PERFORMANCE AND LIFE CYCLE COST ANALYSIS (LCCA) FOR HEAT RESISTANT WALL

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MASTER OF SCIENCE (CIVIL ENGINEERING)

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Thesis submitted to Centre for Graduate Studies, Universiti Pertahanan Nasional Malaysia, in fulfillment of the requirements for Degree of Master Science (Civil Engineering)

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ABSTRACT

The main aim of this study to seek a passive cooling method that can minimize the use of air conditioning system while saving energy consumption. There have three objective in this study. The first objectives is to find out the optimum way in enhancement of green building technology with getting opinions and suggestions from the Green Building Index professional staff. Enforcement and full support by the Malaysian Government identified to give a significant role in achieving the first objective. The second objective is to develop and evaluate an affordable heat resistant wall panel system to improve energy efficiency. Different types of wall panel concept and design were constructed and tested to compare the best performance in thermal resistance. In this study, the Heat Resistant Wall Panel with flowing water shows the best performance in reducing the building's indoor temperature during the simulation. A significant temperature drop was found in this wall panel type: reached 6°C at the extreme temperature (35°C). In order to determine the energy efficiency and cost saving, the Life Cycle Cost Analysis (LCCA) was performed as to complete the third objective. As a result, the Heat Resistant Wall Panel with flowing water inside was discovered as the most suitable solution in reducing indoor temperature and as a way to save energy with the payback value occurred at 9^{th} years later. Furthermore, about 30.6% cost reduced by using the Heat Resistant Wall Panel with flowing water in term of annual maintenance and services cost.

ABSTRAK

Matlamat utama dalam kajian ini bertujuan untuk mencari kaedah penyejukan pasif yang dapat mengurangkan kebergantungan terhadap penggunaan sistem penghawa dingin sekaligus menjimatkan kos penggunaan tenaga elektrik. Terdapat tiga objektif dalam kajian ini. Objektif pertama adalah untuk mengetahui cara paling optimum dalam meningkatkan teknologi bangunan hijau dengan mendapatkan cadangan dan idea daripada kakitangan profesional Indeks Bangunan Hijau (GBI). Penguatkuasaan dan sokongan penuh dari pihak kerajaan Malaysia dikenal pasti untuk memberi peranan penting dalam mencapai objektif pertama. Objektif kedua ialah untuk membangun dan menilai sistem panel dinding tahan panas yang berpatutan untuk meningkatkan kecekapan tenaga. Konsep dan rekabentuk panel dinding yang berbeza dibina dan diuji untuk membandingkan tahap prestasi terbaik dalam rintangan haba. Dalam kajian ini, panel dinding tahan haba dengan air mengalir di dalamnya telah menunjukkan prestasi yang terbaik dalam mengurangkan suhu dalaman bangunan semasa simulasi. Penurunan suhu maksimum yang telah dicapai oleh panel dinding tahan haba dengan sistem air yang mengalir adalah sebanyak 6°C ketika suhu ekstrem iaitu 35°C. Analisa kos kitaran hayat diaplikasikan dalam kajian ini untuk menentukan kadar pulangan balik terhadap pelaburan yang telah dibuat semasa kerja awalan projek yang di mana ianya merupakan objektif ketiga. Jumlah pulangan balik berlaku pada tahun ke-9 dengan anggaran penjimatan kos sebanyak 30.6% dengan menggunakan Panel Dinding Tahan Haba dengan sistem air yang mengalir di dalamnya.

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APPROVAL

The Examination Committee has met on **28 September 2018** to conduct the final examination of **Umi Nadiah Bte Nor Ali** on her degree thesis entitled **'Performance and Life Cycle Cost Analysis (LCCA) for Heat Resistant Wall'**

The committee recommends that the student be awarded the Master of Science (Civil Engineering)

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APPROVAL

This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfilment of the requirements for the degree of **Master of Science (Civil Engineering)**. The members of the Supervisory Committee were as follows.

