UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EXPERIMENTAL STUDY ON THERMAL CONDUCTIVITY PERFORMANCE OF OIL PALM FIBER/POLYESTER PANEL WITH ALUMINUM HONEYCOMB SANDWICH

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY WITH HONOURS

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "Experimental Study On Thermal Conductivity Performance Of Oil Palm Fiber/Polyester Panel With Aluminium " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 20 / 01 / 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology with Honours.

Signature	:	
Supervisor Name	:	DR. MUHAMMAD ZULKARNAIN
Date	:	23/1/2023

DEDICATION

This thesis is dedicated to my mother Norazilah Binti Md.Ali and also my father Azmi Bin Ibrahim, who have raised and support me to be the person I am today. You have been with me from a little child every step by step until now, through good times and bad. Thank you for your love, pray, guidance, and support that you have given to me, helping me to succeed and encouraged me to be confident that I am capable of doing anything I put my mind and effort into it. Thank you for everything.

ABSTRACT

Many industrial sectors nowaday's demands for recyclable materials, lightweight structures, and easy to obtain in nature. Many research efforts have been studied by various researchers previous experiments in terms of knowledge about natural fiber, sandwich panels, and honeycomb structure. The physical oil palm fiber that is salt-water resistant and as shock absorber. Thus, oil palm fiber is an excellent material to reinforced with polyester. The characteristics of sandwich aluminum honeycomb are known as lightweight structures widely used in industrial automotive, naval, and aircraft. This study is about the combination of composite material as sandwich panels with aluminum honeycomb to make experiment on mechanical properties of the specimen. This experiment of oil palm fiber/polyester panel with aluminum honeycomb sandwich to produces the material is lightweight and durable as industrial requirement.The scope of this project is an analytical study that focuses on oil palm fiber with polyester resin as a composite that attaches to aluminum honeycomb as sandwich material. In addition, oil palm fiber is treated with sodium hydroxide to eliminate unwanted particles before being prepared as reinforcement. and standard thermal testing used to analyze the thermal distribution of honeycomb.

ABSTRAK

Kebanyakan industri sekarang membuat permintaan keatas bahan yang dapat di perbaharui, struktur yang ringan, dan mudah diperolehi dalam alam semula jadi. Banyak penyelidikan telah dikaji dengan kajian-kajian terhadap eksperimen dari segi pengetahuan tentang serat semula jadi, komposit panel sandwich, dan struktur pada aluminium honeycomb. Fizikal serat kelapa sawit adalah kalis air masin dan sebagai penyerap gegaran. Disebabkan itu, serat kelapa sawit merupakan bahan yang sesuai untuk di komposkan dengan polyester. Ciri-ciri sandwich aluminium honeycomb terkenal dengan struktur yang ringan yang digunakan dalam industri automotif, perkapalan, dan kapal terbang. Kajian ini adalah tentang kombinasi antara bahan komposit sebagai panel sandwich kepada struktur aluminum honeycomb untuk menbuat penyelidikan keatas mekanikal properti terhadap spesimen tersebut. Dalam penyelidikan ini sarat kelapa sawit yang dikompos dengan polyester resin sebagai panel untuk di sandwich terhadap aluminum honeycomb bagi menhasilkan bahan yang ringan dan daya ketahanan yang kuat untuk memenuhi keperluan industri. Skop projek ini adalah kajian analitikal yang memfokuskan kepada gentian kelapa sawit dengan resin poliester sebagai komposit yang melekat pada sarang lebah aluminium sebagai bahan sandwic. Selain itu, gentian kelapa sawit dirawat dengan natrium hidroksida untuk menghilangkan zarah yang tidak diingini sebelum disediakan sebagai tetulang. dan ujian haba piawai yang digunakan untuk menganalisis taburan haba sarang lebah.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

FRP	-	Fiber-reinforced polymer
k_0	-	Thermal conductivity
L	-	Thickness of the test
L_0	-	Thickness of material
T_3	-	Temperatures of copper plates
T_2	-	Temperatures of copper plates
T_1	-	Temperatures of copper plates
ASTM	-	American Society for Testing and Materials
ISO	-	The International Organization for Standardization
DI NEN	-	Thermal performance of building materials and products
m	-	Meter
K	-	Kelvin
Mm	-	Millimetres
kg	-	Kilograms
Q	-	Heat trasnfer
A	-	Cross-sectional area
dT	-	Temperature difference
dx	-	Sample thickness
W	-	Heat flux
L	-	Distance
ρc	-	Density honeycomb sandwich
ts	-	Thickness of the bee wall
C	-	Side length honeycomb

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Bio-composites are materials created by mixing natural fibre with either a petroleum-derived non-biodegradable polymer or a biodegradable polymer. Bio-composites created from natural fibre and crop/bioderived plastic (biopolymer/bioplastic) are more likely to be environmentally benign, and these composites are referred to as green composites. Natural fibre fillers provide various benefits over typical inorganic fillers, including lower energy costs, a positive contribution to the global carbon budget, higher deformability, biodegradability, combustibility, ease of recyclability, and superior thermal and insulating qualities.

Bio-composites have received significant attention in recent decades as environmental responsiveness and ecological concern have grown. Since composites have several advantages such as low cost, light weight, nontoxicity, biodegradability, and so on. Various natural fillers, such as pineapple, sisal and bamboo, coconut coir, jute, and so on, have previously been described as reinforcements in composites. Aside from that, natural fibres have a far lower thermal conductivity than synthetic fibres and may be employed as a filler in a variety of insulating applications.

There is a growing interest on natural fiber composites in various fields due to these advantages. By example, the palm oil business is by far the greatest contributor to Malaysia's biomass industry. Huge volumes of lignocellulosic materials are found in oil palm trees in the form of empty fruit bunches, mesocarp fibres, palm kernel shells, fronds, and trunks.

Depending on the local environment, energy efficiency may be accomplished by developing adequate roof insulation material. Thermal characteristics vary depending on the substance. In a hot and humid climatic country like Malaysia, the best roofing material is one that reduces or reflects solar radiation. This is done to maintain the building's internal temperature as low as possible. Roof insulation is critical for lowering solar radiation, and most roof insulations on the market are built of inorganic materials with low thermal conductivity that could not be formed naturally.

1.2 Problem Statement

Cooling system and lighting consume the most energy compared to others house appliance. The design of the building envelopes and the materials used have a vital impact in lowering the building's energy usage. When compared to the walls, the roof is more exposed to solar radiation. According to Malaysian climate conditions, the duration of roof exposure to solar radiation is greater than that of walls.

The use of passive design may considerably boost the cooling impact of a structure, hence increasing occupant comfort. However, the use of thermal insulation and specialty construction materials has expanded dramatically in recent years, regardless of whether the region is hot or cold.

As a result, by using Aluminium honeycomb sandwich along with oil palm fiber / polyester panel to produce a low cost, biodegradability, and better thermal insulation capabilities for Malaysia climate.

1.3 Research Objective

The main aim of this project is to study on thermal conductivity performance of oil palm fibre / polyester panel with aluminium honeycomb for equator climate. Specifically, the objective are as follows:

1) To study the thermal and absorption characteristic aluminium honeycomb oil palm fibre/Polyester panels under thermal conductivity prediction.

2) To evaluate the thermal conductivity performances by varied fiber volume content on honeycomb sandwich

1.4 Scope of Research

The scope of this project are as follows:

- The research focus on chop fiber size with random distribution of natural Oil Palm.
- The varied amount of fiber content will be addressed to thermal analysis
- The characteristic of oil palm will be random distribution.
- Standard thermal testing is used to analyze thermal distribution

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Energy efficiency has been acknowledged as a significant strategy for addressing developing difficulties in today's modern society in the use of thermal insulation and specialty construction materials has expanded dramatically in recent years, regardless of whether the region is hot or cold. As technology improves, more and more effective man-made materials for building thermal insulation are being produced. Many of these synthetic items do not degrade naturally when disposed of in landfills because water, air, and soil have little effect on the materials, degradation can take hundreds of years in some cases. The growing environmental impact demands the quest for feasible biodegradable renewable materials for use as building thermal insulation. The combination of composite material as the panel to sandwich the aluminium honeycomb in the centre in order to build the specimen's face sheet panel that is robust, lightweight, and renewable. To create the specimens, previous research on the thermal conductivity performance of oil palm fibre polyester composite and aluminium honeycomb core structure must be conducted via an article, video, and journal that was an experiment and evaluated.

This review is essential for developing an appropriate approach for conducting an experimental investigation on the thermal conductivity performance of oil palm fibre polyester panel reinforced with an aluminium honeycomb sandwich. This is to classification the standard dimension of specimen needed before conducting actual test. With this comprehensive study of oil palm fibre polyester composite panel and aluminium honeycomb information, corrective, and preventive solutions for producing the composite surface panel and sandwich with aluminium honeycomb can be properly planned and executed in a timely and effective manner. The goal of doing a literature review is to look at past studies and experiments on fibre oil palm fibre, polyester resin, and aluminium honeycomb based on the material, technique, equipment utilised, mathematical calculation, benefits, and drawbacks, and so on.

2.2 Natural Fibers

2.2.1 Oil Palm Fibers

The female bunch has around increasingly growing fruits on 100–120 spikelets connected to a peduncle from the axil of a frond. The two primary products of the fruits are palm oil from the outer mesocarp and palm kernel oil from the kernel within the nut. Many studies have been undertaken to investigate the potential of natural fibres as composite reinforcement, and the findings in some cases have revealed that natural fibre composites have high stiffness but not the same degree of strength as glass fibre composites to a peduncle from a frond's axil. The cultivation of the oil palm, Elaeis guineensis, has risen dramatically in recent years due to rising demand for vegetable oils. Short fibres were initially used to reduce the cost of the rubber compound or to increase its processability. Later, it was discovered that reinforcing rubber with short fibres provided good strength and stiffness to both soft and strong rubber matrices. The adhesion between oil palm fibre and rubber matrix was found to be poor, but it may be increased by treating the material at high temperatures and with different bonding agents. The thermal insulation was investigated at conductivity for possible use as a building thermal insulation.

