Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 546-554

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

The Effects of Natural Ventilation Techniques on Indoor Air Temperature for Urban Terrace Houses in oht Humid Climate

Gracie Vanessa Jekop[1], Mohd Azuan Zakaria[1]*

[1]Department of Civil Engineering, Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2022.03.01.066
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Natural ventilation is one of a technique that could improve indoor thermal environment. To this day, urban terrace houses have been develop rapidly and it usually are hotter than the house in a rural are. The aim of the study is to investigate the effect of different natural ventilation techniques on air temperature and relative humidity of a terraced house in Malaysia. The field measurement has been carried out in a single storey terraced housed for three days for each of the case study which consist of day ventilation (case 1: 7a.m. to 7p.m.), night ventilation (case 2: 7p.m. to 7a.m.) and full day ventilation (case 3: 24 hours). The measurement was measured with Thermo Recorder Tr-72U for air temperature and relative humidity. The sensor was placed at 1.5m above ground at the center of the urban terrace house for living room and bedroom. The result shows that case 2 which is night ventilation has the lowest air temperature detected in the urban terrace house during night-time. Case 2 shows a reduction of 6.3˚C for the maximum air temperature between indoor and outdoor air temperature compared to all cases. Night ventilation is the most recommended for the natural ventilation techniques application. This field measurement might give an assist to other researcher and also to the society in the future which shows the effectiveness of natural ventilation that will contributing on saving energy with using less mechanical ventilation.

Keywords: Natural Ventilation, Night Ventilation, Terraced House

1. Introduction

Urban houses have been developed rapidly in Malaysia because of growing housing requirements and account for about 91% of the overall current urban houses whose most common form of housing is landed terraced house [1, 2]. Urban houses usually hotter than a house in a rural area [3, 4]. In order to remove the uncomfortable hot conditions, the occupants of urban houses tend to using air-conditioner instead of a fan. Moreover, dependency on air-conditioner for indoor cooling will resulted to great effect on the environment due to the release of chemical gas such as Chlorofluorocarbon [5, 6, 7]. Therefore,

*Corresponding author: azuanz@uthm.edu.my

some strategies required to overcome the problem which is by natural ventilation. Natural ventilation is one of passive cooling techniques and a proper consideration on natural ventilation strategies could improve the thermal comfort and required less energy for cooling [5, 6, 7]. Poor consideration of ventilation such as providing too hot or too cold of indoor air will give negative effect to the occupant inside the building [8, 9]. Indoor comfort can be satisfied by passive technique, such as natural ventilation [5] and natural ventilation can regulate temperatures effectively when it revealed that in hot and humid climates, natural ventilation has strong potential [10].

Nowadays, the phenomenon of climate change has posed a threat to the human environment. Malaysia is located near the equator and has a warm and humid climate. High solar radiation intensity and high daily air temperature are the most important climatic impacts in Malaysian buildings [11]. Thus, the effectiveness of natural ventilation need to be reassessed to know whether the required strategies is still suitable and potential. Traditional cooling strategies are often considered to be highly important because in the hot humid climate, air-conditioning energy consumption has grown dramatically over the last few decades [12]. However, the effectiveness of natural ventilation strategies for indoor cooling and comfort of urban houses in hot humid climate need to be reassessed due to climate change phenomena and rises of outdoor air temperature in the recent year. The aim of this study is to analyze indoor air temperature and relative humidity between each cases of ventilation that consists of day ventilation, night ventilation and full day ventilation. Natural ventilation is one of the most important thing inside a building, house and other construction. Without this natural ventilation, me might have this kind of uncomfortable situation such as the shelter is too hot. The importance of this study was to find the suitable method to reduce the dependencies on mechanical cooling especially to reduce air temperature and regulate indoor relative humidity.

2. Literature Review

Previously, a field experiment was performed in two adjacent terraced houses in Johor Bahru, Malaysia, from June to August 2007 to investigate the effects of different ventilation techniques, including daytime ventilation and night ventilation. The entire structure was not insulated [12]. Daytime ventilation, in fact, replicates the window opening of current households observed in the previous study, while night ventilation was found to have the lowest indoor air temperature [12]. Night ventilation, as predicted, offers the lowest indoor air temperatures of the open window conditions assessed [13]. Even with night ventilation, the measured operational temperatures surpass the upper limit, particularly after the breakpoint, which is the daytime closed window state [12].

