Indoor Thermal Environment in Residential Buildings at Different Micro-Climates in Malaysia

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Keywords: thermal comfort, indoor air temperature, building simulation, Meteonorm, tropical climate

Abstract. Buildings in tropical climate receive more heat because of the location that's bear equatorial experience warm and humid all the year. Heat surplus causes discomfort to the occupants in the tropical climate. Higher solar and terrestrial radiations reaching the building envelopes contribute to this problem. Occupants respond to indoor thermal discomfort by installation of air conditioning and mechanical fan that can cool down the interior spaces. These appliances increase in electricity consumption and lead to the increasing of carbon emission. It has been reported that most of the electricity consumption in residential buildings is due to the cooling purpose. Thereby this study examines the condition of the indoor thermal environment in residential building that cause the increase of energy consumption. The study also seeks the effects in the thermal environment in residential building may be associated with different microclimates. The simulation conducts in a typically-designed residential building at three different microclimates to look for the best indoor thermal performance. This article discusses the results of an assessment of the level of indoor thermal environment for a typical residential building in different urban locations in Malaysia. Ecotect is used to analyse the hourly indoor temperature during the hottest and the coldest days in 2012, in Six (6) indoor living spaces in a residential building model which are living area (L), kitchen (K) and four bedroom; master bedroom (MB), (B1), (B2) and (B3). The residential building has been modelled for Ipoh (I), Kuala Lumpur (KL) and Johor Bahru (JB) climate. Meteonorm is used to generate hourly outdoor air temperature in I, KL and JB which will be used in Ecotect simulation. The results showed that the highest internal temperature of 38.7 °C was obtained in Living (L) for KL's climate at 1400 hours. Overall, the indoor temperature is higher than the interior design recommended in Malaysian Standards; MS1525:2007, especially for KL climate.

1. Introduction

Overheating is the primary problem of climatic design in warm and humid climates. The climate characterised as high relative humidity and small diurnal temperature difference caused to this problem (Szokolay, 2008). Malaysia is located near the equator lies between latitudes 1° and 7° North and longitude 100° and 119° East. The building is exposed to about six hours of sunshine per day on average ("www.met.gov.my," 2012), (Abu Bakar, 2002). Daily air temperature and mean monthly relative humidity between 24 °C to 38 ° C and 70 % to 90 %, respectively (Dahlan, Jones, Salleh, & Dixon, 2008). The building exposed to intense solar radiation for long term resulting discomfort to the occupants. Residents react to thermal discomfort by using tools that can cool down the interior spaces such as air-conditioning and fans at the expense of an increase in electricity consumption which lead to carbon emissions (Faisal, Aya, Naoki, & Rahman, 2013). Moreover, in addition to solar radiation, lack of thermally efficient buildings (Ismail & Rashid, 2011) has increased thermal discomfort among occupants of buildings in Malaysia . It has been reported that in residential buildings, most of the electricity consumption due to space cooling, with a contribution of 29 % (Kubota, Jeong, Toe, & Ossen, 2011), this is due to a higher rate of electricity consumption from air-conditioning compared with other home appliances. Numerous strategies to improve the thermal efficiency of residential buildings and reduce electricity consumption has been identified by researchers such as the installation of roof insulation (Farhan, Khamidi, Ziela, et al., 2012), the reduction of the thermal conductivity of materials (Farhan, Khamidi, Murni, et al., 2012), the surface chosen with high reflectance (Priyadarsini, Hien, & Wai David, 2008), the installation of the green roof and green wall (Ismail, Samad, & Rahman, 2011, Malys, Musy, & Inard, 2014) and ventilation techniques (Faisal et al., 2013,Kubota et al., 2011). In addition, it is also important that the awareness and willingness of developers, the public and researchers are increased (Yacouby et al., 2012), (Farhan, Khamidi, Yacouby, Idrus, & Nuruddin, 2012) to promote the implementation of the strategy on a large scale in providing thermal efficient residential building. This article presents and discusses the results of an assessment of the level of indoor thermal environment for a residential building in Malaysia at different microclimates. The purpose of the present paper is to examine the condition of indoor thermal environment in residential building and the possible effects of different microclimates on its performance. The findings presented in this article can provide researchers with motivation to develop strategies to improve the thermal efficiency of residential buildings in Malaysia and a foundation comparison to evaluate their effectiveness.