2.2.2 Resins

Resins is any natural or synthetic organic compound consisting of a non-crystalline or viscous liquid substance natural resins are organic compounds that are fusible and combustible, are transparent or translucent, and range in colour from yellowish to brown. They originate in plant secretions and are soluble in a variety of organic liquids but not in water. Synthetic resins are a broad category of synthetic compounds that have certain physical features with natural resins but differ chemically. Plastics and synthetic resins are not readily distinguished. Matrix materials are of different types like metal matrix, ceramic matrix, and polymer matrix. When compared to metal and ceramic matrices, polymer matrices are most typically utilised due to their cost effectiveness, ease of producing complicated components with reduced tooling expense, and excellent room temperature characteristics. Polymer matrices can be either thermoplastic or thermoset. Thermoplastic materials are formed by addition polymerization. Thermoplastics soften or fuse when heated, harden, and become rigid after cooling. Unlike thermosets, thermoplastics can be modified or reused upon the need. Thermoplastics have longer shelf life and higher fracture toughness than thermoset resins. Thermoplastic resins have high viscosity and less creep resistance when compared to thermosets (Barbero, 1998).

Thermosets are formed when two or more components chemically react with each other under ambient conditions or when induced by radiation or heat to form a highly cross-linked network. The process of thermoset production is irreversible. Thermosets are often stiff and unyielding. When compared to thermoplastics, they have superior temperature resistance when exposed to heat and will not creep or deform at higher degrees. Thermoset matrices are created when a resin undergoes an irreversible chemical change into an amorphous cross-linked polymer matrix. Because of their massive molecular structures, thermoset resins provide excellent electrical and thermal insulation. Low viscosity allows for optimal fibre wet out, improved thermal stability, and greater creep resistance in thermosets. Epoxy, polyester, vinyl ester, and phenolics are the most regularly used thermoset resins. Generally, thermoset resins may be designed to provide a wide range of qualities depending on the application.

Epoxy resin has superior adhesive qualities as compared to other resins. It also has low shrinkage after curing, strong chemical resistance, and excellent thermal properties. Epoxies have been employed in advanced composites due to their adherence to a wide range of fibres, outstanding mechanical and electrical capabilities, and high temperature performance. Epoxies are more costly than polyester and have a lower moisture resistance. Polyester has the advantages of being inexpensive, easy to handle, chemically resistant, and having reasonable mechanical characteristics. Polyester and epoxy account for around 85 percent of fibre reinforced polymer composites.

2.3 Distribution Composites

A composite material is made up of two components that have distinct physical and chemical characteristics. When they are mixed, they form a material that is specialised to perform a certain function, such as becoming stronger, lighter, or electrically resistant. They can also help to increase strength and stiffness. They are preferred over traditional materials because they increase the qualities of their basic materials and are useful in a variety of scenarios. Composites are employed in many industries, including aircraft, architectural, automotive, energy, infrastructure, marine, military, and sports & recreation. Read about intriguing composites uses in certain sectors below and come back frequently as we continue to add more applications to this site. Composite materials have significant class of structural elements because the materials are lightweight, flexible, highly corrosion resistance, excellent impact strength, and good fatigue strength. Because of this property, composite materials are being considered as a replacement for traditional materials used in aerospace, automotive, and other industries. With careful selection of matrix and reinforcement can achieve the specialty of composites by engineering the material properties, which are required in the product

The outstanding features of fiber-reinforced polymer composites (FRPs) are their high specific stiffness, high specific strength, and controlled anisotropy (Abbood et al., 2021). FRPs are widely employed in the pulp and paper, semiconductor, metal refining, electricity, waste treatment, petrochemical, pharmaceutical, and other sectors that require high-performance advanced composites for these reasons. Pressure vessels, ducts, fans, stacks, pipelines, elevator buckets, and heat exchangers are examples of FRP goods. Furthermore, a composite is a blend of two or more chemically unique ingredients separated by a district interface as reinforcing particles and matrix. As a result, it possesses a distinct set of qualities that differ considerably from the constituent attributes. As seen in Figure 2.1, two major classes are fibrous composites and particulate composites, with reinforcement in the form of fibres reinforced.

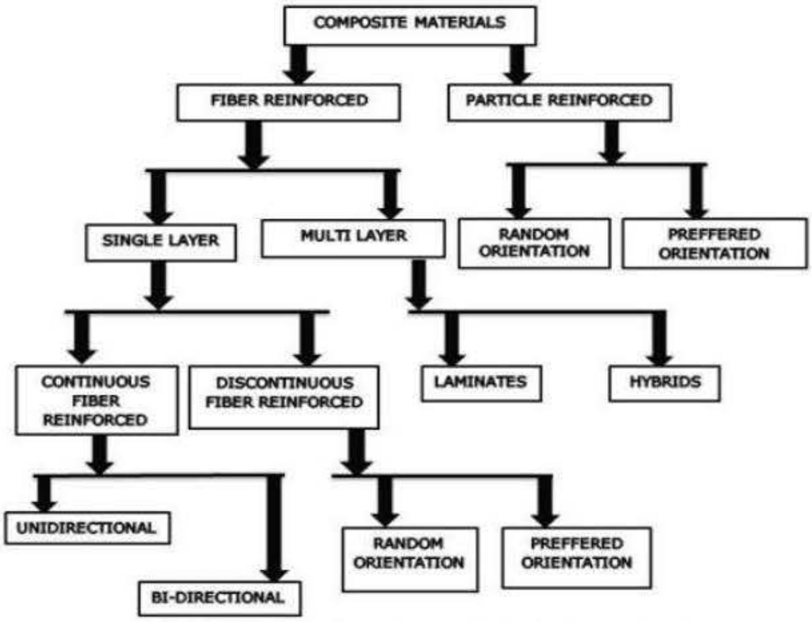


Figure 2.1 Classification of Composite Materials (Luo et al, 2012)

2.3.1 Molding Method of Composites

The molding process about hand lay-up fiber reinforced plastics (FRPs) as Figure 2.2 shown is a process of preparing thermoset polymer matrix composites 100 percent with hand and does not use any machine. After mixing the fibre with the polyester resin and hardener, the material was well mixed and allowed to cure for 24 hours at room temperature to produce the reaction process of the polyester resin and hardener in generating the composite material products. The moulding method for composite materials is substantially different from the moulding process for metallic materials. This is due to the requirement to mould the composite process step by step, as illustrated in Figure 2.2, which depicts the composite preparatory moulding process.

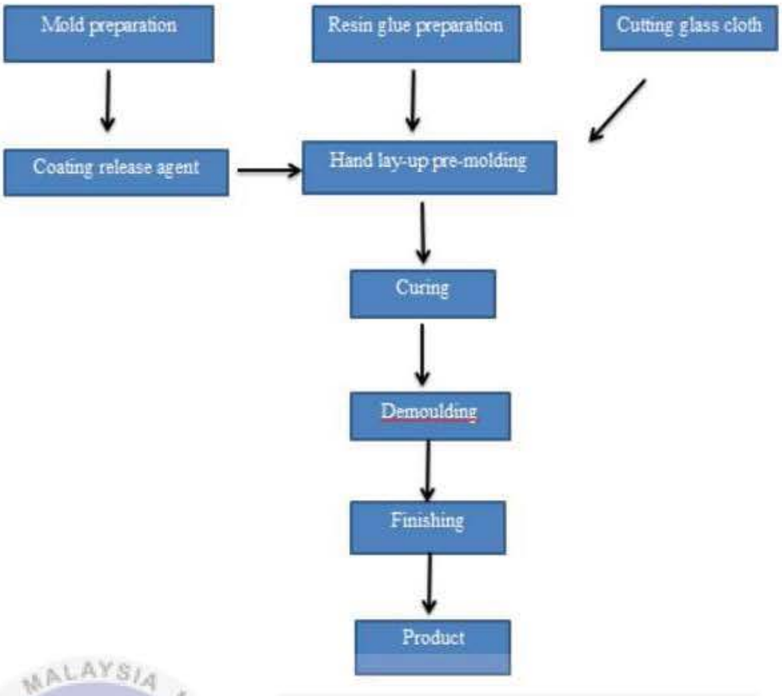


Figure 2.2 The process flow chart of preparing molding process FRP composite by hand lay-up (Achutha Kini et al., 2018)

2.3.2 Characteristic of Composites Materials

Composite materials have different types of composite materials have distinct performance characteristics. However, composite materials have several features, such as the fact that polymer matrix composites are the fastest growing and most extensively utilised composite materials due to inherent properties when compared to conventional materials such as metal. The properties of polymer matrix composites are as follows.

a) High Specific strength and High Specific Modulus.

The benefits of polymer matrix composite materials include high specific strength and modulus. The value ratio of strength and density determined the material's specific strength, whereas the value ratio of modulus, density, and unit dimensions determined the material's specific modulus (Fu et al., 2008). The greater the ratio of modulus, density, and dimensions of the material, the higher the specific strength and specific modulus of the material. Following that, due to indices of measuring bearing capacity and stiffness qualities of the material, this material also falls within the premise of equal weight.

b) Good Fatigue Resistance and High Damage Tolerance

In composite materials, the contact between fibre and matrix can inhibit fracture progression. Unlike traditional materials, composite material damage is not caused by the unstable propagation of the primary fracture, which can induce the development of serial damage such as matrix cracking, interfacial de-bonding, fibre pull-out, and fibre split and break.

c) Good Damping

The natural frequency of vibration of a forced structure is proportional to the square root of the specific modulus of structural materials. As a result, the composite materials have a high inherent frequency, making resonance problematic in general. The interface between fibre and matrix composite materials, on the other hand, has a high ability to absorb vibrational energy, resulting in high vibration damping materials.