Based on Kubota & Toe, 2015, it shows that the indoor-outdoor temperature relationship in terraced houses is segmented for daytime ventilation and nighttime ventilation, most likely due to changes in open window conditions and the thermal mass effect [12]. As comparison to daytime ventilation, the regression line for night ventilation estimates lower indoor operational temperature [12]. The simulation results of a traditional Malaysian terraced house show that indoor thermal comfort can be achieved in naturally ventilated conditions by implementing several passive cooling strategies that avoid external heat on the outer building envelope and night ventilation, even in hot urban climatic conditions [13]. The use of a natural ventilation system will help to mitigate the detrimental impact of solar radiation on rising indoor air temperature [10].

When air conditioning is used, it is effective to minimize the sensible cooling load by 39 to 56 percent relative to the present scenario by using a variety of strategies such as night ventilation and insulating inner surfaces [13]. Nevertheless, night ventilation would minimize the thermal distress encountered by current households that used daytime ventilation in terraced homes, but it would be inadequate to offer indoor thermal relief during the day [12].

3. Methodology

The field measurement were conducted in terrace urban house located in Kuching, Sarawak, Malaysia. This investigated urban terrace house is in an urban area where there is lack of green plant for maybe a better comfort, when in a rural area house will be more colder because of the surrounding green plant such as tree to sheltered the house from direct sunlight. The layout for this urban terrace

house is at intermediate (Figure 1) that make the wind direction flow from the front and the back of the house.

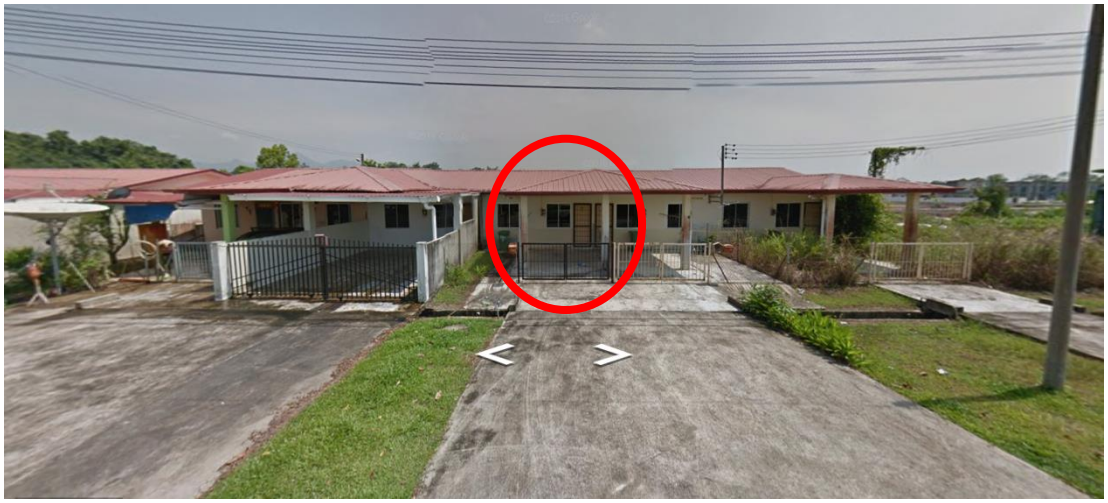

Figure 1: Location of the Terrace Urban House

The field measurement that were recorded in this case study are air temperature and the relative humidity. A thermo recorder sensor called TR-72U were used to get the parameter required which is air temperature and relative humidity. In this case study, it were conducted during daytime ventilation (7 a.m. to 7 p.m.), night ventilation (7 p.m. to 7 a.m.) and full day ventilation (24 hours). Each case study were conducted for 3 days and the sensor would record the data for every 15 minutes interval. During the case study were conducted, natural ventilation (windows and doors) were used to see the effectiveness and also there will be an occupants presence to make the result more realistic.

Measurement were conducted at two different places which is in living room and bedroom (Figure 2). The sensor was placed at 1.5m above the ground and located at the center of the living room and bedroom.

(a) **(b)**

Figure 2: Sensor location in the urban terrace house, (a) Living Room & (b) Bedroom

4. Results and Discussion

4.1 Thermal Condition in Living and Bedroom during Day Ventilation Mode

The graph at Figure 3 shows that the maximum temperature for living room was up to 35.1˚C and meanwhile for the minimum temperature is 28˚C. As for the bedroom, the maximum temperature have been recorded is 34.5˚C and the minimum is measured for 28.1˚C.