2. Methodology

2.1 Simulation Computer Program.

This study utilized two (2) types of software, which are Ecotect and Meteonorm. Ecotect is a computer program package for conceptual building design and environmental analysis tool (www.usa.autodesk.com/ecotect-analysis/,2012). Ecotect provides simple, equally accurate and visualization interface of wide range of performance analysis function such as thermal, lighting, acoustic and shading. This computer simulation program is used to build the residential building model and to obtained thermal performance in double storey residential building design that commonly found in Malaysia. In this study, Ecotect is suitable to comprehend with this research's objectives and used to generate indoor temperature in six (6) indoor living spaces in a residential building model under Ipoh (I) Kuala Lumpur (KL) and Johor Baharu (JB) climate. Meteonorm is used to generate weather data using stochastic models. Data stored in Meteonorm was obtained from weather stations placed at 8,300 locations around the world. These data provide information such as wet and dry bulb temperature, relative humidity, wind speed and direction and cloud cover ("Information on www.meteonorm.com," n.d.). In this study, Meteonorm is used to generate hourly outdoor air temperature in I, KL and JB to be used in Ecotect simulation program. The building simulation program was carried out in the residential building which was naturally ventilated and an intermediate unit.

2.2 Weather Data

The climatic data of I, KL and JB were generated from Meteonorm computer program. The hourly outdoor air temperatures are exported as files in EnergyPlus format (. EPW). Then, this EPW files converted in Ecotect computer program into files that compatible for Ecotect simulation format (.WEA).

2.3 Residential Building Model.

A two-storey residential building model with a floor area of 159.80 m^2 and a height of 3.0 m was developed (Figure 1). The layout of the indoor space (Figure 2) of the residential building model which is commonly used in Malaysia consists of a living area (L), kitchen (K) and a room (B1) on the ground floor and three (3) bedrooms and a hall on the first floor. The bedroom consists of a master bedroom (MB) and two (2) small bedrooms (B2) and (B3). The construction materials used in thermal analysis for the building envelope are clay brick with plaster on both sides for wall, reinforced concrete for floors, beams and columns and clay tiles and steel trusses for roofs.

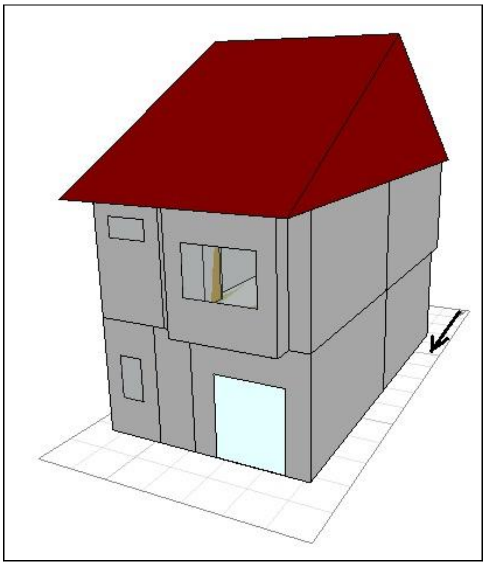

Figure 1. Perspective view of residential building model

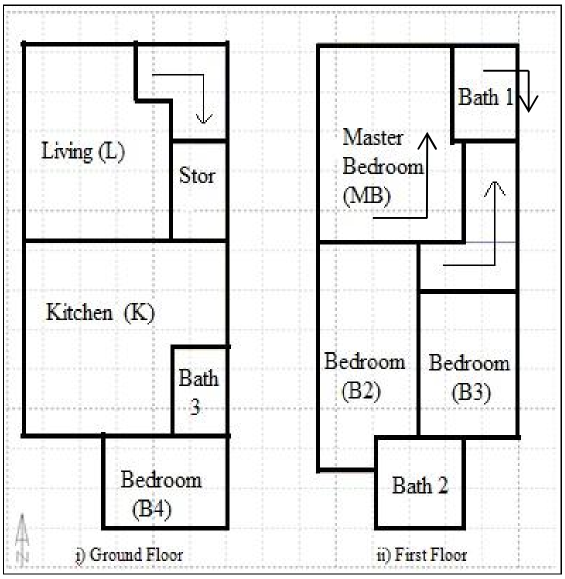

Figure 2. Indoor space layout of residential building model

3. **Data Collection and Analysis**.

