Analysis of heat impacted behavior at vertical façade building based on heat flux mechanism

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Abstract. The most important elements of vertical façade building in open spaces structures are known as urban environment buildings. The building usually plays crucial role to create urban waves that significantly contribute to the urban heat island (UHI) phenomena. This study aims to analyze the mechanism of heat flux. Various types of façade building are measured including brick, concrete, granite and tiles. The analysis based on surface temperatures, ambient temperatures and solar radiation measurements, which were carried out in-situ of the selected façade building materials. The heat characteristics of each building are obtained throughout the day and the surface temperature of each physical element is classified according to temperature and types of material.

Among the façade building materials, granite is more heated in 2.7 times than brick wall and it releases a substantial amount of heat into the atmosphere through radiation and convection. As a conclusion, granite may be not good material for the construction of vertical buildings. These conclusions indicate on the suitability of surfacing materials should be chosen in order to help mitigate the UHI phenomena.

Key words: Building material; Vertical surfaces; Heat flux mechanism; Surface temperature

1. Introduction

A key reason as to why the air temperature in an urban city is much hotter compared to that in a rural area is the surface area and material composition that make up these urban developments. The urban materials with relatively high volumetric heat capacity can generate higher heat storage and temperatures. Heats up the surrounding air both during day and night. Such a phenomenon is widely known as the urban heat island (UHI) effect (Oke, 1987; Gui et al., 2007).

The high concentration of hard surfaces actually triggered many environmental issues. The primary root of heat island in cities is due to the absorption of solar radiation by mass building structures, roads, and other hard surfaces during daytime. The absorbed heat is subsequently re-radiated to the surroundings and increases ambient temperatures at night (Wong and Yu, 2005).

External building surfaces continuously exchange heat with the environment by convection and radiation. This occurs under the influence of varying outdoor conditions such as wind, ambient temperature and solar...
radiation. Knowledge of the convective and radiative heat flows at the external surfaces of the building will allow an accurate estimate of the heat loss or gain through the building envelope (Jayamaha et al., 1996).

In order to realize the anti-heat radiation in urban city, the study must determine the predominant causes of the core problem. One of them is vertical surface of construction material as it contributes heat impact to outdoor environment in urban city. Actually, measurement of the surface temperature distribution over the entire surface of a building is critical to an understanding of the thermal environment. The temperature distribution on a building’s surface varies dynamically due to a large number of factors including temporal variations in weather conditions, such as changes in solar radiation and wind velocity, the relationship between heat gain and the cooling of surfaces exposed to outdoor air currents, and the thermal characteristics of materials. Thus, it is important to calculate the diurnal change in heat flux using the surface of the building.

This study focused on a comparison between different thermal behaviour of four building materials that commonly applied in Johor Bahru city, such as brick, granite, concrete and tiles (as shown in Figure 1). The following factors were then analyzed including type of building material, different height of vertical buildings and impact of materials used towards outdoor environment. The comparative study on materials used in vertical surfaces of buildings based on their thermal effect in order to contribute lower ambient temperatures and fight heat island effect. This study can be used to increase the awareness of urban planners, designers and decision makers on the importance of the choice of construction materials not only for their esthetical aspect but also in function of their effect on local climate and indirectly on energy consumption of whole cities.

![Figure 1: The selected facade buildings in Johor Bahru areas](image)

**2. Principles of the Thermal Heat**

In a typical observation, building wall is affected by all three heat transfer mechanisms; conduction, convection, and radiation. The incoming of solar radiation into the outer wall surface will be converted to heat by absorption and transmitted into the building by conduction. At the same time, convective thermal transmission occurs from air outside of the building to the outer surface of the wall and the inner surface of the wall to the air inside of the building. It makes most portion of heat gains from the outside of the building wall occurs by conduction through the building wall. The energy balance point, where heat-transport mechanisms influencing the temperature are evaluated, is located in the surface of the façade. The outgoing radiation $q''_{rad}$ is described by:

$$q''_{rad} = A \varepsilon \sigma(T_s^4 - T_a^4)$$  \hspace{1cm} (1)

where $A =$ Area of the surface material (m$^2$); $\varepsilon =$ Infrared emissivity of the surface; $\sigma =$ Stefan-Boltzmann constant ($=5.67 \times 10^{-8}$ Wm$^{-2}$K$^{-4}$); $T_s =$ Surface temperatures (°C); $T_a =$ Ambient temperatures (°C). The convection heat transfer was calculated using the formula:

$$q''_{conv} = K_{conv}A(T_s - T_a)$$  \hspace{1cm} (2)

where $A =$ Area of the surface material (m$^2$); $K_{conv} =$ convection heat transfer coefficient (W/m$^2$K); $T_s =$ Surface temperatures (°C); $T_a =$ Ambient temperatures (°C) (Ocana et al., 2004).