Figure 3 shows an average of 4.3˚C for case 1 that indicate the living room air temperature is higher than outdoor air temperature. The average of bedroom air temperature was found higher than outdoor by 4.1˚C. Comparing the condition of living room and bedroom during case 1, it was found that living room is warmer than bedroom in average of 0.2°C. The average temperature differences show only a slight difference between both rooms. This shows that bedroom having slightly better condition than the living room in Case 1. The air temperature for both room are higher than outdoor due to the surrounding of the urban terrace house that surrounded by other terrace house as well.

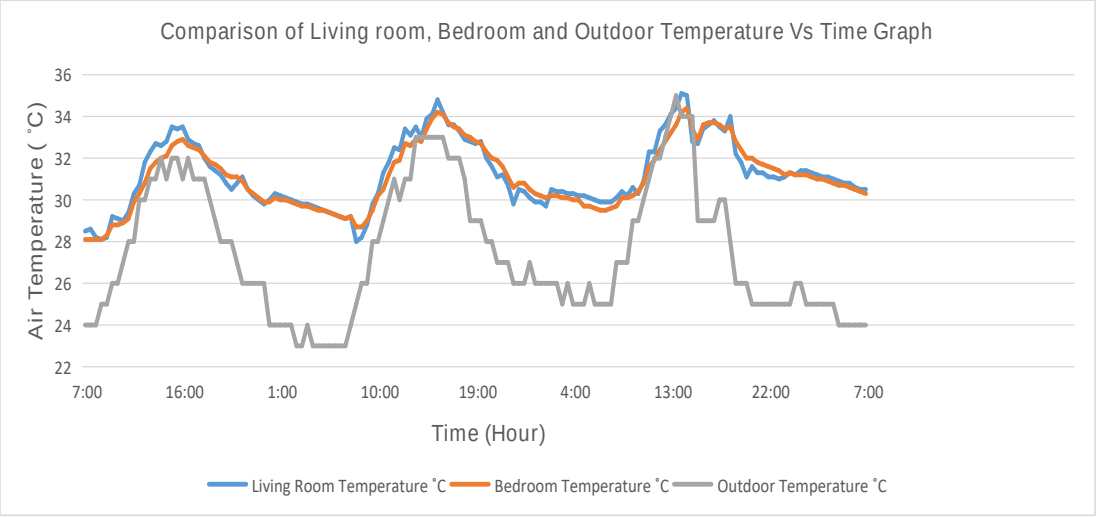

Figure 3: Living Room, Bedroom and Outdoor Air Temperature versus Time Graph for Day Ventilation (Case 1)

4.2 Thermal Condition in Living and Bedroom during Night Ventilation Mode

The graph at Figure 4 shows that the maximum temperature for living room was up to 33.3˚C and meanwhile for the minimum temperature is 28.7˚C. As for the bedroom, the maximum temperature have been recorded is 33.1˚C and the minimum is measured for 28.7˚C.

Graph shown at figure 4 shows an average of 3.1°C for case 2 that indicate the living room temperature is higher than outdoor temperature. The average of bedroom temperature was found higher than outdoor by 3.2°C. Comparing the condition of living room and bedroom during case 2, it was found that living room is cooler than bedroom in average of -0.1°C. The average temperature differences show only a slight difference between both room. This shows that living room having slightly better condition than the bedroom in Case 2. This probably due to air movement from the outside flow through the opening ventilation during nighttime in the living room.

