DEVELOPMENT AND PERFORMANCE EVALUATION OF A THERMAL INSULATION MATERIAL FROM RICE STRAW USING HOT-PRESS

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering

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DECLARATION

I declare that this project report entitled “Develoment and Performance Evaluation of a Thermal Insulation Material from Rice Straw using Hot-Press” is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father

ABSTRACT

This study was conducted to develop the mechanical properties of the rice straw board as the building material. All the three samples were made up with same composition of 80% of low density polyethylene (LDPE) and 20% of the rice straw but different in pre-heating temperature which are 160 °C, 170 °C and 180 °C. The sample are being tested using three different test which is hardness test, tensile test and thermal conductivity to determine the mechanical properties of the rice straw board. Through this study, it can be concluded that sample with 180 °C of pre-heating temperature has the most suitable composition that can be applied as a building material. The rice straw board has the highest hardness, 42 with the lowest value of the thermal conductivity, *k*, 0.4858 W/mK. Furthermore, it also have the maximum load that can be applied to the sample, 167.623 N and also have the highest value of tensile stress, 4.298 MPa.

ABSTRAK

Kajian ini dijalankan untuk mengkaji sifat-sifat mekanik papan jerami padi sebagai bahan binaan. Kesemua tiga sampel terdiri daripada komposisi yang sama iaitu 80% daripada polietilena kepadatan rendah (LDPE) dan 20% daripada jerami padi tetapi berbeza dalam suhu pra-pemanasan iaitu 160 ° C, 170 ° C dan 180 ° C. Sampel ini diuji menggunakan tiga ujian berbeza iaitu ujian kekerasan, ujian tegangan dan kekonduksian terma untuk menentukan sifat mekanik papan jerami padi. Hasil kajian ini, dapat disimpulkan bahawa sampel dengan suhu 180 °C pra-pemanasan mempunyai komposisi yang paling sesuai yang boleh digunakan sebagai bahan binaan. Papan jerami padi ini mempunyai kekerasan tertinggi, 42 dengan nilai kekonduksian termal terendah, k, 0.4858 W / mK. Selain itu, ia juga mempunyai beban maksimum yang tertinggi yang boleh digunakan pada sampel iaitu 167.623 N dan juga mempunyai nilai ujian tegangan tertinggi, 4.298 MPa.

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LIST OF ABBREVIATIONS

MDI	Methylene Diphenyl Diisocyanate
pMDI	Polymeric Methylene Diphenyl Diisocyanate
UF	Urea-Formaldehyde
IB	Internal Bonding
TS	Thickness Swelling
PF	Phenol-Formaldehyde
PP	Polypropylene
PE	Polyethylene
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
EN	European Standard
MC	Moisture Content
MOR	Modulus of Rupture
ASTM	American Society for Testing and Material
HT11	Linear Heat Conduction
UTeM	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOL

E	=	Flexural Modulus
L	=	Support Span
b	=	Width
t	=	Thickness of the Sample
m	=	Slope of the Initial Straight Potion
S	=	Flexural Strength
P	=	Maximum Load
L	=	Support Span
σ_t	=	Tensile Test
w	=	Load Applied
h	=	Thickness of Experiment
q	=	Heat Flux Density
k	=	Thermal Conductivity
A	=	Cross-Sectional Area
$\frac{dT}{dx}$	=	Temperature Gradient
r	=	Radius of Sample
h	=	Height of the Sample
ρ	=	Density
m	=	Mass of Sample
V	=	Volume of Sample
π	=	3.142
I	=	Current
v	=	Voltage
W/mK	=	Watts per Meter Kelvin

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

Malaysia's tropical climate is extremely favourable for the production of various type of unique fruits and vegetables as well as palm oil and paddy. This country seldom affected by the hurricane or another natural disaster. Malaysia has a wetness level of 90% due to its location which is near to the equator. The climate is hot and wet all over the year which is appropriate for several sorts of agriculture such as rubber, oil palm, and rice. Hence, there'll be a leftover from agricultural production which might cause the hazards causing from burn the leftover or leave it to deteriorate in the ground. So, the application of waste material from agricultural production operation will contribute in reducing some waste management issues.

Rice straw is an agricultural waste which may perform as a raw material source for building material. Straw is defined as stems or stalks of certain agricultural product which can get from cereals especially wheat, rice, barley, oat and rye. When cereal crops are treated after being harvest, many types of "by-products" are created and every cereal crops containing variable amounts of chaff, straw, and weed seeds, as well as some grain (Hilman, 1981). Same goes to the rice straw. Rice straw could be a low-value material, renewable nature of straw, easy to find and even appropriate for building material. In the making of rice straw as building material, their physical, mechanical, thermal insulation and chemical properties should be considered.

The term of the thermal insulations is referred to the material that used to lessen the heat transfer rate, otherwise the ways and methods used to lessen heat transfer rate. Thermal insulation can keep surrounded area such as building become warm, or inside the building become cold. Rice straw tends to be fascinating material as the filler in biodegradable polymer composites, due to their good thermal stability compared to another agricultural residue (Lee, 2004a). One researcher assumed that the insulation value for the straw bale walls. The thermal conductivity for the bale straw walls is 0.04 W/mK (Stone, 1999).

Straw bales provide a decent thermal insulation value of 0.067 W/mK that abundant less than the wood and other building raw material (Goodhew, 2005). Other researcher mentioned that the straw bale building density is approximately 112 kg/m³ (Lerner, 2000). Most studies dealing with insulation material (cork, bark, rice straw, hemp, etc.) shows that the low densities between 170 kg/m³ and 260 kg/m³ and low thermal conductivity coefficients between 0.0475 W/mK and 0.0697 W/mK (Kain et al., 2013 ; Wei et. al., 2015; Ali, 2017) The best density for wheat and barley straw is approximately 133 kg/m³, while the ideal density of rice straw is approximately 123.6 kg/m³ (McCabe, 1993). Besides that, an experiment of low density boards with a mix of wheat straw and corn pith of has been done. The different experiment shows that the density of bale is between 54.6 kg/m³ - 78.3 kg/m³ for barley straw bales and 81 kg/m³ - 106.3 kg/m³ for each oat and wheat straw bales (Watts et al., 1995). Furthermore, another experiment has been done and the results show that the equilibrium wetness content is not affected by the density of the sample. The results also show that the thickness swell is larger than linear growth because of the orientation of fibers, parallel to the faces board (Wang, 2002).

In this study, the experiment is to seek out the effect of pre-heating temperature of rice straw board using hot-press, mechanical properties of the rice straw board and the properties of the rice straw as a thermal insulation board. Besides, this experiment will also determine whether or not the rice straw thermal insulation board tend to be interesting for energy saving when it is used in building insulation material.

1.1 PROBLEM STATEMENT

Brick is a core material that is commonly used to build the wall of building especially in Malaysia. At present, brick defects are usually found in buildings. This problem is getting more serious from time to time. Not everybody knows that in the brick making, it uses a very high energy used and can be the reason of environmental pollution as the wall materials have a major impact on the building progress. There are various ways should be taken to develop a new eco-friendly building material to protect the nature from being polluted and to overcome the energy consumption. One of the ways to protect nature is to produce an insulating material by using agriculture waste product or in other words from renewable resources such as wheat straw, oat straw and others. These agriculture waste have their own advantages as thermal insulating material due to the hollow structure, low in density and have great features of heat insulation. Furthermore, the uses of straw not only solve the problem of straw as a waste product but it also helps the building to be more comfortable during summer so that it fits with Malaysia's weather. So, an investigation will be carried out to develop the rice straw's ability to become a new thermal insulation material. Previously, an experiment was carried out using thermo-pressed straw-based thermal insulation due to its simple and efficient production process. However, the experiment took a very long time to prepare thick insulation materials from the traditional platen-pressing process. Therefore, to improve the rice straw thermal insulating properties and efficiencies, a hot-press machine is developed to consolidate the board and cure the adhesive.

1.2 OBJECTIVES

The following objectives are made in order to achieve the target of this study:

1. To produce the thermal insulation board from rice straw material using hot-press.
2. To test the performance of the rice straw board using hardness test, tensile test and thermal conductivity test.

1.3 SCOPE OF STUDY

The scope of the study are listed below:

1. The preparation of the rice straw and low-density polyethylene resin (LDPE) to produce a rice straw board.
2. The experiment will be carried out to test three different types of mechanical test to prove the mechanical and physical properties which are tensile test, hardness test and thermal conductivity test.
3. The hot-press machine will be used to consolidate the board and use a certain temperature which is between 160 °C to 180 °C.

CHAPTER 2

LITERATURE REVIEW

2.1 NATURAL FIBER

Natural fiber is fibers that are formed by plants, animals and geological processes naturally. There are so many kinds of natural fiber that have been found by researcher such as hemp, jute, rice straw, kenaf and others. These natural fiber have their own characteristics that fit to become thermal insulation material. Figure 2.1 shows the type of reinforcing natural fiber which is categorised into two categories. The natural fibers are the renewable sources that can be disposed at the end of its valuable life. This characteristic is called as biodegradable and it is an important characteristic that should have in a competent. High-strength fibers are used as reinforcements in composites materials and these contain steel fibers, glass fibers, synthetic fibers and natural fibers (Ede, 2014). Another researcher said that the insulation based on natural fibers have comparable and sometimes better thermal technical features for example heat capacity or the afore-mentioned thermal conductivity compared to the mineral wool (Hroudova, 2011).