2.4 Honeycomb Sandwich Panels

Honeycomb sandwich panels are created by covering the top and bottom surfaces of the honeycomb with sheets (Figure 2.3). The lower and top surface face sheet material of honeycomb sandwich panels might be metal or non-metal. Honeycomb sandwich panels are created by joining honeycomb cores and surface sheet plates together to form a composite sandwich structure.. The inner skin is an aluminium plate that connects to the honeycomb core, while the outside skin is a slate. An aluminium plate serves as a splint during the multi-layer stone aluminium honeycomb composite board. In a steady state heat transfer situation, the honeycomb panel outside surface is heated. The honeycomb's exterior skin is radiated, and heat exchanged, with the majority of the heat being reflected into the natural environment and the rest being transmitted to the skin.

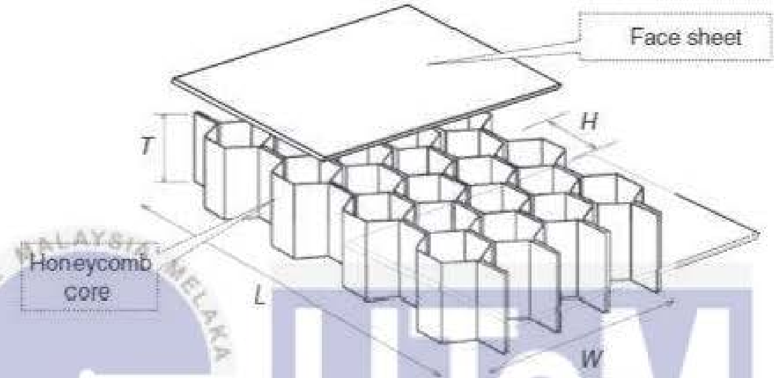


Figure 2.3 Example of Honeycomb Sandwich Panels (Kaman, Mete & Solmaz, Murat & Turan, Kadir. 2010)

2.4.1 Distribution of Honeycomb Sandwich

Honeycomb sandwich structures are increasingly being used in aeroplanes, ships, and bridges because to their superior strength-to-weight and stiffness-to-weight properties. The honeycomb sandwich structure is widely used in several transport engineering applications for its excellent stiffness and strength criterion. The aluminium honeycomb sandwich is requirement of the application on aircraft, naval, vehicles, and other applications because of the lightweight material. Moreover, honeycomb core structure has an isotropic material property. Developments of the sandwich panel were to withstand the high strength to the weight ratio, high bending stiffness, high insulation properties, and excellent sound attenuation properties.

2.4.2 Feature of Sandwich Composite Panel

Sandwich-structured composites are a type of composite material made by bonding two thin but rigid skins to a lightweight but substantial core. The core material is typically low strength, but its increased thickness offers the sandwich composite with high bending stiffness while remaining low density. The natural honeycomb and I-shaped composite beam structure are used in the aluminium honeycomb composite panel construction. The skin of the composite panel is comprised of aluminium sheet with high structural strength, and the section is bending resistant. The core layer is lightweight and has strong shear resistance and stability, mimicking the structure of natural honeycomb. The honeycomb panel has the advantages of natural honeycomb and I-beam structure due to the optimum design of the skin and core layer. Other than that, the honeycomb core is covered by the panel, the air in the cavity reduces the flow, and the small space formed prevents the heat from being transmitted and causes the sound waves to constantly reflect in this local area, reducing the energy. In recent years, the development of aluminium honeycomb panels, its noise reduction ability can reduce the high Hertz, high decibel sound to 100-3200Hz, 20-28dB. Next, good decoration, simple installation, and long life. The keel splicing, dry hanging construction, light weight, high ductility, not easily broken, simple to splice, improves installation efficiency, and lowers installation costs. It is possible to mosaic, and the colour difference may be regulated across a wider range. The original board divides the marble composite board into numerous portions, usually three or four points, and the area of the slab after cutting is several times. The cutting board has a slight colour variation and may be utilised in a vast area, as well as having a more attractive look.

2.4.3 Aluminium Honeycomb Sandwich

As the economy grows, high-end and high-rise buildings sprout up around the world. High-end constructions incorporate green materials like aluminium wall panels and honeycomb panels. In the 1940s, Britain pioneered aluminium bonding technique for aircraft construction, while the Americans developed the'sandwich' configuration utilising aluminium honeycomb panels. Aluminum honeycomb has since been utilised in building, rail, automobile, and marine panels. When compared to other materials of the same volume, aluminium honeycomb sandwich have a specific design that makes them durable to weight ratio, the ability to work well in higher temperatures, moisture-proof and manufacturable. Although aluminium is a heat conductor, because of honeycomb structure makes it a good insulator. Therefore, the aluminium honeycomb panel is used as the curtain wall panel is resistant to air pollution and weathering and may be extensively employed in newly constructed and renovated structures.

2.5 Thermal Conductivity

In the late 1920s and early 1930s, standard measurements of thermal conductivity were established, however methods for determining thermal conductivity were initially created in the 19th century. Early thermal conductivity researchers such as Peclet, Forbes, Christiansen, and Hencky were summarised by (Zarr, R.R., Kumaran, M.K., and Lagergren, E.S., 2002). A sphere, a pipe section, or a vertical slab can be used to measure thermal conductivity, according to Peclet. By measuring the thickness of the ice layer generated on one surface of the specimen and then exposing the other to a freezing liquid, Forbes created a slab method for detecting negative temperatures. A heat flow metre (HFM) was invented by Christiansen after he built a comparison instrument. Copper plates with holes for thermometers were found in it. Test and reference specimens were sandwiched between the plates to evaluate heat conductivity of the two different materials. The test specimen's thermal conductivity, k, was determined using Equation 2.6.

$$k = k_0 \frac{L\,(T_3 - T_2)}{L_0(T_2 - T_1)} \qquad 2.1$$

where k_0= thermal conductivity of the reference material, L and L_0 = thicknesses of the test and reference materials, respectively, and T_3, T_2, T_1 = temperatures of copper plates, starting from the hot plate.

Schmidt measured thermal conductivity using heat flow transducers with low thermal resistance and compensating rubber strips with roughly the same thermal resistance (Zarr, R.R., Kumaran, M.K., and Lagergren, E.S., 2002). Adding a layer with a thermal resistance similar to that being measured, Hencky tweaked the design. Because the underlying physical principles are virtually unaltered, the same method can be applied eighty years later.

However, newer and more precise equipment have been created to improve the accuracy and precision for a broader range of materials and testing situations

2.5.1 Sample of Testing Thermal Conductivity

One of many ways to measure the thermal conductivity is by using ASTM C518. The ASTM C518 is the Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. The physical test method involves testing your material using a hot plate and a cold plate with heat flux transducers to measure how heat in the material flows between the two plates. This test is used to measure thermal conductivity in any number of different materials of various thicknesses and conductivity levels. This test is most typically used to get an accurate measurement of insulation effectiveness.

Insulation material thermal conductivity is measured using two different types of guarded hot plate techniques. The requirements for measuring insulation material thermal conductivity are listed in Table 2.1. For example, ASTM C177, ISO 8302:1991, DINEN 12939, or JIS A 1412-1, the first form of thermal conductivity measurement, it is created such that electrical power, temperature, and sample dimensions are directly measured to obtain thermal conductivity directly. An alternative method known as ASTM C518, ISO 8301:199 or DINEN 12667 comprises one or more heat flux metres in a stack of plates calibrated against reference samples.

Table 2.1 Standard method for measuring thermal conductivity

Standard	Description
ASTM C177	Standard Test Method for Measurement of Steady-State Heat Flux and Thermal Transmission Properties Using the Guarded-Hot-Plate Apparatus
ASTM C518	Standard Test Method for Thermal Transmission Properties in Steady-State Using the Heat Flow Meter Apparatus
DIN EN 12667/ 12939	European Standard for Insulating Material Measurements Using the Heat Flow Meter Method or the Guarded Hot Plate Technique
ISO 8301/8302	Standard Test Technique for Insulating Material Measurements Using the Heat Flow Meter/Guarded Hot Plate Method
JIS A 1412-1: 1999	Thermal Resistance and Related Properties of Thermal Insulations Test Method - Guarded Hot Plate

The effective thermal conductivity of oil palm fibre was measured under steady-state one-dimensional test conditions with heat flow upwards, in accordance with ASTM C518.. The test equipment consisted of a 305 mm by 305 mm constant temperature panel with a centrally positioned 102 mm x 102 mm heat flux transducer. Within the range of 0.005 W/m.K to 0.35 W/m.K, the test equipment yielded readings with 0.2 percent repeatability and 0.5 percent reproducibility.

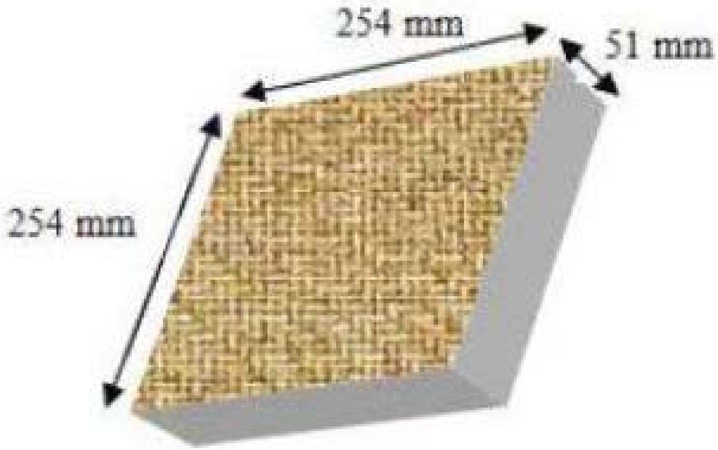


Figure 2.3 Schematic of Oil Palm Fiber test specimen (Manohar, Krishperad & Augustine, St & Trinidad, Tobago & Indies,.2012).