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LIST OF ABBREVIATIONS

ACEM	Association of Consulting Engineers Malaysia
ASTM	American Society for Testing and Materials
CFCs	Chlorofluorocarbons
CO_2	Carbon Dioxide
EN	European Standard
EPS	Expanded Polystyrene Bead
EXMET	Expanded Metal Wire Mesh
GBI	Green Building Index
HCFCs	Hydro Chlorofluorocarbons
HRWP	Heat Resistant Wall Panel
HVAC	Heating, Ventilation and Air-Conditioning
ISO	International Standards Organization
KeTTHA	Kementerian Tenaga, Teknologi Hijau dan Air
LCCA	Life Cycle Cost Analysis
LEED	Leadership in Energy and Environmental Design
NDUM	National Defence University of Malaysia
PAM	Pertubuhan Arkitek Malaysia
PEX	Cross-linked Polyethylene
PVC	Polyvinyl Chloride
RMK	Rancangan Malaysia Ke-
ROI	Return On Investment
TABS	Thermal Active Building System
VAV	Variable Air Volume

CHAPTER 1

INTRODUCTION

1.1 Background

Green building technology became a common research for the last few decades. These themes identified the definition of the advantages related to green building compared to conventional building. Malaysia is located at the tropical climate regime in South-East Asia. 25°C (77 °F) to 35°C (95 °F) is the average range temperature throughout the year stated in weather website (Jabatan Meteorologi Malaysia, 2017). Malaysia's climate is also categorised as equatorial with hot and humid weather throughout the year. It is because of the hazy warm air trapped inside the cities that causes the areas to feel hot. In tropical country like Malaysia, rainy season occurs between mid-October and end of March (Northeast Monsoon season) while the month's rest is windy and sunny (Southeast Monsoon season). Malaysia is no exception to El Nino's effects where this phenomenon occurs at irregular intervals of two to seven years and lasts for as long as half a year to two years. El Nino happens when the temperature of the sea surface in eastern Pacific Ocean becomes warmer. The temperature during El Nino season affects people's comfort as it decreases rainfall in the dry season and becomes hotter. Nowadays, the earth is getting old and it gets

hot rapidly compared to years before. As this problem arises, people take the opportunity to promote and sell air conditioning system that can give comfort to people. Furthermore, from 1.5 million, air conditioner users are expected to increase by 2020 (Damiati, 2016). The cooler system gives the best solution to cool up building area, but the system needs high voltage of electricity to be generated and consumers must pay more for electricity bills. High electricity bill causes burden to consumers especially those with low monthly income. Cooler system produces greenhouse gasses that affect the atmosphere, plus the increase of these gasses will trap more heat thus making this earth hotter. Greenhouses gasses cause global warming and climate change. Urban areas loaded with population, industry, and factories are the most exposed areas with carbon dioxide emissions. Thus, the air conditioner systems are demanded in urban areas due to its increased weather condition compared to rural areas (Shahbaz et. al, 2016).

Climate change in Malaysia became the main issue that must be discussed and resolved. "Brown growth" that happened in the last fifty years in Malaysia is replaced by the era of "green growth" which will help to sustain the quality of Malaysia citizens' lives. One of the main barriers to develop the green building is the old mindset that only thinks about high investment for green technology compared to conventional technology. New mindset needs to be injected among citizens that natural resources cannot be consumed continuously. Early investment in green buildings gets better return of investment (ROI) for long term savings. United State Green Building Council (USGBC) stated projects that achieved LEED rating normally get the return of 20% or more (Bard, 2010). Development of sustainable buildings is more complicated than conventional buildings in which green building needs more investment and research

on resources to construct sustainable buildings. The process of designing and constructing needs involvement from a wide range of professionals. Transferring of knowledge to citizens really gives impact to green building's exposure as it makes project team run their construction activities more effectively (Qian et al., 2015).

