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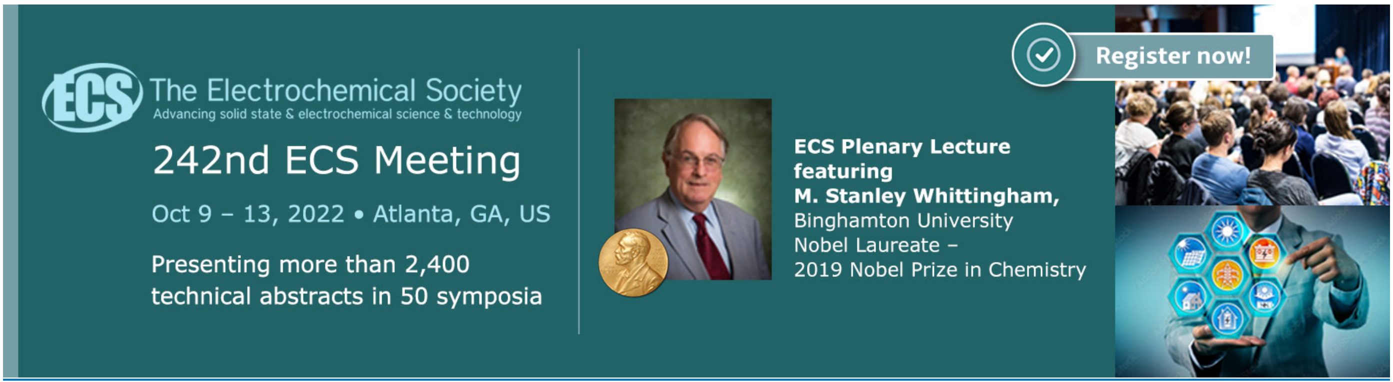

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Thermal characteristics of a residential house in a new township in Johor Bahru

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Abstract. As one of the densest population occurred in Johor Bahru, development of a new township become necessary in order to cater this growth. Rapid urbanization is a factor of degradation of environmental quality which may increase surrounded temperature through urban heat island (UHI) phenomena. Therefore, this paper is investigating thermal comfort for a new township, Bandar Dato Onn in Johor Bahru, in order to understand the thermal characteristics of a new township and for further mitigation of UHI phenomena. Surface temperature, ambient temperature and relative humidity have been collected from a terrace house of Bandar Dato Onn. Thermal characteristics with the features of time lag and decrement factors were discussed based on the collected data. The time lag of 5 to 8 hours and the decrement factors of 0.02 to 0.06 were recorded during a five-day measurement. It was concluded that human thermal comfort may not be achieved as the heating, ventilation and air conditioning (HVAC) system needed for bedroom and living room. Passive energy design is suggested to be included in the house in order to have human thermal comfort while reducing the electricity consumption towards sustainable future.

1. Introduction

As population of Johor in Malaysia increased from 3.46 to 3.66 million [1], between 2012 and 2016, development of new township should be launched to cater the population growth. Johor Bahru is the capital of Johor which consists of the highest population density among districts of Johor.

Urban heat island (UHI) has been identified to be likely occurred in dense developing countries where most of the South-east Asia countries are facing rapid change of natural resources and environment. This change is associated with urbanization, industrialization and economic development [2]. A dramatic growth of urban population is associated with serious degradation of environmental quality [3] which may link to UHI phenomena, increasing surrounded temperature.

Human thermal comfort is one of the considered features in the selection of living criteria. Outdoor thermal comfort may induce good social relationship among the residents where social activities can be conducted frequently. Moreover, the usage of electricity can be reduced if the indoor thermal comfort is achieved. Global warming and rapid urbanization are the main sources of increment of temperature for urban thermal environment [4]. Some mitigations have been suggested to improve human thermal comfort, such as increasing vegetation surface coverage and shading effects for Dutch city, Rotterdam [4].

