UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECT OF COATING THICKNESS ON ROOF TOP THERMAL PERFORMANCE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **EFFECT OF COATING THICKNESS ON ROOF TOP THERMAL PERFORMANCE**

SESI PENGAJIAN: **2014/15 Semester 2**

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisor is as follow:

………………………………

(Profesor Madya Dr. Md Nizam Bin Abdul Rahman)

ABSTRAK

Pemanasan global dan fenomena pulau haba menjadi teruk dari semasa ke semasa. Isu-isu ini menyebabkan peningkatan pengunaan elektrik menyejukan suhu bangunan. Salutan penebat haba semakin menjadi popular dalam kalangan pembinaan bangunan untuk merendahkan suhu permukaan bangunan. Walau bagaimanapun, kurang kajian bertujuan untuk menentukan ketebalan salutan penebat haba yang sesuai di atas keluli bergalvanisi. Disebabkan ini, objektif kajian ini adalah untuk mengaji kesan ketebalan salutan penebat haba terhadap perubahan suhu and fluks haba dan menentukan ketebalan salutan penebat haba yang sesuai di atas keluli bergalvanisi. 6 keluli bergalvanisi yang disalut dengan ketebalan salutan penebat haba yang berbeza telah didedahkan di bawah cahaya matahari untuk tiga hari dari 9.30 pagi hingga 4.30 petang. Data yang direkod telah dianalisis dengan menggunakan one way ANOVA dan Pearson moment correlation analisis. Data yang terdapat dalam kajian ini menunjukkan perubahan suhu dan fluks haba telah diturunkan semasa meningkatkan ketebalan salutan penebat haba. Perubahan suhu dan fluks haba menjadi stable apabila ketebalan penebat haba tersebut melebihi had tertentu. Daripada kajian ini menunjukkan optimum ketebalan salutan penebat haba di atas keluli bergalvanisi adalah 0.3099 mm yang menyumbang perubahan suhu and fluks haba yang terendah. Ketebalan yang melebihi 0.3099 mm didapati tiada membawa penurunan yang lebih lanjut kepada perubahan suhu dan fluks haba.

ABSTRACT

Global warming and heat island issues have getting more serious nowadays. These issues have brought significant consequences to increase the peak demand of electricity used for cooling purpose. Cool roof coatings have recently been introduced to building surfaces to reduce the building temperature. However, there is lack of study on identifying the optimum cool roof coating thickness applied on the substrate. Therefore the objectives in this study are to study the effect of coating thickness on thermal resistance properties such as change in temperature and heat flux and to determine the optimum thickness of coating on galvanized steel substrate. Six galvanized steel substrate coated with different cool roof coating thickness were exposed under sunlight for three days from 9.30 am to 4.30 pm. The data collected was analysed by one way ANOVA and Pearson moment correlation analysis. Results demonstrated that the increase of coating thickness decrease the change in temperature and heat flux, but then become stable when certain limit has been exceeded. This study shows that the optimum cool roof coating thickness is at the range of 0.3099 mm which contributed the lowest amount of change in temperature and heat flux. Any coating thickness more than 0.3099 mm shows no effect in lowering the change in temperature and heat flux.

DEDICATION

To my beloved family

ACKNOWLEDGEMENT

First of all, I would like to express my gratitude and appreciation to my supervisor, Profesor Madya Dr. Md Nizam Bin Abdul Rahman as he is very generous in advising, guiding and encouraging me throughout the completion of my final year project.

Secondly, special thanks to the general manager of Green Conevo Sdn Bhd, Mr. Simon Tan Yu Chai, for giving me an opportunity to cooperate and assist them to conduct this project. I would also like to thank gratefully to all the technicians who assist me when using the equipment and devices in the project period.

Last but not least, thank to my peers who always support me morally and emotionally, and share their knowledge when I faced problem and difficulty during the project period. Without all of them, this project would not be made successfully.

