam
D	Deflection
m	Slope
ρ	Density
v	Volume
m	Mass

LIST OF ABBREVIATIONS

FRP	Fiber reinforced plastic
GRP	Glass reinforced plastic
PUR	Polyurethane
PIR	Polyisocyanurate
PF	Phenolic Foam
EPS	Expanded Polystyrene
XPS	Extruded Polystyrene
ASTM	American Society for Testing and Material
MEKP	Methyl ethyl ketone peroxide

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

A sandwich structure composite is a special class of composite materials that is fabricated by attaching two thin but stiff skins to lightweight but thick core. The core material is normally low strength material but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. As a result sandwich components achieve the same structural performance as conventional materials with less weight. Sandwich structures are used in many applications ranging from buildings to aerospace systems because of their high specific bending stiffness and strength and good acoustical insulation. Sandwich structure also ideal for large ship hulls because of their good shock resistance combined with reasonable affordability. This project is to study the effect of core sandwich structure under flexural test that is to determine the flexural behavior based on core material and to identify the span length of different core material. The other is to investigate performance analysis of sandwich structure in term of energy absorption using different core material.

1.2 PROBLEM STATEMENT

Sandwich composite is highly subject to damage and crack. This damage and defect is very difficult to detect in composite materials. For example in wind turbine, the damage can occur from events such as dropped tools during maintenance or debris impacting during periods of high winds. This will cause delaminations, core disbonds, and crack. The defect will reduce the stiffness of the structures and will damage the fatigue life of the component. Usually, the damage cannot see with naked eye. Besides that, defects can also arise during manufacture, particularly where pre-pregs are not used. This defect can take the form of resin dry spots, skin-core disbonds and such. While the cause and nature of defects are wide ranging the effect is similar. Composite sandwich structure such as wind turbines and wings are subjected to large flexural loadings. Consequently, the flexural behavior of these structures is critical to their use. To overcome this problem, testing methodology that can simulate the flexural loading is needed so that the suitability of composite sandwich constructions can evaluate to the application. In addition, the ability to determine the effect of defects on stiffness and fatigue performance will allow for better service life prediction.

1.3 PROJECT OBJECTIVE

1.3.1 To investigate the effects of core sandwich structure under flexural test.

1.3.2 To investigate the performance of sandwich structure from the energy absorption point of view.

1.4 SCOPE OF STUDY

1.4.1 Determination of flexural behavior based on different core material.

1.4.2 Identification the span length of different core material.

1.4.3 Performance analysis of energy absorption using different core material.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

International research effort continuously looking for new, better, and efficient construction materials. The main goal is to improve the structural efficiency, performance, and durability of civil engineering and transportation applications. In the past decades various sandwich panels have been utilized in the construction of aerospace, marine, architectural, and transportation industry [1]. Lightweight, excellent corrosion characteristics and rapid installation capabilities created tremendous opportunities for these sandwich panels in the industry [1]. This structure provides an efficient use of the materials and utilization to each component to its ultimate limit. The structures offers also very high stiffness-to-weight ratio [10]. It enhances the flexural rigidity of a structure without adding a substantial weight therefore it provides significant advantages in comparison to the use of the material alone for structural system [1]. Sandwich construction has superior fatigue strength and excellent acoustical and thermal insulation [9]. Sandwich structures also ideal for large ship hull because of their good shock resistance combine with reasonable affordability [9].

2.2 HISTORY

Historically, the principle of using two cooperating faces separated by a distance in between was introduced in 1820 by Delau [1]. The first extensive use of sandwich panel was during the World War II. In the “Mosquito” aircraft, sandwich structure was

used, mainly because of the shortage of other materials in England during the war [3]. The faces were made of veneer while the core consisted of balsa wood. One of the early uses of sandwich structure in an aeroplane application was in 1937 where balsa wood core and cedar plywood face sheets was used in the construction of De Havilland albatross airplane [1]. During World War II the first theoretical analysis of sandwich theory was published [1]. By the completion of World War II and in the late 1940's, some of the first theoretical works on sandwich constructions documented [1].

2.3 STRUCTURE IN SANDWICH PANELS

Generally, single layer sandwich structure consists of three main parts that is two face sheets and a core. With an additional sheet, called internal sheet, inserted into the core, a two-layer sandwich panel is then formed.