Green building is one of the outcomes from the concept of sustainable design. Since the energy conservation and green building techniques are becoming mainstream practices for market-rate projects, intentions in gaining the knowledge of buildings' efficiency are welcome. Furthermore, it is to reduce building impacts on human health and the environment over the entire life cycle of the building. In the present development for our communities, it has a large impact on the natural environment as it disturbs the population and nature. Many benefits resulted from the enhancement in green building technology, which related to the scope of environment, economy and social. Among the benefits are effective solid waste management, reduction of the operating costs, i.e. the energy and water consumption, and enhancement of occupant's health and comfort. The Green Building Index (GBI) of Malaysia was developed in 2009 by Pertubuhan Arkitek Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM) to lead the Malaysian property industry towards becoming environmental friendly in future development and construction. The objectives of this project were to share the best way in enhancement of green building technology, to minimise energy consumption and to pursue green growth for sustainability and to improve the effectiveness of the design and construction technology in achieving sustainable green building. There are six (6) Green Building Index (GBI) assessment criteria for new construction; (1) Energy Efficiency, (2) Indoor Environmental Quality, (3) Sustainable Site Planning & Management, (4)

Material & Resources, (5) Water Efficiency, and (6) Innovation. Energy efficiency gives the maximum points in assessment criteria score with 35 points for non-residential and 23 points for residential which is quite high in term of green building requirements (GBI, 2009).

Green Building Index (GBI) also has four (4) rating classifications which are platinum, gold, silver, and certified. Figure 1.1 represents the Green Building Index (GBI) point's allocation chart while Figure 1.2 shows green building index classification.

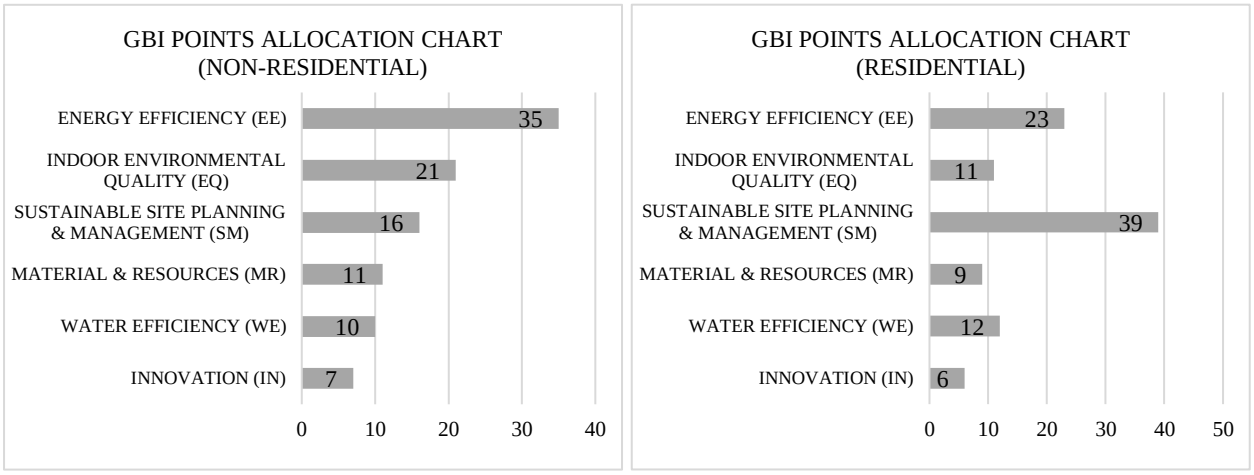

Figure 1.1 Green Building Index (GBI) allocation chart of residential and non-residential building (GBI, 2009).

POINTS	GBI RATING
86 + points	Platinum
76 to 85 points	Gold
66 to 75 points	Silver
50 to 65 points	Certified

Figure 1.2 Green Building Index (GBI) classification by GBI rating tools (Green Building Index, 2009).

Furthermore, this contribution focused on enhancing green growth for sustainability and resilience in RMK-11. Goals in achieving green building were determined to enhance the development of green building technology. Go green is a strategy as the need and desire to be more energy efficient and environmental friendly. The cost of building materials and the management of the construction give contributions towards affordable building price with the incorporation of green building features.