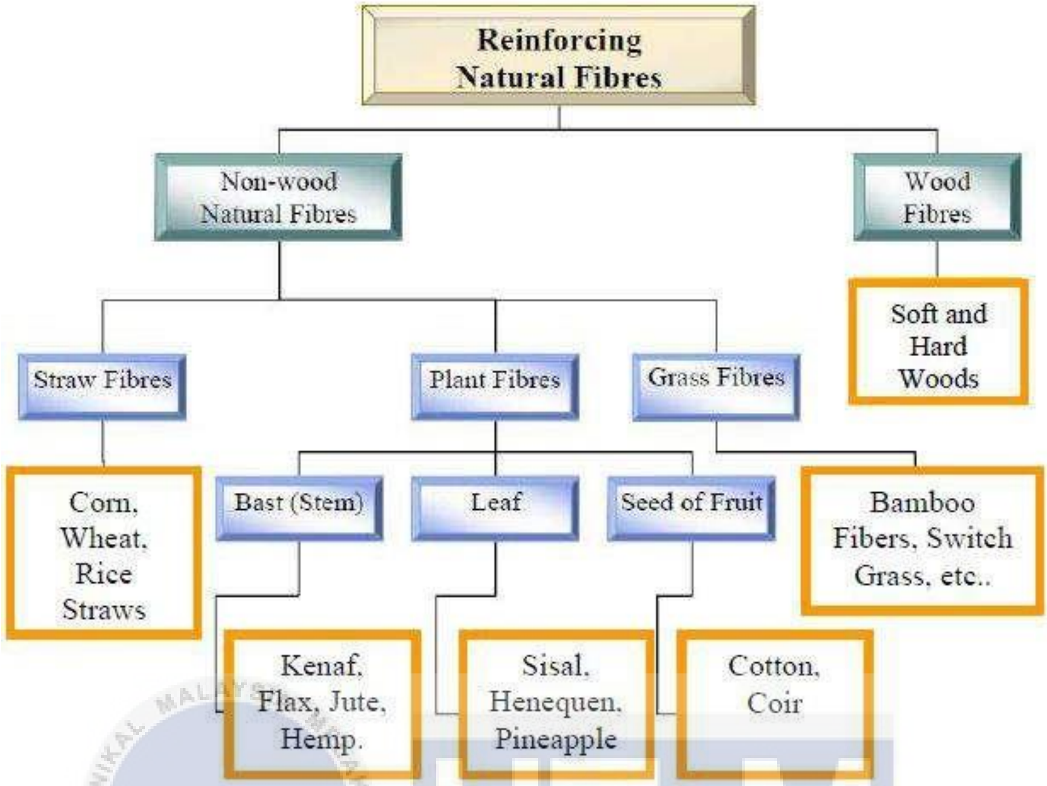


Figure 2.1: Categories of Natural Fibre

(Source: Ni, 1995)

2.1.1 Rice Straw

Rice straw's scientific name is Oryza sativa L which is the vegetative part of the rice plant. According to the researcher, the rice straw can be burned and left on the field before the next plowing, plowed down as a soil improver or used as a feed to the animals (Kadam et al., 2000). The rice straw can be cured in order to enhance its nutritional value. These treatments are aims to enhance the feed intake and digestibility of feed. This treatments can be improve through several treatments such as mechanical, chemical, heat and pressure treatments. In mechanical treatments, the rice straw can be cut and grinded that can reduce the time passage in the rumen and expand feed intake (Doyle et al., 1986). Between the numerous agricultural straws, rice straw possibly will be very fascinating materials as a filler in polymer composites since its thermal stability compared to the other agricultural waste. Besides, rice straw particles have a very great value of the porosity in the rice straw and among particles that leads the thermal insulation and humidity of the thermal insulating material (Wei et al., 2015). Rice straw might be used as a biodegradable eco-friendly reiorcement in polypropylene composites at end of use to shrink the environmental contamination instead of having a strong reinforcement effect. (Grozdanov, 2006).

2.1.2 Coconut Husk

Coconut husks are usually being wasted after the extraction of the coconut fruit. It has a high lignin and cellulose content. Coconut husk’s chemical composition contains of cellulose, lignin, pyroligneous acid, gas, charcoal, tar, tannin and potassium. This natural fiber can be altered into a fuel source with additional value which can be switched by wood and other traditional fuels. Furthermore, the coconut husk could be a good thermal conductivity and does not need a chemical binder to produce. However, if it is tends to be used in the construction sector, due to its high moisture content and water absorption (Panyakaew et al., 2008). Another researcher also proves that the coconut fibers can be used as a sustainably to enhance the properties of concrete especially in the tropics where this fiber is rich and are not used economically in the spirit of wealth waste (Anthony et al., 2015).

2.1.3 Jute

Jute is commonly grown in India and Bangladesh. It took two to three months to mature and then the whole thing was prepared to be harvest. The length of jute at this growth in maturity is between three to five meters**.** The jute is one of the inexpensive natural fiber and it is renewable resources. The jute fibers originated from the stem and ribbon (outer skin) and the fibers are extracted by the process of retting. The process of retting contains of bundling jute stalks and submerging them in slow water. After the recovery process, stripping process is carried out which is non-fibrous matter in the jute is scraped off. The fibers of jute are gained from the dig and grab process in the jute stem.

Korjenic et al. (2011) have found that a new renewable organic thermal insulating material containing of jute, flax and hemp and used bicomponent fibers as a binder with comparable building physics and mechanical properties for convectional insulation materials. Deepak (2015) also determined that even the mechanical properties of jute or polyester composites does not process strengths and modules as high as those of conventional composites but it have well strengths compared to wood composites and some plastics.

2.1.4 Bagasse

Bagasse is the fibrous matter which still stays after sugarcane stalks are being crushed to extract the juice. Besides, bagasse also well-known as a residue product from sugar production. Bagasse is made up of approximately 40% cellulose, 24% hemicellulose and 25% lignin. It is dry spongy waste which left after the extraction of juice from sugar cane. According to the data from the United Nations Food and

Agriculture Organization, the quantity of sugarcane produced in the world in 2010 was roughly 1711 trillion tonnes. In Malaysia, the extraction of juice in sugarcane are quite famous among the Malaysians. Instead of being wasting and waiting to be disposal, this bagasse can be treated by extracting the fiber that can be used to produce a valued product such as particle board and fibreboard. A potential solution is the revolution of bagasse into high quality panel products.

2.1.5 Sunflower

Sunflower or its scientific name Helianthus annus L is one of Turkey's leading industrial plants and cultivated mainly for oil production. Apart from that, the waste product of sunflower is used for animal feed, fertilizers or heat production. In Turkey, 700 hectares of land were used for sunflower agriculture farm and causing waste sunflower stalks about 3 to 3.5 million tons every year (Bektas, 2005).

Mati-Bouche et al, (2014) conducted an experiment to develop a new bio-based isolating composite made from chitosan and sun-flower's stalks particles. At the end of the result shows that the thermal conductivity of the composites is 0.056 W/mK have been gained with the proportion of chitosan of 4.3% and a particle grading better than 3 mm. Figure 2.2 shows that Jean-Denis (2015) concluded the main physical and chemical properties of the sunflowers.

	Bark	Pitch
Density (kg/m³)	350	29
Cellulose percentage (%)	48	31.5
Lignin percentage (%)	14	2.5
Porosity (%)	53	56
Diffusion coefficient (10^{-5}mm²/s)	1.4	110
Young's Modulus (GPa)	6.4	1×10^{-3}
Strength (MPa)	31	2.3×10^{-3}
Heat Capacity (J/kg.K)	1400	1300
Thermal Conductivity (W/mK)	0.12	0.039

	Bark	Pitch
Density (kg/m³)	350	29
Cellulose percentage (%)	48	31.5
Lignin percentage (%)	14	2.5
Porosity (%)	59	63
Diffusion coefficient (10^{-5} mm²/s)	3.8	200
Young's Modulus (GPa)	4.6	0.15×10^{-3}
Strength (MPa)	25	3.3×10^{-3}
Heat Capacity (J/kg.K)	1400	1300
Thermal Conductivity (W/mK)	0.12	0.039

Figure 2.2: Main Physical and Chemical Properties of Sunflower Stems

(Source: Jean-Denis, 2015)

2.1.6 Kenaf

Kenaf (hibiscus cannabinus L) is yearly herbaceous plant of the Malvacea family which can be grownup under a variety of climate conditions. Kenaf can to reach a height of three to five meters within three to five months and supplies between 12 and 25 t/ha of biomass per year when planting under warm and wet conditions (Paridah et al., 2011). The kenaf fibers also can are found in the bast (bark) and in the core (wood). Lignocellulosic fibers as well as kenaf may be possible raw material for the production of medium density fibreboard (MDF). MDF is a composite fiber material containing of refined wood fibers, adhesive (resin), processing additives and least wax amount.

2.2 BINDER

Binder is a material or element that used as a reinforced material which holds materials together and sometimes can be a filler in between them. Binder also is known as a resin or matrix. The binder perform as a glue which offers adhesion or coating in the making of natural fiber board. Kamke et al. (1996) believed that for a given resin content, a constant distribution of small resin spots produces particle boards with the best properties. There are two different types of synthetic binder which are thermoset and thermoplastic. Thermoset is well-defined as synthetic materials which strengthens during heating but cannot be reshaped or reheated successfully after its initial heat formation. The example of thermoset resin is amino resin, epoxy resin and polyurethanes resin. Meanwhile, the thermoplastic is defined as a material that become softer when heated and become hardens over again when cooled. The example of the thermoplastic resin is polyethylene resin, polypropylene resin and polyethylene resin.

Some researcher assumed that the solution of resin could be enter and diffuse into fibers too easily, since the fiber in the mixing procedure is wet and hot, which clarifies the higher consumption of resin (Frashour, 1990). Moreover, Roger et al. (1993) conclude that composite materials are categorised as natural synthetic and inorganic matrix composite as shown in Figure 2.3 below.

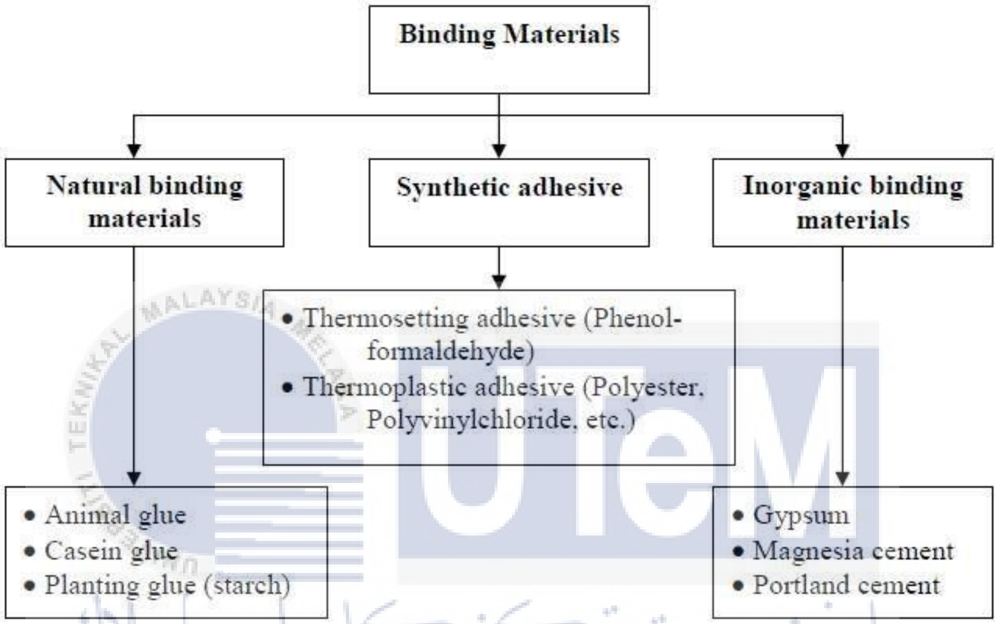
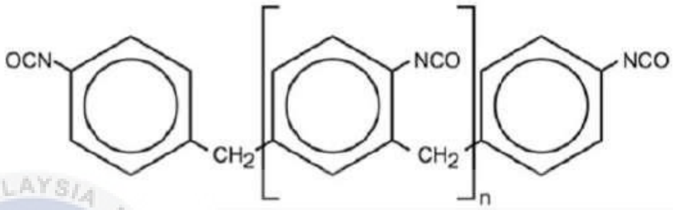


Figure 2.3: Types of Binding Materials

(Source: Roger et al., 1993)

2.2.1 Methylene Diphenyl Diisocyanate (MDI)

Methylene diphenyl diisocyanate (MDI) is used in the preparation of polyurethane resin and spandex fibers, and to bonding of rayon and nylon rubber. Figure 2.4 shows the structure of MDI found by Tury et al. (2003). Grigorious (1998) identified the straw was appropriate for the producing of high quality particleboard surface layers in mixture with polymeric diphenylmethane diisocyanate (pMDI) resin or mixture of urea-formaldehyde (UF) and polymeric diphenylmethane diisocyanate (MDI). MDI binders are irreplaceable and respond with both the moisture in the material and the hydroxyl groups, which make up the lignocellulosic furnish. Thitiwan et al. (2012) led an experiment subsequent in good physical, mechanical and thermal properties for thermal insulation from narrow-leaved cattail fibers bonded by MDI throughout hot-pressing process.