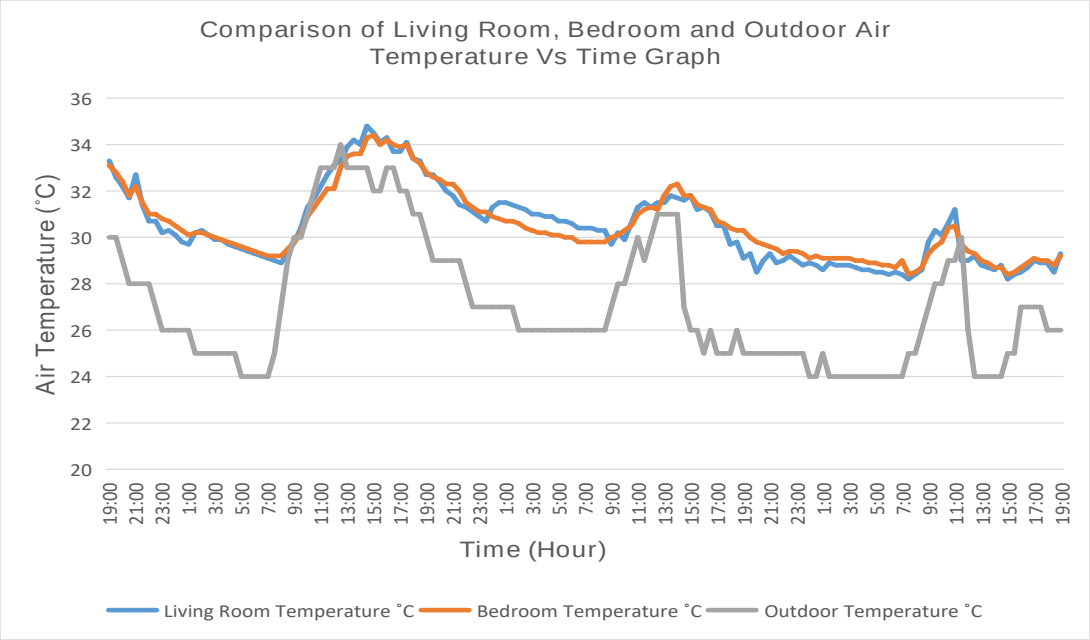

Figure 4: Living Room, Bedroom and Outdoor Air Temperature versus Time Graph for Night Ventilation (Case 2)

4.3 Thermal Condition in Living and Bedroom during Full Day Ventilation Mode

The graph at Figure 5 shows that the maximum temperature for living room is 35.4°C and the minimum temperature is 29.9°C during daytime. During night-time, living room recorded a maximum temperature of 33°C and the minimum is 28.3°C in the living room. As for the bedroom, it shows a maximum temperature of 35°C during daytime and the minimum is up to 29.7°C. During night-time, bedroom measured a value of 33°C for the maximum temperature and meanwhile for the minimum temperature, bedroom recorded a temperature of 28.9°C.

Figure 5 shows on average, during daytime, it was found that living room temperature was higher than outdoor by 4.2°C. During nighttime, living room obtained an average of 2.1°C for air temperature that shows it higher than outdoor. For bedroom, on average it was found that indoor temperature was higher than outdoor by 4.0°C during daytime. During nighttime, the average of bedroom was higher than outdoor by 2.4°C. Comparing the condition of living room and bedroom during case 3, it was found that living room is warmer than bedroom in average of 0.2°C during daytime and cooler than bedroom during nighttime with an average of -0.3°C. This shows that bedroom having slightly better condition than the living room during daytime. This might happen due to less activities happen in the bedroom during daytime. However, during nighttime, living room having slightly better condition than the bedroom. This probably due to more air movement from the outside flow through the opening ventilation during nighttime. Furthermore, the living which have a dimension of 3.5 m width and 3.2 m length can effects the air temperature inside the room due to the small size of room.