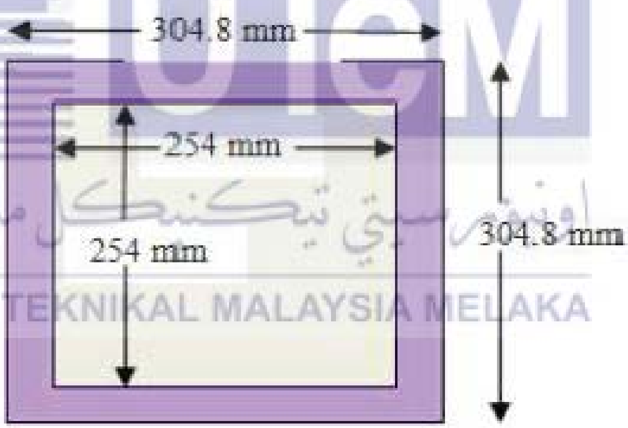


Figure 2.4 Schematic of Polystyrene specimen holder (Manohar, Krishperad & Augustine, St & Trinidad, Tobago & Indies, 2012).

Thermal conductivity measurements were taken on test specimens that were 51 mm thick and 254 mm square (Figure 2.4). The specimens were held in a polystyrene specimen container made of 25.4 mm thick polystyrene strips and 51 mm height (Figure 2.5). Oil palm fibre samples were drawn at random from a stockpile that had been allowed to acclimate to laboratory conditions. The fibres were packed into the specimen container, resulting in a 51 mm thick slab-like specimen.. By altering the mass of the fibre within the fixed size specimen container, the density of the test specimen was altered.. When the fibre was randomly placed in the slab-like batt, the strands were typically perpendicular to the direction of heat transfer across the test specimen. After that, the minimal specimen test density was calculated using the lowest practicable density for which the material remained without visible settling under gravity. The clamping force between the test equipment's constant temperature plates set the highest test density limit. The oil palm fibre batt, 51mm thick, has a minimum test density of 20 kg/m3 without settling. The highest test density employed was 120 kg/m3 because the clamping force between the test equipment's constant temperature plates could not compress specimens of higher density to the requisite 51 mm thickness.

Density (kg/m^3)	Thermal Conductivity λ (W/m.K)		
	20°C mean temp.	25°C mean temp.	30°C mean Temp
20	0.09167	0.09466	0.09824
30	0.07576	0.07777	0.07809
40	0.06754	0.06801	0.06950
50	0.05961	0.06115	0.06316
60	0.05987	0.06006	0.06041
70	0.05730	0.05829	0.05997
80	0.05699	0.05690	0.05813
90	0.05607	0.05733	0.05796
100	0.05550	0.05690	0.05784
110	0.05580	0.05733	0.05800
120	0.05642	0.05782	0.05890

Figure 2.4 Sample Result determined thermal conductivity for oil palm fiber. (Manohar, Krishpersad & Augustine, St & Trinidad, Tobago & Indies, 2012)

2.6 Formulas

$$Q = -kA\frac{dT}{dx} \qquad 2.2$$

Where: Q = heat transferred (W), A = cross sectional area (m2), k = thermal conductivity (W/m.K),dT = temperature difference (K), dx = sample thickness (m)

$$K = (Q/A) / (\Delta T / \Delta L) \qquad 2.3$$

where K is the thermal conductivity (W /m-K), Q is the heat flux (W), A is the specimen's cross-sectional area (m2), T is the temperature differential (K), and L is the overall distance (m).

$$\rho_C = 4126(\frac{t_s}{C}) \qquad 2.4$$

Where: ρc is the density of the aluminum honeycomb core, kg/m^3;

ts is the thickness of the bee wall, mm;

C is the side length of the honeycomb, mm.

2.7 Summary

Since manufacturers nowadays rely on recyclable materials that are lightweight, robust, and economical to produce their products. Natural fibres, such as oil palm fibre, are a simple material to produce in many tropical locations across the world, with the material properties required for industrial applications. As a result, natural fibre provides good reinforcing in thermoplastic and thermostat matrices (Geethamma et al., 1998). Oil palm fibre is a by-product of other industries that can be utilised for thermal insulation in the cores of masonry block walls for example as a loose-fill insulator. Thus, it was the impact of employing oil palm fiber–insulated masonry walls to improve energy efficiency and thermal comfort in residential homes. Furthermore, the husk of oil palm fiber where it is thick and coarse with durable fiber that waterproof and has resistant to damage by saltwater and microbial degradation the mechanical properties and the dynamic characteristics of the coir fiber-reinforced composite are vital (Ray, 2005). This describe that oil palm fiber has durability to withstand damage of water and can be used for long term material intended for low cost-residential buildings in a hot, dry climate. Thermal conductivity measurements of innovative products must be quick and precise if this goal is to be achieved. In this case, a guarded hot plate apparatus or a heat flow metre apparatus are commonly used to measure the thermal conductivity or thermal resistance of building insulations. In order to use either approach, specimens must be between 300 and 600 mm in length and width, and 20 and 200 mm thick. The development of new insulations frequently does not have access to samples of this size. The thermal conductivity of tiny insulation samples was measured using an alternate method in this investigation. Thermal conductivity measurements could be expedited and cost-effectively performed with smaller specimens rather than standard-sized ones. The methodology, which is described in this paper, makes use of a heat flow meter, and is based on work by Mukhopadhyaya et al (2011)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study, the oil palm fiber polyester panel reinforced with aluminium honeycomb will be elaborated about how the research design of the specimens, proposed methodology to study on thermal conductivity performance of oil palm fiber polyester sandwich panel to aluminium honeycomb. To ensure the experiment's accomplishments, study aimed to investigate the best materials, equipment, and parameters to employ in the fabrication process to avoid failure. Moreover, the methodology is consisted of the research of previous study on composite polyester resin, aluminium honeycomb core structure and study on thermal conductivity of oil palm fiber. This is to avoid the failure happen in the designing, modelling, fabricating, testing, and analysis the specimens to fulfil objective of this study.

3.2 Research Design

This thesis presents a design of sandwich aluminium honeycomb with composite oil palm fiber/ polyester resin panel. The main material is oil palm fibers that have been soaked and sun-dried for 24 hours to separate oil and small particle at the oil palm fiber. Next, the composite oil palm fiber polyester panel dimension is 6 × 65× 65 mm engineering drawing of the surface panel by combination of the oil palm fiber and polyester resin to produce an excellent damping ratio and stiffness of the panel. Next, the middle will be an aluminium honeycomb with 120° angle of each honeycomb side. The design of aluminium honeycomb is known as lightweight and excellent energy absorption that is widely used in the automotive, naval, and aircraft industries to produces lightweight parts.

The combination of the composite oil palm fiber polyester as the surface panel to sandwich aluminium honeycomb are estimated length 180mm, width 60mm and thickness 30mm dimension of the specimen. The design of this specimen will consist of three-layer that are upper and lower surface is composite panel that will sandwich aluminium honeycomb at the middle as Figure 3.1 that will be testing on Linear heat conduction experiments to study on thermal conductivity.

Figure 3.1 3D drawing of oil palm fiber/ polyester panel with Aluminium Honeycomb Sandwich

3.3 Proposed Methodology

This experimental will consist of three (5) specimens of sandwich specimen. This specimen will consist of three layer of part that are upper panel, aluminium honeycomb at the middle and bottom panel. The panel is made with varied of fibre content specimen mixed with polyester resin: 2 wt % (6g), 4 wt % (12g), 6 wt % (18g), 8 wt % (24g), 10 wt % (30g). The ratio of polyester resin and hardener is 94:6, which is the mixer of 94g polyester resin and 6ml of hardener need to mix to form the composite surface panel as Table 3.1 shown. After finished fabricating the panel surface, the panel surface will sandwich the aluminium honeycomb to fabricate the specimen as linear heat conduction for testing measurement.

Table 3.1 Ratio of polymer, resin and fiber used

Polymer (g)	Hardener (g)	Fiber (g)	Weight Total (g)	Fiber Weight (wt %)	Hardener (wt %)
282.24	11.76	6.00	300	2%	4%
276.48	11.52	12.00	300	4%	4%
270.72	11.28	18.00	300	6%	4%
264.96	11.04	24.00	300	8%	4%
259.20	10.80	30.00	300	10%	4%

3.3.1 Experimental Setup

The methodology for this study is to fabricate oil palm fiber-reinforced with polyester resin as sandwich panel to aluminium honeycomb structure.

1) Separated the oil palm fiber from the oil palm skin and soaked it with sodium hydroxide and alkaline water. To remove small object and oil attached on the fiber.
2) Sun-dried the oil palm fiber for few hours until the fiber perfectly dry from the as shown Figure 3.2 below

Figure 3.2 Oil palm fiber

3) Fabricated the mould box by shaping and cutting the plate of dimensional of 6 × 300 × 300 *mm* of mould box and the moulding area at the centre is 6 × 200 × 200 *mm* to composite.

4) Cover the bottom of the moulding with plastic film to avoid leaking happen as shown in figure 3.3. The specimen panel fabrication starts with the separated each oil palm fiber.

Figure 3.3 Moulding plate with plastic film

5) Weight the fiber according to each percentage the specimen that will be prepare of oil palm fiber mixed in the panel as shown in figure 3.4 and figure 3.5. After that, mix the polyester and hardener resin according to ratio 94:6 that is 94g polyester resin mix 6ml of hardener.

