Asian Journal of Environment, History and Heritage
December 2019, Vol. 3, Issue. 2, p. 21-28
ISSN 2590-4213 e-ISSN 2590-4310
Published by Malay Arts, Culture and Civilization Research Centre,
Institute of the Malay World and Civilization

CHANGES IN INDOOR AIR TEMPERATURE DUE TO DIFFERENT OPERABLE PANEL WINDOW AT MOSQUE DURING *RAMADHAN*

(PERUBAHAN SUHU UDARA DALAMAN MASJID TERHADAP OPERASI PANEL TINGKAP YANG BERBEZA KETIKA RAMADHAN)

Nur Baitul Izati Rasli, Nor Azam Ramli & Mohd Rodzi Ismail

Abstract

Jemaah need to gain a feeling of comfort, peace, and serenity during their religious congregations especially during Teraweh prayer as it takes a longer time indoor (about one h and 30 min). Hence, this study was conducted to evaluate the temperature change (T) (°C) at different operable window (i.e. close and open windows). The monitoring was conducted within the main prayer hall of Masjid Seri Ampangan for four h and 30 min from 18:00 to 22:30 h (before Maghrib until Teraweh prayers). T and relative humidity (RH) were measured using an indoor air quality probe (IQ-610) Graywolf Model whereas air speed hot wire (AS-201) Graywolf Model was used to measure air movement (AM). The results indicated that the T within the main prayer hall could be reduced by lowering the percentage of the dead wall (%) (i.e. Open window). The 7.98 %, difference in average percentage of dead wall between close window (98.49 %) and open window (90.51 %) has reduced the T by 0.46 °C within the main prayer hall of the mosque. Therefore, this study suggested that perhaps by increasing the opening area (reducing dead wall) could reduce the T within the main prayer hall of mosques.

Keywords: Air Movement, Dead wall, Mosque, Temperature, and Opening area.

Abstrak

Jemaah perlu mendapat keselesaan, kedamaian, dan ketenangan semasa melakukan aktiviti-aktiviti keagamaan terutamanya semasa solat Teraweh kerana ia mengambil yang lebih lama (kira-kira 1 jam dan 30 minit). Oleh itu, kajian ini dijalankan untuk menilai suhu (T)(°C) apabila panel tingkap mempunyai operasi yang berbeza (panel tingkap yang tertutup dan terbuka). Pemantauan dilakukan di dalam dewan solat utama Masjid Seri Ampangan selama empat jam dan 30 min dari pukul 18:00 hingga 22:30 jam (sebelum Maghrib hingga solat Teraweh). T dan kelembapan relatif (RH) diukur dengan menggunakan indoor air quality probe (IQ-610) Graywolf Model manakala air speed hot wire (AS-201) Graywolf model digunakan untuk mengukur pergerakan udara (AM). Keputusan menunjukkan bahawa T di dalam dewan solat utama dapat dikurangkan dengan menurunkan peratusan dinding mati (%). Dengan perbezaan sebanyak 7.98%, diantara peratusan purata dinding mati untuk tingkap tertutup (98.49%) dan tingkap terbuka (90.51%), T dapat diturunkan sebanyak 0.46 °C di dalam dewan solat utama masjid. Oleh itu, kajian ini mencadangkan dengan meningkatkan kawasan terbuka berkemungkinan dapat mengurangkan T dalam dewan solat utama masjid.

Kata Kunci: *Pergerakan udara, Dinding mati, Masjid, Suhu, dan Kawasan pembukaan*

INTRODUCTION

Abdullah et al. (2016) stated that mosques should be within an acceptable thermal comfort region as *Jemaah* need to gain a feeling of tranquillity, peace, and serenity when praying in mosques Ibrahim et al. (2014). Nevertheless, Malaysia's Industrial Code of Practice (ICOP) had set the limit for indoor air temperature between 23^{o}C-26^{o}C to ensure that the occupants are protected from poor indoor air temperature that could adversely affect their health and well-being; and reduce their productivity (DOSH 2010).

The fresh air can effectively distribute into the building by natural ventilation for the occupants' comfort by using the natural forces of wind. It could introduced air into the building space by cross ventilation (Yang and Clements-Croome 2013). Cross ventilation is the wind pressure differences. The example movement of air through cross ventilation is shown in Figure 1 (Yang and Clements-Croome 2013). It is functional to enhance the flow of air movement through a building caused by a wind-generated pressure drop across it (MS 2014). Hence, this research aims to evaluate the temperature (T) (°C) at the different operable window (i.e. close and open window panels) as the open window could promote cross ventilation to occur.

