UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND ANALYSIS OF SANDWICH BEAM MAKE BY COMBINATION OF KENAF CORE AND BAST

Thesis submitted in accordance with the requirements of the
University Technical Malaysia Melaka (UTeM) for the Degree of
Bachelor of Engineering (Honours) Manufacturing (Material Engineering)

By

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (*Material Engineering*). The members of the supervisory committee are as follow:

Mohamad Haidir Bin Maslan
(Main Supervisor)

ABSTRACT

The purpose of doing this research is to study the properties of kenaf stem to make kenaf sandwich beam with a suitable thickness based on the simulation of actual kenaf stem. Also study and finds the best parameter for the composite structure. This sandwich beam laminates consist of the bast and core fiber of kenaf stem and the polyester composite thermoset. The kenaf fiber is supplied by Forest Research Intitutes Malaysia (FRIM), Kepong, Kuala Lumpur and separated by using Vibratory Screen Machine in FRIM Bioresource Composite Laboratory. The composite panel is fabricated by cold press techniques. For the mechanical testing, the standard of the testing is referred to ASTM D5083 for tensile testing and ASTM C393-00 for flexural testing. This sandwich beam will be made with laminates of different size of bast and core. The fiber is dried in the oven for half an hour at temperature 80 °C. The preparation for open mould is done by using mild steel to fabricate the specimen. The techniques of compression molding is used to fabricate the kenaf fiber reinforce polyester composite specimens. The composite is compressed at 10 Bar pressure at room temperature and left it cured in 24 hours. The removal composite panel is then left at room temperature for 2 weeks to ensure the composite is well dried before cutting process into desired size based on ASTM standard and deciding size. The same procedure is done for fabricating sandwich beam. From the previous research, the homogenous composite panel from the weight of fiber is 20%. Based on the results of the mechanical testing for single material, the sandwich beam was fabricated from the calculation and analysis before. The optimum and suitable thickness from calculation is done for sandwich beam. The two specimen for sandwich beam was fabricated which are the specimen from the calculation and the other one is from the random thickness. Based on mechanical testing between specimen from calculation and random, it shows that the specimen from calculation can support higher load compared to specimen from random thickness.

ABSTRAK

Penyelidikan ini adalah bertujuan untuk mengkaji sifat-sifat batang pokok kenaf bagi menyediakan rasuk terapit yang mempunyai ketebalan yang sesuai dengan berdasarkan simulasi sebenar batang pokok kenaf tersebut. Parameter yang terbaik untuk rasuk terapit ini juga dikaji. Rasuk terapit ini dilapisi dengan bahagian empulur dan juga kulit kenaf dan diperkuatkan dengan komposit termoset poliester. Gentian kenaf dibekalkan oleh Institut Penyelidikan Perhutanan Malaysia (FRIM), Kepong, Kuala Lumpur dan ia telah siap dipisahkan dengan menggunakan '*Vibratory Screen Machine*' di Makmal Komposit Kayu, FRIM. Bahan komposit ini telah disediakan menggunakan kaedah tekan sejuk. Bagi ujian mekanikal, piawaian yang dirujuk adalah ASTM D5083 bagi ujian tegangan dan ASTM C393-00 bagi ujian kelenturan. Rasuk terapit ini akan dibuat dengan lapisan di antara kulit dan empulur batang kenaf yang telah diproses dengan saiz yang berbeza. Gentian telah dikeringkan di dalam oven selama satu setengah jam pada suhu 80 °C. Pengacuan terbuka telah dibuat daripada kepingan besi keluli lembut bagi menghasilkan spesimen. Komposit dimampatkan pada tekanan 10 Bar pada suhu bilik dan dibiarkan mengeras selama 24 jam. Setelah dikeluarkan daripada acuan, panel komposit dibiarkan pada suhu bilik selama 2 minggu bagi memastikan komposit kering sepenuhnya sebelum dipotong mengikut dimensi ukuran piawaian ASTM. Prosedur yang sama telah dijalankan bagi menghasilkan komposit gentian daripada kulit dan empulur kenaf diperkuat dengan poliester. Dua rasuk terapit telah dihasilkan iaitu daripada pengiraan dan satu lagi daripada ketebalan secara rawak. Mengikut kajian yang sebelum ini, komposit yang homogen ialah 20% berat pengisi gentian. Nilai ketebalan yang sesuai dan paling optimum melalui perkiraan telah digunakan untuk menghasilkan rasuk terapit. Berdasarkan keputusan daripada ujian mekanikal yang telah dibuat , didapati bahawa tahap bebanan yang boleh diterima adalah berbeza. bergantung kepada ketebalan. Rasuk terapit yang disediakan dengan ketebalan melalui pengiraan dapat menahan beban dan juga daya dengan nilai kekuatan yang lebih tinggi berbanding alur terapit yang ketebalannya adalah secara rawak.

