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Faculty of Mechanical and Manufacturing Engineering Technology

PREPARATION OF CEMENT MORTAR WALL INCORPORATED WITH COCONUT OIL/PARAFFIN EUTECTIC PHASE CHANGE MATERIALS (PCM) FOR BUILDINGS PASSIVE COOLING APPLICATIONS

MUHAMMAD MUSTAQIM BIN ROSMAN RIZAL

B091910381

Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours

2023

DECLARATION

I declare that this Choose an item. entitled “Preparation of the Cement Mortar Wall Incorporated with Coconut Oil/Paraffin Eutectic Phase Change Materials (PCM) for Buildings Passive Cooling Application” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : MUHAMMAD MUSTAQIM BIN ROSMAN RIZAL

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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 (Refrigeration And Air-Conditioning Systems) with Honours.

Signature : ....

Supervisor Name : ALUDIN BIN MOHD SERAH
Pensyarah
Jabatan Teknologi Kejuruteraan Mekanikal
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

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DEDICATION

This study is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave the strength when I thought of giving up, continually provided the moral, spiritual, emotional and financial support.

To my beloved brother, sisters, friends, mentor and classmate always share the words of advice and encouragement to finish my study.

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ABSTRACT

Compressor-driven air conditioning systems are most popular methods to meet the ever increasing demand for cooling in buildings sectors. The obvious drawback of these air-conditioning devices is the high electrical energy consumption. Building sectors in Malaysia consume almost 14.3% of total energy, with residential and commercial buildings accounting for 53% of total energy consumption. To produce electricity, power generation stations require to use coal or gas as it combustion sources. This releases particularly CO_2 gas to atmosphere and contribute to global warming. Another detrimental consequences of utilizing conventional vapour-compression refrigeration systems is the high ozone deplection potential (ODP) posses by the refrigerant used as working fluids in the systems particularly when the refrigerant leak to atmosphere. Therefore, it is important to develop new energy-efficient technologies in buildings sector for air-conditioning applications. For example, incorporation of phase change material (PCM) into building materials could increase the thermal inertia of buildings thus provide thermal comfort for the occupants and reduce the electric energy consumption. PCM utilized the night temperature swing to absorb heat from the inner space of a buildings when the temperature rise above the PCM melting temperature. During this phase change process, PCM melts. At night when the surroundings temperature drops, the PCM solidify back to its solid state. Therefore, PCM-incorporated buildings materials could be utilized as a mean of passive cooling of buildings in hot climates. The main purpose of this study is to prepare macroencapsulated PCM that can be incorporated into cement mortar wall. The eutectic PCM is prepared by mixing paraffin and coconut oil at various mixing ratio to obtain the optimal mixing ratio that suit the thermal comfort temperature at 26^0C~28^0C. Both coconut oil and paraffin are organic PCM that most compatible with buildings materials. The optimum eutectic PCM is of mixing ratio 95% coconut oil and 5% paraffin wax, with a melting point of 28^0C. Adding more coconut oil and reducing paraffin wax mass resulted in lower melting points. However, this temperature range is not suit with Malaysia climate in particularly. The PCM applications are hindered by the low thermal conductivity of the PCM-incorporated building materials. To optimize heat transfer via enhancement of thermal conductivity, the shell for the macroencapsulated PCM were made of two different materials i.e., clay and aluminium ring. The thermal performance of the PCM-incorporated cement mortar wall was investigated using a reduced-scale test room, outdoor test and night to days simulation test. Based on the reduced-scale thermal test, the aluminium ring MPCM incorporated with mortar achieves a stable temperature in the approximately of 31^0C on the mortar wall surface when exposed to 35^0C. Increasing the quantity mass of PCM resulted in 1.3^0C lower mortar wall surface temperature. The cubicle PCM mortar show the ability to act efficiently as a latent and sensible thermal energy storage. The outdoor test show the temperature cubicle mortar with PCM increased slowly to 39.9^0C when directly exposed to sunlight for 3 hours where as cubicle mortar without PCM was 41.8^0C. The temperature different is 2^0C with 45^0C of surrounding temperature. The day to night simulation test for the thermal performance of the PCM mortar. The cubicle mortar with PCM can stabilize indoor temperature at 27^0C after 30 minutes with 25^0C surrounding temperature. The cubicle mortar without PCM only maintain the same indoor temperature only for 5 minutes. The situations shows that cement mortar incorporated with PCM are reducing the indoor temperature fluctuation and can increase thermal mass in buildings via la tent and sensible heat transfer.

