Energy Savings Performance of Heat Resistance Wall Panel (HRWP) System

Umi Nadiah Nor Ali, Norazman Mohamad Nor, Maidiana Othman, Vikneswaran Munikanan

ABSTRACT--- This study investigated the thermal resistant performance of wall panel (Heat Resistant Wall Panel) with embedded PVC pipe and water flowing in it.The flowing water concept that was applied in this study is regulated from rainwater harvesting system. This is to minimize the electricity and water bills while reducing the indoor building temperature. By observing the results, it shows that the internal surface temperature of the heat resistant wall panel is 3℃ lower than conventional building wall. In addition, a comparative analysis of energy saving costs has been calculated to identify energy efficiency for typical building with air-conditioning system and typical building with the Heat Resistant Wall Panel which resulted about 33% of cost savings.

Index Terms — Energy saving, green building, heat resistant wall panel, sustainable system.

I. INTRODUCTION

A. Malaysia Target

Energy consumption and carbon dioxide (CO_2) reduction are always a main agenda of any government of a develop nations. Researchers, engineers, architects, developers and professionals are responsible to participate in this agenda. This strategy is in line with the voluntary target on reducing the Green House Gas (GHGs) emissions by up to 40% by the year 2020 [1].

GHGs emissions comprises several types of gasses such as carbon dioxide (CO_2), Chlorofluorocarbon (CFCs), Hydrofluorocarbon (HFCs), Methane (CH_4), and Nitrous Oxide (N_2O). However, carbon dioxide contribution to GHG emissions is the most significant. Carbon dioxide emissions are caused by the abundance of energy consumption in our daily routine. High demand energy consumption led to increase the carbon dioxide emissions and then earth pollution issue will arise [2].

This research focus on reducing the energy consumption in the residential and building sector. In Malaysia, buildings consume up to 40% of the electricity generated in the country [1]. This energy consumption is expected to rise up to 50% by the year 2030. Malaysia was listed in the top 30 greenhouse gas emitters with 221% carbon dioxide emission in the world on between 1990 to 2004 [3]. The increasing demand of buildings for residential and commercial is rising all over the world due to the population growth. In 2011, Malaysia recorded as the third largest energy user in the residential sector with 16% approximately of the total Malaysia energy use. Total energy consumption is expected to increase if no preventive measures or mitigation are taken on this matter [4].

Since that, the energy use by the building occupant's is increased and become a major issue of concern over carbon dioxide and GHG emissions. Furthermore, today's lifestyle and affluence has led to greater GHG emissions in developing countries [5]. Urbanizing world today increase dramatically on energy demand and electricity consumption due to the economic growth. Fig. 1 shows the world population who lives in cities which indicated about 70% population in 2050. This can be assumed that population in cities consume about 80% of energy production worldwide. Moreover, the International Energy Agency (IEA) estimates the energy demand rise from 67% to 74% by 2030. This amount approximates that 89% of the increase in CO_2 from energy use in developing countries [6].

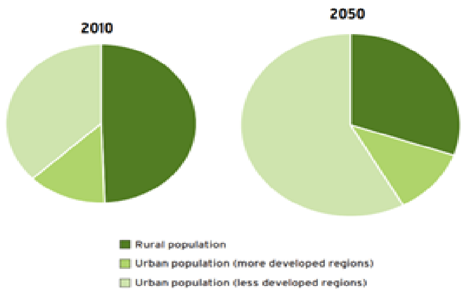

Fig. 1: World's population in 2010 and 2050 [2]

B. Malaysia Action

Energy saving is the main topic in this study as to enhance the energy efficiency (EE) as stated in Green Building Index (GBI), green rating tool for buildings. Green Building Index established on 2009 and it is developed by the Association of Architect Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM). The purpose of these organizations implementation is to drive Malaysian property industry towards more environment friendly and to improve human life quality.GBI rating tool is the same concept as the BREEAM (United Kingdom), LEED (USA), GREENSTAR (Australia) and CASBEE (Japan). However, these rating tools depend on the country climate and environment nature, thus the name of rating tools for each country is different. GBI Malaysia rating consists of six criteria and one of the listed criteria is the Energy Efficiency (EE) [7].

Revised Manuscript Received on February 11, 2019.

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In order to minimize the overconsumption of energy, the Electrical Equipments Labelling Programme and Energy Awareness Campaign were introduced in Malaysia as a mitigation measure. This campaign is one of the initiative in National Energy Efficiency Master Plan (NEEMP) to promote a sustainable living concept and to educate the public about the energy saving. Malaysian government's effort is to reduce 10% electricity consumption by 2020 [8].