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LIST OF ABBREVIATIONS, SYMBOLS, NOMENCLATURES

SYMBOL -	EXPLANATION
b	Width of specimen
d	distance
E	Modulus of elasticity
F	force
in	inche
F_s	Shear stress
%	Percent
f.s	Safety factor
h	Thickness
mm	Milimeter
I	Moment of inertia
L	Length
M	Bending Moment
m	Mass
UP	Unsaturated Polyester
ASTM	American Standard Testing Material
KFRUPE	Kenaf Fiber Reinforced Unsaturated Polyester
FRIM	Forest Research Institute of Malaysia
MEKP	Methyl Ethyl Ketone Peroxide
PMCs	Polymer–Matrix Composites
MMC	Metal Matrix Composites (MMC)
CMC	Ceramic Matrix Composites (CMC)
PMC	Polymer Matrix Composites (PMC
FRP	Fiber Reinforced Polymers (FRP)

CHAPTER 1

INTRODUCTION

1.1 Background

Many fibers are produced and the natural fiber is commercialized. In past few years, the demand that use of natural fiber as reinforcement is increased. The increasing is because of the economy factor and the environments to change the fiber synthetic as reinforcement. The advantages of natural fiber are because of the low cost, easy to find, lightweight and high strength to weight ratio. Besides, the uses of natural fiber in manufacturing industry are increasing. This is because of the insufficient sources and also followed by increasing of the construction materials based on the mineral sources such as aluminum, steel and also the forest trees.

Sandwich beams with composite face-sheets and a lightweight foam core are commonly used in lightweight structures. The applications of sandwich beams are pulp and paper industry, particleboards, automotive industry, packaging, textiles and much more. In these initial applications, the sandwich beams were fabricated from a wide variety of materials that included titanium alloy, carbon, glass and Kevlar. Today sandwich beam can be fabricated from most types of materials such as papers, plastics, metals and ceramics. However as the technology behind the production of sandwich beam improves the ability to innovate new honeycomb materials become more difficult.

1.2 Problem statement

In the world of composite manufacturing the manufacturer always find the best materials for sandwich beam that have the outstanding properties. This study will use two types of materials kenaf as a reinforcement and polyester as a matrix for making sandwich beam which followed by mechanical testing in order to investigate the suitable thickness base on actual kenaf stem, layers and the compabality of the kenaf and polyester skin.

1.3 Objectives of the research

a) To investigate the mechanical properties of the sandwich beam from the combination of polyester and kenaf stem for possible use in composite structure.
b) To investigate the suitable thickness of sandwich beam based on the simulation of kenaf stem.
c) To find the best parameter for this composite structure.

1.4 Scope of the thesis

This thesis will require student to do a study on the sandwich beam by combination of kenaf and polyester. Kenaf stem is processed and separate it in bast and core. Thus, before understanding the material selection, we need to explore the possible usage and applications of this sandwich. A few models of sandwich beam will be made based on the simulation of natural kenaf tree. Besides, the thickness and layers of the sandwich beam using each material will be studied. There will be a few tests performed to find out the tensile strength, compression and bending of each of the sandwich beam.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The basic principle of a sandwich was discovered in 1820 by a French inventor named Duleau. The sandwich laminate is an extremely efficient structural design. The structural of sandwiches are a special form of laminated composite in which thin, strong, stiff, hard and there also combined with thick, relatively soft, light and weaker cores to provide a lightweight composite stronger and stiffer in most respects. Basically, a sandwich construction are includes the two laminates which is outer and inner. The core material is made as a spacer and adhesive for bonding of laminates. Besides, common materials for the laminates are composite, metal or wood. The core can be made of paper, honeycombs made of impregnated aramid-paper or thermoplastics and all kind of foams. Even though the using of sandwich laminates for many companies and for variety of products are popular but it is still hard to find the reliable design information. The example of sandwich laminate is as shown in Figure 2.1.

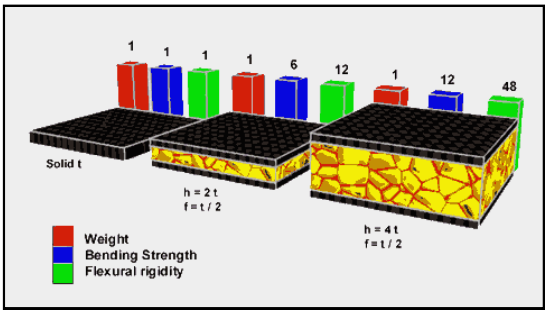

Figure 2.1: Figure of results of sandwich laminate

2.2 Composite

Composites are combinations of two materials in which one of the materials, called the reinforcing phase and another one is matrix. The reinforcing phase is in the form of fibers, sheets or particles. The matrix is the monolithic material into which the reinforcement is embedded and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. The strength of the resin or fiber composite depends primarily on the amount, arrangement and type of fiber reinforcement in the resin. Typically, the higher the reinforcement content provides the greater the strength.