Polymeric MDI n = 0, 1, 2 ...

Figure 2.4: Structure of Polymeric MDI

(Source: Tury et al., 2003)

2.2.2 Epoxy

Epoxy is the thermosetting matrix or resin materials, having at least one or more epoxide groups in the molecule. The epoxide also formed as oxirane or ethoxyline group and is considered to be an epoxy polymer unit (Yu, 2009). The benefits and usage of epoxy resins can be attributed both to the resin chemical structure and hardener and to the network achieved after treatment (Alamri et. al, 2012). Another researcher used sunflower stalks and cotton textile waste to produce a thermal insulation materials with epoxy as a binder and then the results show that the samples had small coefficients of heat transfer (Binici et al., 2014).

2.2.3 Urea-Formaldehyde

Urea-formaldehyde (UF) resins are made by the response between the urea and formaldehyde. UF is one of the greatest important types of adhesive resins which is a polymeric condensation product of formaldehyde with urea and generally used to fabrication of wood-based composite panels such as plywood, particleboard and fiber board. In other words, the industry of wood panel is a main user of UF resin adhesive. The use of UF as a main adhesive by the forest products industry due to many benefits. The benefit of UF is low in cost, lost cure temperatures, water solubility, resistance to microorganisms and to abrasion, durability, superb thermal properties and lack of colour, exclusively for the cured resin. The weaknesses of UF are the lack of resistance to moist conditions especially in combination with the heat. So, UF resins are typically used for the fabrication of products intended for interior use only. Boquillon et al. (2004) found that the properties of UF resins in wheat straw particleboards were poor, specifically for strength of internal bonding (IB) and the thickness swelling (TS).

2.2.4 Phenol-Formaldehyde

Phenol-formaldehyde (PF) resin is also an alternative adhesive. It is a very heavy-duty resin and has an irreversible cure reaction. Regardless the costs is higher and temperatures raising up nowadays, PF also can be integrated into a fibreboard production plant by altering the temperatures to gain the required speed (Conner, 2001). The petrochemical-based phenol- higher pressure formaldehyde adhesive, has been frequently used in the production of wood-based panels (Yang et al., 2009).

2.2.5 Polypropylene

Polypropylene (PP) is one of the thermoplastic binders which have been used a lot in industries in the creating of a useful product. Thermoplastic is a material that hard when in cooled condition but become soft when heated. Anand (2008) said that any leftover material in the production cycle can be cut and reprocessed through the mixing stage due to the usage of thermoplastics. These materials have their own benefit of being eco-friendly due to the usage of PP.

2.2.6 Polyethylene

Polyethylene (PE) is also one of the thermoplastic binders which have been used a lot in the industries in the making of a useful product. There are two types of polyethylene such as high density polyethylene (HDPE) and low density polyethylene (LDPE). Figure 2.5 shows the result from an experiment by the researcher that used wheat straw filled with HDPE composites. It shows that the lower the percentage of the HDPE used, the higher the hardness of the composite.

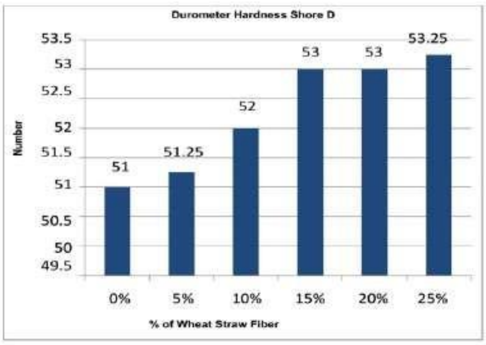


Figure 2.5: Variation in Hardness of Wheat Straw filled HDPE Composites

(Source: Dr. Sahai, 2017)

2.3 H0T-PRESS MACHINE

A hot-press machine is a high-pressure machine that used to consolidate and to cure the adhesive in the natural fiber board. During the hot-pressing process, the synthetic resin binder is commonly added to perform as a adhesive to the fibers together to form a composite material. Carvalho et al. (2003) believed that the hot-pressing process refers to a process where the board is under the combined temperature and pressure function. The function of the hot-pressing process is subjected to the evaporation of moisture to rise the density of board, the glue solidification and the distribution of waterproof agents and the compositions in the raw materials which are subjected to a series of physical and chemical fluctuations to form a bonding force among the fibers and form the products confirming to quality requirements. In the hot-pressing process, the energy is straight distributed into the full board and absorbed by the asymmetric molecules, and the energy is then changed into heat. The basic principle of hot-pressing is the application of heat, which can triggers the chemical components of the raw material used. Basically, the raw material is placed inside the mold and after that the mold is placed inside the hot-press machine. The mold will be pressed depends on the limitations set up. According to the researcher, an enough heat and pressure must be applied to melt down lignin throughout the full board, letting for a good distribution of lignin among the fibers through the manufacturing process (Mancera et al., 2008; Zhou et al., 2010).

2.4 COLD-PRESS MACHINE

A cold press molding process is also known as a closed mould process. Fibers are placed on the mold in the form of mats and overlap in the pinch-off area. Then, the resin is poured into the mold. After that, the press is lowered and the mold will closed. Figure 2.6 shows the example of cold press process. The only different between cold press and hot-press is only temperature. Hot-press process used a certain temperature and pressure to consolidate and cure the adhesives while cold press only use pressure to form the board.

Figure 2.6: Cold Press Process

(Source: Gabriela et al., 2018)

2.5 EFFECT TOWARDS RICE STRAW BOARD USING HOT-PRESS MACHINE

2.5.1 Thermal Insulation

The word of thermal insulation talk about to the material used to lessen the heat transfer rate and methods used to lessen the amount of heat transfer. Thermal insulation also means a material is skilful of blocking the transmission of heat from one side to another side straightforwardly. In the heat transfer, conduction is the thermal energy transfer adjoining molecules in a mixture due to a temperature gradient. Besides, thermal insulation prevents the heat from escaping or entering the container. Panyakaew (2011) mentioned that the manufacturing of low density thermal insulation boards made from coconut husk and bagasse without the use of chemical binding activities. The conclusions from the experiment are both thermal insulation boards have thermal conductivity values between 0.046 W/mK to 0.068 W/mK which were near to the conventional insulation materials such as cellulose fibers and mineral wool. The effective use of stalk bales as thermal insulation among the cover of buildings material were conducted by the rising numeral of successful existing projects all over the place in the world. (Thomson, 2014; Shea, 2013). These environment-friendly thermal insulation materials are best insulating components for building materials as wall or roof for energy conservation except for relative lower bonding strength and sensitive to moisture and humidity. The comparison of the thermal conductivity of the selected material and other materials that are stated in the literature is given in Table 2.1.

Table 2.1: Selected Material's Density and Thermal Conductivity

	Density (kg/m³)	Thermal Conductivity (W/mK)	Source
Oil Palm Fibre	100	0.0567	Manohar. 2012a
Sugarcane	686	0.0461	Manohar, 2012a
Coconut Husk with Phenol Formaldehyde	510 - 540	0.1036	Khedari et al., 2003
Bagasse	90 - 100	0.0483	Manohar et al., 2006
Corn Cub	211	0.1390	Pinto et al., 2012
Oil Palm Frond	108 - 141	0.0340 - 0.0830	Sihabut, 2010
Rice Hull	149	0.0449	Yarbough et al., 2005

2.5.2 Moisture Content

According to the researcher, most natural fibers absorb more moisture than the synthetic fiber (Swamy, 2004). Moisture content effects the processibility, shelf-life, usability, and product quality. Moisture content be influenced by on the circumstances at the time of baling and during subsequent storage and the transport. The effect of moisture content on thermal insulation conductivity varies with the kind of insulation depends on the composition, properties and internal structure of the material used that can be discover out the heat transfer condition and the capacity of the moisture storage of the material (Abdou, 2013). The composition of wood and straw of natural fiber are quite similar which is both of them consist largely of cellulose and inorganic content.

2.5.3 Board Density

Based on the previous research by Wei et al (2015) as shown in Figure 2.7, they discovered that the density of the rice straw thermal insulation board is higher, the thermal conductivity of the rice straw thermal insulation board is also higher. When increases the board density, the increasing of the solid substances and the decreasing of the voids in the board. The boards with the higher composition had the best mechanical and physical properties. Suleiman (1999) said that the solid substances are increases as the board density increases and decrease of the voids. The thermal conductivity of a solid substance is greater than the air as the part of the voids which leads to a higher conductivity of the entire material.

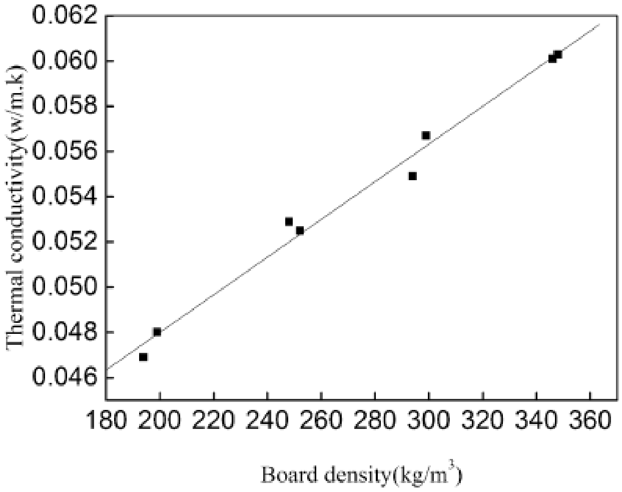


Figure 2.7: Effect of Board Density on Thermal Conductivity of Rice Straw Board

(Source: Wei et al., 2015)

2.5.4 Particle Size

Particle size is an important factor that effect the thermal conductivity of a thermal insulation board. The greater the quantities of fine particles with bigger surface need more adhesive, which can reduce the resin distribution of the unit area of the straw particles, thus decreasing the mechanical properties of the boards (Li, 2010). Yang et al. (2003) said that the composite boards with rice straw without assuming the dimension and wood particles with the specific gravities of 0.4 and 0.6 and found that the composite boards are appropriate to be a sound absorbing insulation in wooden constructions.