2.3.1 Faces/Skin

The faces adhesively bonded to the core to obtain a load transfer between the components. This way the properties of each separate component is utilized to the structural advantages of the whole assembly leading to a very high stiffness-to-weight and high bending strength-to-weight ratio. Typically, the facing layer realized by aluminum plates, high pressure laminates, and glass fiber reinforced plastics. Basically, the skins are thin, stiff, and very strong. Figure 1 below show the example of skin part in sandwich structures.

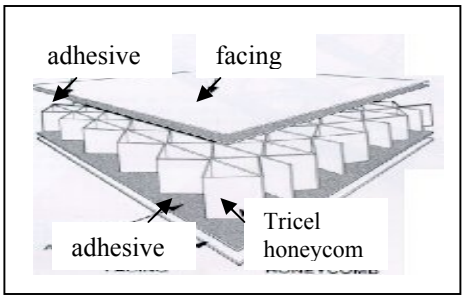

Figure 2.1 The skin of the sandwich panels [5]

2.3.2 Principle of Skin

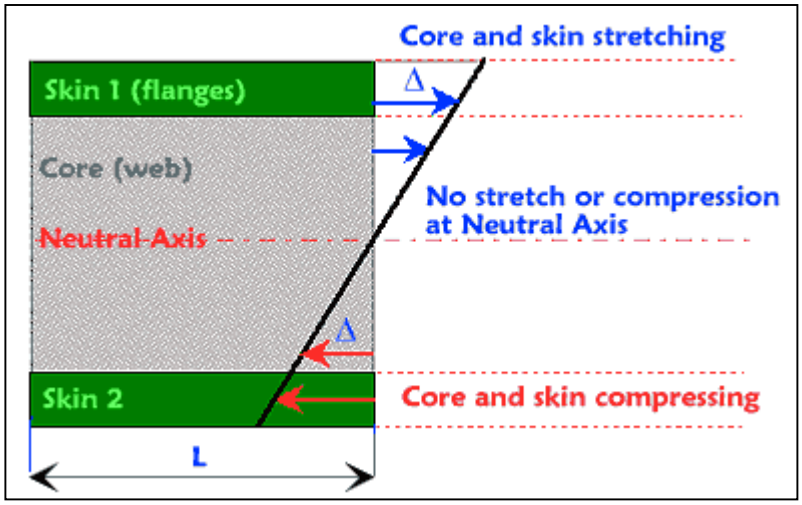

Figure 2.2 How the stress acts on the skin [4]

From the Figure 2.2, it shows how the stress acts on the skin of the sandwich structures when load is applied. If the panels bend, the core and the skin elongate and shrink linearly from the neutral axis. The thick black line represents the new section of the panel after bending. Because the skin are glue to the core, both of them will stretch the same amount where they bond together but physical properties are completely different and therefore will react differently to this elongation. Equation below will show the relation between stress and strain.

$$\varepsilon = \frac{\Delta}{L} \tag{2.1}$$

Strain = amount of stretch (in)/original length (in)

$$\sigma = E\varepsilon \tag{2.2}$$

Stress (psi) = Modulus of elasticity (psi) x strain

Logically, the force acting on the skin is larger than the core because of the large modulus of elasticity for the skin material. Equal strain at the boundary multiplied by larger modulus will produce larger stress in the skin.

2.3.3 Fiberglass

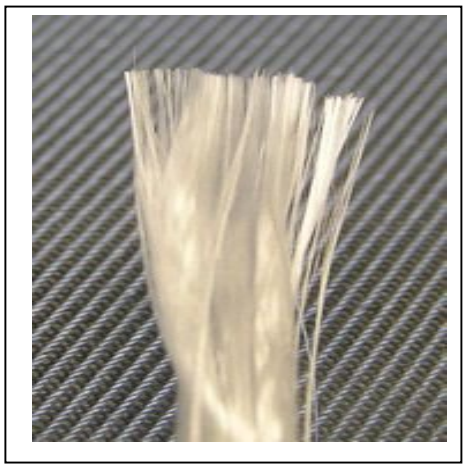

Figure 2.3 Fiberglass [6]

Fiberglass or also called glass fiber (Figure 2.3) is a material made from extremely fine fiber of glass. It is use as a reinforcing agent for many polymer products. The basis of textile grade glass fiber is silica, SiO_2 and in pure form it's exists as a polymer $(SiO_2)_n$. It has no true melting point but softens up to $2000\,^oC$ where it starts to degrade. Glass fibers are useful because of their high ratio of surface area to weight. The resulting composite material, properly known as fiber-reinforced polymer (FRP) or glass-reinforced plastic (GRP), is called "fiberglass" in popular usage in the industries.