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ABSTRAK

Sistem penyaman udara dipacu pemampat adalah kaedah paling popular untuk memenuhi permintaan yang semakin meningkat untuk penyejukan dalam sektor bangunan. Kelemahan jelas peranti penyaman udara ini ialah penggunaan tenaga elektrik yang tinggi. Sektor bangunan di Malaysia menggunakan hampir 14.3% daripada jumlah tenaga, dengan bangunan kediaman dan komersial menyumbang 53% daripada jumlah penggunaan tenaga. Untuk menghasilkan tenaga elektrik, stesen penjanaan kuasa perlu menggunakan arang batu atau gas sebagai sumber pembakaran. Ini membebaskan terutamanya gas CO_2 ke atmosfera dan menyumbang kepada pemanasan global. Satu lagi akibat yang memudaratkan penggunaan sistem penyejukan mampatan wap konvensional ialah potensi penyusutan ozon (ODP) yang tinggi yang dimiliki oleh penyejuk yang digunakan sebagai cecair kerja dalam sistem terutamanya apabila bahan penyejuk bocor ke atmosfera. Oleh itu, adalah penting untuk membangunkan teknologi baru yang cekap tenaga dalam sektor bangunan untuk aplikasi penyaman udara. Sebagai contoh, penggabungan bahan perubahan fasa (PCM) ke dalam bahan binaan boleh meningkatkan inersia haba bangunan sekali gus memberikan keselesaan terma kepada penghuni dan mengurangkan penggunaan tenaga elektrik. PCM menggunakan ayunan suhu malam untuk menyerap haba dari ruang dalaman bangunan apabila suhu meningkat melebihi suhu lebur PCM. Semasa proses perubahan fasa ini, PCM cair. Pada waktu malam apabila suhu persekitaran menurun, PCM menjadi pepejal kembali kepada keadaan pepejalnya. Oleh itu, bahan bangunan yang diperbadankan PCM boleh digunakan sebagai cara penyejukan pasif bangunan dalam iklim panas. Tujuan utama kajian ini adalah untuk menyediakan PCM berkapsul makro yang boleh dimasukkan ke dalam dinding mortar simen. PCM eutektik disediakan dengan mencampurkan parafin dan minyak kelapa pada pelbagai nisbah campuran untuk mendapatkan nisbah bancuhan optimum yang sesuai dengan suhu keselesaan terma pada 26^0C~28^0C. Kedua-dua minyak kelapa dan parafin adalah PCM organik yang paling serasi dengan bahan binaan. PCM eutektik optimum ialah nisbah pencampuran 95% minyak kelapadan 5% lilin parafin, dengan takat lebur 28^0C. Menambah lebih banyak minyak kelapa dan mengurangkan jisim lilin parafin menghasilkan takat lebur yang lebih rendah. Walau bagaimanapun, julat suhu ini tidak sesuai dengan iklim Malaysia khususnya. Aplikasi PCM dihalang oleh kekonduksian terma rendah bahan binaan yang diperbadankan PCM. Untuk mengoptimumkan pemindahan haba melalui peningkatan kekonduksian terma, cangkerang untuk PCM berkapsul makro diperbuat daripada dua bahan berbeza iaitu, tanah liat dan cincin aluminium. Prestasi terma dinding mortar simen yang diperbadankan PCM telah disiasat menggunakan bilik ujian skala kecil, ujian luar dan ujian simulasi malam ke hari. Berdasarkan ujian haba berskala kecil, gelang aluminium MPCM yang digabungkan dengan mortar mencapai suhu yang stabil dalam kira-kira 31^0C pada permukaan dinding mortar apabila terdedah kepada 35^0C. Meningkatkan kuantiti jisim PCM menyebabkan 1.3^0C suhu permukaan dinding mortar lebih rendah. Mortar PCM kubikel menunjukkan keupayaan untuk bertindak dengan cekap sebagai simpanan tenaga haba terpendam dan waras. Ujian luar menunjukkan suhu mortar kubikel dengan PCM meningkat secara perlahan kepada 39.9^0C apabila terdedah terus kepada cahaya matahari selama 3 jam manakala mortar kubikel tanpa PCM ialah 41.80C. Perbezaan suhu ialah 2^0C dengan 45^0C suhu sekeliling. Ujian simulasi siang ke malam untuk prestasi terma mortar PCM. Mortar kubikel dengan PCM boleh menstabilkan suhu dalaman pada 27^0C selepas 30 minit dengan suhu sekeliling 25^0C. Mortar kubikel tanpa PCM hanya mengekalkan suhu dalaman yang sama hanya selama 5 minit. Situasi menunjukkan bahawa mortar simen yang digabungkan dengan PCM mengurangkan turun naik suhu dalaman dan boleh meningkatkan jisim haba dalam bangunan melalui pemindahan haba terpendam dan masuk akal.