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LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

A	-	Area of specimen
ANOVA	-	Analysis of Variance
df_b	-	Degree of freedom between group
df_w	-	Degree of freedom within group
E	-	Insulation temperature difference, ℃
EPDM	-	Ethylene Propylene Diene Monomer
F	-	F test
HVAC	-	Heat, vntilation and air-conditioning
h_{ci}	-	Convective heat transfer coefficient
H_0	-	Null hypothesis
H_1	-	Alternative hypothesis
M	-	Number of variables between groups
n	-	Number of variables within group
N	-	Total number of variables
NASA	-	National Aeronautics and Space Administration
NIR	-	Near Infrared Reflectance
q_{12}	-	Radiant heat flux
r	-	Pearson moment correlation, r
r^2	-	Correlation of determination
SS_b	-	Sum of squares between groups
SS_w	-	Sum of square within groups
TBC	-	Thermal Barrier Coatings
TPO	-	Thermoplastic Poly-Olefin
T_0	-	Internal ambient air temperature
T_e	-	External surface temperature
T_i	-	Internal surface temperature
T(t)	-	Time-dependent midpoint temperature
T_i	-	Initial midpoint temperature
T_f	-	End midpoint temperature

T_{0n}	-	Temperature of interior surface for nth test plate, ℃
T_{1n}	-	Temperature of interior surface for nth insulated test plate, ℃
T_1	-	Outdoor air temperature, K
T_2	-	Internal roof temperature, K
t	-	Time
UV	-	Ultraviolet
VIS	-	Visible Light
Y	-	Y variables
X	-	X variables
Σx_t^2	-	Summation of variables within group and square them
Σx^2	-	Total summation of variables
Σx_n^2	-	Summation of squared of variables within group
Σx	-	Total amount of x distributions
Σy	-	Total amount of y distributions
Σxy	-	Total amount of x and y distributions
Σx^2	-	Total amount of x square distributions
Σy^2	-	Total amount of y square distributions
b	-	Fitted parameter
β_0	-	y-intercept
β_1	-	Gradient of the line
σ	-	Stefan-Boltzmann constant, 5.67×10^{-8} W/m^2 K^4
θ	-	Concrete roof's midpoint temperature (dimensionless)
ε_1	-	Emissivity of infinite surface 1
ε_2	-	Emissivity of infinite surface 2
$\varepsilon_{i, ir}$	-	Emissivity of infrared radiation

CHAPTER 1

INTRODUCTION

This chapter briefly explains about the introduction of the research, include introduction to thermal protective roof coating, objectives of the research, scope of study and lastly the research hypothesis.

1.1 Introduction to cool roof coating

Because of the global warming and urban heat island issues, many of the buildings such as hotels, office towers, apartments and factories would be focus more on the building design and building components to countermeasure the energy consumption problem, especially roofing as it always directly exposed to the solar radiation . The roofing materials tend to absorb the solar radiation which consists of visible light, infrared and ultraviolet. Bear in mind that the infrared and ultraviolet known as the main source of heat absorbed by the buildings. As the roofing materials absorb the thermal load from the solar radiation, more cooling energy will be needed to reduce the temperature of buildings. This will increase the electricity consumption as more unit loads are required for building cooling purpose. Therefore, to avoid these problems, passive cooling methods are employed to minimize the building envelopes' temperature and reduce the electricity consumption (Pisello and Cotana, 2014). A cool roof coating is one of the passive cooling methods. It is often consists of materials with high solar reflectance and high thermal emittance. When the solar radiation directed to the thermal protective roof coating, it would reflected certain amount of heat radiation back to the atmosphere. As a result, the cool roof coating acts as a thermal barrier coating to minimize the heat penetrated into the indoor of the buildings thus consumption of electricity as the heat, ventilation and air-conditioning (HVAC) loads can be reduced (Pisello and Cotana, 2014).