Figure 3.4 282g of resin

Figure 3.5 12g of hardener

6) Pour some mixed polyester resin into the mould and separate the resin to cover the area. Then, insert the oil palm fiber by separate the fiber equally in the mould area and repeated the step layer by layer until it covers the surface of the mould. Figure 3.6 shows the resin and hardener are put together in one mould plate. Let the panel 24 hours for curing process.

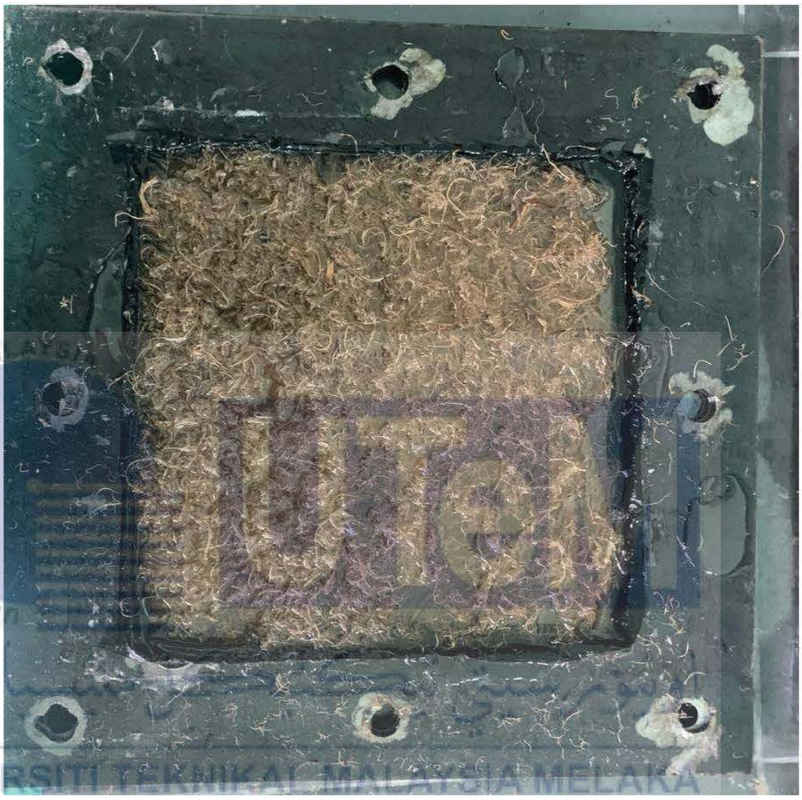


Figure 3.6 After pouring resin and hardener

7) Separated the composite panel from the mould box as shown in figure 3.7 and cut the composite surface panel in dimension 6 ×65 ×65 mm of each surface panel used to cut machine and grinding the surface panel to flat the surface panel. Figure 3.8 shows the cutting process of the composite panel.

Figure 3.7 Composite panel after cure

Figure 3.8 cutting composite into desired size

8) Cut the aluminium honeycomb dimension of 2 ×62 ×62 mm. The sandwich specimen is consisting of three (3) layer part, upper panel, aluminium honeycomb at the middle and bottom panel.

9) Resin is used as the glue agent to combine each part as sandwich specimen and let the glue attachment completely dry as shown in figure 3.9.

Figure 3.9 specimen after sandwich together

10) The specimen dimension 6 ×65 ×65 mm that follow the measurement for linear heat conduction experiment as the specimen width must be minimum twice the thickness of the specimen and not exceed six time of width specimen measurement.

11) The specimen length must be equal to support span length plus 50mm or plus one half the sandwich thickness.

12) After successful fabricate all specimens for testing to discover the thermal properties of the specimen with different percentage mixer of fiber composite panel reinforced with aluminium honeycomb structure.

3.4 Flow chart of the process

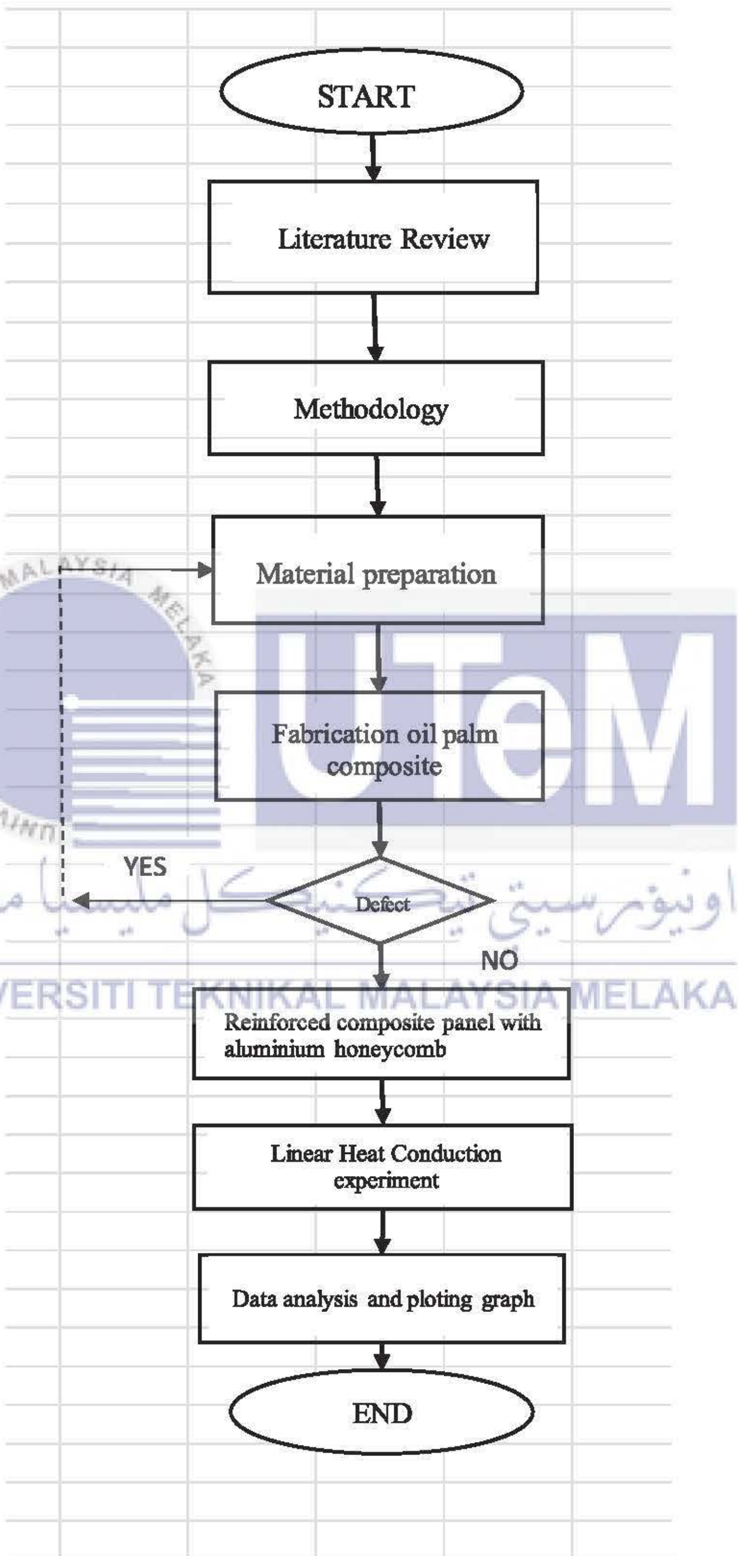


Figure 3.10 flow chart of experiment

3.4.1 Parameter

The measurement each part of the specimen is shown in Figure 3.11 and Figure 3.12. Figure 3.11 shown the dimension drawing of aluminium honeycomb and Figure 3.12 The dimensions of the real specimen where each item is merging are displayed. This model was 3D drawing used Solidwork 2021 software, the dimensional measurement was in millimetre (mm).

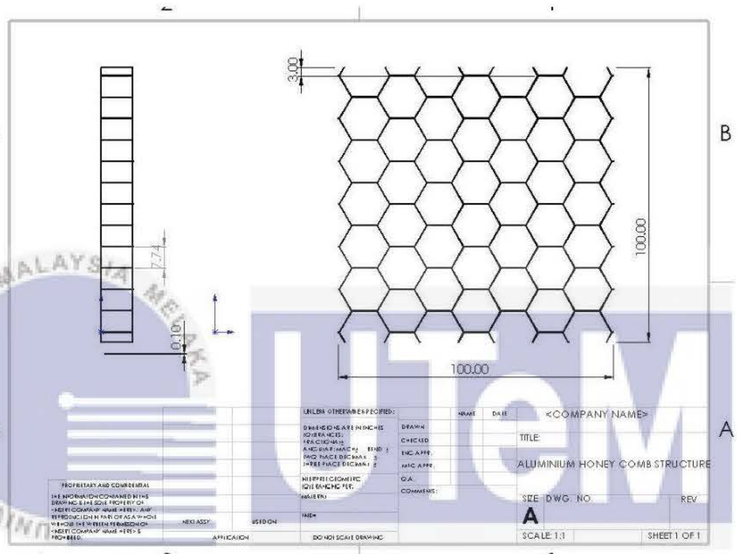


Figure 3.11 Drawing of honeycomb using Solidworks

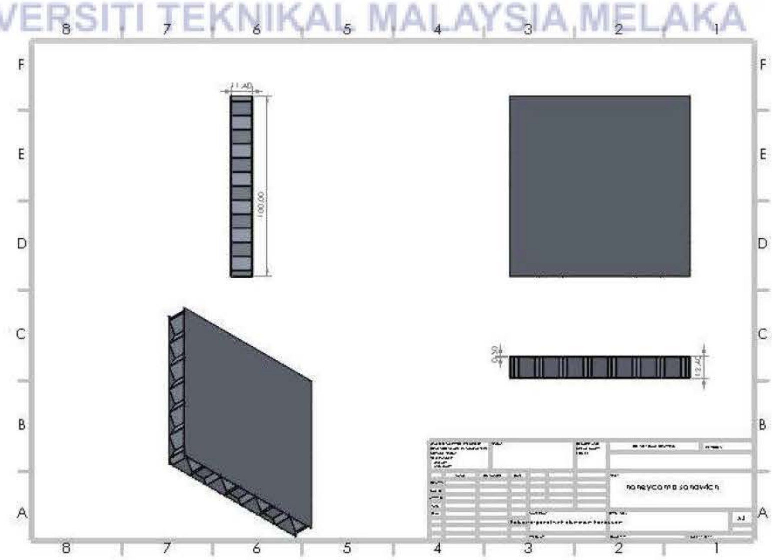
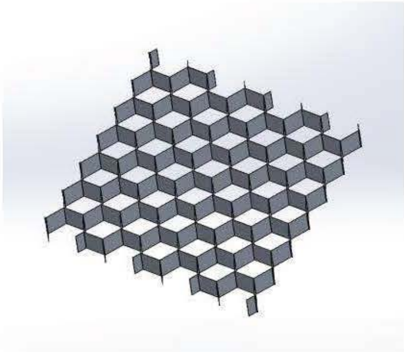