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LIST OF SYMBOLS AND ABBREVIATIONS

CO_2	-	Carbon dioxide
CFC	-	Chlorofluorocarbon
DSC	-	Differential scanning calorimeter
FTIR	-	Fourier Transform Infrared Spectroscopy
GWP	-	Global warming potential
GPC	-	Geopolymer concrete
g	-	Grams
HCFC	-	Hydrochlorofluorocarbons
HFC	-	Hydrofluorocarbons
kg	-	Kilogram
kJ	-	Kilojoules
MPCM	-	Macroencapsulated Phase Change Material
NaOH	-	Sodium Hydroxide
Na_2SiO_3	-	Sodium Silicate
ODP	-	Ozone deplection potential
PCM	-	Phase change material
SEM	-	Scanning electron microscopy
UCS	-	Universal compression test
XRD	-	X-ray diffraction analysis
M^2	-	Meters square

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CHAPTER 1

INTRODUCTION

1.0 Background

World has been strugling from energy and environment crisis already because of the reliance on finite fossil resources, which are rapidly depleting and causing carbon dioxide (CO_2) emmision. Therefore, energy efficiency is critical. Economic development and population increase are expected to have an impact on the country's rising energy demand. Take, for example, the buildings sector in our nation. Malaysia uses 14.3% of total energy, with residential and commercial structures accounting for 53% of total electrical energy usage. As a result, building energy efficiency is essential for reducing total energy use while also promoting environmental and economic sustainability. Figure 1 shown the global enegy comsumption by sectional shares.

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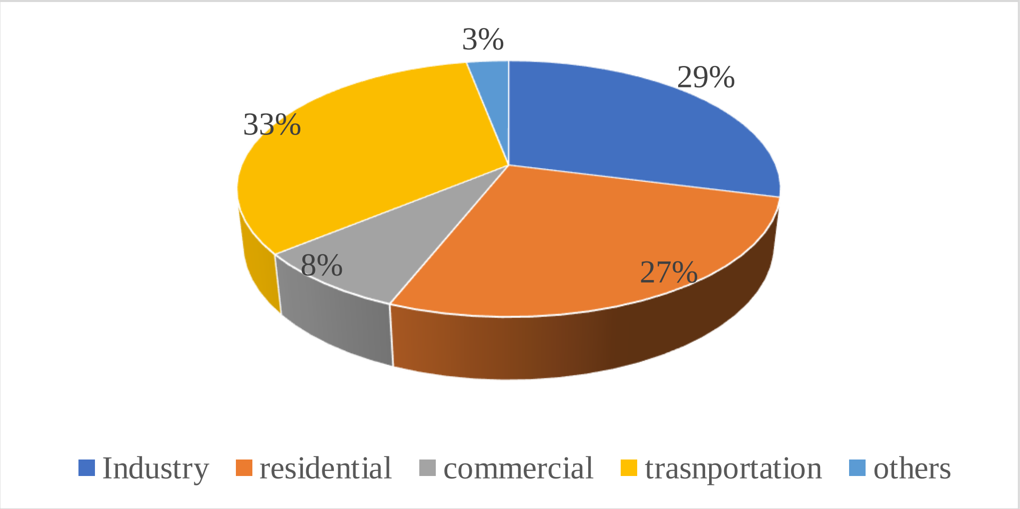

Figure 1 : Global energy consumption by sections.

Global warming occurs because of the emision of greenhouse gases in the atmosphere particularly CO_2 gas emmision. In order to remove the excess heat and to control the humidity of air in an enclosed space, many people use air conditioning device to achieve a more comfortable interior space environment. However, using air conditioning device require high energy comsumption especially during midday and as the device working fluid such as refrigerant undergoes transition from a liquid to a superheated vapour where this transition causes rapid absorption of heat from the surrounding environment. Furthermore, most refrigerants are recognised to be hazardous to the environment, contributing to global warming and ozone depletion. Greenhouse gases like carbon dioxide, as well as emissions from some refrigerants, contribute to global warming by collecting infrared light and storing it in the atmosphere. Figure 1.2 illustrate the global warming index for global temperature.