1.2 Problem Statement

Hot and humid weather in Malaysia caused the increase in energy consumption due to the usage of mechanical system for thermal comfort. Usually, it is very hot and humid especially in the cities due to the urban lifestyle. Roof and wall surfaces could reach up to 60°C because they are more exposed to direct sunlight (Li, 2005). Air conditioner is required to maintain indoor temperature and give comfortable result to users (Tan, 2013). However, the usage of air conditioner system required high-energy consumption and resulted in high electricity bill. This planet is under serious threat of global warming, thus immediate actions must to be taken to overcome this matter. The larger contribution of greenhouse emission gasses was identified by carbon dioxide (CO_2) and this can be seen in Figure 1.3 and 1.4. Figure 1.3 represents a number of emissions from people activities in the United Kingdom in which each piece of the pie represents the result of emissions from human activities, while Figure 1.4 represents the amount of air-polluting emission in Malaysia in the year 2007 to 2008. These charts indicated that the largest emissions are from Carbon Dioxide (CO_2). Carbon dioxide in Figure 1.4 was reported by the Malaysian Department of Environment (2010), where the emissions are caused by many sources. Carbon dioxide (CO_2) emissions were found to be increasing in developed countries and one of the sources was from ventilation and air conditioning (HVAC) systems which contributed 60% amount of energy consumption in buildings (Mardiana and Riffat, 2015).

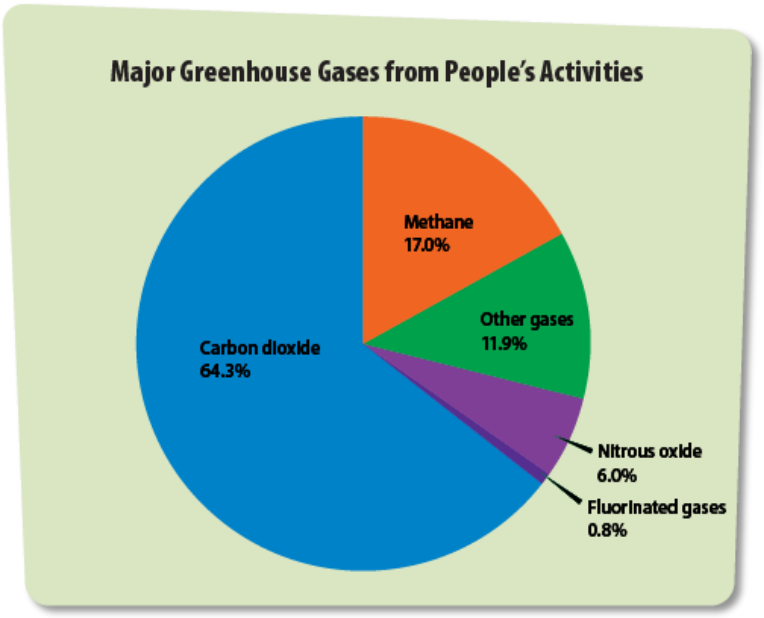

Figure 1.3 Greenhouse emission gasses from human activities in United Kingdom (IPCC, 2014).

