Heat Conductivity Resistance of Concrete Wall Panel by Water Flowing in Different Orientations of Internal PVC pipe

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Abstract. Green building technology and sustainability development is current focus in the world nowadays. In Malaysia and most tropical countries the maximum temperature recorded typically at 35°C. Air-conditioning system has become a necessity in occupied buildings, thereby increasing the cost of electric consumption. The aim of this study is to find out the solution in minimizing heat transfer from the external environment and intentions towards going green. In this study, the experimental work includes testing three types of concrete wall panels. The main heat intervention material in this research is 2 inch diameter Polyvinyl Chloride (PVC) pipe embedded at the center of the concrete wall panel, while the EPS foam beads were added to the cement content in the concrete mix forming the outer layer of the wall panel. Water from the rainwater harvesting system is regulated in the PVC pipe to intervene with the heat conductivity through the wall panel. Results from the experimental works show that the internal surface temperature of these heat resistance wall panels is up to 3°C lower than control wall panel from plain interlocking bricks.

1. Introduction
Hot and humid weather is the common climate in tropical countries like Malaysia. The El-Nino phenomenon happened in Malaysia in 2016 which affect the surround temperature with the highest temperature recorded at 37.4 °C [1-3]. In order to get a comfortable interior space, huge amount of electricity been consumed for cooling purpose at that period. An amount of average electricity consumption is shown in figure 1 where indicated more than 40% of the energy consumption of residential building is dedicated to cooling [4,5]. Dependency on the air-conditioning system demand high energy usage and increase in electricity cost. Malaysian government was formulated a National Energy Efficiency Master Plan (NEEMP) from mid-2008 to 2010 as to promote energy efficiency thus reduce the greenhouse gas emissions. This is one of effort by Malaysia government in reducing the electricity consumption by 10% in the year 2020 [6]. In order to reduce dependence on the use of air-conditioning system, the Architects, Engineers, Scientist, Professors, and Researchers play their role in addressing this studies [7]. A few research on the related problem has been done, one of the possible solution by a recent study is introducing the Thermal Building Active Systems (TABS). The concept applied in this study is adapted by TABS which embedded steel-welded pipes were used as to heat and cool the building space [8]. In this study Polyvinyl Chloride (PVC) pipe grade O is used to study the impact at lower installation cost. The objective of these studies is to reduce the dependency on the use
of air-conditioning system where contribute in releasing carbon dioxide (CO2) thus affect the climate change and electricity cost.

![Average Electricity Consumption Breakdown (%) – CACCET & WCPJ](image)

**Figure 1.** Household electricity consumption breakdown conducted by CETDEM through CACCET (Creating Awareness on issues to Climate Change, Energy Usage and Transport) & WCPJ (Working with the Community on Energy Efficiency at Household Level in Petaling Jaya) which is listed as one of the projects commissioned under 9th Malaysia Plan [5].

### 2. Literature Review

#### 2.1 Carbon Dioxide (CO2) emissions in Malaysia

Household electricity consumption play the main role in reducing greenhouse gasses since the researchers realized an important target for energy conservation [9]. Carbon dioxide (CO\textsubscript{2}) emissions by households is completely difficult to manage through laws and regulations. This happens due to individual behaviour to comply with the regulations regarding energy consumption issues [10]. Malaysia recognized as the third largest energy user in the economy by the residential sector. The residential sector in Malaysia is the third largest energy user in the economy in 2011. In order to overcome this problem, the Malaysian government has introduced Electrical Equipment Labelling Programme and Energy Awareness as corrective measures [11]. Malaysia is rapidly growth in term of industrialized economy in the last four decades which attributed to accelerates 235.6% carbon emissions increase from 1990 to 2005 [12]. Mitigation measures and any alternative must be taken in order to reduce future carbon dioxide (CO\textsubscript{2}) emissions as is expected to release about 285.73 million tonnes in 2020 [13].

#### 2.2 Thermal Active Building Systems (TABS)

Winter and summer season affect the indoor environments of the residential and commercial buildings. There are sorts of equipment nowadays as to give comfort effect to building users. However, these equipment consumed large amount of energy that contributed high electricity cost. Rising the number of buildings and factories, more energy consumption definitely happen so that affect the energy sources. Therefore, thermally active building systems were introduced on 21\textsuperscript{st}-century which the green building design been a trend that time [14]. Activating the mass of the building is basically thermo-active systems work in order to heating and cooling process. By the concept of water flowing in pipe as to influence the temperature of the concrete and thereby activate the transfer of energy. This concept required less energy in cooling and heating, thus lower expenses needed in building service equipment and electricity. Thermal active building systems is another method of temperature control to replace the conventional all-air systems. Embedded pipes that carry water in concrete slabs developed an interaction between
surrounding room air and its structure. The peak load reduces by activate the thermal storage capacity of the buildings concrete slabs is the main advantage of using TABS. However, this system still have the disadvantages and challenges such as lack of skilled workers, high in prelim cost, and more difficult to predict in maintenance costs [15].