Thermal bioclimate and its influence as urban design factor have been discussed in Cuba [5]. The obtained results may provide information to create space for tourism and usable in the reconfiguration of cities [5]. Thermal comfort surveys have been conducted in the city of Belo Horizonte, Brazil to evaluate thermal comfort conditions and identify potential thermal adaption processes [6]. Behavioural adaptation is suggested to be considered in designing strategies for urban planning [6].

Thermal comfort is one of the considered factors in urban planning and development by avoiding UHI phenomena for developing countries. Therefore, this paper investigates the thermal characteristic of a terrace house in Bandar Dato Onn Township where climatic data will be collected for further analysis. Suggestions have been made in order to achieve human thermal comfort in this new city development.

2. Data collection

Surface and ambient temperatures have been recorded inside and outside the house. The surface temperature was collected through thermocouple wire type-T with Graphtec Midi data logger, whereas, the ambient temperature was obtained by using HOBO data logger.

2.1. Location selection

The data collection was performed in a residential terrace house of Bandar Dato Onn. Bandar Dato Onn is one of the latest township development in Johor Bahru to cater the population growth. The location of the site investigation was set at a residential house of Bandar Dato Onn.

2.2. Site setup

The experimental setup is shown in figure 1 where the red line was the location of the measurement of surface temperature. The red lines or measured walls were located at Bedroom 1 and living room where direct sunlight was radiated on the morning and afternoon respectively. The data have been collected for five day period for further thermal performance analysis.

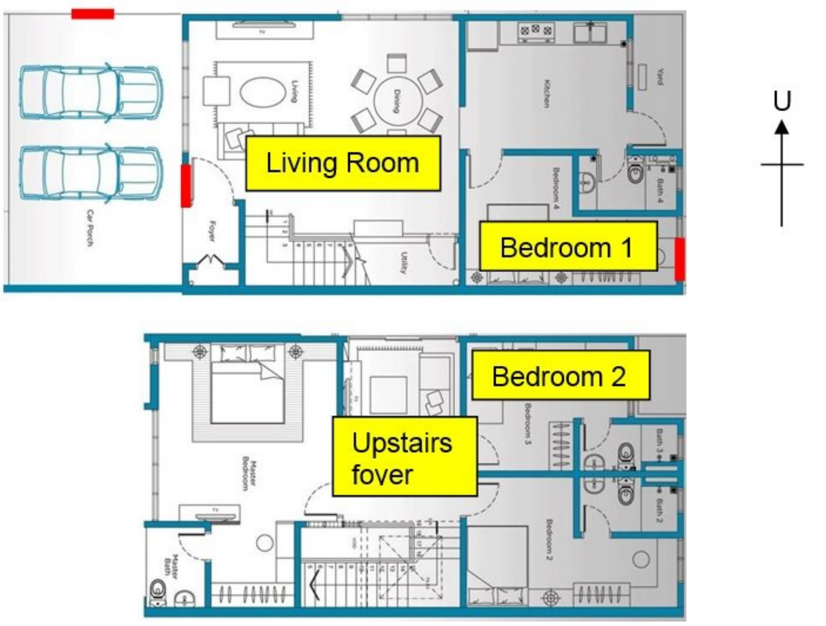

Figure 1. Floor plan of the site.

3. Results and discussion

3.1. Ambient temperature and relative humidity

Surface temperature, ambient temperature and relative humidity have been recorded and analysed for human thermal comfort study. Figure 2 showed the ambient temperature of living room, bedroom 1, bedroom 2 and upstairs foyer. Bedroom 1 has a constant ambient temperature as it was not occupied and the door was closed all the time. Although it was around 29°C to 30°C, the room was isolated from the temperature variation from nearby space. For bedroom 2, it was occupied and air-conditioning was operated on the night time where the temperature was kept under 25°C. The temperature could rise up to 31°C at night time unless air-conditioning was set on. Ambient temperature at living room was recorded high in first two days where air-conditioning system was switched on for human thermal comfort. For next three days, the temperature was expected to be achieved the highest during evening time. Upstairs foyer had a normal temperature variation according to the testing period.