2.6MECHANICAL AND PHYSICAL TEST OF THERMAL INSULATION BOARD

2.6.1 Tensile Test

Tensile test is a test to develop reaction when something such as fiberboard were pulled apart when a force is applied to it in tension. Previously, an experiment was carried out by Zhang et al. (2016) where there are three specimens for the tensile test were cut from five bio-boards which named A, B, C, D, and E. The specimens from every board are made under different heating temperature. Based on that experiment, the relationship of stress-elongation for every specimen from five different bio-boards was similar. The rupture stresses of the tensile test were in the range of 3 MPa to 17.22 MPa.

2.6.2 Thermal Conductivity Test

Thermal conductivity is defined as the rate of heat is transferred by conduction through a unit cross-section area of a material, when the temperature gradient exists perpendicular to the area. It is well known that board density is one of the important factors that affect the mechanical properties of the board. Ferrandez-Garcia et al. (2017) said that the thermal conductivity value of the rice straw without binder panels using hot-press machine was so mean which in ranged from 0.076 W/mK to 0.091 W/mK. These values were not affects by the particle size nor the pressing time.

2.6.3 Flexural Test

Flexural testing generally used to determine the flex or bending properties of a material. The purpose of conducting the flexural test is to determine the flexural strength and flexural modulus. The definition of flexural strength is the maximum stress at the outermost fiber either on the compression or tension side of the sample while flexural modulus can be calculated from the slope of the stress-strain deflection curve. Previously, an experiment was carried out to determine the flexural properties of the rice straw fiber composites. Sudhakar et al. (2014) determine the average flexural strength and a flexural modulus from five specimens using equations (2.1) and equation (2.2).

Flexural Modulus:

$$E = \frac{Lm}{4bt^3} \tag{2.1}$$

where, (L) is the support span (64 mm), (b) is the width, (t) is the thickness of the sample, (m) is the slope of the initial straight portion of the load-deflection curve.

Flexural Strength:

$$S = \frac{3PL}{2bt^2} \tag{2.2}$$

where (P) is the maximum load, (L) is support span, (b) is the width, $(t)$is the thickness of the sample.

Based on the result, the higher the percentages weight of the rice straw, the less the flexural strength. The results were presented in Figure 2.8.

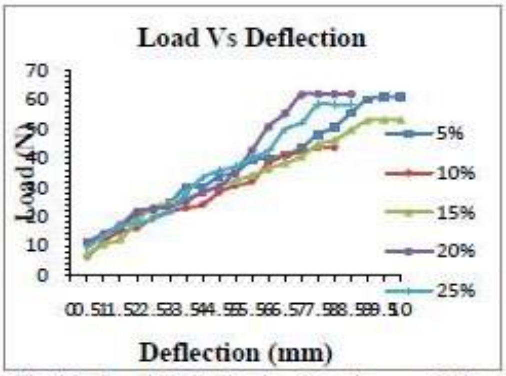


Fig 6.8: Load Vs Deflection for mixture of Rice Straw /PP composites

% Wt of Rice Straw	0%	5%	10%	15%	20%	25%
Flexural strength (MPa)	45.53	40.04	28.65	34.92	40.7	38.3

Table 6.7 (a): Flexural Strength vs Percentage Weight of Rice Straw

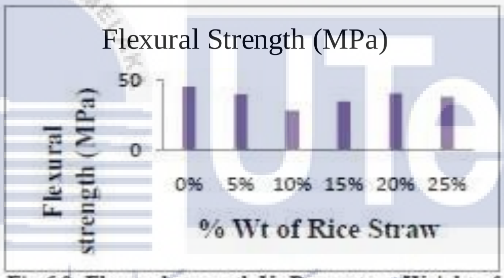


Fig 6.9: Flexural strength Vs Percentage Weight of Rice Straw

Figure 2.8: Result of Flexural Test

(Source: Sudhakar et al. 2014)

2.6.4 Thickness Swelling Test

Recently, an experiment was carried out by the researcher to investigate the increasing of ratio in the thickness after immersion in water for 24 hours. Sample with dimensions 50 mm × 50 mm × 40 mm was used. The thickness swelling (TS) of the specimens were examined according to the European Standard (EN) EN 1609. For the results, the change of the TS of rice straw thermal insulation board with the particle moisture content (MC) is shown in Table 2.2. Obviously, the higher the MC, the higher the TS of the rice straw thermal insulation board. It as shown the higher the MC, the increase the thermal internal bonding (IB) and the decrease of the modulus of rupture (MOR) of the rice straw thermal insulation board.

Table 2.2: Effect of Moisture Content of Rice Straw in Three Different Test

(Source: Wei et al., 2015)

MC (%)	**IB (MPa)**	**MOR (MPa)**	**TS (%)**
10	0.0127 (0.00059)	0.4 (0.028)	13.86 (0.62)
14	0.0132 (0.00054)	0.56 (0.032)	17.49 (1.24)
18	0.0112 (0.00076)	0.39 (0.034)	20.4 (0.92)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The materials and methods used in this experiment work are shown in this chapter with a detailed description of the process. Generally, this experiment is to determine the thermal insulation property and to produce the thermal insulation board from rice straw material using hot-press machine in different temperature but same pressure applied. The flow chart in Figure 3.1 will give a better view and explanation of this study. The flow chart has sequence and guides from the start till the end of the study. This flow chart also will explain the step in order to complete this study and also will help in solving the problem to make sure all the objective of this study are archived.

Initially, this study begins with the finding of the material to be used. Then, the process followed by the preparation of raw material which is the rice straw and polyethylene resin. After the preparation of rice straw particles and low density polyethylene (LDPE) resin, the fabricating process of the rice straw board using a hot-press machine will be done. To determine mechanical properties, the samples need to test using three types of test which are tensile test, hardness test, and thermal conductivity test. All the step in making the rice straw board were shown in this chapter.

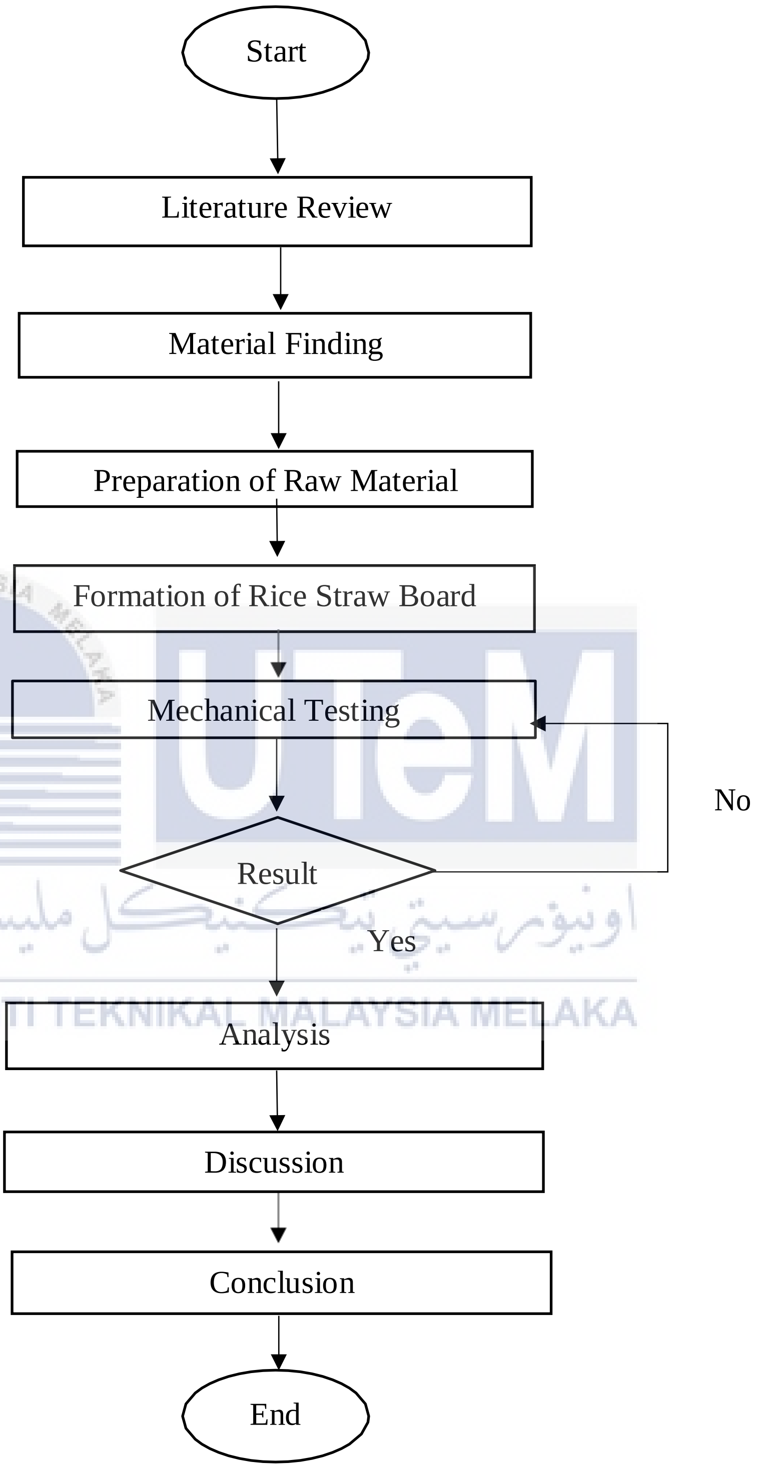


Figure 3.1: Flow Chart

3.2 PREPARATION OF MATERIAL

3.2.1 Preparation of Rice Straw

Figure 3.2 shows the process taken for the process of the dried paddy plant transformed into the rice straw particles. This process only takes 1-2 weeks to get the rice straw particles.