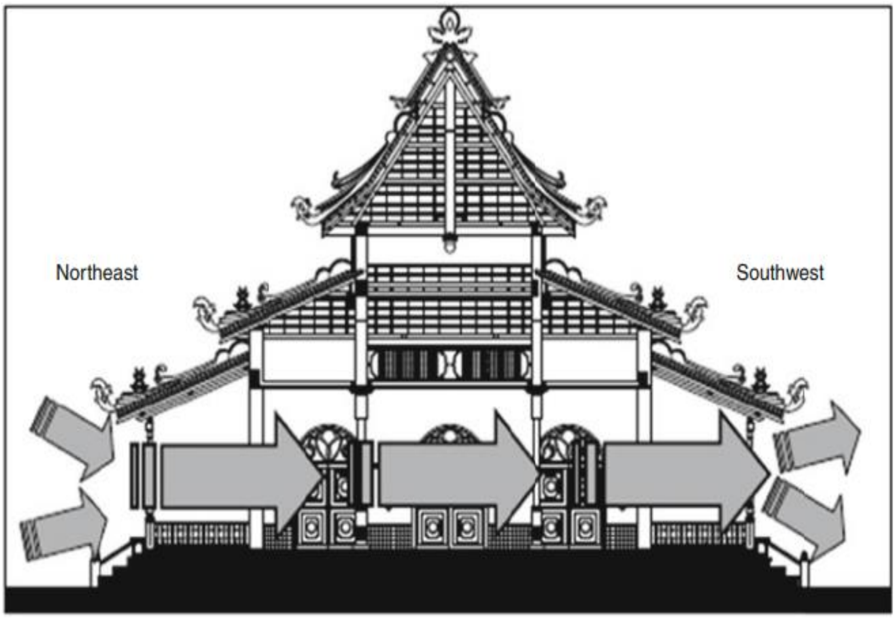


Figure 1. The air movement of cross ventilation design analysis, viewing toward Southeast façade in the traditional Malacca Mosque, Malaysia [Source: Professor Vivian Loftness at Carnegie Mellon University] (Yang and Clements-Croome 2013)

MATERIALS AND METHODS

Sampling Locations

This study was conducted at *Masjid Seri Ampanga,* which use passive and mechanical ventilations (fan) within the *Seberang Perai Selatan, Pulau Pinang* area. *Masjid Seri Ampangan* has a longitude of N5.148894 and latitude of E100.487500.

Selection of Monitoring Instruments

An Indoor Air Quality probe (IQ-610) was used to measure temperature (T) and relative humidity (RH), whereas air movement (AM) was monitored by Hot-Wire Air Speed (AS-201). Both of the instruments used were from Graywolf Model. The instruments were placed on a tripod with 1.2 m from the floor at the centre of main prayer halls. Readings of all the parameters were obtained after 30 minutes to 1 hour to stabilize with 1-minute real-time average (100% data logging).

Sampling Method

The monitoring at the *Masjid Seri Ampangan* was conducted from 18:00 to 22:30 h (4 hours and 30 minutes). The monitoring covered before *Maghrib* prayers until *Teraweh* prayers for two days at the different operational window (i.e. Day1: close windows and Day 2: open windows). The outdoor temperature was assumed to be similar as both days has similar, i.e. dry with very little wind. The monitoring schedule for *Maghrib*, *Isyak*, and *Teraweh* prayers is as shown in Table 1 whereas the monitoring within the main prayer halls of *Masjid Seri Ampangan* is as shown in Figure 2.

Table 1. Monitoring schedule of *Masjid Seri Ampangan* for *Maghrib*, *Isyak*, and *Teraweh* prayers

Time (h)	Session	Activities	Parameters Monitored
18:00 to 22:30	*Maghrib*, *Isyak*, and *Teraweh* prayers	Before *Maghrib* prayers During *Maghrib* prayers Between *Maghrib* and *Isyak* prayers During *Isyak* and *Teraweh* prayers	T, RH, and AM