**3. Methodology and equipment**

The study consists of in situ temperature measurements on the building surfaces of selected buildings around Johor Bahru city in order to measure the UHI phenomena. The study was conducted in various influences of weather and climates; which deserved in a consistent date measurement for 3 month observation begun from June till August 2010. The month is selected because prolong clear and shiny...
condition compared to other months. Ambient temperature and wall surface temperature were measured by thermocouple (T type). Solar radiation intensity was measured by a pyranometer (EKO MS 602, Eiko Seiki Co.). A pyranometer with accuracy is 2% in the 0-2000W/m² band, for the registration of the global solar radiation falling on a horizontal plane. As the thermal impact to the materials was measured using infrared thermometer (62 Mini, FLUKE) and infrared thermography procedures was used.

4. Results and Discussion

The heat gain from the in the facade buildings is given in function of physical characteristics and of materials used. The heat exchanges that occur on façade buildings are more intense between their external surfaces and their environment. As closer the surface temperature is to the air temperature, as lower is the transmission of heat to the environment by convection and by radiation (Prado et al., 2005).

Average measured temperatures and heat fluxes are listed in Table 1. The data showed that the types of material have a tremendous effect on façade surface temperatures and it has a more profound impact on heat flux. The result indicates that lower surface temperatures contribute to decrease the temperature of the ambient air as heat of convection and radiation are lower especially for tiles. Heat of convection and its subsequent emission to the atmosphere were significantly higher for granite than for concrete and brick wall.

Table 1: Average measured temperatures, heat fluxes, and weather data

<table>
<thead>
<tr>
<th>Place</th>
<th>Material</th>
<th>Average surface temperature (°C)</th>
<th>Average ambient temperature (°C)</th>
<th>Average solar radiation (W/m²)</th>
<th>Average heat of convection (W/m²)</th>
<th>Average heat of radiation (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menara Tabung Haji</td>
<td>Granite</td>
<td>37.3</td>
<td>31.5</td>
<td>94.6±43.2</td>
<td>102.3±49.6</td>
<td>27.0±17.3</td>
</tr>
<tr>
<td>Foh Chong Building</td>
<td>Tiles</td>
<td>34.7</td>
<td>32.4</td>
<td>133.0±46.3</td>
<td>29.5±11.8</td>
<td>0.9±0.4</td>
</tr>
<tr>
<td>Menara TJB</td>
<td>Concrete</td>
<td>35.7</td>
<td>32.3</td>
<td>63.5±38.1</td>
<td>77.5±40.3</td>
<td>29.8±18.6</td>
</tr>
<tr>
<td>Hospital Sultanah Aminah</td>
<td>Brick wall</td>
<td>33.8</td>
<td>31.6</td>
<td>86.7±16.6</td>
<td>39.6±55.2</td>
<td>19.4±30.0</td>
</tr>
</tbody>
</table>

Figure 1 shows the temperature difference between surface and ambient temperature and solar radiation at peak hours. Solar peak hours can be defined as the period when radiation would be the dominant source of heating (Memon et al., 2009). As shown in different construction materials, granite showed the highest difference between surface and ambient temperature while the solar radiation depicted at highest rather than others. It means that granite was absorbed more heat than others. The basic knowledge of two material properties is important to heat storage which is defining as thermal conductivity and heat capacity. Therefore, materials with high thermal conductivity tend to transfer the heat energy through their thickness. Thus, materials with high heat capacity are able to store more heat per square meter area.
Figure 2 (a) & (b) presents the calculated heat of convection and radiation for different types of construction materials. Figure 2 (c) represent the $\Delta$heat_{average} which is define as heat of convection minus heat of radiation. $\Delta$Heat_{average} indicates that the amount of heat will increase of ambient temperature as well as contribution UHI impact. This is due to the results that $\Delta$heat_{average} of granite materials with 75.2 Wm$^{-2}$ is the highest value compare to others and it parallel with the surface temperature (see in Figure 1).

It can be expected that the heat trapped for each materials was the major contribution to the UHI impact. For example, granite material will be used as vertical wall buildings, the heat energy will increase further to make area becomes hotter. This is because the absorbed heat was released back to the surrounding environment and warmed the ambient near the material surface throughout of the day. It makes human thermal discomfort.

5. Conclusion

Among the construction materials, granite is more heated in 2.7 times than brick wall and it releases a substantial amount of heat into the atmosphere through radiation and convection. Based on the observed data of surface temperatures and heat output to the outdoor space, it can be concluded that granite, concrete and brick could increase the surface temperatures for façade buildings and persistently absorb heat impact during midday. As a conclusion, granite may be not good material for the construction of vertical buildings.

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7. References