Figure 3.12 Drawing of oil palm fiber with aluminium honeycomb sandwich

3.4.1.1 Material

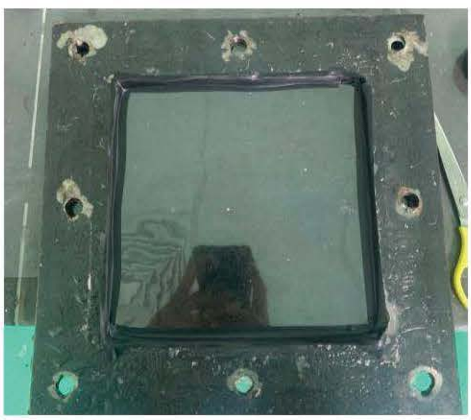
Table 3.2 List of Material

No.	Material	Figure	Function
1.	Oil palm fiber		Main material for fiber composite with polyester resin to produces as surface composite panel of specimen.
2.	Polyester Resin		Polyester resin is use as bonding matrix of oil palm fiber to produce reinforced with high strength to weight characteristics.
3.	Polyester Hardener		The reaction of hardeners mixer with polyester resin will form a thermosetting polymer, that are favourable mechanical properties, high thermal and chemical resistance. Polyester has a wide range of applications include fiber composite, plastic materials,

			adhesives for structural, and many other purposes.
4.	Aluminium Honeycomb		Aluminium honeycomb produces a higher strength and weight ratio structural material. The hexagonal shapes can produce a variety of geometric cell shapes and the properties depend on the foil thickness and cell size.

3.4.1.3 Equipment

Table 3.3 Equipment

No.	Equipment	Figure	Function
1.	Electronic balancing		Measure the weight of each material use to produce sample.
2.	Laboratory oven		Laboratory oven use for drying
3.	Mould plate		To shape the fiber-reinforced with a mixture of polyester resin and hardeners to produces a fiber composite panel for the aluminum honeycomb sandwich.

4.	Cutting machine		For cutting the composite panel into desired dimensions.
5.	TQ TD1002A (MK11) Linear Heat Conduction Experiment		Experiment that introduces the principles of linear heat conduction and thermal conductivity.

3.5 Testing Method

The experimental was conducted at Heat Transfer laboratories, FTK UTeM. TQ TD1002A (MK11)Linear Heat Conduction Experiment as shown in Figure was chosen to conduct the linear heat test on the specimen of oil palm fiber/polyester panel with aluminium honeycomb sandwich to obtained thermal conductivity. There were five specimen with varied percentage of oil palm fiber that have been prepared which is 2 wt %, 4 wt %, 6 wt %, 8 wt %, and 10 wt %. This experiment has a solid brass bar of circular cross-section, made in two sections with an interchangeable middle section. It mounts on a base plate with a clear schematic of the experiment layout. This experimental of linear heat conduction was conducted by apply 30 W of power then placed the specimen and wait for 10 minute before record the reading. The reading can be taken at T_3 and T_5 since we only need before and after temperature. Analysis is also done based on the graph that will be displayed, where it will be discussed how the result occurred as well as the impacts and implications of attaining the result that was stated. The graph that will be attached is related to thermal conductivity against the amount of fiber in each sample. Then an analysis will be made based on the graph and a discussion about the experiment conducted will be presented.

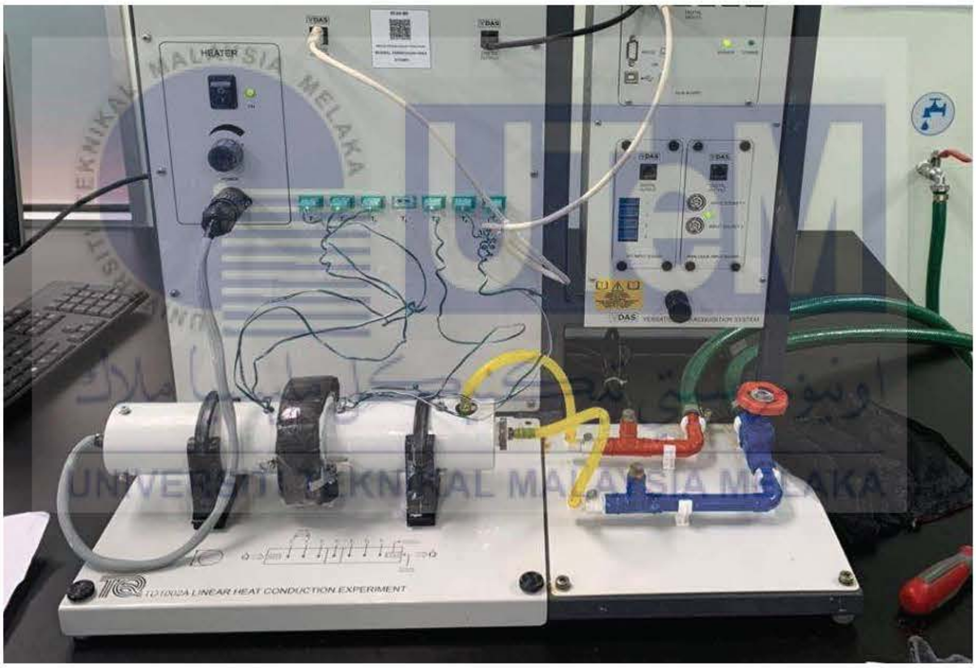


Figure 3.13 TD1002A (MK11) Linear Heat Conduction Experiment

3.6 Limitation of Proposed Methodology

The combination of oil palm fiber reinforced polyester panel reinforced with aluminium honeycomb has its limitation. Firstly, the mixture of oil palm fiber with epoxy has disadvantages in that the oil palm fiber is flammable that is not suitable to use in applications with high temperatures such as, engine parts that generated high heat or temperature. Furthermore, each resin product has a different mixing ratio for example 1:1 or 2:1 between resin and hardener, but there is also a complicate one such as 100:45 as the ratio detail on the packaging or containers.

The mixing ratio must be measure as the detail to mixture fiber and resin, if did not make measurement correctly on the resin, this will cause the specimen do not cure proper;y or not work optimally. Lastly, the aluminium honeycomb also has the problem that it has no "materials with memory". This is because when apply the impact to the core laminate will causes the honeycomb to deform irreversibly to the face panel will resilient and move back to its original position. As the result, the area with unbonded skin will causes reduce to thethermal properties of the specimen.

3.7 Summary

This chapter presents the proposed methodology in order experimental study on the thermal conductivity of composite oil palm fiber/polyester panel reinforced with aluminium honeycomb to a good thermal conductivity for roofing in our equator climate. The primary focus of the proposed methodology to fabricate the specimen to find the thermal characteristic composite panel with sandwich the aluminium honeycomb by experimental the specimen on standard test method for linear heat conduction test. Furthermore, before fabrication of the specimen, the study was firstly done by engineering drawing the 3D model of specimen using *Solidwork 2021* software. Moreover, the material use to fabricate the specimen preparation of composite panel oil palm fiber mixed with polyester resin, hardener resin, and equipment use to fabricate the panel. Thus, sandwich aluminium honeycomb to produces the specimen as dimension need for test measurement as ASTM C518 require for standard test method for steady-state test on the specimen.

Finally, there are several limitations methodology occupants for the process to fabricate the specimen. Specimen content of oil palm fiber mixed with polyester are flammable, this made the specimen not suitable to use at high-temperature part. Next, the ratio mixture of polyester resin and hardener must follow the detail ratio on the container to make sure the composite fiber with polyester works optimally. After that, the problem of aluminium honeycomb that went apply force on the honeycomb laminate core structure will cause deformation at the face panel and as the result will reduce the mechanical properties.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the result and analysis on the experimental study on thermal conductivity performance of oil palm fiber / polyester panel with aluminum honeycomb for equator climate. This chapter will consist of the prediction the the thermal happens to the specimen in actual experimental. Furthermore, to make analysis of the result obtain in experiment that have been conduct on the laboratory of linear heat conduction test according to ISO9001 standard manufacturer to investigate the thermal conductivity each of the specimen.

4.2 Validation

Thermal properties of stainless copper were established in this case using linear heat conduction testing. The linear heat test results for copper are presented in Table 4.1. The experimental procedure is mentioned in the table at 89 °C at T_1 and 40.5 °C at T_2 with a thermal conductivity of 314.97 $W.m^{-1}.K^{-1}$. Copper has a thermal conductivity of 398 $W.m^{-1}.K^{-1}$ according to the Thermtest instrument data. Based on these findings, it is determined that the linear heat conduction experiment is accurate, with an error of 0.2% from the experimental approach.

