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

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2019

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 ℃, 170 ℃ and 180 ℃. 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 ℃ 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.

ACKNOWLEDGEMENTS

Praise to Allah Almighty who has guided me along the journey of completing this study successfully. Without His helps and guidance, I would never been able to achieve what I have accomplished now. Every person and detail that has come along of this work is a result of His blessings. A big thanks to my family especially my beloved parents, Ismail bin Harun and Hamidah binti Mohammad Wali have supported me along the way with their countless efforts to get me through this undertaking such as providing me advices, financial supports and much more than that cannot be written down in a single page. They deserve my gratitude after God and His Messenger. My deepest gratitude goes to my supervisor, Dr. Md Isa bin Ali for giving me much time, attention and guidance to make sure I am success in this study. He is very patient and encouraging in finishing my work. I also wish to acknowledge the Mechanical Engineering Laboratory staffs especially, Mr. Mohd Rizal bin Roosli, Mr. Faizal bin Jaafar and Mr. Wan Saharizal bin Wan Harun who helped me a lot and provided me with the place and the equipment to do the research work. Finally, I took this opportunity to thank all the people that I might have missed mentioning in this section for your time and support in producing this final year project. Thank you to everyone especially my housemates for being there for me, your support will never forgotten and shall be rewarded by Allah.

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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/m^3 (Lerner, 2000). Most studies dealing with insulation material (cork, bark, rice straw, hemp, etc.) shows that the low densities between 170 kg/m^3 and 260 kg/m^3 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/m^3, while the ideal density of rice straw is approximately 123.6 kg/m^3 (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/m^3 - 78.3 kg/m^3 for barley straw bales and 81 kg/m^3 - 106.3 kg/m^3 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).

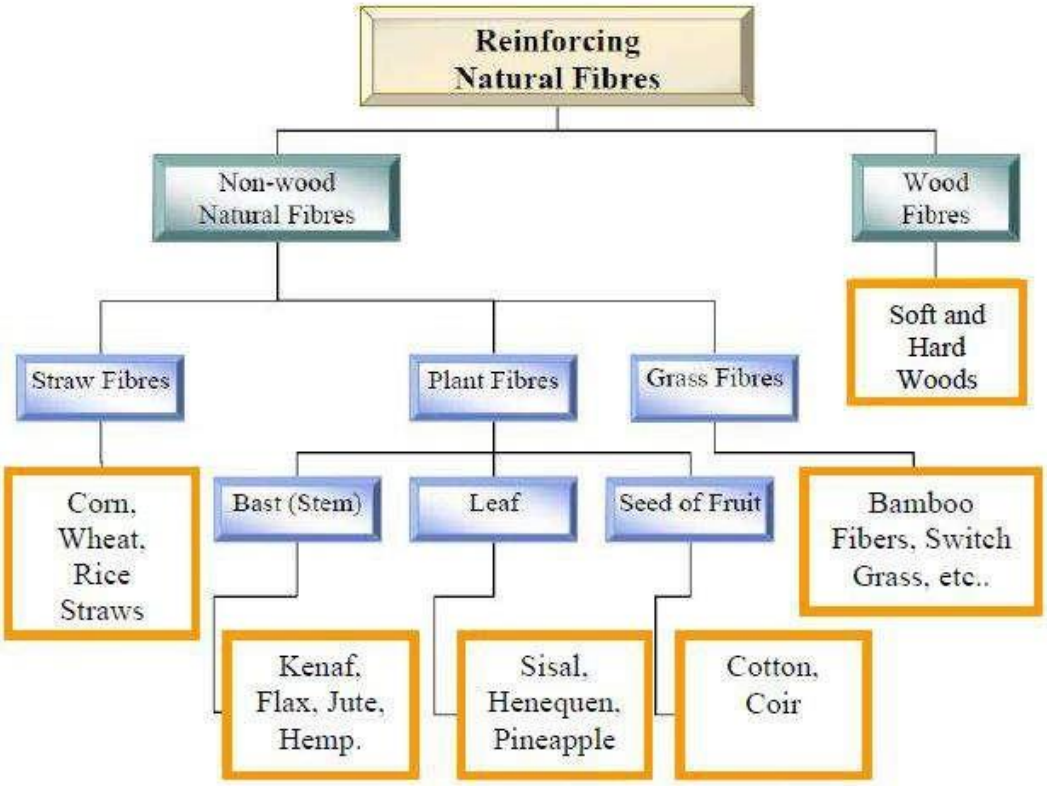

Figure 2.1: Categories of Natural Fibre

(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