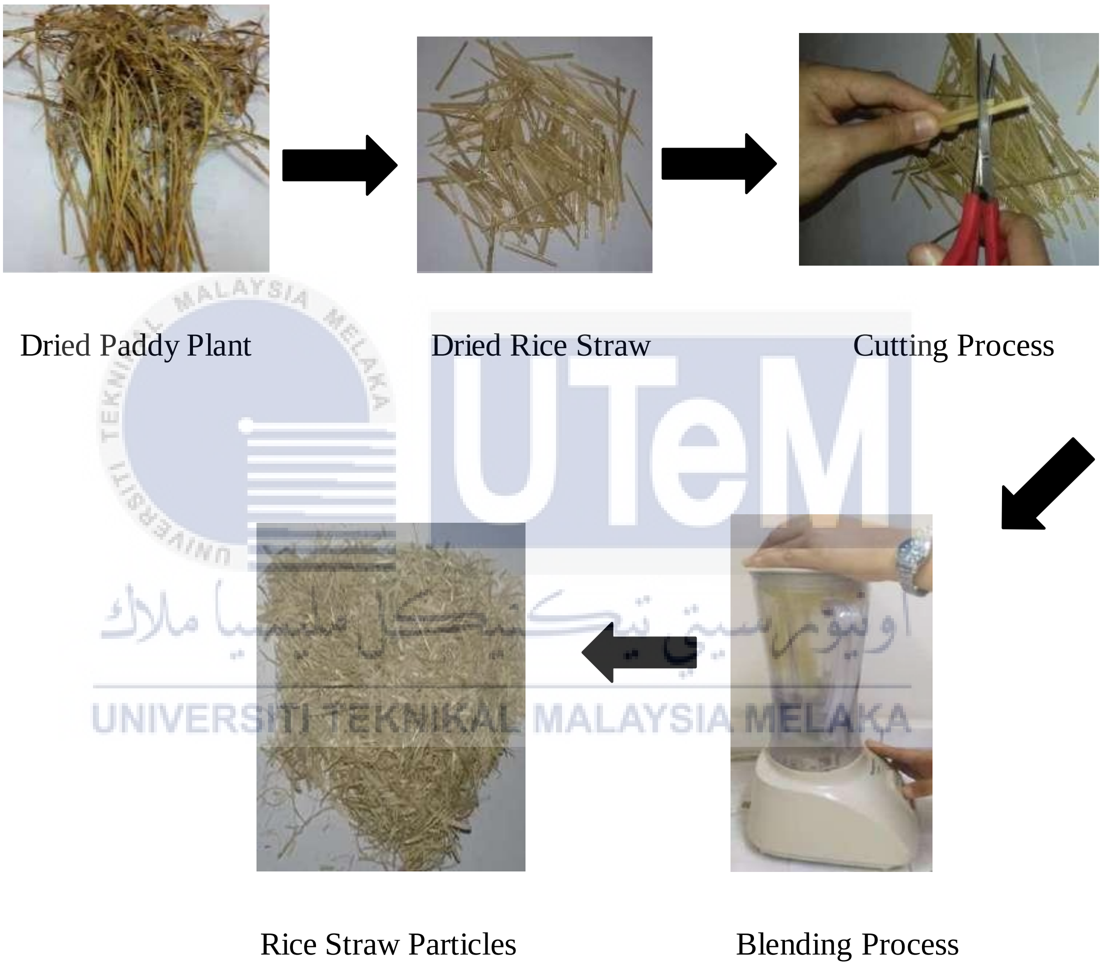


Figure 3.2: Preparation Rice Straw Particles

This process was started by the dried paddy plant were left under the sun until the rice straw is fully dried during sunny days naturally. After that, the dried paddy plant was cut until the rice straw is found in the rice stalk. If the rice straw does not fully dry, then the rice straw was left under the sun again until it fully dried. Next, the rice straw were chipped into the particles with a length of approximately 50 – 80 mm. Then, the rice straw was shredded up to 10 – 20 mm before being blended using 350 W blender machine. It took about 3 – 5 minutes to blend the rice straw to become the rice straw particles.

3.2.2 Formation of Low Density Polyethylene (LDPE) Resin

Figure 3.3 below shows the process of the formation of the low density polyethylene resin (LDPE) as a binder in this experiment and to hold the material together. This process took 2 weeks to get the polyethylene particles.

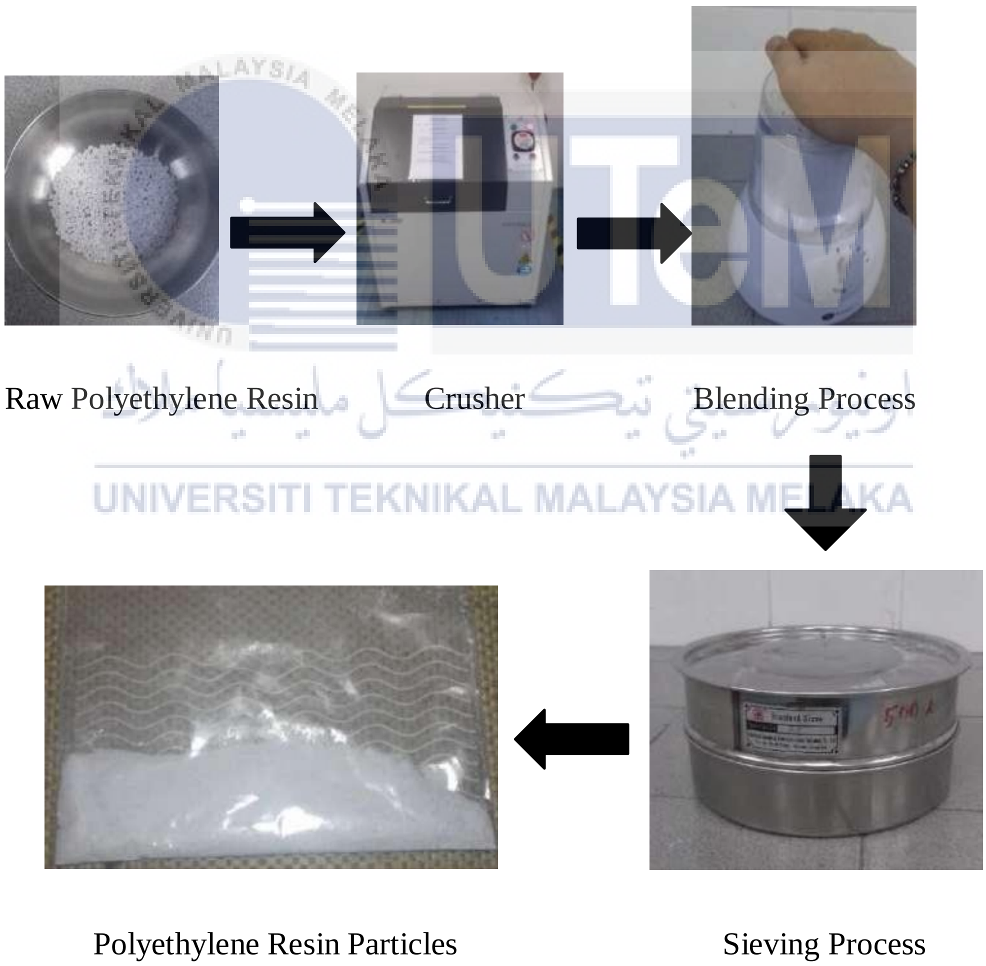


Figure 3.3: Formation of Polyethylene Resin

The raw polyethylene resin were put in the crusher machine which is available at Fasa B (UTeM). It took 500 s to become partially crushed. Then, the polyethylene that partially crushed were blended using a 350 W blender machine. It took 2 – 3 minutes to blend the polyethylene. After that, the sieving process was done in order to get a very fine polyethylene resin. The size of diameter used to sieve the polyethylene resin is 500 μm. After 2 – 3 minutes of the vibration, the end product of polyethylene resin particles was formed. This process were repeated from the first step until the last step to get more polyethylene resin.

3.2.3 Formation Rice Straw Board

In this study, rice straw and low density polyethylene resin (LDPE) are used in the formation of the rice straw board. The formation of the rice straw board were shown in Figure 3.4.

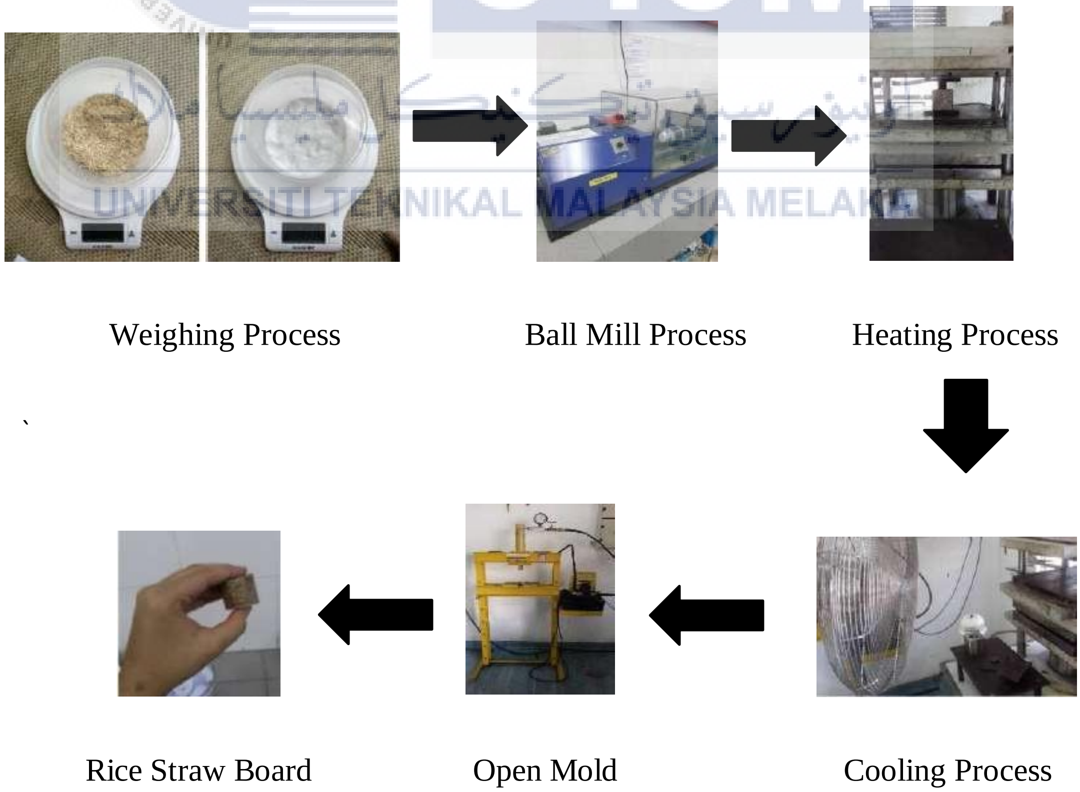


Figure 3.4: Formation Rice Straw Board

The formation rice straw board began with the process of weighing the rice straw particles and the polyethylene resin particle. In this study, the composition of the mixture made to form the rice straw board is 80% of low density polyethylene resin (LDPE) particles and 20% rice straw particles. The total mass of the mixture is 12.5 g.