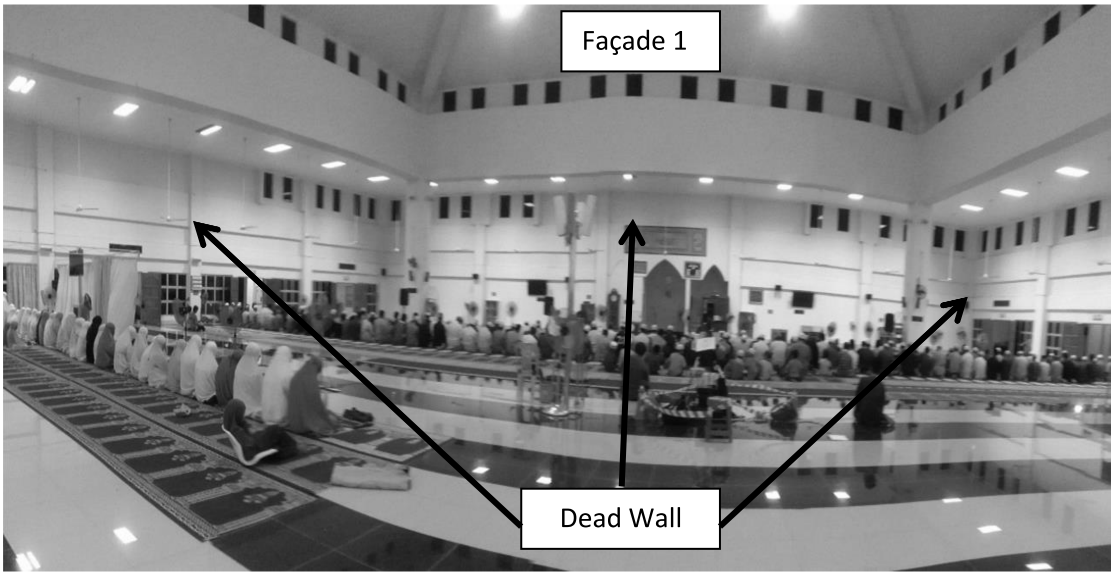


Figure 2. The monitoring within the main prayer hall at *Masjid Seri Ampangan*

Determination of Façade, Window to Wall Ratio (WWR), and Dead Wall within the Main Prayer Hall

The façades in the mosque were divided into four (i.e. Façade 1, Façade 2, Façade 3, and Façade 4). The front side of the main prayer hall which is the *qiblat* area was represented as Façade 1. Façades 2, 3, and 4 represented the left, rear, and the right sides, respectively of the main prayer hall of *Masjid Seri Ampangan*.

WWR was calculated by adding all the glazing areas (i.e. Windows, and doors) and divided by each façade areas. The total glazing area of the façade and the average WWR were calculated according to Eqs. (1) and (2), respectively.

$$\text{Total glazing area of facade} = \frac{\text{Opening (glazing area)} + \text{Window (glazing area)} + \text{Door (glazing area)}}{\text{Facade area}} \quad (1)$$

$$\text{Avg. WWR} = \frac{\text{Glazing area (F1)} + \text{Glazing area (F2)} + \text{Glazing area (F3)} + \text{Glazing area (F4)}}{4} \quad (2)$$

A dead wall is defined as a wall without opening, which includes bricks, concrete, glass, and wood. Dead wall areas were calculated by subtracting all the active panels (i.e. Open doors and windows) for each façade and divided by the façade area, and the average percentage of dead walls was calculated according to Eqs. 3 and 4, respectively.

$$\text{Dead Wall} = \frac{\text{Wall Area - Opening Area (open) - Window (open) - Door (open)}}{\text{Facade Area}} \quad (3)$$

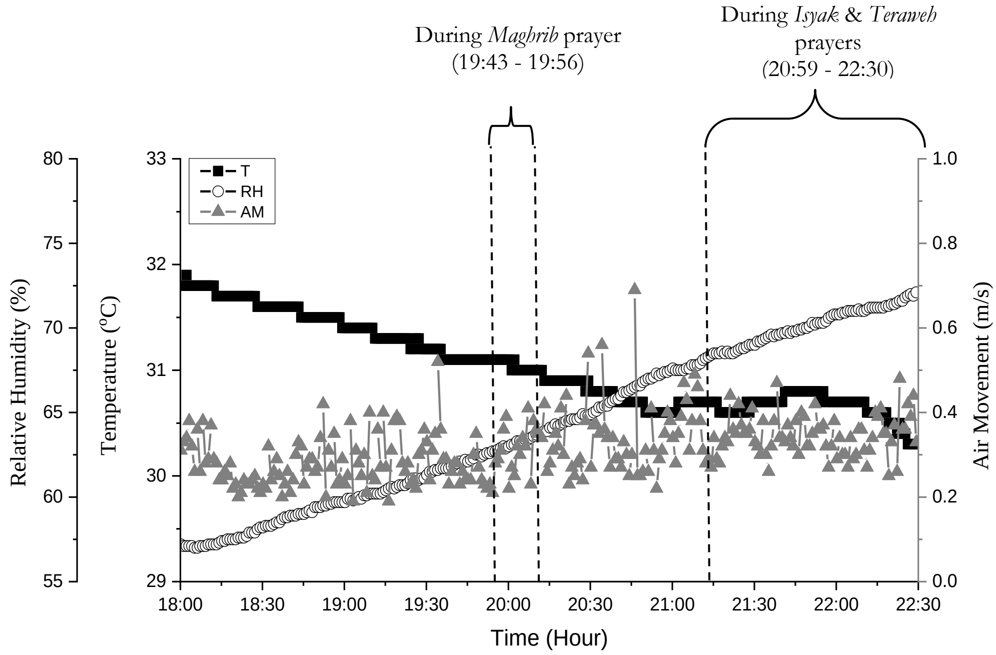
$$\text{Avg.Dead Wall}(\%) = \frac{\text{Dead Wall(F1)} + \text{Dead Wall(F2)} + \text{Dead Wall(F3)} + \text{Dead Wall(F4)}}{4} \text{X100} \quad (4)$$