The main electricity provider is Tenaga Nasional Berhad (TNB) Malaysia since 1990's. Based on the TNB record, the demand for electricity has been increase for the past few years. This is due to the rising in population [9].

There are many alternatives to minimize the electricity consumption by using concept of energy efficiency (EE) for the building system. Reduce use of air-conditioning system for cooling the building with green concept is the main purpose of this study. In 2011, the researcher from Africa investigated four sustainable alternative-energy cooling system option in conjunction with the conventional air-conditioning systems. Active mass cooling, night flushing, roof spraying, and roof pond were the alternative applied for keeping the peak room temperatures low. Based on the results, the roof spray system showed the most effective results in keeping the room temperature during peak hour. Furthermore, the heat from the outdoor environment are contributing to the indoor building temperature. Washington D. C. implemented and introduced the roof-spray system in 1934 on the roof of three-story building apartment to reduce heat gains. Water used in this concept is continuously to wet the roof surface to maintain the indoor building temperature. The roof-spray system significantly can reduce 72% of the heat loads in net energy transfer within 24-hour period. However, the net energy transferred was reduced to 80% with the combination concept of roof-spray and night flushing. It can be concluded that the roof-spray technique would give energy savings of 70% with the indoor building temperature could reduce by approximately 6.9 °C (from 33.97 °C to 27.04 °C) [10].

Recent study by few researchers [11] found that hydronic radiant heating or cooling systems could give indoor thermal com-fort during the peak hours in a building. This system can be applied to floor, wall, ceiling and slab panel as a surface that provides heating or cooling to space.Furthermore, this system is circulating water based where water carries the heat load by radiation and convection process through the pipes or tubing. Radiant panel systems originate from Korea and China a thou-sand years ago. Two types of radiant panel heating or cooling installation types, which are wet installation and dry installation. Wet installation is a traditional method that required the electric cable, mats or tubing embedded in a concrete structure. This type of installation is more expensive compared to dry installation. However, this wet installation has a large thermal mass of concrete that preserves the heating or cooling effect for several hours after the system is turned off. The opposite way of wet installation is a dry installation that easier to set up and convenient type. The tubing for heating and cooling purpose are not embedded in a concrete structure. The advantage of this type is resulting fast in heating or cooling process. Since the tubing not embedded in concrete, it does not have thermal mass to pre-serve the heating and cooling capacity. Hence, this dry installation type needs to operate at a high temperature then increase the energy consumption [12].

The construction types of radiant systems based on ISO 11855-2 for design, dimensioning, and operation principles. There are four basic construction types which are i) the pipes embedded within the surface layer; ii) the pipes embedded in building structure (TABS); iii) the pipes embedded in a layer at the inner of ceiling or wall (capillary surface system); and iv) the metal pipes integrated into panel (radiant panel). These construction types have difference effect regarding the cooling or heating performance for a panel [13].

The thickness and thermal conductivity of the screed are important factors to retrieve high cooling effect which influence the cooling capacity. Based on the ISO 11855-2, the normal centre-to-centre distance of pipe tube is around 100 mm to 150 mm or more [14].For effective effects, the smaller distance between pipes is required. In a recent study, higher cooling capacity resulted when the radiant floor cooling system is combined with the convective air system. This happened because the floor system takes care of sensible load (dry bulb temperature of building) and the air system take care of the latent load (wet bulb temperature of the building). Hence, the dew point temperature lowered by removing moisture from the air [15]. In addition, the higher cooling effects can be reached when the supply temperature is lowered. The geothermal cooling system and rainwater harvesting cooling system are recommended as a future research [16].

II. MATERIALS

Iron pipe was used in early 1907 in England for hydronic radiant floor. This method for cooling or heating was spread in the United States using copper and steel tubing pipe of the late 1940's. However, these material not suitable due to metal fatigue or chemical incompatibilities with concrete. During the 1960's, a new polymer material called cross-linked polyethylene (PEX) was developed as a sheathing for underwater cable. The material eventually revolutionized the hydronic floor heating market worldwide [17].In this study, the material that used for the Heat Resistance Wall Panel is 50 mm diameter of PVC pipe. The PVC pipe was selected in this study to reduce the material cost compared to copper and PEX pipe which are expensive. Additionally, PEX and PVC tubing pipe has a similar life expectancy according to the manufacturer's guarantees. The durability comparison of pipes is shown in Table 1.

