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EXPERIMENTAL ANALYSIS ON CORRUGATED GLASS/ EPOXY PLATE IMPOSED TO COMPRESSIVE LOAD

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This project report attached here to, entitled **"Experimental Analysis on Corrugated Glass/Epoxy Plate Imposed to Compressive Load"** prepared and submitted by **Nora bt Osman** as a partial fulfilment of the requirement for the degree in Bachelor of Engineering with Honours in Mechanical Engineering and Manufacturing System is hereby read and approved by:

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Finally, I hope that this project will provide guidance to science and engineering students, educator, and all researchers who are working in this field. Also, I hope that my thesis will be significant value to all readers. Thank you.

ABSTRACTS

Throughout this project, compression test has been carried out on corrugated glass/epoxy composite plates. The plates/specimens were fabricated using hand lay-up method, where three layers of glass fibre were impregnated with mixer of epoxy resin and hardener. Glass epoxy with included angles of 0°, 120°, 150°, and 180° have been used as the specimens throughout this study. Compression test was carried out to identify the effect of compression loading on transverse surface area of the corrugated (sine web) glass/epoxy composite plates. From the test result, the initial and mean loads were obtained from compression load-displacement data. Then, the effects of each included angle and their specific energy absorption has been drawn for all the tested specimens.

ABSTRAK

Melalui projek ini, ujian kemampatan telah dijalankan terhadap kepingan bahan komposit *glass/epoxy* yang beralun. Kepingan/spesimen tersebut telah dibuat melaui kaedah yang dinamakan kaedah *hand lay-up*, dimana tiga lapisan kaca gentian dilekatkan antara satu sama lain menggunakan campuran bahan pengeras dan resin *epoxy*. *Glass Epoxy* dengan sudut beralun 0°, 120°, 150°, dan 180° yang telah dihasilkan, akan digunakan sebagai bahan spesimen sepanjang ujikaji ini dijalankan. Ujian kemampatan ini dijalankan untuk mengkaji kesan beban mampatan terhadap luas permukaan melintang kepingan *glass/epoxy* yang beralun. Melalui keputusan eksperimen, beban permulaan dan beban purata akan diperolehi melalui data beban mampatan-perubahan panjang spesimen. Kemudian, kesan sudut dan haba serapan tertentu bagi setiap spesimen juga akan ditentukan.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Among the major development in materials in recent years, are *composite materials*. In fact, composites are now one of the most important classes of the engineered materials, because they offer several outstanding properties compared to conventional materials. A *composite material* is the combinations of two or more chemically distinct and insoluble phases; its properties and structural performances are superior to those of the constituent acting independently (Kalpakjian S. *et al*, 2001).

A *composite material* in the traditional sense is defined as materials system that composed of two or more physically different phases whose combination procedure desirable overall properties that are different from those of its constituents. Present days researchers have pushed the envelope on this kind of thinking and beyond its traditional definition by creating new made 'engineered composites' and 'smart materials'. Our need for such materials is continuously growing and they will play a major role in many areas of our lives. For example, smart coatings, nano particulate materials for high temperature applications, electronic-ceramic structure, piezo-ceramics in structure, fibre optics smart materials, etc., are the way of the future. A clear understanding of these engineered composites requires an interdisciplinary thought process grounded in sound fundamental knowledge of traditional composite materials [Sankar J., 1999].

The concept of this fibrous reinforcement is very old. There are biblical references to straw-reinforced clay brick in the ancient Egypt (Daniel I. M. *et al*, 1994). The oldest example of this composite is the addition of straw to clay in the making of mud huts and of bricks for structural use. This combination dates back to 4000 B.C. In that application, the straws are the reinforcing fibres, and the clay is the matrix (Kalpakjian S. *et al*, 2001).

Another example of a composite material is the reinforcement of *masonry* and concrete with iron, which was begun in the 1800s. In fact, concrete itself is a composite material consisting of cement, sand and gravel. In reinforced concrete, steel rods impart the necessary tensile strength to the composite; concrete by itself is brittle, and it generally has little or no useful tensile strength (Kalpakjian S. *et al*, 2001).