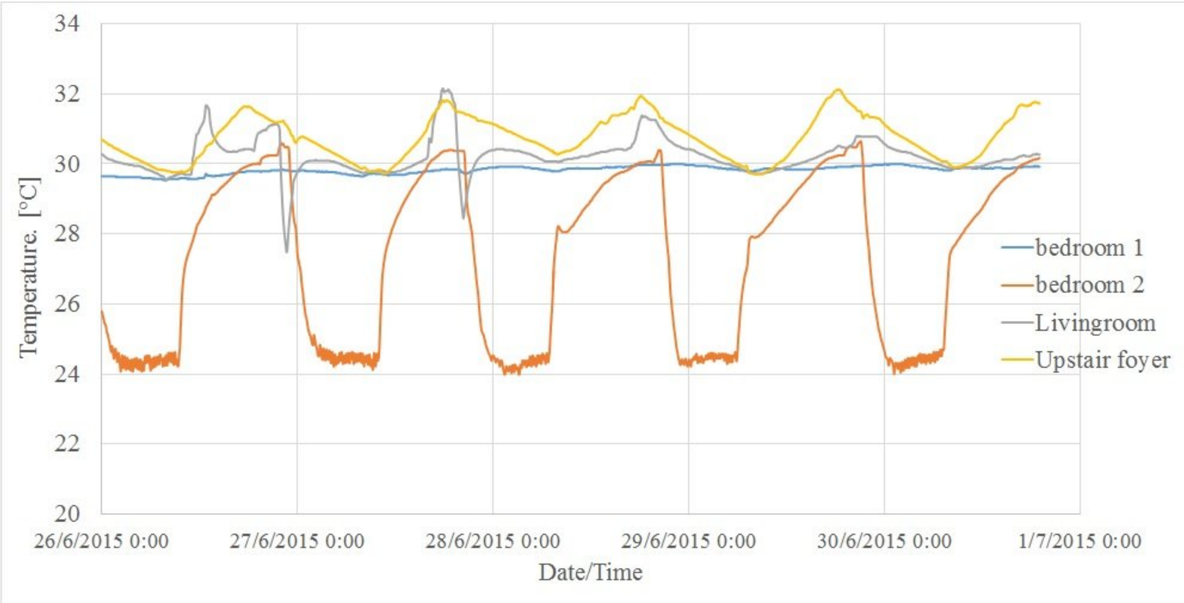

Figure 2. Ambient temperature for all locations.

For figure 3, relative humidity graph has been plotted. There was a drastic drop of relative humidity for living room and bedroom 2 when the air-conditioning system was operating. Other spaces were recording the indoor relative humidity ranged 65 to 80% during the test period. Rain may not affect much on indoor relative humidity.