RESULTS AND DISCUSSION

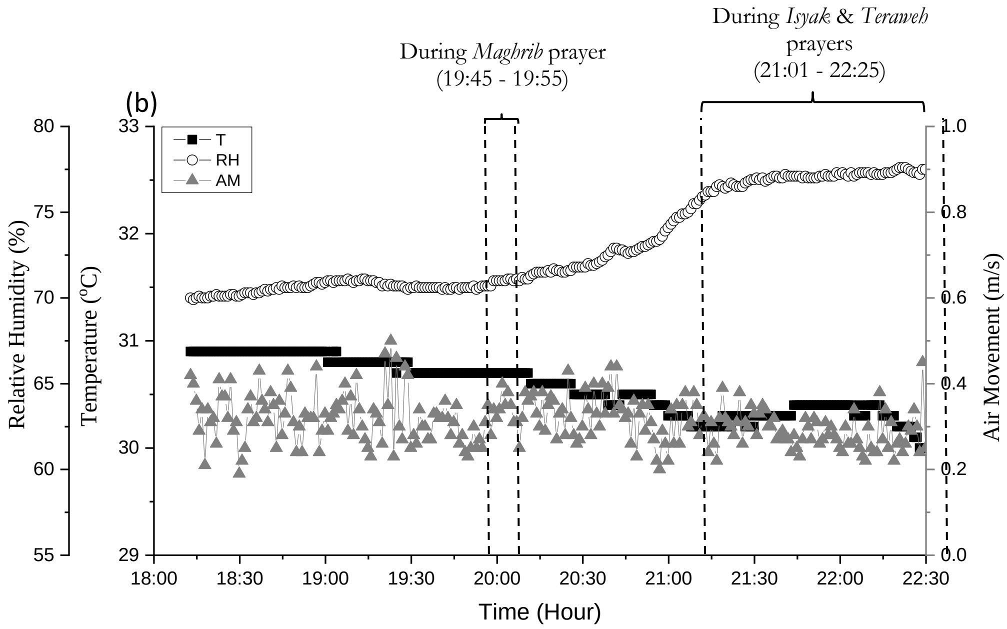
Table 2 shows the maximum, minimum, and average of T, RH, and AM within the main prayer hall of *Masjid Seri Ampangan* with the different operable window in accordance to the acceptable limit by ICOP (DOSH 2010). Meanwhile, Figure 3 shows the fluctuations of T, RH, and AM within the main prayer hall of *Masjid Seri Ampangan* at different operable windows (a) close and (b) open before *Maghrib* until *Teraweh* prayers. The results show that the average T at the opened window was slightly lower than the closed window. However, both T has exceeded the ICOP limit of 23 to 26 °C. The range of T at the closed window was 30.30 to 31.90 °C, meanwhile at the opened window was 30.10 to 30.90 °C. T at both closed and opened windows had similar trending which is the T was slightly decreased from during *Maghri*b prayer to during *Isyak* and *Teraweh* prayers.