Composite materials are gaining increased recognition as materials suitable for both structural and non-structural components. The applications of polymer composites have increased for a number of reasons. These include reduced cost due to part consolidation and lower tooling investment, reduced weight due to high strength and stiffness to density ratio, and increased design freedom compared with metals. Glass fibre reinforced polymer composites are currently used in a number of automotive structural components and marine/boat building components [Abidin M. H., 2003].

Composite structure has a wide range of applications. The applications have mainly been driven by the fact that composites materials can be tailored made per specification for an optimum design. This means that the properties can be easily modified to suit the design. Since composite properties are directional, the design of composite should be done carefully since this would greatly affects the mechanical properties of composite (Daniel I. M. *et al*, 1994).

In aircraft and automotive structure, to manufacturing cost constraints and stringent, weight is the main concern and therefore composite material are being proposed for many applications. In aerospace, automobile and marine structures, composites are applied because of their high stiffness and strength with respect to their weight. In addition, composite material has high corrosion resistance, thermal expansion, and high thermal resistively (Daniel I. M. *et al*, 1994).

1.1 Energy Absorption of Composite.

Numerous studies have shown that composite materials can be efficient energy absorbing materials. Composite material could stand for high loads and then provide a significant increase the energy absorption compared to similar metal structures (Callister, W.D., 1999).

The energy absorption capability of composite structure depends upon the mechanism by which the structure collapses. Various composite structural elements have been experimentally studied by several researchers for its energy absorption characteristics. Result obtained from these studied have indicated that the energy absorbed depends on such design parameters such as the material system, lay-up and cross section geometry (Daniel I. M. *et al*, 1994).

1.2 Corrugated Plate

According to Clyne T.W. (1996), when two layers of different material are joined, this result in unbalanced moment, M, because of different Poisson ratio of different type of materials that contain in that composite material. Thus, balancing this moment requires the generation of curvature or corrugated shape of the composite plate.

Composites afford the unique possibility of designing the material and structure in concurrent process. The large number of degrees of freedom available enables material optimization for several constraints simultaneously, such as minimum weight and maximum dynamic stability. In the case of the conventional materials, optimization is limited due to the few degrees of freedom available, usually one or two geometric parameters (Callister W.D., 1999).

Application such as aircraft control surface, underground and underwater vessels, thin skin in compression, and sport products such as bicycles and tennis rackets require small deflections under working loads, high buckling loads, and low weight. Thus, the main concern in designing process for this case is high specific stiffness [Courtney, 2000].

1.3 Scope and Objectives of the Project

The objectives of studying and implementing this project are;

I. To investigate and digest the effect of the included angle of the fabricated corrugated plate when imposed to compressive loading.

II. To analyze the mechanical properties of the glass/epoxy when subjected to axial load.

III. To study and compare the rate of energy absorbed by the various degree of sine web corrugated glass/epoxy plates when imposed to compressive load.

In order to obtain the objectives, the moulds with different composite corrugated angles are designed and fabricated. This process is being done by hand made process. Initially, the composite is fabricated by a process that called *hand lay up* technique. It was adopted where glass fibre were impregnated with epoxy resin. Then, compression test was done on the corrugated specimens. Finally, based on experimental results, evaluations and analytical studies were done.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In the last two decades, the technology of composite materials has experienced a rapid development due to the unusual combinations of properties required for the modern technologies. In aerospace and transportation application,low density, strong, stiff, abrasion and impact resistant and not easily corroded materials are needed (Callister, W. D., 1999).

Composites have found a widely used in practically all engineering disciplines (Harris B. 1986). In aerospace, composites are used for helicopter rotor blades, rocket nozzles and re-entry shields. In automotive engineering, the applications range from doors to body moulding. In chemical engineering, composites are used for containers, pipe work, pressure vessels and others. In civil engineering, composites have found important used as glass reinforced plastics and form work of concrete. In electrical engineering, the application range from the high strength insulators to printed circuit boards. Bioengineering uses carbon fibre composites as prosthetics devices, and other composites have been used to manufacture heart valve (Ertas A. *et al*, 1996).