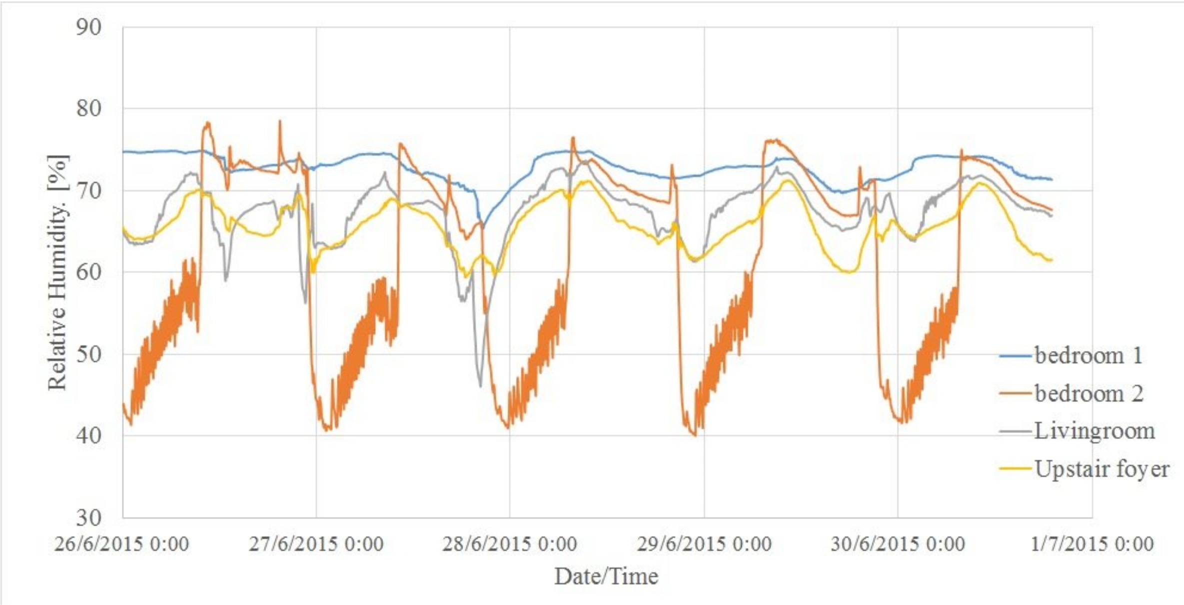

Figure 3. Relative humidity for all locations.

3.2. Surface Temperature

The surface temperature and relative humidity of bedroom 1 were shown in figure 4. The outside wall surface temperature obviously fluctuated as compared to inside wall surface temperature and ambient temperature. The relative humidity was inversely varied with outdoor surface temperature. The outdoor temperature fluctuation was doubtedly influenced to the indoor environment. For the inside walls, when facing to the East, left indicated beside with bathroom, whereas, right indicated the wall shared with next house. Both surface temperatures have almost constant variation throughout the testing period.

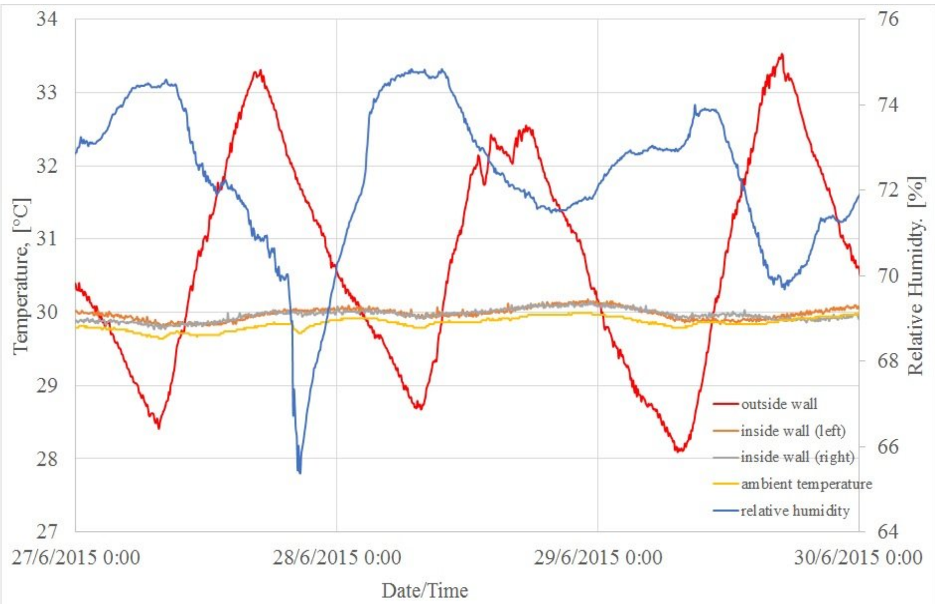

Figure 4. Recorded temperatures and relative humidity for bedroom 1.