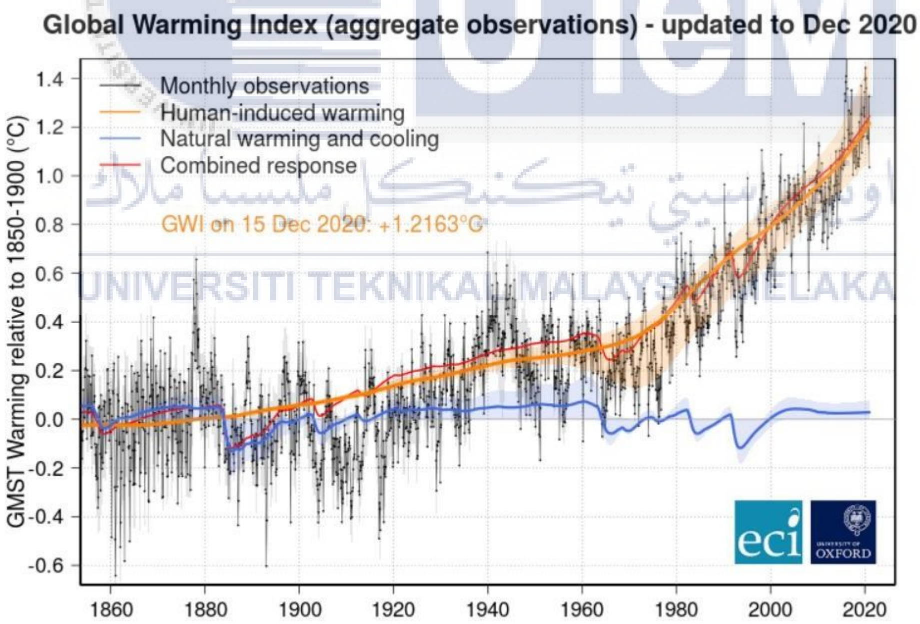

Figure 1.2 : Global warming index (global temperature)

In other words, building sector have a significant environmental impact and are responsible for a considerable portion of CO_2 emissions. In order to improve the situation PCM

(Phase Change Materials) has been extensively researched to be incorporated in buildings material contain considerable amount latent heat to be absorb or release during phase transition. They have been used in a variety of thermal energy storage applications. This is especially beneficial in the building sector, where PCMs are potentially utillised in a wide range of building structural components and materials to achieve better temperature regulation regardless of exterior weather conditions. Figure 1.3 shows the working principal of PCM.

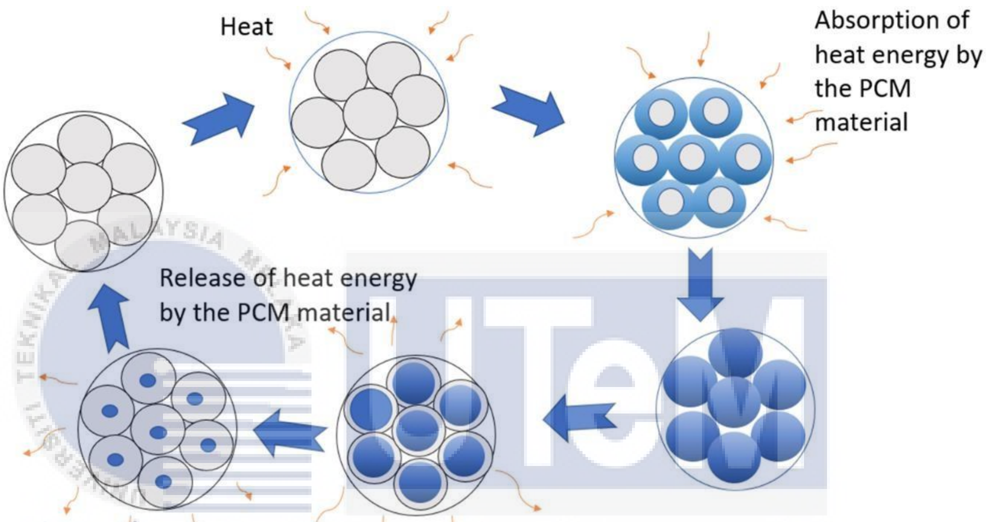

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Figure 1.3 : The working principle of PCM.

PCMs have a large latent heat storage capacity, allowing them to collect latent energy while transforming from a solid to a liquid phase and then release it when returning to a solid phase. It collects surplus thermal energy in a building component during the day through the melting process, and when the temperature lowers at night, it solidifies and releases the thermal energy back into the environment. PCM also increase the thermal mass at the building envelope via sensible thermal energy storage.