When two or more materials are combined and retain their identities by without dissolving or merging completely into each other, the result is a composite material. Such material has a different composition and has properties different from any of the individual materials that were made. The substance combined to form a composite is called constituents. Since the constituent retain their individual identities, the properties of the composites are influenced by the properties of the constituents. Thus, a composite may have the strength of one constituent, the density of another, and the thermal properties of a third. Any numbers of property combinations are therefore possible (Linbeck J. R., 1995).

Opposed to one that occurs or forms naturally, composites, is a multiphase material that is artificially made. The constituent phases must be dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as consequences of natural phenomena (Callister W. D., 1999).

Therefore, scientist and engineers have ingeniously combined various metals, ceramics and polymer to produce a new generation of extraordinary materials. Most composites have been created to improve the combination of material characteristics such as stiffness, toughness, and ambient and high-temperature strength (Callister W.D., 1999).

2.1 Composites Material

A *structural composite* is a material system consisting of two or more phases on a microscopic scale, whose mechanical performance and properties are designed to be superior to those of the constituent material acting independently. One of the phases is usually discontinuously, stiffer, and stronger and called *reinforcement* (Daniel I. M. *et al*, 1994).

The reinforcement material usually stiffer and stronger than the matrix material. It may be in the form of particles, short fibres (whisker), or continuous fibres. The matrix is generally a weaker phases, lower density, stiffness and strength than the fibres or whiskers. The purpose of the matrix is manifold, namely for support, protect and stress transfer. The combination of fibres and matrix can be very high strength and stiffness yet still have low density (Daniel I. M. *et al*, 1994).

The properties of composite material depend on the properties of the constituent, geometry, and distribution of the phases. One of the important parameters is the volume (or weight) fraction of the reinforcement, or fibre volume ratio. The distribution of the reinforcement determines the homogeneity or uniformity of the material system. The more no uniform is the reinforcement distribution, the more heterogeneous is the material and the higher is the probability of failure in the weakest area. The geometry and orientation of the reinforcement affect the anisotropy of the system (Daniel I. M. *et al*, 1994).

The phases of the composite system have different roles depend on the type and application of the composite material. In the case of low to medium performance composite material, the reinforcement, usually in the form of short fibres and particles, provides some stiffening but only a few local strengthening of the material. The matrix, on the other hand, is the main-load bearing constituent governing the mechanical properties of the material (Daniel I. M. *et al*, 1994).

In the case of high performance structural composites, the usually continuous-fibre reinforcement is the backbone of the material that determines its stiffness and strength in the direction of the fibres (Daniel I. M. *et al*, 1994). Fibre-reinforced composite materials consist of fibres of high strength and modulus embedded in or bonded to a matrix with matrix interfaces (boundary) between them (Callister, W.D., 1999). In this form, both fibres and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone (Lindbeck J.R, 1995).

In general, fibres are principle load-carrying members, while the surrounding matrix keeps them in the desired location and orientation, act as a load transfer medium between them, and protect them from environmental damages. The inter phases, although small in size, can play an important role in controlling in the failure mechanisms, fracture toughness and overall stress-strain behaviour of the material (Daniel I.M *et al*, 1994).

Two phases of composite materials are classified into three broad categories depending on type, geometry and orientation of the reinforcement phase as illustrated in the chart of Figure 1.0. It is consisting of particulate filler, discontinuous fibres or whiskers and continuous fibres (Daniel I.M *et al*, 1994).