According to figure 5, the surface temperature and relative humidity are shown for the living room. The investigated wall at outdoor environment consists of two, where "far" indicated wall at car porch (refer Figure 1) and near indicated wall at main entrance. Higher temperature was recorded at outer wall at car porch as there was no shading and exposure to direct sunlight in the afternoon. On the other hand, the wall at main entrance showed slightly lower temperature than at car porch at the evening, but exhibited higher temperature at midnight until the next morning. This correspond to the location of the measurement taken where the wall at car porch re-emitted the heat to the surrounding environment by convection process due to lower temperature at outdoor to achieve thermal equilibrium. However, the area of the main entrance was enclosed by the car porch that might trap the heat within the area causing less heat released to the outer environment and obtained a higher surface temperature. Meanwhile, ambient temperature and inside wall surface temperature behaved constantly during the testing observation.

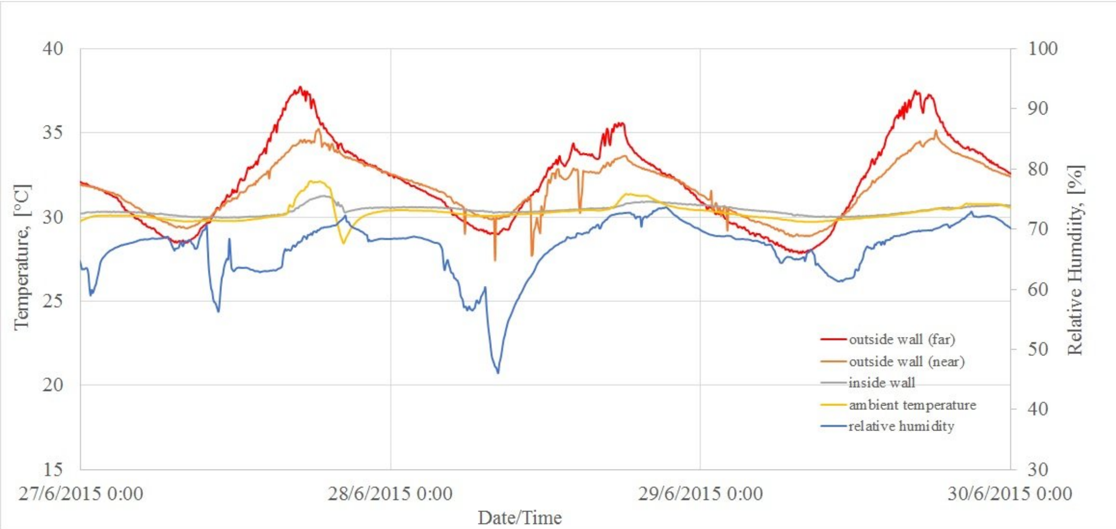

Figure 5. Recorded temperatures and relative humidity for living room.

4. Discussion

Time lag and decrement factor are two characteristics to determine the heat storage capabilities of any materials [7]. Time lag is referred as the times used for heat wave to propagate from outer to inner surfaces, whereas, decrement factor is decreasing ratio of its amplitude during the heat propagation [7].

The thermal variations between indoor and outdoor surface temperatures were ranged 2.37°C and 3.4°C for bedroom 1 as shown in figure 6. Living room was not included in the analysis due to the non-appropriate temperature distribution of indoor wall surface temperature. Time lag was measured the time taken between outdoor maximum temperature to indoor maximum temperature. For bedroom 1, the recorded time lag was ranged 355 to 530 minutes. The time lag showed a 5 to 8 hours of new amplitude to be occurred.

Table 1 shows decrement factor for bedroom 1. The decrement factor included the materials of paint, concrete cover and brick. The small indoor amplitude variation contributed to lower decrement factors. Another factor that contributing to the decrement factor was the applied HVAC system at the testing period.