Simulation of the outdoor air temperatures (T_o) is done by loading the weather files; .WEA file in Ecotect after the model of a residential building was constructed in 3D editor canvas. Then, hourly indoor air temperature (T_i) in L, K, B1, B2, B3 and MB indoor living spaces in the model of residential buildings under I, KL and JB on the hottest and coldest day of 2012 were produced. The hottest day is the highest peak daily temperatures as recorded in .WEA weather file, which varies with location. The coldest day is the lowest daily temperatures recorded. The highest indoor ($T_{i,highest}$) temperature during the hottest day and coldest day is determined. Finally, the indoor temperature in the residential building model is compared with the indoor design condition recommended in MS1525: 2007; which range in 22 - 28 °C (Department of Standards Malaysia, 2007).

4. Results and Discussion.

Figures 3 to 5 present the indoor temperature profile of L, K, B1, B2, B3 and MB indoor living space during the hottest day of the year under climate I, KL and JB, respectively. Each climate shows the highest indoor temperature at difference indoor living spaces. As seen in Figure 3, Ipoh climate, living area (L) gives the highest indoor temperature of 37.9 °C at 1200 hours. Figure 4 illustrates highest indoor temperature in KL climate was in bedroom 3 (B3); 38.7 ℃ at 1400 hours. The distribution of indoor temperature in JB climate peaked at 34.5 °C in bedroom 1 (B1) also at 1400 hours. The lowest hourly indoor temperature range of 28° C – 30 °C, was obtained under JB climate. Based on this analysis, in all three microclimates the values of hourly indoor temperature were higher than the indoor design conditions recommended in MS1525: 2007 which is marked by a dotted line at 28 °C.