The combination of two or more material with the different phases is to attain more stable element and properties. It is because the properties of each component can contribute in combination. (*Richardson,1987*). There are three main situations that mean of the materials are composite:

a) Consists of two or more material which is the physically are different and can be separate it mechanically.
b) The properties of composite produced are excellent and extremely good in certain case compared to individual component.
c) By spreading method, composite can be made by combining the material to attain the optimum properties.

The reinforcement contributes to support the load under testing such as flexural, tensile, impact and so on while the matrix material give the composite make stiffness. The application of load to the composite will cause the force to move from fiber reinforcement to fiber reinforcement through the matrix. Normally, the stiffness of matrix is followed by brittleness. However, the combination of fiber reinforcement and matrix can made more strong material. (Rozman et al.,1998a; Rozman *et al*.,1998b; Abdul Khalil *et al*.,2001 dan Abdul khalil *et al*.,2002a)

2.2.1 Matrix

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. The common matrix used for fiber reinforced plastic or thermoset composite process such as Epoxy, Unsaturated Polyester (UP), Vinylester, Urea Formaldehyde, Urethanes, Melamine, Phenolics, etc.The most common man-made composites can be divided into three main groups:

a) **Polymer Matrix Composites (PMC) or Fiber Reinforced Polymers (FRP)**

   PMC or FRP are the most commonly used composites. These materials use a polymer-based resin as the matrix, and a variety of fibers such as glass, carbon and aramid as the reinforcement. Natural polymer, thermoplastic polymer and thermosets polymer are in family of Polymer Matrix Composites.

b) Metal Matrix Composites (MMC)

   MMC composites are increasingly found in the automotive industry. They use a metal such as aluminium as the matrix, and reinforce it with fibers such as silicon carbide.

c) Ceramic Matrix Composites (CMC)

   CMC composites are used in very high temperature environments. They use a ceramic as the matrix, reinforced with short fibers, or whiskers such as those made from silicon carbide and boron nitride.

2.2.2 Reinforcement

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous or discontinuous. Discontinuous MMCs can be isotropic and can be worked with standard metalworking techniques such as extrusion, forging or rolling.

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses whiskers, short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide. The advantages of natural fibers are:-

a) Low specific weight which results in a higher specific strength and stiffness than glass. This is a benefit especially in parts designed for bending stiffness.
b) It is a renewable resource, the production requires little energy, CO_2 is used while oxygen is given back to the environment.
c) Producible with low investment at low cost which makes the material an interesting product for low-wage countries.
d) Friendly processing, no wear of tooling, no skin irritation
e) Thermal recycling is possible where glass causes problems in combustion furnaces.
f) Also good thermal and acoustic insulating properties.

The disadvantages of natural fibers are

1) Lower strength properties particularly its impact strength
2) Variable quality depending on unpredictable influences such as weather
3) Moisture absorption which causes swelling of the fibers
4) Restricted maximum processing temperature.
5) Lower durability and fiber treatments can improve this considerably
6) Poor fire resistance
7) Price can fluctuate by harvest results or agricultural politics.

2.2.3 Characteristics of Composite

Composites are anisotropic materials which their strength is different in different direction. Their stress-strain curves are linearly elastic to the point of failure by rupture. The polymeric resin in a composite material, which consists of viscous fluid and elastic solids, responds viscoelastically to applied loads. Although the viscoelastic material will creep and relax under a sustained load, it can be designed to perform satisfactorily. It is also highly desirable qualities which are high resistance to elevated temperature, abrasion, corrosion, and chemical attack.

2.2.3.1 Properties of Composites

The basic principle behind fiber-reinforced polymers is to combine fibers that bear mechanical loads with polymer matrices that distribute these loads over the fibers. The matrix also protects the fibers. Because composites are a mixture of resin and reinforcing fibers, the properties of the end product are a combination of the properties of the resin on its own and the fibers on their own. Generally, composites have many excellent structural qualities include high strength, material toughness, fatigue endurance and light weight.