After that, the mixture was poured into the bottle and then placed in the ball mill machine for 45 minutes in order to ensure the mixture is mixed well. Meanwhile, the hot-press machine is being heated up to 160 °C for pre-heated. After the mixture is mixed well, the 12.5 g of the mixture was filled carefully into the mold of the rice straw board with the dimension $140\ mm \times 60\ mm \times 3mm$.

When the temperature reached 160 °C, the mold filled the mixture was put inside the hot-press machine. Leaving it for 15 minutes for the heating process, then the compression process took place at the pressure of 500 psi for another 5 minutes. After the total time of 20 minutes, the mold has been taken out from the hot-press machine for the cooling process. This cooling process was set up to be at 15 minutes. Then, the rice straw board were taken out from the mold carefully using H-Frame 10 ton. These steps were repeated to another sample for 170 °C and 180 °C with rectangular shape mold.

3.3 HOT-PRESS MACHINE

The formation of the rice straw board process was conducted by using the hot-press machine, Motorise Hydraulic Molding Test Press machine shown in Figure 3.5. This machine will consolidate the board and to cure the resin.

Figure 3.5: Motorise Hydraulic Molding Test Press Machine

3.3.1 Mold

In this process, two types of mold that were used which are rectangular shape mold and cylinder shape mold. Rectangular shape mold is used for the tensile test and hardness test. Meanwhile, cylinder shape mold is used for the thermal conductivity test. Two pieces of OHP plastic sheet will be placed on the top and bottom surfaces of the mold to prevent the boards from sticking and easy to take out from the mold. The mold shape are shown in Figure 3.6 and Figure 3.7.

Figure 3.6: Rectangular Shape Mold

Figure 3.7: Cylinder Shape Mold

3.3.2 Procedure

Hot-Press Process

1. Switch on the temperature switch for the upper mold and the lower mold.
2. Set the desired temperature.
3. Adjust the pulley pressure to get the desired temperature.
4. Place the mold on the hot mold space after the machine has reached the desired temperature.
5. Press the compress button and press the stop button if the upper mold and lower mold meet and reach the desired pressure.
6. Switch on the timer switch and set the desired time.
7. Remove the mold after the process completed.
8. Switch off the temperature switch and timer switch.

3.4 SAMPLE PREPARATION

In this experiment, three samples of rice straw named A, B and C have the same dimension of rectangular shape of mold, while D, E and F have the same dimension of cylinder shape of mold. All the samples were prepared at the same applied pressure and same of pressing time which is 500 psi and 15 minutes. The only different in this experiment is the heating temperature which is between 160 °C until 180 °C.

Based on the literature review, researcher used to press rice straw/thermoplastic composite at 190 °C for 7 min at 30-35 bar (Hossein, 2016). Another researcher also used to press rice straw fibreboard at 150 °C for 20 min and 6MPa of pressure. (Wanrong et al., 2017). In the laboratory, the hot-press machine only used 180 °C for the maximum heating temperature. So, three different level of heating temperature will be applied on the board using the hot-press machine in the process of forming the sample which is 160 °C, 170 °C, and 180 °C. Table 3.1 shows the sample for tensile test and hardness test while Table 3.2 shows the sample for the thermal conductivity test.

Table 3.1: Sampling of the Rice Straw Board for Tensile Test and Hardness Test

Sample	Pressure (psi)	Temperature (°C)	Heating Time (min)	Pressing Time (min)	Cooling Time (min)
A	500	160	15	5	15
B	500	170	15	5	15
C	500	180	15	5	15

Table 3.2: Sampling of the Rice Straw Board for Thermal Conductivity Test

Sample	Pressure (psi)	Temperature (°C)	Heating Time (min)	Pressing Time (min)	Cooling Time (min)
D	500	160	15	5	15
E	500	170	15	5	15
F	500	180	15	5	15

3.4.1 Sample for Hardness Test and Tensile Test

Figure 3.8 and Figure 3.9 shows the sample that have been done by using hot-press machine. The samples will be used in hardness test and tensile test.

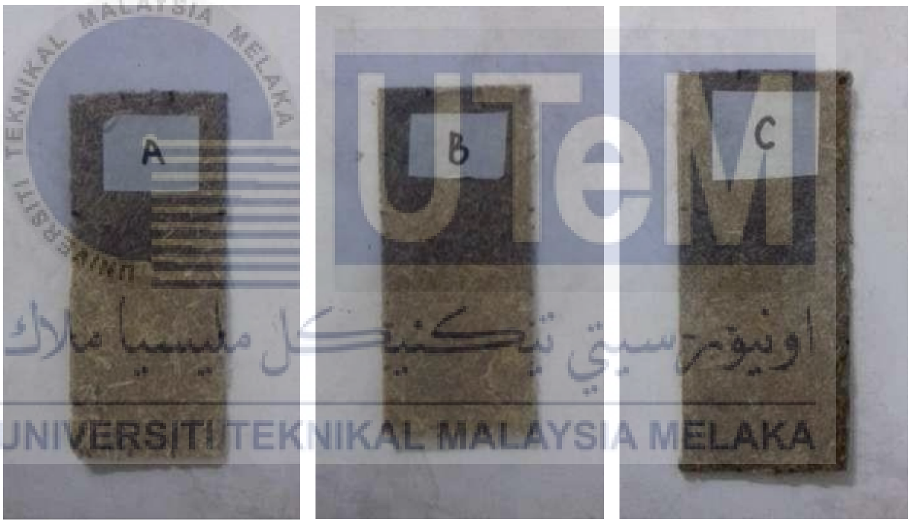


Figure 3.8: Sample for Hardness Test and Tensile Test

Figure 3.9: Sample for Hardness Test and Tensile Test after Cutting Process

3.4.2 Sample for Thermal Conductivity Test

Figure 3.10 shows the sample that have been done by using hot-press machine. The samples will be used in thermal conductivity test.

Figure 3.10: Sample for Thermal Conductivity Test

3.5 MECHANICAL TESTING

3.5.1 Hardness Test

The hardness test is a test that enables to evaluate rice straw board properties such as strength and ductility of the board. This test was carried out using Digital Shore Tester, Durometer in Figure 3.11. This test is based on American Society for Testing and Materials (ASTM) standard which is ASTM D2240. The dimension of the sample is shown in Figure 3.12.

Figure 3.11: Shore D Durometer

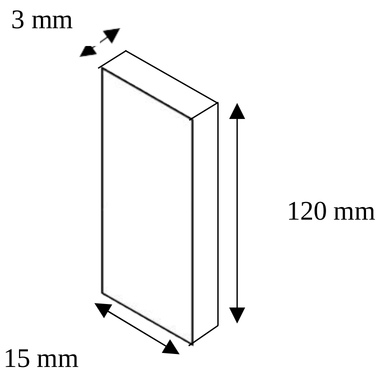


Figure 3.12: The Dimension of the Sample for Hardness Test

3.5.2 Tensile Test

Figure 3.13 shows the Instron R-8872 Universal Testing machine used for the tensile test. The purpose of this test is to determine how the rice straw board will react to forces that were applied in tension. As the rice straw board is being pulled, the strength of the rice straw board and how much it elongate will be seen. The dimension of the sample is 120 mm × 15 mm × 3 mm shown in Figure 3.14. The test is done based on American Society for Testing and Materials (ASTM) standard which is ASTM D638. 2 mm/min of load speed was applied while conducting the test.

Figure 3.13: Instron R-8872 Universal Testing Machine of Tensile Test

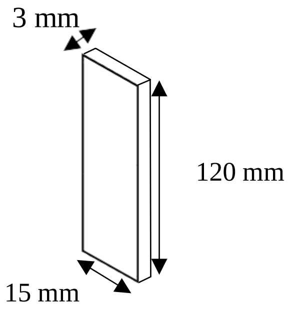


Figure 3.14: The Dimension of Sample for Tensile Test

In the tensile test, the samples will be cut from every sample board respectively. Tensile stress (σ_t) will be obtained by the results of the tensile test. The stress will be calculated using the equation 3.1:

$$\sigma_t = \frac{W}{bh} \tag{3.1}$$

where (σ_t) is a tensile stress,(W) is a load applied, (b) is the width of the experimental area, (h) is the thickness if the experimental area.

3.5.3 Thermal Conductivity Test

Armfield Linear Heat Conduction in Figure 3.15 is used to calculate the measurement of the heat flow and temperature gradient that enables to determine the thermal conductivity of the material. The design lets the thermal conductivity of thin samples of insulating material to be determined. Figure 3.17 shows the dimension of the sample that used the cylinder shape mold.

Figure 3.15: Armfield Linear Heat Conduction

Figure 3.16 shows the schematic diagram for the construction of Linear Heat Conduction (HT11).

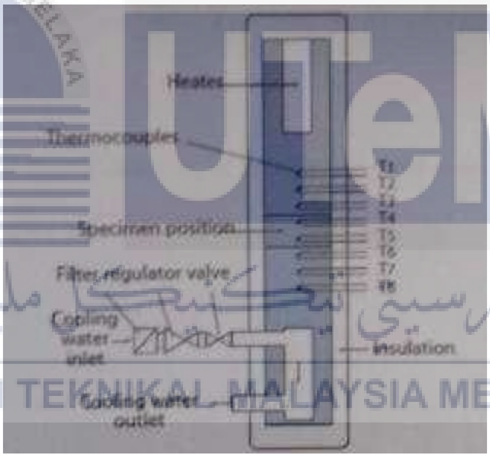


Figure 3.16: Schematic Diagram showing Construction of HT11

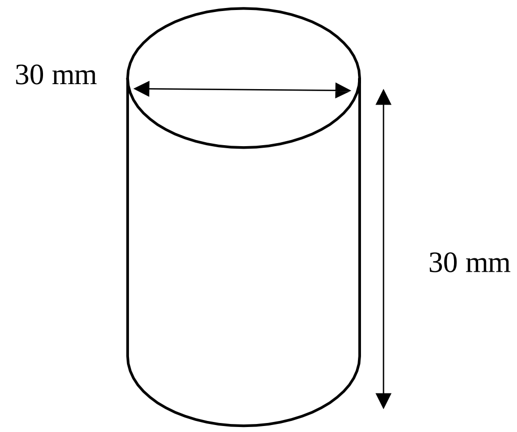


Figure 3.17: The Dimension of the Sample for Thermal Conductivity Test

Based on the measurements of the temperature and heat flux difference across the sample thickness, the thermal conductivity will be determined as shown in Eq. 3.2 and Eqn. 3.3.

$$q = -kA\left(\frac{dT}{dx}\right) \tag{3.2}$$

where, (q) is the heat flux density, (k) is the thermal conductivity, (A) is the cross-sectional area of the sample and $(\frac{dT}{dx})$ is the temperature gradient.

$$A_{surface} = \pi r^2 \tag{3.3}$$

where, (π) is 3.142, (r) is the radius of sample and (h) is the height of the sample.