The type of the PCM are classified into three main substance that is organic, inorganic and eutectic. The eutectic PCM is created from homogenous combination of materials which is melts or solidifies at a certain temperature that lower than melting point of any of the constituents. From the past research, it show that the most suitable euectic PCM combination for buidings materials is organic-organic such as fatty acid and paraffin. Coconut oil or known as fatty acid, is a bio based PCM that develop from nature and have excellent heat storage properties. Paraffin that consist of a mixture of hydrocarbon molecules is also have high latent heat storage and widely use in industries.

There are three basic methods for combining PCMs with building construction materials, that is, impregnation, direct addition, and encapsulation. Composites made using the impregnation and direct addition method are reported to have poor stability due to liquid leakage during phase transition proven which than can lead to overall materials deterioration. The encapsulation method has been proven to be one of the best options for overcoming the leakage problem of the solid-liquid PCMs.

There are several reports on incorporation of PCM into buildings concrete made of portland cement. Portland cement is the most common matrix used in buildings sector. Despite its widespread use. Figure 1.4 shown the illustration of the PCM that intergrated into buildings wall.

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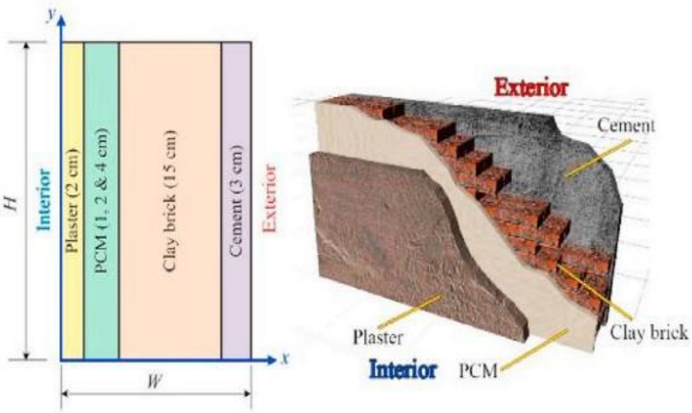

Figure 1.4 : Illustration of the PCM incorporated into buildings wall.

Both the weather and the construction site affect the PCM's thickness and placement in the wall. For instance, they advised positioning the PCM close to the outdoors in warm weather. However, under cooling conditions, a placement indoors is preferable. The use of PCM into buildings materials can reduced the total energy consumption and increase the thermal efficiency.

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1.1 Problem Statement

Global warming cause global climate change due to the human activites such as industrial activites or deforestation that lead to increases heat-trapping greenhouse gas levels in Earth’s atmosphere. This will also affect human and other in many aspect. Due to the global warming phenomena and the change of people life style, demand on cooling especially in building sector has increased tremendously. These air conditioning device are active device mean that electrical energy required to operate them.

Building is built to act as many purpose for human such as factory for working place or house that provide occupants thermal comfort. The building's basic structure is a concrete wall that provides security, shelter, and a thermal barrier against external heat. Many people use air conditioning to remove heat and adjust the humidity of air in confined spaces, resulting in a more comfortable interior atmosphere. However using air conditioning systems require substantial amount of energy comsumption especially during midday. The air conditioning devices use refrigerant as a heat transfer medium, but refrigerants containing CFCs have a higher ozone deplection potential (ODP), which is harmful to the ozone in the atmosphere.

PCM are act as passive cooling in building sector that can minimize the usage of electrical energy consumption. Some PCMs are not suitable for use in buildings, which can result in leakage when the material going through phase changes. PCM also classified into different type and usage. The paraffin is one of the organic type PCM which have high latent heat storage but the melting point of the paraffin is range of between 60^0C~62^0C and not compactible with Malaysia temperature. So the PCM cannot absorb heat and achive it full potential. The alternative way is to combine the paraffin with other materials such as coconut oil to reduce the melting point and attain thermal comfort for the buildings.

1.2 Research Objective

The main aim of this research is to prepare cement mortar wall incorporated with coconut oil/paraffin eutectic PCM for buildings passive cooling. Specifically, the objective are as follows :

a) To incorporated macroencapsulated coconut oil/paraffin eutectic PCM into cement mortar wall.

b) To determine the optimum parameters for the macroencapsulated PCM such as mixing ratio and the type of encapsulation shell materials to attain the optimum thermal performance of the mortar wall.

c) To investigate the thermal properties of the cement mortar wall by using reduced-scale test room, outdoor thermal test and night to days simulations test.

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.3 Scope of Research

I. Preparation of the macroencapsulated coconut oil/paraffin PCM into cement mortar wall.

II. Determination of the best parameters for the macroencapsulation PCM

III. Thermal characterization of the PCM cement mortar wall.