The primary advantage of a sandwich composite is very high stiffness-to-weight and high bending strength-to-weight ratio. The sandwich enhances the flexural rigidity of the structure without adding substantial weight. The other advantages of composite structural are includes ease of manufacturing, fabrication, handling and erection. Sandwich structures have in several applications to have fatigue strength, acoustical insulation and additional thermal insulation. The absorption of mechanical energy can in some deformation modes is multiplied compared with monocoque structures due to an imposed shorter mode of buckling waves. The use of cellular cores obviates the need to provide additional thermal insulation, ensuring low structural weight, since most cellular cores have a low thermal conductivity.

2.2.3.2 Loading Conditions

Composites by made up of resin and reinforcing fibers can tests with kinds of loads during their lifetime. There are four main direct loads that any material in a structure has to withstand which are tension, compression, shear and flexure**.**

2.2.3.3 Tensile

Tension or tensile test is the mechanical test for material performs. The tests are simple, relatively inexpensive and fully standardized. The response of a composite in tension is mainly dependent of the tensile stiffness and strength properties of the reinforcement fibers. As fibers have their highest mechanical properties along their lengths, the orientation of the fibers influences the response to tension to great extend. Good complete tensile properties will determine by reaction of the pulling materials during testing and it may show the strength by the elongation. A curve will result showing how it reacted to the forces being applied. The point of failure is of much interest and is typically called its Ultimate Strength or UTS on the chart as shown in Figure 2.2.

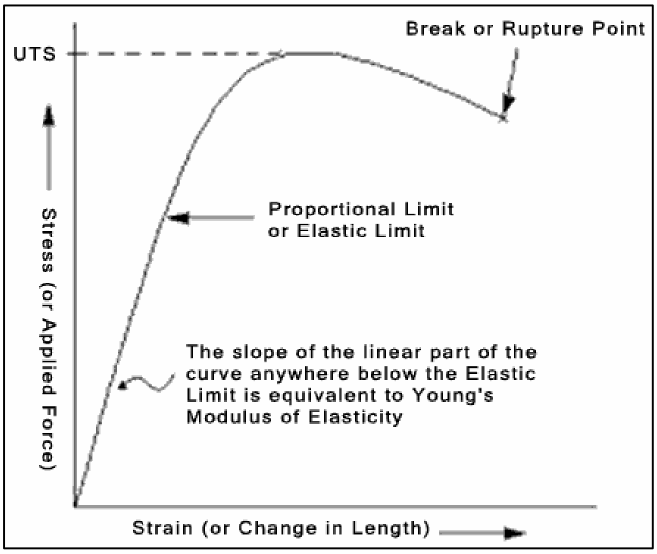

Figure 2.2: Graph of stress vs strain (Ultimate Strength)

This test method covers the determination of the tensile properties of thermosetting reinforced plastic using test specimens of uniform nominal width when tested under defined conditions of pretreatment, temperature, humidity and testing machine speed. This test method can be used for testing materials of any thickness up to 14mm (0.55 in). (ASTM D5083-96, Standard Test Method for Tensile Properties of Reinforced thermosetting Plastics Using Straight-Sided Specimens)In Hooke's Law, for most tensile testing of materials will notice that in the initial portion of the test, the relationship between the applied force or load and the elongation the specimen exhibits is linear. Define of Hooke's Law where the ratio of stress to strain is a constant, $E = \sigma/\varepsilon$. The formula for the tensile stress is:

$$\sigma = \frac{F}{A}$$

Where,

σ= tensile stress

F= tensile force over the rod

A= the cross sectional area of the rod

2.2.3.4 Shear

When a composite is experiencing a shear load, this load is trying to slight adjacent layers of fibers over each other. For a composite to withstand shear loads, the resin must have good mechanical properties as well as high adhesion to the reinforcement fiber. To indicate this property in a multilayer composite (laminate), a value for the Interlaminar Shear Strength (ILSS) is often used.

2.2.3.5 Flexural

Flexural testing is also a mechanical testing to measures the behaviour of materials subjected to simple bending loads. This testing is commonly used on brittle materials such as composite, ceramics, stone, masonry and glasses. It can also be used to examine the behavior of materials which are intended to bend during their useful life such as wire insulation and other elastomeric products. Flexural testing involves the bending of a material, rather than pushing or pulling to determine how much the material can bend before it breaks as well as the relationship between bending stress and deflection.

The flexural test method measures behavior of materials subjected to simple beam loading. It is also called a transverse beam test with some materials. Maximum fiber stress and maximum strain are calculated for increments of load. Results are plotted in a stress-strain diagram. Flexural strength is defined as the maximum stress in the outermost fiber. This is calculated at the surface of the specimen on the convex or tension side. Flexural modulus is calculated from the slope of the stress versus deflection curve. If the curve has no linear region, a secant line is fitted to the curve to determine slope. A flexure test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline to ensure the primary failure comes from tensile or compression stress the shear stress must be minimized.