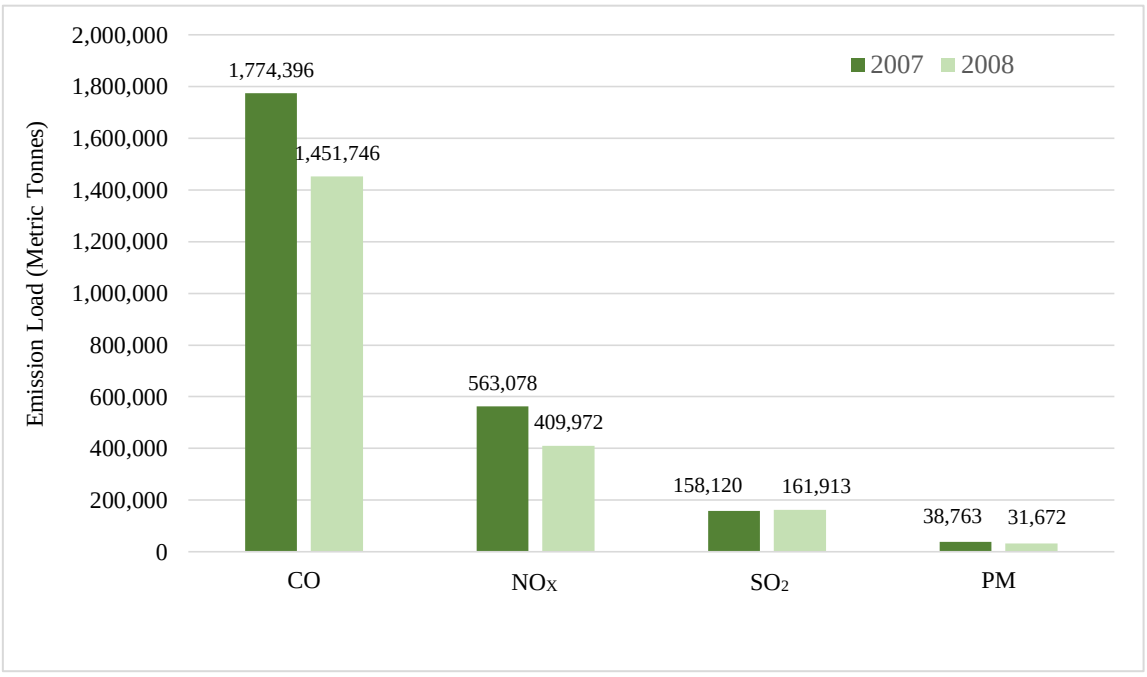

Figure 1.4 Malaysian Air Pollution Emission of 2007-2008 (Shahrul et al., 2013)

Electricity sources are one of the most important resources for humans in their daily routines. Fossil fuels, coal, and gas are the main sources for electrical supply in this earth. In the meantime, the price of fossil fuels is expected to continue to rise. It will burden the nation and the people in terms of economy. Figure 1.5 indicates that energy industries have the highest percentage for sources of carbon dioxide emissions in 2011 (NRE, 2015).

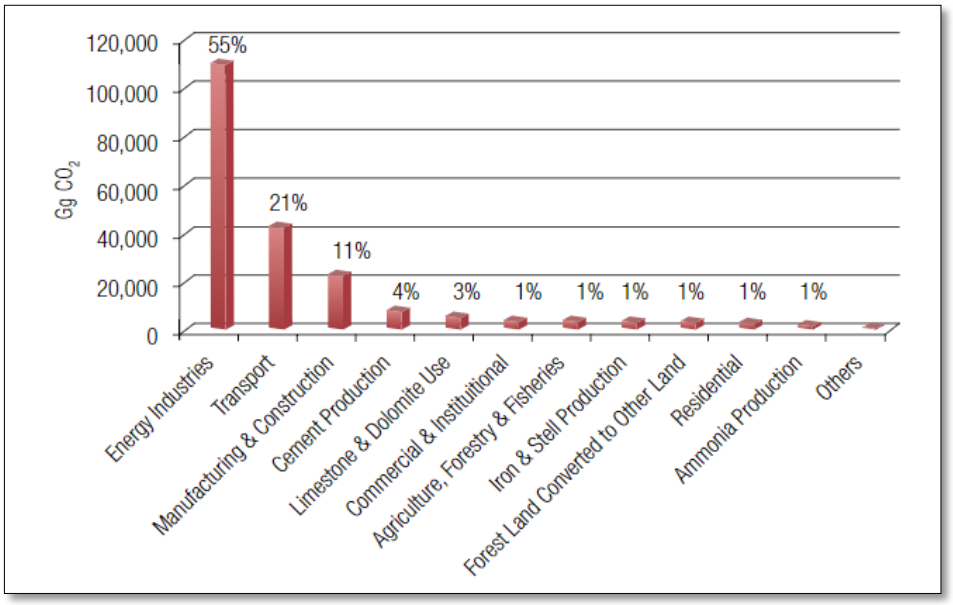

Figure 1.5 Sources of Carbon Dioxide (CO_2) emissions in Malaysia

(NRE, 2015)

The previous Prime Minister of Malaysia, Dato' Sri Haji Mohammad Najib bin Tun Haji Abdul Razak challenged all researchers in Malaysia to find the solution in greener mix of electric supply. Green energy has been called as 'fifth fuel' and become an alternative to the energy greener mix (KETTHA, 2012). Many countries took initiative and commitment on these ecological concerns in order to reduce carbon emission as their targets for the next generations. Sustainability achieved by energy