From the analysis, HVAC system was still needed in day 1 and 2 for the space of bedroom where the heat from the outer surface was released to inner space at night time. Although the decrement factor was low, however, human thermal comfort may not be achieved. Therefore, it is suggested that the passive energy design should be applied in order to achieve thermal comfort and reduce the electricity consumption. Further detailing on the passive design should be investigated in the next stage of study.

Table 1: Temperature variation and decrement factor for bedroom 1.

Exp. Day	Outer		Inner		Temp. amplitude		$f = A_i/A_o$
	Max.	Min.	Max.	Min.	A_o	A_i	
2	33.07	28.47	30.04	29.81	4.60	0.23	0.05
3	33.28	28.67	30.01	29.92	4.61	0.09	0.02
4	32.51	28.09	30.13	29.86	4.42	0.27	0.06
5	33.48	28.51	30.07	29.91	4.97	0.16	0.03

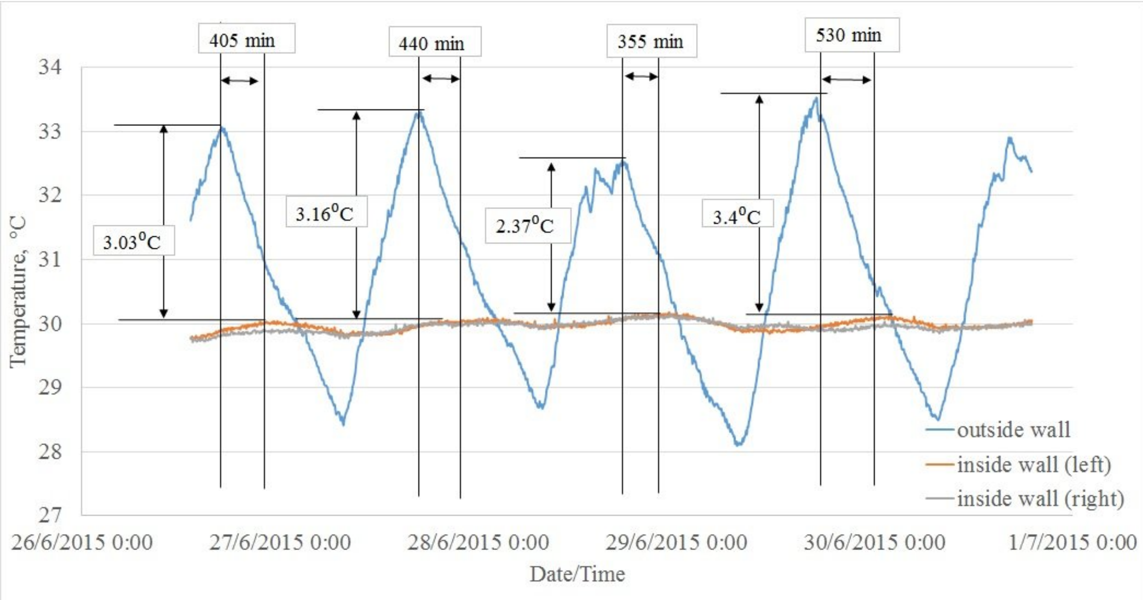

Figure 6. Thermal variations of indoor and outdoor surface temperatures and the time lag.

5. Conclusion

A thermal characteristic of a terrace house of a newly developed township in Johor Bahru, Bandar Dato Onn, has been performed. Surface temperatures, ambient temperatures and relative humidity were collected. From the collected data, the time lag of 5 to 8 hours and decrement factors of 0.02 to 0.06 have been recorded for bedroom 1. Although low decrement factors have been found, the human thermal comfort may not be achieved for day 1 and 2, as HVAC system was still needed for living room and bedroom 2. Passive energy design is recommended for better human thermal comfort and reduction of electricity consumption. This study was carried out in one of the residential house where larger data collection around Bandar Dato Onn area (residential and commercial areas) is suggested for better representation of the thermal characteristics of this new township.

6. References

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