2.3 Thermally Active Building Systems with Geothermal Energy Design Basics
In other way in applying an embedded water based in the central concrete core of a building’s construction, a contribution to environmental protection by integration of horizontal and vertical collectors in the ground is conjunction thermal utilisation of ground energy that provides cooling and heating solution. This concept is illustrated in figure 2 where shown the orientation of embedded pipes. Understanding the ground condition is one of the requirement needed before an excavation process regarding this design concept. The calculation methods related to the heat transfer via the subsurface is mentioned in ISO EN 13370 as a reference and guideline [16].

The heat exchangers tube are made of PE and aluminium with the diameter limitation is less than 25mm, while the tubes spacing is about 10 to 30 cm [17].

2.4 Insulation
Many studies were done related to this matter as to improve the thermal performance in building space. Several input was taken as consideration including the construction materials, building orientation, perspective of building type, etc. The main objective of the previous studies is to reduce the consumed energy [18,19]. A lot of insulator types with different effects and usage as to fit the building’s function. One of the insulator material is Expanded Polystyrene (EPS) which is used in this research. EPS is widely used in building construction recently due to its behaviour, mainly lighter and cheaper. EPS also has a good thermal resistance value as an insulator material in building construction due to its tough and rigid characteristic [20]. EPS is the replacement of glass wool insulator today due to its behaviour that tends to deform over the time. Figure 3 describes thermal insulation performance between this materials [21]. EPS excellent in term of durability, it is proved by the usage in damp proof membrane. EPS was proved as a reasonable insulator and quite cheap in term of price. Table 1 shows constants values for thermal conductivity between different materials [22].
Insulator materials function as heat resistant which minimize the unwanted heat from going through into the building internal area so that the building’s thermal performance is improved. Table 1 shows a list of alternative materials for insulation and its thermal conductivity values.

**Table 1.** Constant values of thermal conductivity among different materials [22].

| Material | Density [kg/m³] | Specific heat [J/kgK] | Material constant, \( M_j \) | Thermal conductivity (declared value), \( \lambda_{\text{measured}} \) [W/mK] | Thermal conductivity after correction (design value), \( \lambda_0 \) [W/mK] |
|----------|-----------------|-----------------------|-----------------------------|---------------------------------|---------------------------------|
| EPS 30   | 10.22            | 1460                  | 14922                       | 0.049                           | 0.0694                          |
| EPS 100  | 17.5             | 1460                  | 25550                       | 0.037                           | 0.0525                          |
| FIBR     | 39.67            | 750                   | 29754                       | 0.039                           | 0.0462                          |
| EPS 150  | 23.7             | 1460                  | 34602                       | 0.036                           | 0.0511                          |
| EPS 200  | 27.5             | 1460                  | 40150                       | 0.035                           | 0.0497                          |
| NPS      | 28.57            | 1460                  | 41710                       | 0.039                           | 0.0548                          |
| B30      | 1400             | 880                   | 1232000                     | 0.57                            | 0.57                            |
| PLASTER1 | 1650             | 920                   | 1518000                     | 0.810                           | 0.81                            |
| PLASTER2 | 1850             | 880                   | 1628000                     | 0.990                           | 0.99                            |
| CONCRETE | 2400             | 840                   | 2016000                     | 1.550                           | 1.55                            |

To find the best insulator material, some calculations need to be done. From Equation 1, the stored thermal energy capacity of the wall can be defined [22].

\[
W = M_c \cdot A \cdot \Theta
\]  

Where;
\[
\Theta = t_j - t_e
\]
- \( t_j \) = average temperature of the layer number \( j \) (insulator)
- \( t_e \) = temperature outside
- \( A \) = surface area (m²)
- \( M_c \) = material constant

3. Materials and methods

3.1 Materials

Lightweight concrete is used to reduce dead load of concrete wall panel and easy to handle. The density of lightweight concrete is lower than ordinary concrete, thus it will also contribute in-term of heat transfer resistance. The density of lightweight concrete range is mention in ASTM C 330 which is between 1442 kg/m³ and 1842 kg/m³ compared to normal concrete density with range of 2240 to 2400 kg/m³ [23]. Perlite was selected in this research as the main component in the lightweight concrete mix proportion. The lightweight concrete design mix proportion is presented in table 2. The compressive strength of cube sample was tested at 7 days and 28 days. Table 3 show the compressive strength results of lightweight concrete cube sample.
Table 2. Lightweight concrete mix design.