ISBN: 978-1-61804-259-0

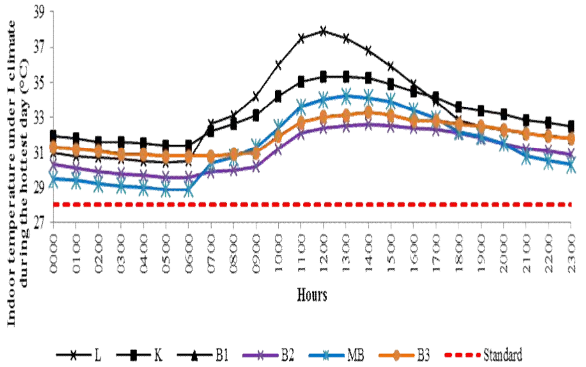

Figure 3. Indoor temperature in Ipoh during the hottest day

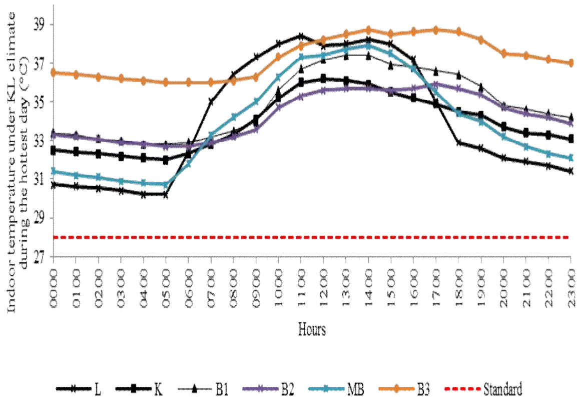

Figure 4. Indoor temperature in Kuala Lumpur during the hottest day

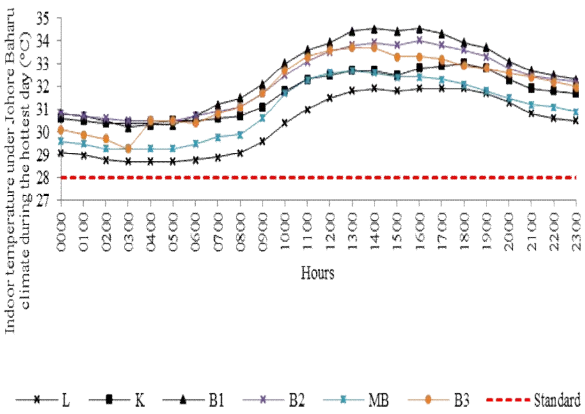

Figure 5. Indoor temperature in Johor Baharu during the hottest day

Figures 6 to 8 present the indoor temperature profile of L, K, B1, B2, B3 and MB indoor living space during the coldest day of the year under climate I, KL and JB, respectively. Ipoh climate demonstrates the highest indoor temperature during the coldest day at the same indoor living space as the hottest day. Meanwhile the result in KL and JB climate indicated in different indoor living spaces. For Ipoh climate the highest indoor temperature (T_i) of 34.1 °C at 1200 hours in living area (L), the highest indoor temperature in KL climate given in living area (L) with 37.7 °C at 1400 hours and JB climate in bedroom 3 (B3) is 33 °C at 1400 hours. The lowest hourly indoor temperature (T_i) range of 26 °C – 29 °C, was obtained under JB climate. However, the values of hourly indoor temperature were higher than the indoor design conditions recommended in MS1525: 2007 found under KL climate. The analysis show the hourly indoor temperature during the coldest day in KL climate is higher than 28 °C.

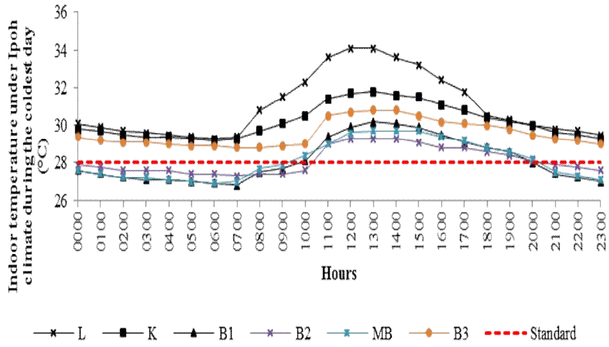

Figure 6. Indoor temperature in Ipoh during the coldest day

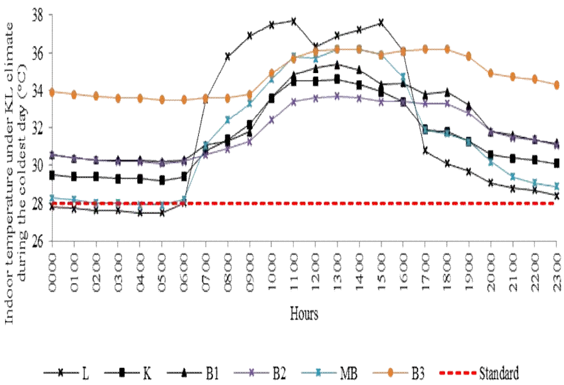

Figure 7. Indoor temperature in Kuala Lumpur during the coldest day

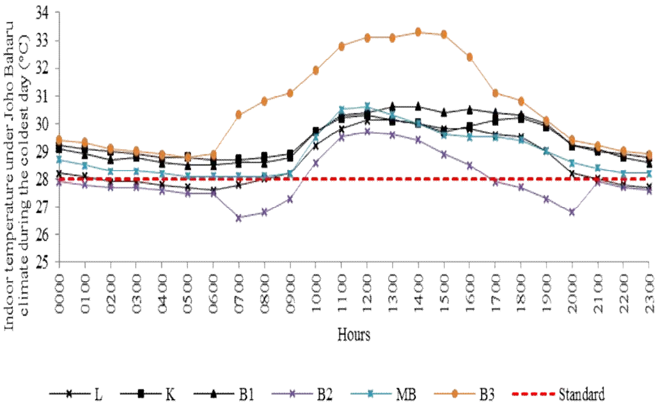

Figure 8. Indoor temperature in Johor Baharu during the coldest day

5. Conclusion.

In general, the hourly indoor temperature is higher in KL climate either during the hottest or the coldest day rather than I and JB climate. The study exhibited that the highest indoor temperature of 38.7 °C was obtained in the bedroom 3 (B3) under KL climate at 1400 hours. While the lowest indoor temperature revealed in JB climate during the coldest day, range of 26 °C – 29 ℃. However, the hourly indoor temperature of all the three location studied is higher than the indoor temperature design recommended in MS1525: 2007 for thermal comfort condition in building. Thus it can be conclude that the microclimates affect the design of the residential building resulting variation on the level of indoor thermal environment. Hence, this finding provides potential information on the performance of indoor thermal conditions in different locations of the selected residential buildings design. The developers and building designers should take consideration of microclimates factor in providing sustainable indoor thermal environment in residential building. Further research is encouraged to explore strategies in reducing the indoor temperatures in residential buildings in order to fulfil the indoor design conditions recommended in MS1525:2007.

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