Table 1: Life expectancy of pipes

Technical Characteristics	Copper	PVC	PEX
Life Expectancy	Over 50 years of service life	~ 20-50 years of service life	~ 25-50 years of service life

III. METHODOLOGY

This study investigated the annual energy saving cost using radiant cooling panel system namely Heat Resistance Wall Panel. This wall panel system was designed using the same principles of embedded radiant panel. However, the Heat Resistance Wall Panel used lightweight concrete as to reduce the dead load of concrete wall panel and PVC pipe was used to reduce the construction cost. 50 mm diameter of PVC pipe “Class O” is vertically embedded at the center of the concrete panel. Vertical pipe position in wall panel was applied using the same concept of car radiator in transferring heat by water circulation [18]. The construction of the wall panel is referred to the ISO 11855-2 which indicated as Type E. The details design of the Heat Resistance Wall Panel is shown in Fig. 2.

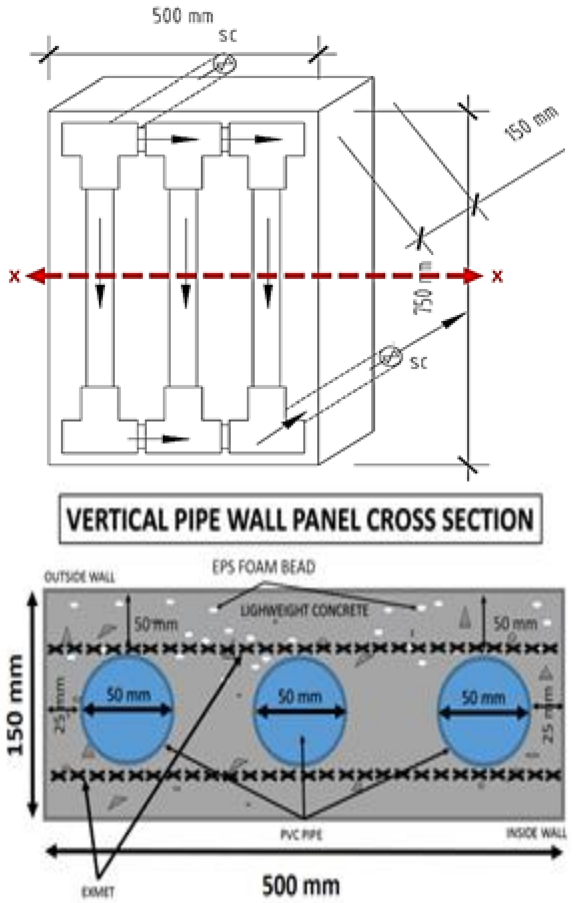
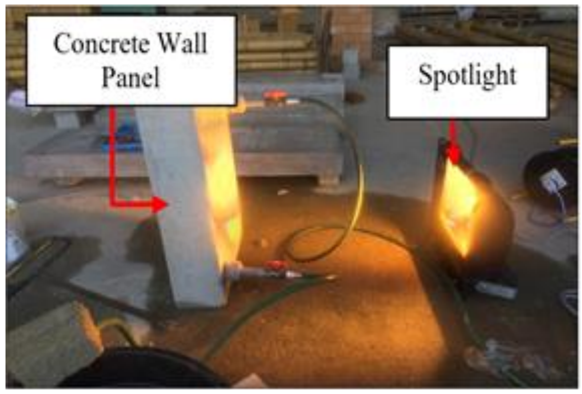


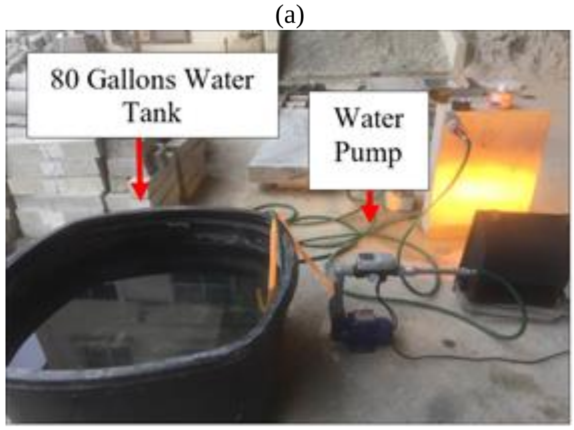
Fig. 2: The details of the pipes position in the Heat Resistance Wall Panel (HRWP) lab sample

1 % of expanded polystyrene bead was added in the wall panel mixing to give additional insulating effects to resist heat from going through the wall into building area [19]. In this study, a 400-Watts spotlight was used as a heat source during the experiment. The wall surface exposed to the spotlight is indicated as external wall surface and the other side is considered internal wall surface. The experiment conducted for 7 hours continuously (1000 am to 1700 pm). The cooling performance of the wall panel was observed at the wall surfaces using the specified thermometer [20].