| Cement (kg/m³) | Perlite (kg/m³) | Fine Aggregate (kg/m³) | Coarse Aggregate (kg/m³) | Water (kg/m³) | Super Plasticizer (%) | Concrete Density (kg/m³) |
|---------------|----------------|------------------------|--------------------------|---------------|----------------------|------------------------|
| 789           | 409            | 409                    | 818                      | 727           | 1                    | 1570                   |

Table 3. Compressive strength of lightweight concrete cube.

| Sample No. | Density (kg/m³) | Day of curing | Compressive Strength (N/mm²) |
|------------|-----------------|---------------|-----------------------------|
| 1          | 1434            | 7 Days        | 6.74                        |
| 2          | 1481            | 28 Days       | 7.12                        |
| 3          | 1570            | 28 Days       | 10.2                        |

3.2 Design
In this paper, three types of heat resistance concrete wall panel will be investigated. Types I is plain interlocking brick wall panel act as control wall panel. Type II is the heat resistance concrete wall panel with 50mm diameter PVC pipe “Class O” is vertically embedded at the center of the concrete panel. Type III is the heat resistance concrete wall panel with 50mm diameter PVC pipe “Class O” is transversely embedded at the center of the concrete panel. The details of dimensions and designs of the heat resistance wall panel (HRWP) are shown in figure 4, figure 5 and figure 6. Water will be regulated in the PVC pipe to prevent the heat from reaching the interior wall of the building.

**Figure 4.** Control wall panel from plain interlocking brick

**Figure 5.** Heat Resistance wall panel with vertical PVC pipes
3.3. Experimental Setup
A series of heat transfer tests was arranged such that the temperature variation across the wall thickness over period of time. The experimental arrangement is demonstrated in figure 5. 400 Watts spotlight was used as to simulate heat from sunlight. The spotlight was placed at 1m from the wall panels. Each experiment conducted for 7 continuous hours, from 1000 am until 1700 pm. The surface temperature was measured at every one hour interval by using Digital Thermometer 2103 (ELE International) at five marked point on the concrete surface. Besides the surface temperature, humidity and ambient temperature also been taken during the experimental process to ensure consistence external environment (Figure 7).

4. Result and Discussion
4.1. Experimental Results
The maximum temperature of the samples external surface was about 35°C. This is compatible with the actual external wall temperature of surrounding building during noon which can be refer in table 4 where the data collected by an experimental work at every an hour. In this study, five marked point was
indicated to obtain the surface temperature as to get the average temperature of the wall. The results are presented in table 5 and illustrated in figure 8.

**Table 4. Temperature data of NDUM Concrete Laboratory Wall Panel by sunlight**

| Time (7 Hours) | Temperature of NDUM Concrete Laboratory Wall Panel (°C) |
|---------------|-------------------------------------------------------|
|               | External | Internal |
| 1000 am       | 26       | 26       |
| 1100 am       | 30       | 28       |
| 1200 pm       | 32       | 29       |
| 1300 pm       | 33       | 30       |
| 1400 pm       | 34       | 31       |
| 1500 pm       | 35       | 32       |
| 1600 pm       | 35       | 32       |
| 1700 pm       | 34       | 31       |

**Figure 8.** Temperature variations of the exterior and interior surfaces with different types of heat resistance wall panel.

From the graph plotted, the internal vertical pipe layout seems to perform better in-term of internal surface temperature different between two types of heat resistance wall panel, which are vertical pipe layout, and transverse pipe layout, especially during mid-day (1200 PM – 1500 PM). The vertical pipe layout perform like a heat radiator where water from top will flow down in three parallel down pipes (refer figure 3) and it will speed up the flushing out of heat from the wall. While in transverse pipe the water flow in one single flow (refer figure 4) and will take longer time to remove heat from the wall. In general, it is proven that the temperature of interior surface in heat resistance wall panel is 3°C lower than the control interlocking brick wall panel at the extreme temperature. However, the interlocking brick can only provide minor heat insulation to the interior wall.

**Table 5. Temperature data between control wall panel with heat resistance wall panel.**

| Time (7 Hours) | Q SPOTLIGHT (W / m²) | Ambient Temperature (°C) | Temperature of Wall Panel (°C) |
|---------------|---------------------|--------------------------|--------------------------------|
|               |                     | Control – Interlocking Brick Wall |                               |

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### 5. Conclusions
The results presented in this research shows that different in interior temperature of the three types of wall panel. Wall panel with water flowing in PVC pipe inside give cooler effect to the interior surfaces. Heat that emitted from spotlight to wall panel surface is absorbed by water flowing in vertical pipe wall panel before it reached the internal wall. Hence, this experiment proves that the theory on flowing water inside PVC pipe with vertical layout in concrete wall panel can reduce the interior surface temperature, perform better than the interlocking brick wall. Eventually, as to going green and go to nature with less usage of electricity for air-conditioning system can be achieved.

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