Procedure:

1. Linear heat conduction experiment setup and the schematic diagram of the construction of the apparatus are shown in Figure 3.15 and Figure 3.16.
2. Clamp the sample section in place.
3. Switch on the front mains switch.

4. Turn on the cooling water and adjust the flow rate of water approximately 1.5 liters per minute. The actual flow can be checked using a stopwatch and measuring cylinder.
5. Set the Heater Voltage to 9 volts, Adjust the voltage control potentiometer to 9 volts on the top panel meter with the selector switch set to position V.
6. When the temperatures are stable record the current temperatures T2, T3, T6, T7 and T8 using the selector switch to select each required value in turn.
7. Repeat the procedure with a different sample.

CHAPTER 4

RESULTS AND DISCUSSION

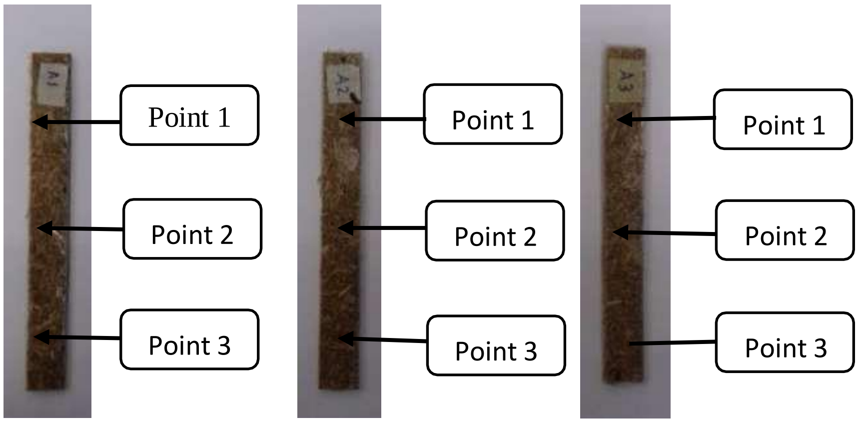
4.1 INTRODUCTION

This chapter presents the results and discussion of the work to achieve the objectives. The first objective of this study is to produce the rice straw board using hot – press machine. The rice straw board has been produced successfully in the previous chapter. In order to prove the mechanical and physical properties of the rice straw board that stated in the second objective, there are three types of test were conducted which are hardness test, tensile test and thermal conductivity test. So, in this chapter, all the result were shown to prove that all the objectives were achieved. The discussion and analysis of the result also stated in this chapter.

4.2 HARDNESS TEST

Hardness test was carried out using Digital Shore Tester Durometer. The dimension follows ASTM D2240 for composite materials. It is known that the test apparatus is dimensionless. Table 4.1, 4.2 and 4.3 shows the reading of the hardness test of the rice straw board with different sample while Figure 4.1, 4.2 and 4.3 shows the sample for hardness test. This test is taken at three different points. Then, the three reading were calculated to get the average reading. Then comparison was made in discussion afterwards.

Sample A (Heating Temperature = 160 °C)



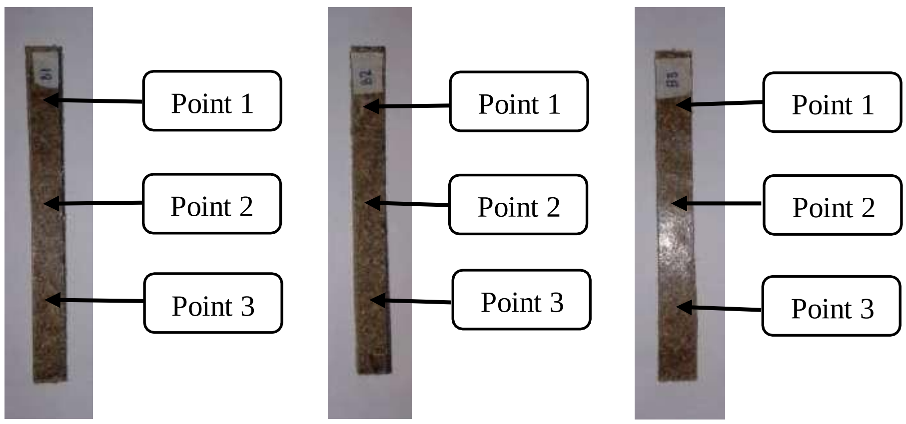
A1 A2 A3

Figure 4.1: Sample A

Table 4.1: Hardness Test Result for Sample A

Sample	Result			Average
	Point 1	Point 2	Point 3	
A1	22	12	19	17.67
A2	42	42	27	37.00
A3	22	36	19	25.67
Average				26.78

Sample B (Heating Temperature = 170 °C)



B1 B2 B3

Figure 4.2: Sample B

Table 4.2: Hardness Test Result for Sample B

Sample	Result			Average
	Point 1	Point 2	Point 3	
B1	22	29	37	29.33
B2	45	37	42	41.33
B3	41	39	34	38.00
Average				36.22

Sample C (Heating Temperature = 180 °C)

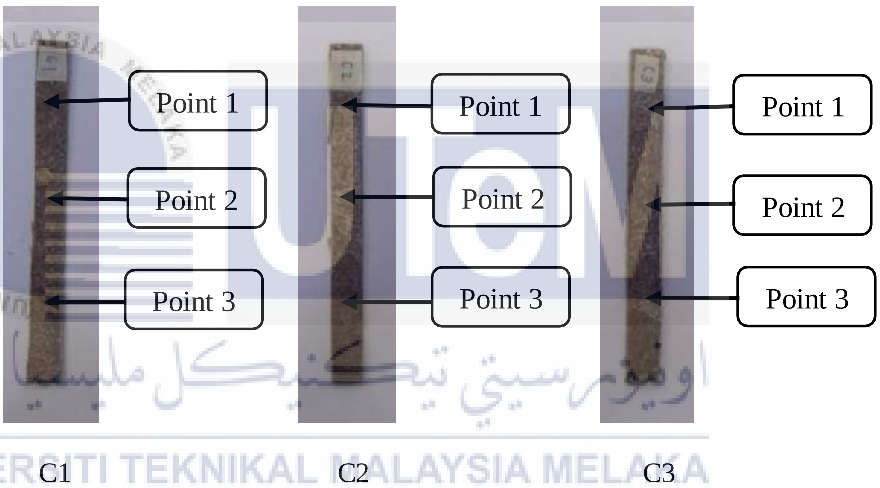


Figure 4.3: Sample C

Table 4.3: Hardness Test Result for Sample C

Sample	Result			Average
	Point 1	Point 2	Point 3	
C1	38	38	43	39.67
C2	41	48	44	44.33
C3	40	43	43	42.00
Average				42.00

Figure 4.4 shows the results of the hardness of the rice straw board against the heating temperature. Obviously, Sample C which has 180 °C heating temperature has the highest hardness than the other two samples which is 42.00 while sample A which have 160 °C heating temperature has the least value of hardness which is 26.78. Through this hardness test, it can be concluded that as the highest temperature of the hot-press during heating process, the highest the value of hardness of the rice straw board. This is because when the temperature of heating is higher, the bonding between particles becomes stronger. Besides, the lignin content of rice straw is higher which contribute the higher measured hardness of the board.

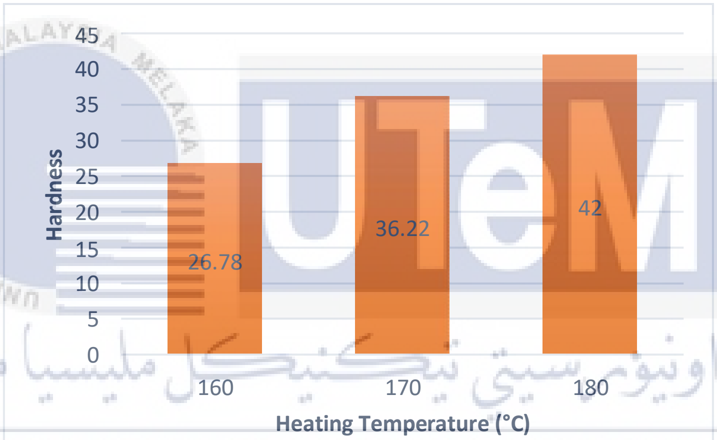


Figure 4.4: Average Hardness against Heating Temperature (℃)

4.3 TENSILE TEST

Tensile test was carried out using Instron R-8872 Universal Testing Machine. The tested sample used is the same as for the hardness test. Each sample were divided into three parts to get an average of maximum load and tensile stress. The dimension of the sample follows the standard ASTM D638 for composite materials. Table 4.4, Table 4.5, and Table 4.6 below shows the result from each sample from the tensile test.

Sample A (Heating Temperature = 160 °C)

Table 4.4: Tensile Test Result for Sample A

Sample	Maximum Load (N)	Tensile Stress at Maximum Load (MPa)
A1	85.204	2.185
A2	147.993	3.795
A3	84.969	2.179
Average	106.055	2.720

Sample B (Heating Temperature = 170 °C)

Table 4.5: Tensile Test Result for Sample B

Sample	Maximum Load (N)	Tensile Stress at Maximum Load (MPa)
B1	104.211	2.672
B2	90.352	2.317
B3	155.659	3.991
Average	116.741	2.993

Sample C (Heating Temperature = 180 °C)

Table 4.6: Tensile Test Result for Sample C

Sample	Maximum Load (N)	Tensile Stress at Maximum Load (MPa)
C1	152.996	3.923
C2	141.487	3.628
C3	208.387	5.343
Average	167.623	4.298

Based on the Figure 4.5, it is obviously shown the average value of maximum load and the average value of the tensile stress is raising up as the temperature of the pre-heating of the rice straw board increase. The rice straw board that have temperature of 160 °C heating gives the lowest average value of maximum load and tensile stress. Meanwhile, the rice straw board that have heating temperature of 180 °C give the highest average value of maximum load and tensile stress. This is because when heating temperature is higher it makes the bonding between particles becomes stronger. Obviously, with the higher rice straw content, the interfacial area between rice straw and low-density polyethylene (LDPE) is increased. Through the past studies, the researcher conclude that the result of the tensile test were in the range of 3 MPa to 17.22 MPa. By referring that result, the result from this study is acceptable because the maximum tensile stress at the maximum load is 4.298 MPa.

