# INDENTATION STUDY OF HONEYCOMB SANDWICH COMPOSITE MATERIALS

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To my beloved father, mother and my entire family member.

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# ABSTRACT

This study was conducted to quasi-static indentation study of composite sandwich panels made of glass/vinylester facesheets and polypropylene honeycomb core. Composite sandwich panel with different material types including chopped strand mat and plain woven glass/vinylester were analyzed numerically and experimentally. The effects of different parameters such as types of material, number of layers of facesheets and consequently the thickness of facesheets and the loading rate on indentation behavior were studied numerically and experimentally and the obtained results were compared together. The results of the research study showed that the maximum applied load on composite sandwich panel made of plain woven glass/vinylester and energy absorption properties is higher than chopped strand mat glass/vinylester. Also, the results of experimental tests showed that loading rate have big effect on load-deflection and energy absorption properties of composite sandwich panel and by increasing the loading rate, the maximum applied load and energy absorption properties of sandwich panel with honeycomb core is increased and there is direct relation between the loading rate and the indentation properties of sandwich panel. The results of finite element analysis and experimental tests were compared together and it has found that there is difference between the obtained results.

# ABSTRAK

Kajian ini melibatkan ujikaji kuasi statik lekukan bagi plat sandwich diperbuat dari gentian kaca/poliester kulit permukaan dan teras polipropina. Panel komposit sandwich yang di perbuat dari bahan yang berlainan terdiri dari jenis gentian kaca bersulam dan rawak dianalisa secara ujikaji dan kajian berangka. Kesan dari beberapa angkubah seperti jenis bahan, ketebalan, kulit permukaan dn kadar kelajuan beban bagi kelakuan lekukan di analisa secara ujikaji dan berangka dan keputusan yang di perolehi di buat perbandingan. Daripada keputusan yang diperolehi dari ujian, di dadapati beban maksimum dan tenaga serapan yang maksimum di perolehi dari permukaan kulit yang di perbuat dari gentian kaca jenis sulam. Dari keputusan ujikaji di dapati kadar kelajuan beban juga mempengaruhi kadar serapan tenaga, dimana apabila kadar kelajuan beban bertambah akan meningkatkan kadar serapan tenaga sebelum panel tersebut gagal. Keputusan yang diperolehi menunjukkan ada pertalian yang rapat diantara kadar kelajuan beban dan sifat bahan sandwich dari segi ujian lekukan. Keputusan dari ujikaji juga dibuat perbandingan dengan kaedah berangka.

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## LIST OF SYMBOLS

| | | |
|---|---|---|
| $t$ | - | The thickness of facesheets |
| $E$ | - | Energy absorption |
| $F$ | - | Load |
| $\delta$ | - | Deflection of sandwich panel |
| $E$ | - | Modulus elasticity |
| $v$ | - | Poison ratio |
| $G$ | - | Shear modulus |
| $\sigma$ | - | Stress |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Composite materials are composed of reinforcements such as fibres, particles, and flakes that surrounded in a matrix (resin) such as polyester, epoxy, and vinylester. The resin holds the fibres together to create products with any shape and transfer the applied load to the fibres and the fibres improve the physical and mechanical properties of the resin and most of the applied loads are taken by the fibres. Fibre reinforced polymer materials unlike common materials such as steel and aluminum are not isotropic materials and they are anisotropic. The mechanical properties of anisotropic materials are not same in any direction and the mechanical properties are different in different directions while the mechanical properties are same in any direction in isotropic materials. Therefore, fibre reinforced polymers are directional materials or in other words, the optimum mechanical properties are in direction of reinforcement. Therefore, the fibres are placed in the composite materials according to the applied load. Also, the type and direction of reinforcements are selected according to the application.

Fibre reinforced polymer materials have been used in a wide range of applications, the primary focus of which involves either mass reduction or resistance to corrosive environments. Consequently the aerospace, motor sport and boating industries have dominated FRP usage. These would indicate that FRPs possess

substantial potential for the production of structures which are not only low in mass, but are practical, cost competitive alternatives to more traditional materials.

A comparison of materials properties of common materials such as aluminum and steel and composite materials such as carbon/epoxy and E-glass/epoxy were listed in Table 1. It can be seen from Table 1.1 that the composite materials provide several advantages such as high stiffness to weight ratio over the common materials. Although the fibre reinforced polymer materials have several advantages, but the cost of this materials are the disadvantages of composite materials.

**Table 1.1:** A comparison of representative material properties

| Type of materials | Density ($kg/m^3$) | Tensile Strength (MPa) | Tensile Modulus (GPa) | Max. Elastic (%) | Specific Tensile Strength (Ult.) ($MPa/kg/m^3$) | Specific Tensile Modulus ($Mpa/kg/m^3$) |
|---|---|---|---|---|---|---|
| **Carbon/Epoxy** | 1750 | 1000(UTS) | 100 | 1.0 | 0.57 | 57 |
| **E-glass/Epoxy** | 2540 | 700 (UTS) | 40 | 1.75 | 0.28 | 16 |
| **Steel** | 7850 | 350 (Yield)<br>480 (UTS) | 200 | 0.18 | 0.06 | 25 |
| **Aluminium** | 2800 | 110 (Yield)<br>151 (UTS) | 69 | 016 | 0.05 | 25 |

Composite sandwich materials are special types of composite materials that are manufactured by bonding two skins (Facesheet) to a core (Figure 1.1). The facesheets are very thin and stiffness of them is very high and the core materials usually are light and thick in comparison with the facesheets. Any type of materials such as aluminum, steel, carbon/epoxy and glass/vinylester can be used as facesheets the materials such as aluminum honeycomb, Polypropylene honeycomb, foam core can be used as core materials in sandwich panels and this materials usually have low strength and low weight materials, but higher thickness of these materials provide the sandwich composite materials with high bending stiffness with low weight.

