POTENTIAL DESIGN PARAMETERS FOR ENHANCING THERMAL COMFORT IN TROPICAL TERRACE HOUSE: A CASE STUDY IN KUALA LUMPUR

Nasibeh Sadafi, Elias Salleh, Lim Chin Haw and Mohd. Fakri Zaky Jaafar
Department of Architecture, Faculty of Design and Architecture,
Universiti Putra Malaysia, Malaysia

ABSTRACT

Thermal comfort conditions in residential buildings vary according to the designs, modifications of the house and adaptation of the occupants. While air-conditioning is the most popular form of adaptation, natural ventilation is still relied upon for some parts. This study investigates thermal comfort performance of terrace housing in Kuala Lumpur, Malaysia, using Fanger's predicted mean vote (PMV) thermal comfort index. A case study of a terrace house was carried out in a housing scheme in Kuala Lumpur where field measurement was conducted during a three-day recording in naturally-ventilated space of the house. The study showed that the house was thermally comfortable for almost fifteen hours during day and night. Comfort conditions mostly occurred during night hours while around noon hours could be considered as critical times. To improve the thermal conditions, ceiling fans were used to increase the indoor air velocity. However, it was observed that this measure did not improve the thermal comfort condition when the air temperature had reached its maximum level. On the other hand, reducing the solar heat gain could improve the thermal comfort condition of the house.

Keywords: Thermal Comfort, Terrace House, Predicted Mean Vote

1. INTRODUCTION

The concerns over global warming and the need for reduction of high emission of greenhouse gases demand the utilization of strategies for indoor climate modification in promoting comfortable indoor environment (Givoni, 1994). In warm humid tropics, overheated building interior is common due to solar penetration through the building envelope and windows and lack of ventilation (Rajapaksha et.al., 2003). Terrace houses, as one of the most common typologies of residential buildings in Malaysia, are also faced with these problems. Due to the high density of the building blocks and crowded dwellings, a large number of buildings do not fulfill the requirements for thermally comfortable environment. Several studies have been undertaken by researchers in Malaysia in relation to thermal comfort in residential buildings (Abdulshukor, 1993; Zainal, 1996; Ahmad, 2002, Zainudin et.al., 2006). The main scope of these studies was to find the neutral temperature according to the country's tropical climate. Findings revealed a higher comfort temperature in comparison with those recommended by international standards where in naturally-ventilated buildings the upper range of comfort could be stretched with the aid of higher natural air movement. The main concern was the variations of air temperature and its effects on the occupant's thermal sensation. The study finds a dearth of comprehensive studies on the thermal performance of terrace houses in Malaysia.

This study has two main objectives:

1) To measure the thermal comfort conditions in a case study terrace house located in Kuala Lumpur, Malaysia.
2) To model the comfort conditions of the case study terrace house by investigating the thermal variations in the building.

According to climatic evaluations for Malaysia, April is considered as one of the hottest months during the year (MMR, 2007). So the monitoring of thermal behavior for this case study building was conducted on site between 10^{th}-13^{th} April 2007. This paper discusses the results of the building's thermal performance by calculating the predicted mean vote (PMV) as well as utilizing computer simulation which help to assess the improvement of the thermal condition based on the suggested alterations.

2. THERMAL COMFORT

The first major issue about climate is the comfort level (Salleh, 2004). This thermal sensation is affected by environmental factors: air temperature, mean radiant temperature, air movement, humidity as well as the clothing worn and the activity being performed. There have been several attempts by researchers to produce a unified mean of assessing thermal comfort by taking into account some or all of these factors into a single index.

An elaborate prediction of thermal comfort at steady-state conditions had been carried out by Fanger (1970). Even though his experiments were conducted in temperate climate, Fanger proposed that PMV can be used for the tropics by applying the method based on the findings of Ellis (1953). In his work, Ellis investigated European and Asian subjects in Singapore and the established thermal neutrality was found to be similar to the value proposed by PMV.

While several field studies using the Fanger's PMV-PPD (Predicted Mean Vote-Predicted Percentage of Dissatisfied) method seem to agree with the results obtained, a study by de Dear et al. (1998) has found discrepancies with it. It found that PMV can predict the comfort temperature for air-conditioned buildings more accurately as opposed to naturally-ventilated buildings where people are more acceptable to higher internal temperatures. These new trends produced an extension of the PMV model for naturally-ventilated buildings in warm climates (Fanger and Toftun, 2002). In the latter study, an expectancy factor is proposed for non-air-conditioned buildings which will be multiplied with PMV. Current study applies the expectancy factor of 0.9.

Table 1: Expectancy Factor for Non Air-conditioned Buildings in Warm Climate (Source: Fanger and Toftun, 2002)

Expectation	Classification of non-air-conditioned buildings		Expectancy factor, e
	Location	Warm periods	
High	In regions where air-conditioned buildings are common	Occurring briefly during the summer season	0.9-1.0
Moderate	In regions with some air-conditioned buildings	Summer season	0.7-0.9
Low	In regions with few air-conditioned buildings	All seasons	0.5-0.7

The basis of Fanger's (1970) comfort index was obtained from conducted experiments where the thermal sensation votes indicated the personally experienced deviation to the heat balance. The index is based on a seven point scale, from -3 [cold] to +3 [hot], 0 being neutral (optimum). Fanger's (1970) PMV formula is:

PMV=

$$
\begin{aligned}
&= (0.028 + 0.3033e^{-0.036M}) \times \{(M - W) && \text{Internal heat production} \\
&- 0.42[(M - W) - 58.15] && \\
&- 3.05[5.733 - 0.000699\,(M - W) - Pa] && \text{Heat loss by skin diffusion} \\
&- 0.0173M(5.867 - Pa) && \text{Latent respiration heat loss} \\
&- 0.0014\,M(34 - T_a) && \text{Dry respiration heat loss} \\
&- 3.96 \times 10^{8} \times fcl[(T_{cl} + 273)^4 - (T_{mrt} + 273)^4] && \text{Heat loss by radiation} \\
&- fcl \times h_c(T_{cl} - T_a)\} && \text{Heat loss by convection}
\end{aligned}
$$

Where M: metabolism (w/m2)
W: external work, equal to zero for most activity (w/m2)
M: metabolism (w/m2)
Icl: thermal resistance of clothing (clo)
fcl: ratio of body's surface area when fully clothed to body's surface area when nude
Pa: partial water vapor pressure (Pa)

3. TERRACE HOUSE

Commonly called link or terrace house, they are attached houses with similar façade treatment. Terrace houses are the ubiquitous form of housing in Malaysia in single or double stories. Each house unit occupies a rectangular lot with a land area between 130 and 170 square meters. The choicest unit, located on a corner lot, is usually twice as large as the intermediate lots. With such spatial constraints, the planning of these houses is usually predictable and mundane: deep living spaces, a smaller rear kitchen, and bedrooms with toilets. On the upper floors are the master bedroom (including toilet) and bedrooms. Nevertheless, this typology remains the mainstay of the country's mass housing strategy (Salleh, 1989). However, due to low benefits, developers have not put much effort into these sectors as compared to the medium and high-end sectors. Several studies in Malaysia have revealed that the modern terrace houses have not been built according to the country's climatic features (Takahashi, 1981; Mohamad Ali, 2003). Many of the houses have been built in unsuitable orientations without appropriate shading design. Furthermore,