The temperature of the HRWP surface was measured at every hour interval using thermometer at marked point on the concrete surface. The experiment setup arrangement (Fig. 3) for test was adapted from previous research by [21].



(a)



(b)

Fig. 3: (a) 400 Watts spotlight as heat source at 1m distance from the Heat Resistance Wall Panel (HRWP); (b) 80 Gallons of rainwater used for circulating water inside the HRWP

IV. RESULTS AND DISCUSSION

From the experimental result in this study, the researcher found that this Heat Resistance Wall Panel system (HRWP) could reduce the internal wall surface temperature from the outside environment temperature by 6 °C.In order to determine the energy saving cost associated with this technology, a simple calculation was done based on the rate provided by local energy provider (TNB). The simple calculation between the proposed and existing system were calculated in Table 2.

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Table 2: Energy cost saving comparison

Heat Resistance Wall Panel (HRWP) with Flowing Water	Fully Dependence on Air-Conditioning System
- Daily usage time of water pump as to generate the water circulation in building wall is 6 hours - Assume 1-hour energy consumption of air conditioner to give cool effect at the beginning hour - Water pump energy power = 0.37 kW (Source: Water pump manufacturer) - TNB rate for = RM 0.2180 for 1 Kwh (For HRWP system) = 0.37 kW x RM 0.2180 = RM 0.08 per hour (For AC system) = 0.75 kW x RM 0.2180 = RM 0.16 per hour If used 6 hours for water pump per day = RM 0.08 x 6 hours = RM 0.48 per day Usage for one month (HRWP + AC) = (RM 0.48 x 31 days) + (RM 0.16 x 31 days) = RM 19.84 per month Total cost of energy for a year = RM 19.84 x 12 months = RM 238.08 per year	- Daily usage time of Air-conditioner system in Malaysia is 6 hours (Kubota, 2011) - Assuming electric consumption by 1 HP air- conditioner = 0.75 kW (Source: Air-conditioner manufacturer) - TNB rate = RM 0.2180 for 1 Kwh = 0.75 kW x RM 0.2180 = RM 0.16 per hour If used 6 hours per day = RM 0.16 x 6 hours = RM 0.96 per day Usage for one month = RM 0.96 x 31 days = RM 29.76 per month Total cost of energy for a year = RM 29.76 x 12 months = RM 357.12 per year
Total of energy consumption per year (For HRWP system) = 0.37 kWh x 6 hours x 365 days = 810.3 kWh/year (+) (For 1 hour AC system) = 0.75 kWh x 1 hour x 365 days = 273.75 kWh/year Total = 810.3 + 273.75 = 1084.05 kWh/year	Total of energy consumption per year = 0.75 kWh x 6 hours x 365 days Total = 1642.5 kWh/year
Difference = RM 119.04 equal to 119.04/357.12 x 100 ~ 33% saving. (This amount can be saved every year with using Heat Resistance Wall Panel system)	

From the experimental process, it was found that the water circulation concept in concrete wall panel could reduce the indoor building temperature by resisting the heat transfer through the wall into building area. Radiator concept flowing water applied in this study lowered the internal wall surface temperature by 6 °C. Furthermore, about 33% electricity cost could be saved with the application of the HRWP in a building system as to support the existing cooling method. Moreover, the energy consumption could also reduce the carbon dioxide (CO_2) emissions.

V. CONCLUSION

The study has been successful in highlighting the Heat Resistance Wall Panel system can be used as an effective way to reduce the indoor building temperature with lower energy consumption. The embedded pipe with flowing water inside the concrete wall panel improve the system

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performance. Heat transmitted form external wall surface to the internal wall panel surface is absorbed by water flowing in the wall before it reached the internal wall surface. Hence, the experimental results proves that the HRWP with flowing water inside PVC pipe in concrete wall panel concept can reduce the interior wall surface temperature significantly, thus reducing dependency on air conditioning system and increase energy efficiency.

ACKNOWLEDGMENT

The authors would like to thank the Ministry of Higher Education Malaysia, and the National Defence University of Malaysia (FRGS/1/2018/TK10/UPNM/01/1) for providing financial support and facilities for this research.

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