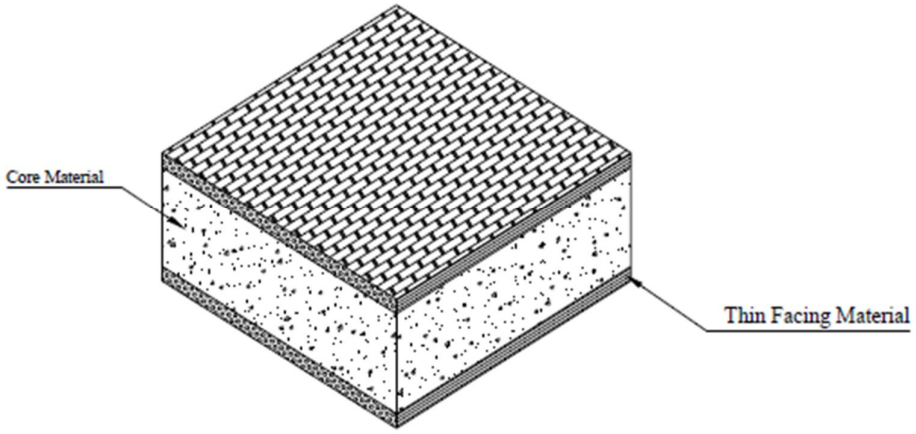


**Figure 1.1** The schematic of composite sandwich panel.

The structures that naturally have the geometry of honeycomb shape are known as honeycomb structures. The minimum amount of materials is used in honeycomb materials. Therefore, the cost of raw materials in honeycomb materials is very low but the manufacturing process has a high effect on the cost of these materials. Different types of materials such as paper, aluminum, steel, composite materials and plastic can be used in fabrication of honeycomb materials. Aluminum honeycomb, polypropylene honeycomb and paper honeycomb are three examples of honeycomb materials (Figure 1.2).

(a) Aluminum honeycomb (b) paper honeycomb (c) polypropylene honeycomb

**Figure 1.2** Three types of honeycomb core materials.

Polypropylene honeycomb material is one of the widely used honeycomb materials that are used in composite sandwich panel. This material is made of polypropylene materials. In this material, the ratio of strength to weight is high and the resistance to chemical and corrosion and energy absorption property is very high and thermoforming ability and recyclable is two other advantages of this material.

## 1.2 Introduction

This study deals with experimental and numerical investigations of composite sandwich panel with polypropylene honeycomb core and different number of layers of chopped strand mat and woven glass/vinylester including two, three and four layers under quasi static indentation loading. Experimental tests were conducted on composite sandwich panel subject to indentation loading with different loading rate including 4mm/min, 6mm/min and 8mm/min by using Instron universal testing machine. All of the specimens for experimental testing were fabricated by using vacuum bagging process. For different types of sandwich panels with polypropylene honeycomb core, the contact force-displacement curves and energy absorption-displacement curves of composite sandwich panel were determined and analyzed and the obtained results were compared together.

Also, the numerical investigation of composite sandwich panels was studied by using ANSYS Workbench Software. In this section, static analysis of composite sandwich panels with polypropylene honeycomb core subject to indentation loading were modeled and studied and the deformation behaviour and stress behaviour of sandwich panels were determined and compared with the results of experimental tests.

## 1.3 Scope of study

The scopes of this research are listed below:

- Literature study on composite material and composite sandwich material subject to different types of loading including indentation loading.

- Preparation of different forms of composite sandwich materials with polypropylene honeycomb core and different number of layers of chopped strand mat and woven glass/vinylester facesheets by using vacuum bagging process.

- Perform experimental quasi-static indentation tests on composite sandwich panel and data collecting.

- Calculating the contact force-displacement curves and energy absorption-displacement curves of composite sandwich panel at different loading rate.

- Finding the effect of different parameters such as the number of layers and type of facesheets and the loading rate on indentation properties of composite sandwich panel.

- Finite element analysis of composite sandwich panel with polypropylene honeycomb core subject to indentation loading.

- Comparing the results of finite element analysis with the experimental and validate.

- Defining the stress and deformation behaviour of composite sandwich panel subject to indentation loading numerically.

## 1.4 Statement of problems

Composite sandwich panels are made of two facesheets and core material. The type of facesheets and core material and the geometry of sandwich panel are

most important factors in designing of sandwich panel. Therefore, understanding the effect of these parameters such as the thickness of facesheets and type of materials of facesheets on mechanical behaviour of these structures is important in design and analyze of these structures. Therefore, In this research, the effect of different parameters such as the type of materials including chopped strand mat and woven glass/vinylester and the loading rate on mechanical properties of sandwich panel with polypropylene honeycomb core especially indentation properties were studied experimentally and numerically and the force-displacement curve and energy absorption-displacement curve were determined.

## 1.5 Layout of thesis

This thesis is consist of six chapters; Introduction, Literature review, finite element analysis, Experimental procedure, Results and discussion and Conclusions and recommendation. Chapter 1 defines composite materials and composite sandwich panels, introduction, state of problems, objective and scope of the study. In Chapter 2, history of composite materials and literature reviews on the subject of composite sandwich panel and different types of loading on these types of materials. In Chapter 3, finite element analysis of composite sandwich panels subject to indentation loading was presented. In Chapter 4 the experimental procedure of composite sandwich panels with polypropylene honeycomb core was defined. In Chapter 5, the results of experimental tests and finite element analysis were described and the effects of different parameter on indentation properties of composite sandwich panel were studied and the experimental results and numerical results were compared together. In Chapter 6, Conclusions were drawn from the experimental and numerical results and then recommendation was presented.

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