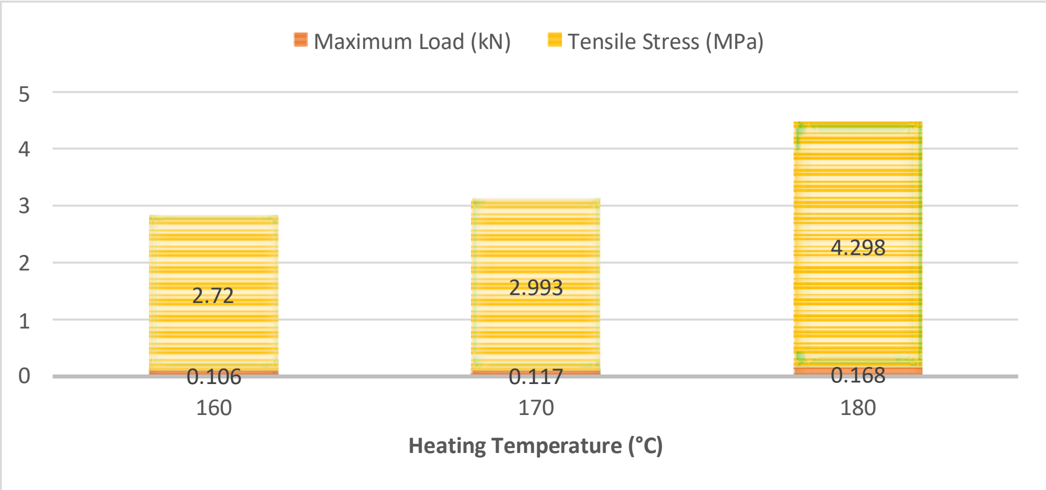


Figure 4.5: Average Maximum Load (kN) and Tensile Stress (MPa) against Heating Temperature (°C)

4.4 THERMAL CONDUCTIVITY TEST

Thermal conductivity test was conducted using Armfield Linear Heat Conduction. Table 4.7 shows the data for thermal conductivity test. Cylinder shape of sample were used in this test to get the value of the thermal conductivity, *k*.

Table 4.7: Data for Thermal Conductivity Test

	T2 (°C)	T3 (°C)	T6 (°C)	T7(°C)	T8 (°C)
Sample D	80.5	80.2	28.3	28.2	27.9
Sample E	96.1	95.6	28.3	28.2	27.9
Sample F	103.6	102.9	28.3	28.2	27.9

4.4.1 Calculation of Thermal Conductivity, *k*

Voltage (V): 9 V

Current (I): 0.095 A

Diameter (mm): 30 mm

Length Sample (mm): 30 mm

Area of sample (A) = πr^2

$= \pi(15 \times 10^{-3})^2$

$= 7.0686 \times 10^{-4}\ \mathrm{m}^2$

Power (Q) = IV

= 9 (0.095)

= 0.855 watt

Sample D (Heating Temperature = 160 °C)

$$T_{hot} = T_3 - \frac{T_2 - T_3}{2} \qquad T_{cold} = T_6 + \frac{T_6 - T_7}{2}$$

$$= 80.2 - \frac{80.5 - 80.2}{2} \qquad = 28.3 + \frac{28.3 - 28.2}{2}$$

$$= 80.05\ °C \qquad = 28.35\ °C$$

$$\Delta T = T_{hot} - T_{cold}$$

= 80.05 – 28.35

= 51.70 °C

$$k = \frac{Q(\Delta L)}{A(\Delta T)}$$

$$= \frac{(0.855)(30\times10^{-3})}{(7.0686\times10^{-4})(51.70)}$$

$$= 0.702\ {}^{W}/_{mK}$$

<u>Sample E (Heating Temperature = 170 °C)</u>

$$T_{hot} = T_3 - \frac{T_2 - T_3}{2}$$

$$= 95.6 - \frac{96.1-95.6}{2}$$

$$= 95.35 °C$$

$$T_{cold} = T_6 + \frac{T_6 - T_7}{2}$$

$$= 28.3 + \frac{28.3-28.2}{2}$$

$$= 28.35\ °C$$

$$\Delta T = T_{hot} - T_{cold}$$

$$= 95.35 - 28.35$$

$$= 67\ °C$$

$$k = \frac{Q(\Delta L)}{A(\Delta T)}$$

$$= \frac{(0.855)(30\times10^{-3})}{(7.0686\times10^{-4})(67)}$$

$$= 0.5416\ {}^{W}/_{mK}$$

<u>Sample F (Heating Temperature = 180 °C)</u>

$$T_{hot} = T_3 - \frac{T_2 - T_3}{2}$$

$$= 102.9 - \frac{103.6-102.9}{2}$$

$$= 102.55\ °C$$

$$T_{cold} = T_6 + \frac{T_6 - T_7}{2}$$

$$= 28.3 + \frac{28.3-28.2}{2}$$

$$= 28.35\ °C$$

$$\Delta T = T_{hot} - T_{cold}$$

$= 102.55 - 28.35$

$= 74.2\ °C$

$$k = \frac{Q(\Delta L)}{A(\Delta T)}$$

$$= \frac{(0.855)(30\times10^{-3})}{(7.0686\times10^{-4})(74.2)}$$

$$= 0.489\ {}^{W}/_{mK}$$

Based on Table 4.8 and the graph shown in Figure 4.6, it shows that the value of thermal conductivity is sloping downwards as the temperature of heating increase. It is shown that sample F has the least value of thermal conductivity which is 0.4859 W/mK while sample D has the highest value of thermal conductivity which is 0.702 W/mK. From the past studies, rice straw tends to be good materials as a filler in the polymer composites since their good thermal stability compared to the other agricultural waste. The higher the temperature of the pre-heating, the lower the value of the thermal conductivity, *k*. This is because natural fiber are well known their low density and the great value of thermal conductivity. Besides, rice straw also have a great porosity value in the rice straw among particles, which affect the thermal insulation and the humidity of the thermal insulation. Thus, the value of thermal conductivity, *k* that close to 0 is good for thermal insulation for building purpose. This condition can lessen the heat transfer through the composite and present the better thermal insulation properties.

Table 4.8: Thermal Conductivity Value

Sample	Thermal Conductivity $\left({}^{W}/_{mK}\right)$
D	0.7020
E	0.5416
F	0.4859

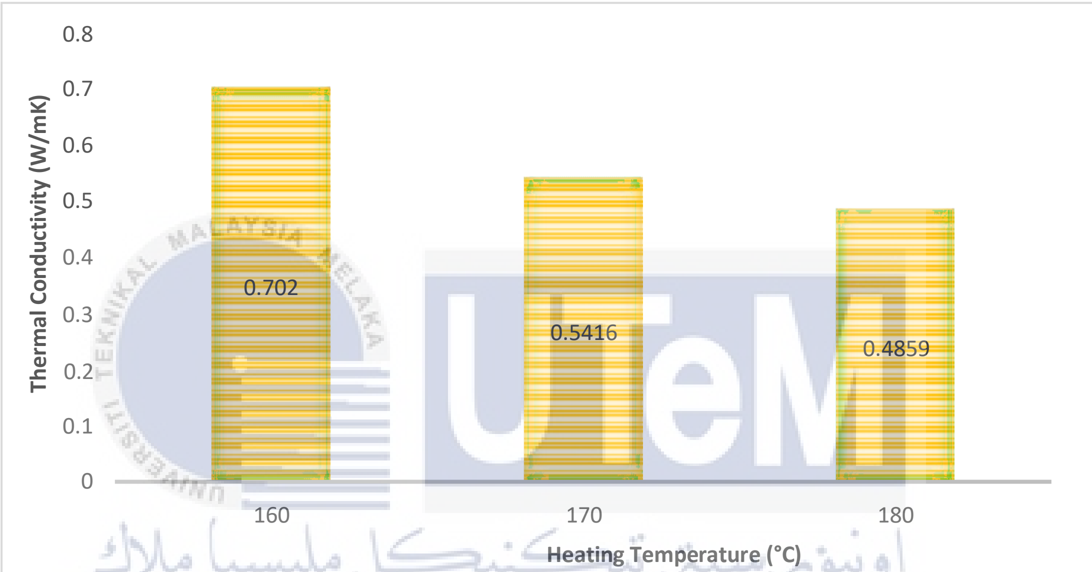


Figure 4.6: Thermal Conductivity (W/mK) against Heating Temperature (°C)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Generally, the study is about determined the mechanical properties of the rice straw board. The exact technique of fabricating the rice straw board can contributes the mechanical properties of different heating temperature. Due to the different heating temperature, the comparison between the results from mechanical testing were done in order to decide the best sample are being selected to be applied in applications of the building material.

The properties of the rice straw and polyethylene composites show that the rice straw tends to become as a biodegradable eco-friendly building material. Hence, can reduce the environmental pollution that become more serious from time to time.

The most suitable of the rice straw board that can be applied as building material is the highest value of heating temperature with 180 °C. The rice straw board has the highest hardness, 42 with the lowest value of the thermal conductivity, *k*, 0.4858 W/mK. Furthermore, it also have the maximum load that can be applied to the sample, 167.623 N and also have the highest value of tensile test, 4.298 MPa.

All the process had been successfully done and kept on track followed the Gantt charts that are presented in the Appendix.

5.2 RECOMMENDATION

From the study conducted, there are several recommendation can be done in order to enhance the results of the mechanical testing such as:

i. More sample should be made and tested in order to show more difference of mechanical properties among the samples.

ii. The mechanical properties of the rice straw board could be improve by modification composition of the rice straw and the low density polyethylene (LDPE).

iii. More types of test should be done suchas flexural test and impact test in order to prove the mechanical and physical properties of the rice straw board.

iv. Varies testing parameter such as heating time, compression time and cooling time.

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APPENDICES

GANTT CHART

GANTT CHART FYP (SEMESTER 1)

TASK NAME / WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Discussion with supervisor														
Research project														
Writing Chapter 1														
• Introduction/ Background														
• Problem statement														
• Objectives														
• Scope of Study														
• General Methodology														
Progress Report Submission														
Writing Chapter 2														
Writing Chapter 3														
Presentation Preparation														
Proposal Submission														

GANTT CHART PSM 2 (SEMESTER 2)

TASK NAME / WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Discussion with Supervisor														
Preparation of raw Material														
Preparation of Rice Straw Board														
Experimental Testing														
Literature Review														
Writing Chapter 3														
Writing Chapter 4														
Progress Report Submission														
Writing Chapter 5														
Presentation Preparation														
Report Submission														
Seminar														