Table 4.1 Stainless copper experimental results

Material	Temperature (°C)		Thermal conductivity $(W.m^{-1}.K^{-1})$
	T_1	T_2	
Stainless copper	89	40.5	314.97

$$\textit{Thermal conductivity, K (copper)} = \frac{Q\Delta L}{A(T2-T1)} = \frac{90(0.12)}{0.707\times10^{-3}(89.0-40.5)}$$

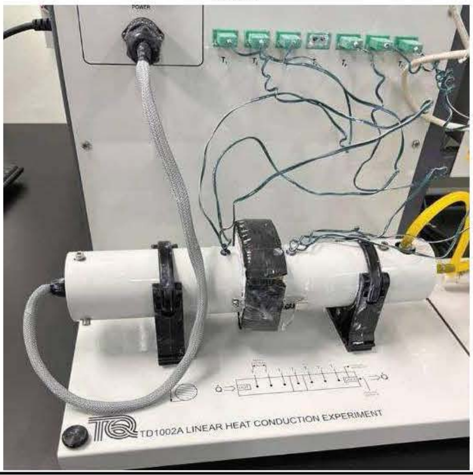
$$= \mathbf{314.97}\ \boldsymbol{W.m^{-1}.K^{-1}}$$

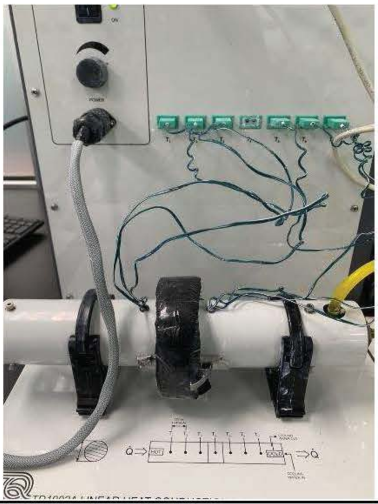
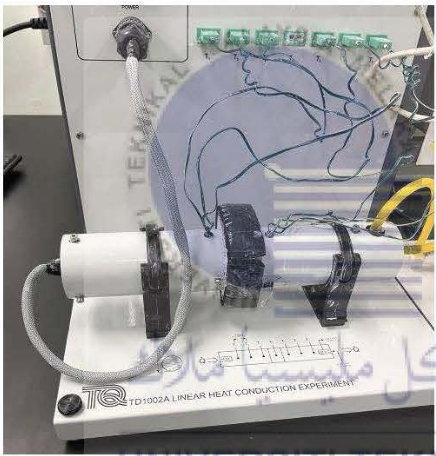
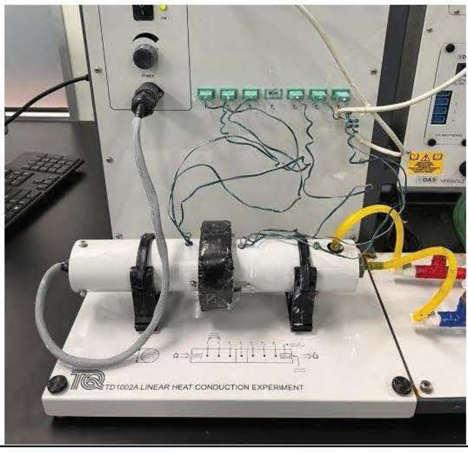
$$\text{Percentage of error, (\%)} = \frac{398-314.97}{398}\times 100\% = \mathbf{0.2\%}$$

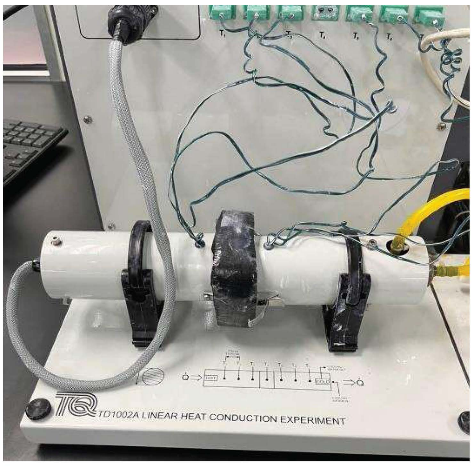
4.3 Result of Linear Heat Experiment

The table below shows result of each specimen by percentage of fiber. This experimental was conducted with 30 W power. The specimen was insulated with insulator around the specimen to prevent heat loss.

Table 4.2 Temperature recorded of the specimen

Fiber wt%	Thickness (m^2)	Temperature (°C)	
		T_1	T_2
2% 	0.035	45.3	32.4

4% 	0.034	50.8	30.1
6% 	0.034	57.5	26.4
8% 	0.037	63.6	23.6

10% 	0.037	71.5	21.2

The analysis on the data obtained from the linear heat conduction experiment that shown in Table above. The graph of fiber percentage versus temperature is as shown in Figure 4.2. The specimen with 10 wt % has the highest T_1 with 71.5 ºC than specimen 2 wt % with 45.3 ºC. This was because the specimen with high input temperature are denser with oil palm fiber than the 2 wt % since it only contains 6 g of fiber while 30 g for 10 wt %

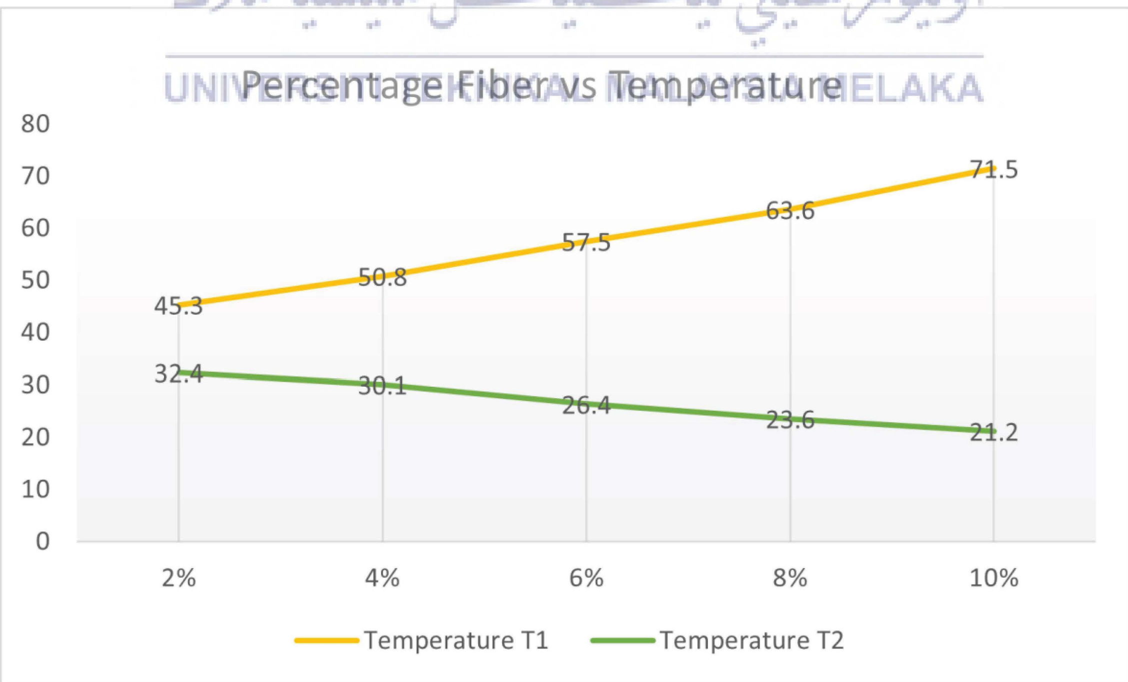


Figure 4.1 Graph fiber content versus temperature

4.3.1 Calculation of Thermal Conductivity

Power = 30W

Cross section area, A= length x width
= 0.062m x 0.062m
= 3.844 x10^{-3} m^2

Thermal conductivity, K (2 wt %) $= \frac{Q\Delta L}{A(T2-T1)} = \frac{30(0.055)}{3.844\times10^{-3}(45.3-32.4)}$

$= \mathbf{33.274\ W.m^{-1}.K^{-1}}$

Thermal conductivity, K (4 wt %) $= \frac{Q\Delta L}{A(T2-T1)} = \frac{30(0.054)}{3.844\times10^{-3}(50.8-30.1)}$

$= \mathbf{20.359\ W.m^{-1}.K^{-1}}$

Thermal conductivity, K (6 wt %) $= \frac{Q\Delta L}{A(T2-T1)} = \frac{30(0.054)}{3.844\times10^{-3}(57.5-26.4)}$

$= \mathbf{13.421\ W.m^{-1}.K^{-1}}$

Thermal conductivity, K (8 wt %) $= \frac{Q\Delta L}{A(T2-T1)} = \frac{30(0.057)}{3.844\times10^{-3}(63.6-23.6)}$

$= \mathbf{11.121\ W.m^{-1}.K^{-1}}$

Thermal conductivity, K (10 wt %) $= \frac{Q\Delta L}{A(T2-T1)} = \frac{30(0.057)}{3.844\times10^{-3}(71.5-21.2)}$

$= \mathbf{8.844\ W.m^{-1}.K^{-1}}$

Thermal conductivity may be evaluated using the same method as above: power times distance divided by cross section times beginning temperature minus final temperature. Based on the experiment's findings, the power value has been set at 30 watts for each sample. The start and end temperatures are also included in the experiment data. In order to continue with the calculation for thermal conductivity, the value for the cross section must be determined using the cross section formula for a rectangle, which is cross section area equal to length times width. The cross section area for the above-determined cross section value is 3.844×10^{-3} m^2. The thickness of the specimen plus 0.01 for the distance to the first end point, multiplied by the starting temperature point's distance, is used to determine the distance value, d. As a consequence, the thermal conductivity value may be calculated using the thermal conductivity formula and the information that is previously known.