Glassmakers throughout history have experimented with glass fibers, but mass manufacture of fiberglass was only made possible with the advent of finer machine-tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. What is commonly known as "fiberglass" today, however, was invented in 1938 by Russell

Games Slayter of Owens-Corning as a material to be used as insulation. It is marketed under the trade name Fiberglas, ® which has become a genericized trademark.

2.3.4 Properties of Fiberglass

Glass fibers are useful because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity of 0.05 W/m-K.

Glass strengths are usually tested and reported for "virgin" fibers: those which have just been manufactured. The freshest, thinnest fibers are the strongest because the thinner fibers are more ductile. The more the surface is scratched, the less the resulting tenacity [13]. Because glass has an amorphous structure, its properties are the same along the fiber and across the fiber [12]. Humidity is an important factor in the tensile strength. Moisture is easily adsorbed, and can worsen microscopic cracks and surface defects, and lessen tenacity.

In contrast to carbon fiber, glass can undergo more elongation before it breaks [12]. The viscosity of the molten glass is very important for manufacturing success. During drawing (pulling of the glass to reduce fiber circumference) the viscosity should be relatively low. If it is too high the fiber will break during drawing, however if it is too low the glass will form droplets rather than drawing out into fiber.

2.3.5 Core

The core is the structure that placed between two thin faces of the sandwich structure. The core material is normally low strength material but its higher thickness provides the sandwich composite with high bending stiffness with overall low density [7]. The function of the core is to support the thin skin so that they don’t deform and stay fixed relative to each other. The core of a sandwich structure can be almost any material

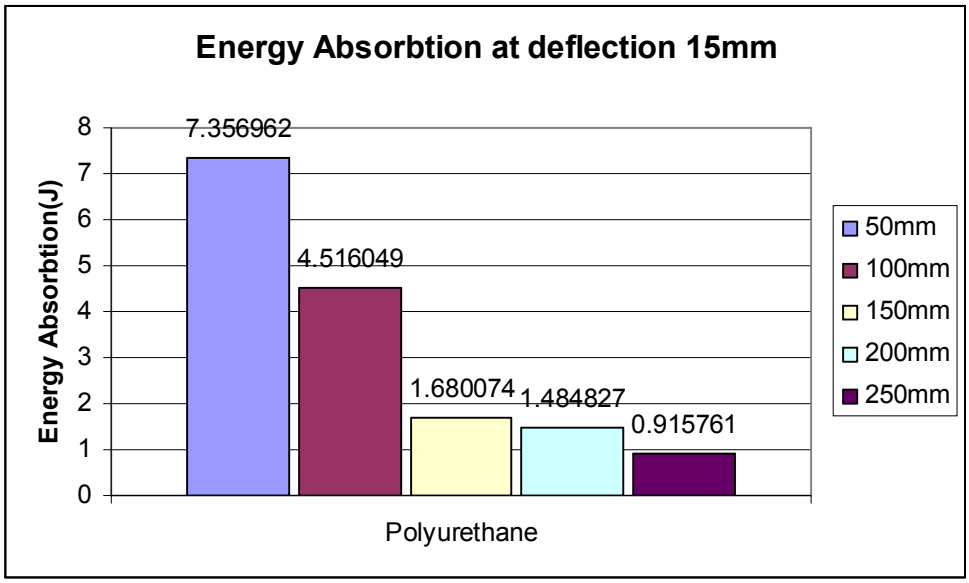

Figure 4.6 Energy absorption for polyurethane core at deflection 15mm

From Figure 4.6, the maximum energy values were obtained at 50mm span which is 7.356962J and then values were started to decreasing. The value of energy absorption decreased at 100mm span and this decrement continues at span 150mm, 200mm and 250mm. The lowest energy absorption occurred at 250mm span which is 0.915761J. The others specimens started from 100mm to 200mm span, the energy absorption are located in the range of 5.0J to 1.0J. The specific energy absorption for polyurethane core are summarize in Table 4.8.