1.2 Problem statement

Many researches publications reported the thermal performance on different types of the roof coating system. However, there is very few publication on the relationship between the cool roof coating thicknesses on the metal substrate to their thermal performance. Dow (n. d.) stated that it is important to know the proper film thickness in roofing industry. However, the evaluation on the optimum cool roof coating thickness on the roof thermal performance by manufacturer is lacking. Thus, it is essential to ascertain the optimum thickness of the cool roof coating to be applied onto the metal roof surface. This can minimize the cost the cool roof coating application and maximize its thermal performance.

1.3 Objectives

In order to address the statement mentioned earlier, the objectives of this study are:

i. To study the effect of coating thickness on thermal resistance properties.
ii. To determine the optimum thickness of coating on galvanized steel substrate.

1.4 Scope of study

This research focused on the application of ceramic filled acrylic coating onto galvanized steel substrate by using roller and exposed under sunlight. The relationship between the coating thickness and thermal performance of the applied coating was investigated but its mechanical properties are not covered in this study. Throughout the study, the change in climate other than the temperature was assumed to be insignificant.

1.5 Research Hypothesis

The hypothesis testing of this study is used to investigate the relationship between the thicknesses of cool roof coating to the thermal properties as can be elaborated as the thicker the coating thickness, the better the substrate thermal properties until a certain limit being exceed. Therefore, the null hypothesis and alternative hypothesis are set as:

H_0 = different thickness will have same performance
H_1 = different thickness will have different performance

One way ANOVA analysis at 90% confidence level and Pearson moment correlation analysis were used as analysis tool to determine the relationship between the coating thickness and the thermal properties.

CHAPTER 2

LITERATURE REVIEW

This chapter explained about the literature reviews of the previous studies on passive cooling methods that done by researchers in order obtain the current state of technology and helps to get the relevant information before conducting the experiment. Literature review acts as a crucial stage before the experiment execution as it provides scientific facts, theories, concept, information, experimental process and many criteria related to the researches and ease of works for the future works.

2.1 Building energy consumption issues

The planet is now getting engulfed by environmental issues, especially global warming and urban island effect issues. According to Santamouris (2014), major buildings in the world are exposed under global warming and urban heat island and absorbed the heat and solar radiation that increase the temperature of the buildings. To maintain comfortable living condition in such building, ventilation and air-conditioning system (HVAC) have to be utilized. This will significantly increase the electricity usage. Such statement was supported by Campanico et al. (2014) who claimed that the electricity will be increased further as the issue of global warming progresses. To address these problems, several aspects has been identified to reduce the amount of solar radiation absorpted by the buildings as discussed in the Chapter 2.3 on Passive Cooling Method.

2.2 Heat transfer theory on roof coating application

It is important to understand the theory on how heat is being transferred from external environment to the internal surface when the roof is directly exposed to the sunlight. Basically, there are three ways for the heat to be transferred through a medium, which are conduction, convection and radiation.

2.2.1 Conduction

Keeler and Burke (2009) stated that when the external ambient temperature is high, the roof surfaces tend to absorb the solar radiation and make the roof itself to be heated up. The molecules of the heated external roof surface obtain the heat energy and vibrate rapidly and collide with the cooler molecules. Now the cooler molecules become warms and the warmer molecules become cools. In another word, the higher temperature will heat the molecules up and then transfer into the indoor through the roof material. This phenomenon is known as conduction.

2.2.2 Convection

Som (2008) and Keeler and Burke (2009) also elaborated that when air or liquids get the heat transferred from other medium, it will undergo expansion. This expansion makes the air or liquids decrease in density and prone to flow upwards because of buoyancy. At this stage the heat is being transferred to another fluids by forming a current of convection when they flow upwards.

2.2.3 Radiation

According to Som (2008) and Thirumaleshwar (2009), all objects which temperature is higher than 0 ˚K, radiation will be occurred and is emitted in electromagnetic wave. Electromagnetic waves generally obey the laws of light as the waves can travel at