4.3.2 Thermal Conductivity Analysis

Table 4.3 Thermal conductivity of the specimen

Fiber (wt%)	Thickness (m^2)	Temperature (°C)		Thermal Conductivity ($W.m^{-1}.K^{-1}$)
		T1	T2	
2%	0.035	45.3	32.4	33.274
4%	0.034	50.8	30.1	20.357
6%	0.034	57.5	26.4	13.421
8%	0.037	63.6	23.6	11.121
10%	0.037	71.5	21.2	8.844

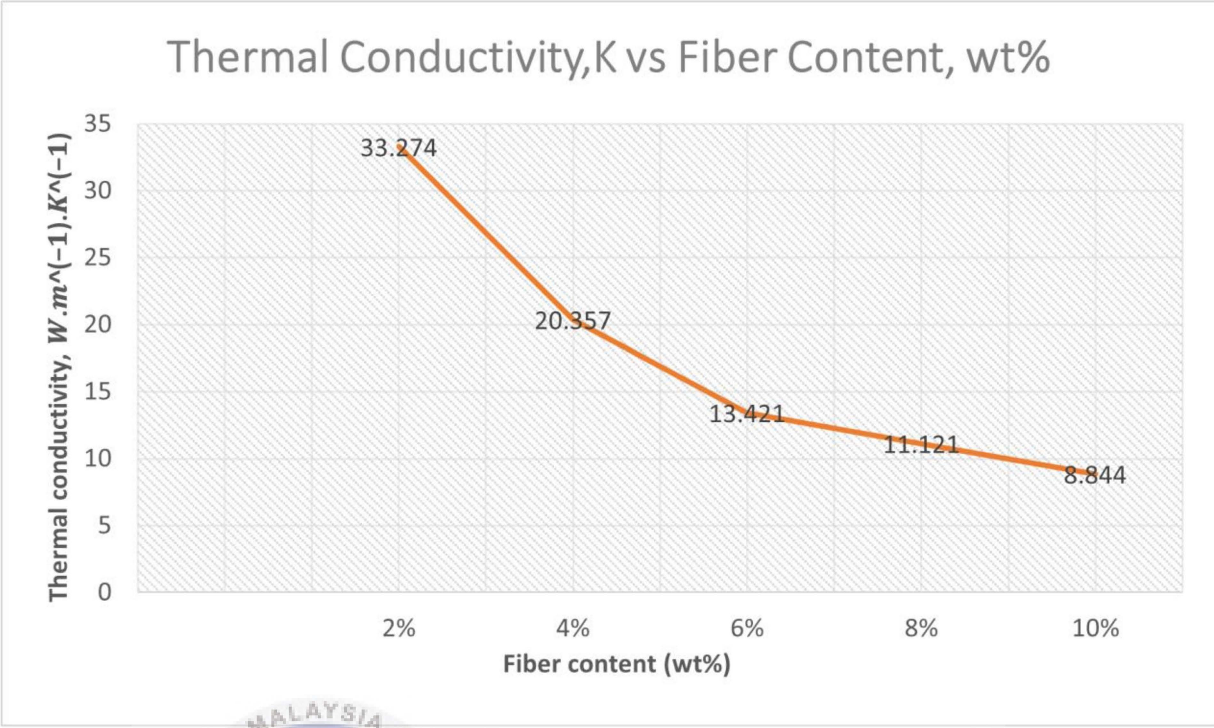


Figure 4.2 Thermal conductivity versus fiber content graph

Based on the graph, it is possible to make an analysis on the 2 wt % quantity of fibre. The thermal conductivity value of 2 wt % fibre, which is calculated using the thermal conductivity formula for each sample, is found to have the highest value, at 33.274 $W.m^{-1}.K^{-1}$. This reveals that the original sample, which was devoid of fibre, is inadequate for the projects goal of finding a material that can replace the existing material in the tent to be utilised as insulation against heat. This is as a result of the sample with two percent fibre dissipating far more heat than the other samples. The graph next depicts a decrease in the 4 wt % fibre sample. Thermal conductivity decreased from 33.274 to 20.357 W. $m^{-1}K^{-1}$ value. This illustrates that adding 4 wt % fibre to the sample slows the rate of heat transmission. This exhibits oil palm fiber's capacity to prevent heat from travelling through it. The third sample, which accounts for 6 wt % of the fibre content in the composite sample, had a reduction in thermal conductivity of 13.421 W. $m^{-1}.K^{-1}$. At 8% and 10% oil palm fibre content, the thermal conductivity value decreased by 2.3 and 2.2 from the baseline value to 11.121 W. $m^{-1}.K^{-1}$ and 8.844 W. $m^{-1}.K^{-1}$, respectively.

It is feasible to demonstrate that oil palm fibre has a favourable influence on composite materials by reducing their thermal conductivity values by conducting a research based on the difference in thermal conductivity values at 2 wt % and 4 wt %. Oil palm fibre has the ability to reduce the rate at which heat flows through a material. When compared to the contents of 2 wt % and 8 wt % fibre, this demonstrates that the thermal conductivity value of a material falls with increasing oil palm fibre concentration. This, however, affects how consistently and in what manner oil palm fibre is organised within a material.

4.4 Summary

The experimental findings are methodically put out in this chapter 4, where you can see the differences in thermal conductivity values for each honeycomb sandwich composite sample. Discussions and analyses were also carried out to assess the influence of differences in each sample's thermal conductivity value and fibre content %. Using the information and replies from this chapter, it is feasible to develop a conclusion about the project being carried out, which will be explained in chapter 5.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objective to obtain thermal conductivity of oil palm fiber / polyester panel with aluminium honeycomb sandwich on linear heat conduction test is completed. This thesis started with made some research on previous study and experimental that have been made to oil palm fiber as composite materials, other material are aluminium honeycomb that to be sandwich it with the composite to obtained thermal conductivity of the specimen with references to ASTM C177 and ASTM C518. This helpful to develop the methodology of this experimental study on composite sandwich on thermal properties. Next, the success of this objective is shown in the construction of a composite sample to be utilised as a specimen experiment using the procedure that has been established. Furthermore, the second objective is to evaluate the thermal conductivity performance of the honeycomb sandwich by varied oil palm fibre reinforcement in order to achieve the project's goal, where the thermal conductivity value for each sample provided, which is a sample with a difference in terms of the quantity of oil palm fibre, can be translated and analysed with good to make a comparison. Furthermore, the goal of studying the thermal absorption of the specimen under thermal conductivity prediction was accomplished.

Based on the observations discussed on previous chapter, it can be concluded that the amount of oil palm fiber loading in the composite panel will influenced the thermal absorption of the composite oil palm / polyester panel with aluminium honeycomb. It was discovered that oil palm fibre is a very effective thermal insulator, which is consistent with the basic objectives of this project, as the major goal of employing this honeycomb sandwich with oil palm reinforcement is for outdoor usage as a shelter. Furthermore, based on the findings of the experiment, the sample containing oil palm fibre had a lower thermal conductivity value. This totally supports the belief that oil palm fibre is a viable material for use as a composite, achieving the next project aim of requiring a lightweight and portable material. Nevertheless, the findings achieved in this experiment are greatly reliant on many major parameters, including the thickness of the composite during the test, the temperature employed during the experiment, and how uniformly and regularly the oil palm fibre is organised in the composite. This element has a significant impact on the findings acquired to guarantee that the results obtained are correct.

Lastly, oil palm fibre provides excellent properties for usage in a variety of sectors, including building. Because of this unique property of natural oil palm fibre, it will be in great demand in the future. Reinforced oil palm fibre is a good material to utilise as reinfocement for composites since it is highly durable, can insulate heat effectively, and has a low thermal conductivity value when compared to other fibre materials.

5.2 Recommendation

Some recommendations for future work can be made. The guideline for thermal testing of oil palm fiber polyester panel reinforced with aluminum honeycomb must be improved. The recommendations are as follows:

i) Type of resin

Despite the use of polyester resin, there were others resin types such that can be use such as vinyl ester resin, thermosetting polymer resin and others resin should also be research and studying to achieve improvement the mechanical and physical properties of composite oil palm fiber polyester with aluminum honeycomb.

ii) Testing method

The project's testing tool selection may benefit from some improvement. Because the testing tool is a linear heat conduction machine, a perfect measurement of the specimen with the machine's form is required, making this the first improvement suggestion because the tool is not appropriate for measuring the rate of heat flowing.

iii) Sample

Furthermore, because the insulating sample used is less compatible with the original speciment for the linear heat conduction experiment, heat spreading via the speciment gap is more likely when using this machine. Furthermore, more elaborate processes and tactics, such as levelling the composite surface, must be applied initially.

More elaborate processes and tactics, such as levelling the composite surface, must be applied initially. Before deciding to use low pressure manually, it became clear throughout the experiment that achieving a clean top surface for the composite was challenging. As a result, the experimental period is lengthened and sometimes complicated.

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APPENDICES

APPENDIX A Gantt Chart PSM 1

TIME (WEEK) / ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Attend Projek Sarjana Muda (PSM) briefing															
Identify title forPSM															
Meet SV and report discussion															
Finding the related journal, article,book for references															
Start drafting Chapter 1,2, and 3															
Draft report & slides submission to SV															
Final eLogbook,report and slide submission															

Presentation, Q&Awith a panel															

APPENDIX B Gantt chart PSM 2

NO	ACTIVITIES	October			November				December				January			
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Sem break	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
1	PSM 2 Briefing															
2	Material preparation															
3	Specimen fabrication															
4	Laboratary test															
5	Chapter 4 data and analysis															
6	Chapter 5 discussion and conclusion															
7	Conclusion and recommendation															
8	Full report revise by supervisor															
9	Submit 4 pages summary															

10	Submission of thesis report															
11	Submit Technical paper to panel															
12	Presentation for PSM 2															