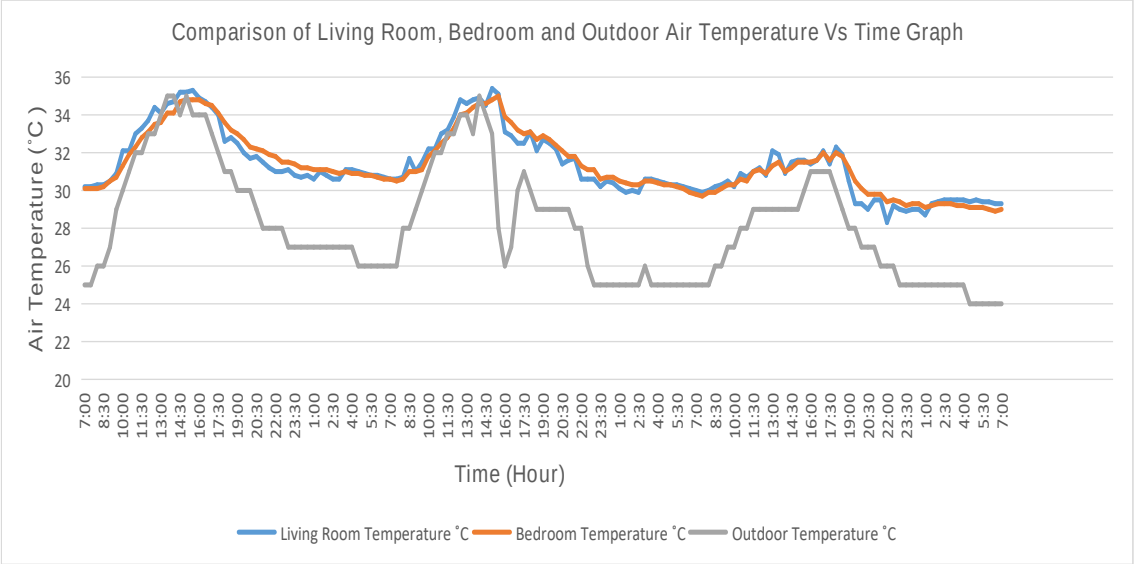

Figure 5: Living Room, Bedroom and Outdoor Air Temperature versus Time Graph for Full day Ventilation (Case 3)

4.4 Temperature Differences Between each Cases

As shown in Figure 6 below, case 3 shows a highest differences of 7.1°C during daytime and the lowest differences is recorded of -0.4°C. As for case 2, the differences shows only 6.3°C during night-time and meanwhile for the lowest, it shows a differences of -1.0°C. Case 1 for the highest differences shows a different for only 6.9°C that occurred during daytime and meanwhile for the lowest differences, it shows only -1.0°C differences.

Figure 6 below show the graph of comparison of indoor and outdoor air temperature difference versus time between each cases in the living room. On average, during case 3 it was found that indoor air temperature was higher than outdoor by 3.2˚C. Case 2 was found that indoor air temperature was higher than outdoor by 3.4˚C in average. The average for case 1 shows that indoor temperature was higher than outdoor by 3.6˚C. When compare the condition of each cases, it was found that case 1 is hotter than case 2 and case 3 which shows the highest differences of indoor and outdoor temperature of 3.6˚C.

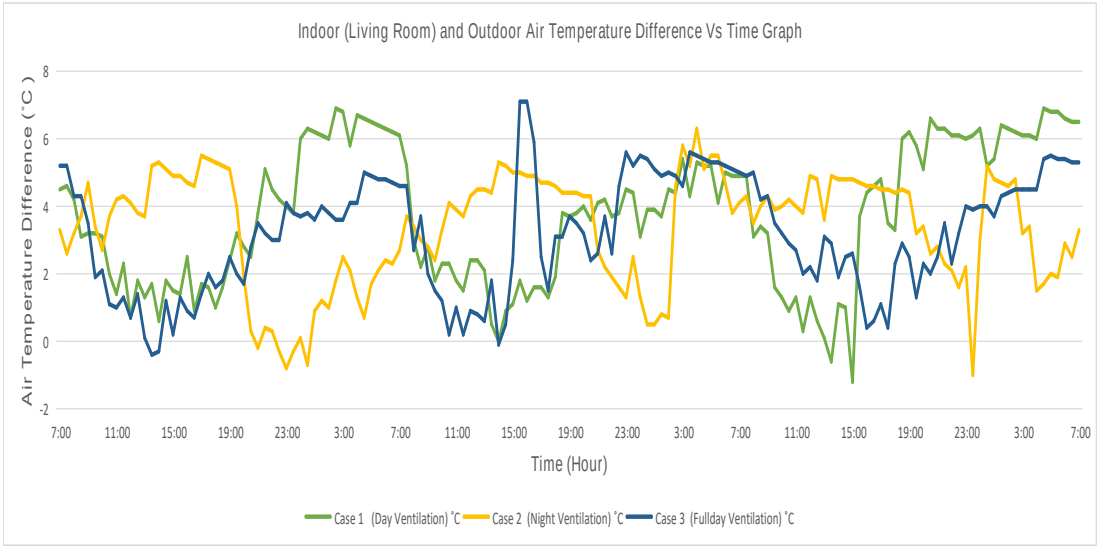

Figure 6: Differences of Indoor and Outdoor Air Temperature versus Time Graph in Living Room between each cases

As shown in Figure 7 below, case 3 shows a highest differences of 7.9°C during daytime and the lowest differences is recorded of -0.9°C. As for case 2, the differences shows only 6.3°C during night-time and meanwhile for the lowest, it shows a differences of -1.3°C. Case 1 for the highest differences shows a different for only 6.8°C that occurred during daytime and meanwhile for the lowest differences, it shows only -1.4°C differences.

Figure 7 below show the graph of comparison of indoor and outdoor air temperature difference versus time between each cases in the bedroom. On average, during case 3 it was found that indoor air temperature was higher than outdoor by 3.2˚C. Case 2 was found that indoor air temperature was higher than outdoor by 3.4˚C in average. The average for case 1 shows that indoor temperature was higher than outdoor by 3.6˚C.