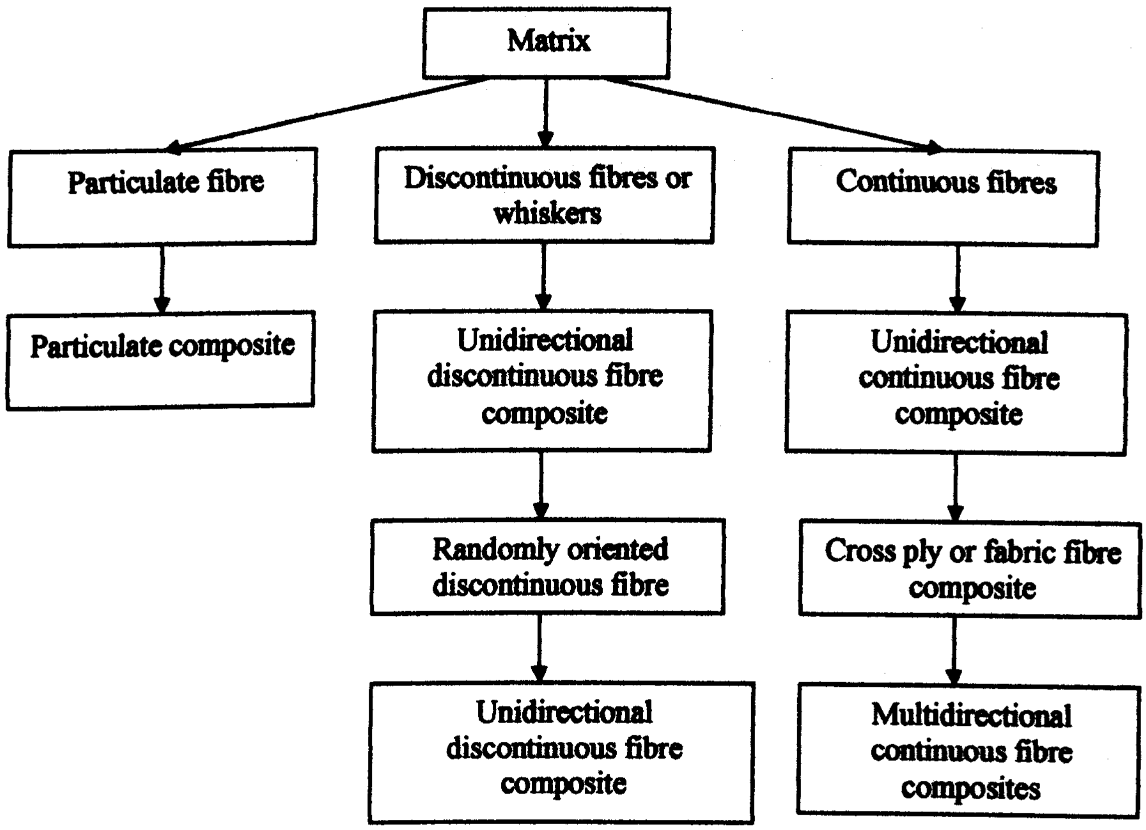

Figure 2.0 Classification of composite material

Particulate composite consists of particles of various sizes and shapes randomly dispersed in the matrix. Due to the randomness of particle distribution, these composites can be regarded as a quasi-isotropic. Particulate composites may consist of non-metallic particles in a non metallic matrix (concrete, glass reinforced with mica flakes, brittle polymers reinforced with rubber-like particles); metallic particles in non-metallic matrices, metallic particles in metallic in metallic matrices, and non-metallic particles in metallic matrices (Daniel I.M *et al*, 1994).

Discontinuous or short fibre composites contain short fibres or whiskers as the reinforcement. These short fibres, which can be fairly long compared to the diameter, can be either all oriented along one direction or randomly oriented. In the first instance, the composite material tends to be markedly anisotropic or, more specifically, orthotropic, whereas in the second it can be regarded as quasi-isotropic (Daniel I.M *et al*, 1994).

2.1.1 Glass Fibres

Fibres are assumed to be elastic spheroids that are embedded in a ductile polymer matrix. Furthermore, the ductile matrix behaves elastoplastically under arbitrary 3D loading/unloading histories. All fibres are assumed to be non-interacting for dilute composite medium and initially embedded firmly in the matrix with perfect interfaces. After the interfacial debonding between fibres and the matrix, these partially debonded fibres are regarded as equivalent, transversely isotropic inclusions [Lee H. K., 2000]

Glass can be made in the form of fibres which can be used to strengthen materials, make strong materials, or provide insulating properties. The material thus constructed is known as fibre-glass. *Glass fibre* can also be used to communicate using light due to the internal reflection of a beam of light passing lengthways along the fibre. Such fibres can be many kilometres in length (Khazanov V.E *et al.*, 1995).