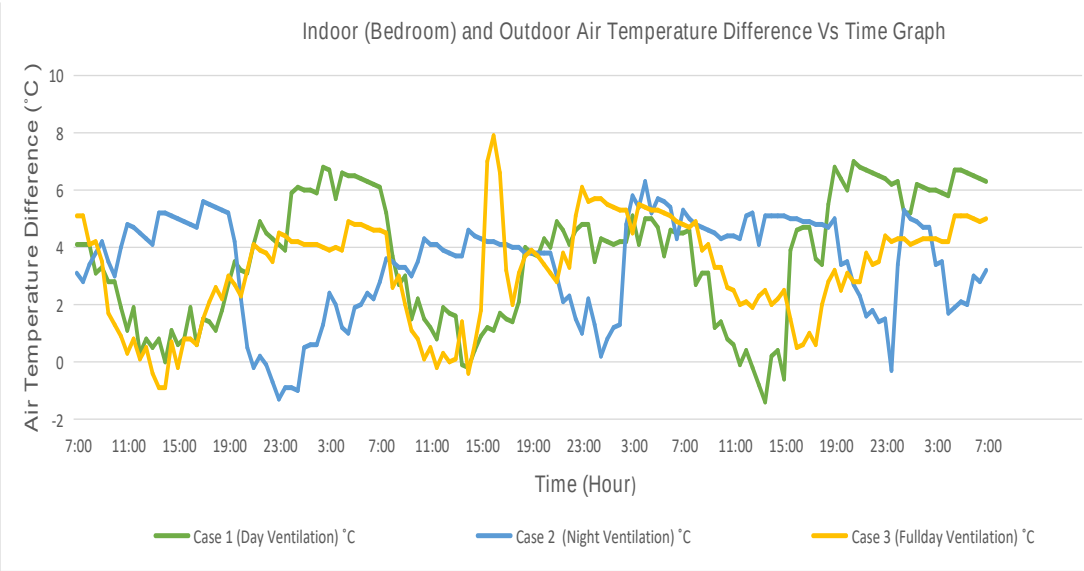

Figure 7: Differences of Indoor and Outdoor Air Temperature versus Time Graph in Bedroom between each Cases

4.8 Summary

Each cases showed a different readings of all parameters involved. It clearly shows that indoor air temperature is much higher than outdoor air temperature. From the previous graph, it shows a dramatically different in the temperature differences which from the indoor and outdoor temperature. It shows that the outdoor temperature is much lower than the temperature inside the house.

Several factor might take places in affecting the thermal performances inside the house. A lack of air circulation inside the house also affecting the performances when there is no present of positive pressure from the outside to getting rid of the negative pressure from the inside. The factor also include a presence of occupants inside the house which can affect the thermal performances by the heat from the occupants body. Occupants' activities also giving an effect for the higher air temperature in the living room for each cases. Furthermore, the surrounding of the terrace urban house also giving an effect towards the rises in the air temperature.

5. Conclusion

The effects of the natural ventilation techniques might giving a great impact to the urban terrace house. This study conduct a field measurement by applying natural ventilation techniques that considered opening windows and doors for the natural ventilation. The purposes of this field measurement help to identify the thermal performances by applying the natural ventilation technique. However, the result of the data taken on this field measurement shows a different result from each of case study. One of the main contributors on the effects of the higher temperature might be the location of the urban terrace house which is located in the intermediate house. It can cause limited positive

pressure of air to enter the house which the flow only from the front and the behind of the urban terrace house. As expected, case 2 which is night ventilation shows a lower air temperature for both room and it means by night ventilation is preferable for the natural ventilation techniques. Night ventilation is the most recommended for the natural ventilation techniques application and by applying the techniques might reduce the cost of the electricity because less energy of using mechanical ventilation by the occupants.

5.1 Recommendation

There are several recommendation regarding this study to ensure future use. The recommendations are the field measurement should be conducted during a good weather to make the result more precisely. In addition, the interval time for the sensor to take the reading need to be adjusted and equated for both indoor and outdoor. Furthermore, the field measurement can be conducted on the same day for all cases to make the results more accurate. Last but not least, the parameter for this field measurement need to be added such as the air velocity or the wind speed to make the overall result more realistic and accurately for thermal comfort assessment.

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for all the support and grateful for all guidance through the process.

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