Table 2. The maximum, minimum, and average of T, RH, and AM within the main prayer hall of *Masjid Seri Ampangan* with the different operable window in accordance to the acceptable limit by ICOP (DOSH 2010)

Parameter / **ICOP Limit**	**Air Movement (0.15 – 0.5 m/s)**			**Temperature (23 – 26 °C)**			**Relative Humidity (40 – 70 %)**		
Window Operation	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Close	0.19	0.69	0.31	30.30	31.90	31.04	57.10	72.10	64.17
Open	0.19	0.47	0.31	30.10	30.90	30.58	69.90	77.60	73.16



(a)



(b)

Figure 3. The fluctuations of T, RH, and AM within the main prayer hall of *Masjid Seri Ampangan* at the different operable window (a) close and (b) open before *Maghrib* until *Teraweh* prayers

Next, there was no difference in an average of AM (0.31 m/s) at both closed and opened window; and the values were within the acceptable limit of 0.15 to 0.5 m/s. The ranges of AM at the closed and opened window were 0.19 to 0.69 m/s and 0.19 to 0.47 m/s, respectively. The AM at both closed and opened window also fluctuated since before *Maghrib* prayer performed as the fans were in operation. The average RH (64. 17 %; range: 57.10 to 72.10 %) at the closed was within the acceptable limit of ICOP whereas at the opened window did not (73.16 %; range: 69.90 to 77.60 %). The RH at both conditions also was inversely proportional to the T.

Table 3 shows the WWR of each façade and its average of *Masjid Seri Ampangan*. The WWR of façade 1 was 0.06, meanwhile for facades 2, 3, and 4 had the same value of 0.16. The average WWR was 0.14 which might not influence the high T within the main prayer hall as its lower than 0.25. A study by Al-Tamimi et al. (2011) in the student residential building in Malaysia, suggested that thermal comfort can be enhanced at 0.25 WWR.

Table 3. The WWR of each façade and the average of *Masjid Seri Ampangan*

Window-to-wall Ratio (WWR)				
Façade 1	Façade 2	Façade 3	Façade 4	Avg.
0.06	0.16	0.16	0.16	0.14

Table 4 shows the percentage of the dead wall (%) for each façade and its average of *Masjid Seri Ampangan*. The percentages of the dead wall (%) at façades 1, 2, 3, and 4 during the closed windows were 100.00 %, 95.97 %, 100.00 %, and 97.98 %, respectively. Meanwhile, the percentages of the dead wall (%) during the opened window were 100.00 %, 85.32 %, 89.37 %, and 87.34 %, respectively. The different average of dead wall between closed window panel (98.49 %) and opened window panel (90.51 %) was 7.98 % and the average T was reduced for 0.46 °C when the window was opened.

Table 4. The percentage of the dead wall (%) for each façade and its average of *Masjid Seri Ampangan*

Window Operation	**The percentage of the dead wall (%)**					**T (°C)**
	Façade 1	**Façade 2**	**Façade 3**	**Façade 4**	**Avg.**	**Avg.**
Close	100.00	95.97	100.00	97.98	98 .49	31.04
Open	100.00	85.32	89.37	87.34	90.51	30.58

This result indicated that lowering percentage of the dead wall could decrease the T within the main prayer hall. Perhaps the fresh outdoor air could pass through the opening (open window) to the indoor by creating direct physiological cooling (Elbayoumi et al. 2015). Application of the natural ventilation system could reduce the indoor air T (Al-Tamimi and Syed Fazil 2010) and could promote the cross ventilation. Event though, the reduction in the average T in this study was 0.46 ˚C, it still showed that when the windows were opened, it could introduce to the cross ventilation which is caused by the wind pressure differences, hence reducing the average temperature. The cross ventilation is functional to enhance the flow of air movement through a building caused by a wind-generated pressure drop across it (MS 2014). The T within the main prayer hall could be reduced by increasing the opening area of façades to introduce cross ventilation to occur.

The small reduction in T was probably due to two possible factors. First, the measurements were carried out at the middle of prayer hall of 40 m length times 40 m width, which was too far away from the windows. Secondly, the dominant influence of fans (mechanical ventilations). Measurements nearer to the window panel opening should give a steeper reduction in T. Mosques with high WWR or even permanent opening at Façade 2, 3 and 4, should result in lower indoor temperatures, hence providing comfort to the *Jemaah*. The example of the mosque with a wide opening area that allows the cross ventilation to occur is as in Figure 4.

Future design and alterations of façade should take into considerations WWR and opening to promote movement of air hence lowering indoor temperature.

Figure 4. The mosque with a wide opening area that allows the cross ventilation to occur at (a) *Masjid Kapitan Kling* and (b) *Masjid Tengkera*

CONCLUSION

This study was conducted out to evaluate the T (°C) at the different operable window (i.e. close and open window). It was carried out from 18:00 to 22:30 h during *Maghrib* to *Teraweh* prayers within the main prayer hall of *Masjid Seri Ampangan*. The results showed that lowering average percentage of the dead wall (%) (i.e. Open window) could reduce the average T within the main prayer halls. Increment of 7.98 %, of the different average percentage of dead wall between close window (98.49 %) and open window (90.51 %) decreased the average T by 0.46 °C. This study suggested that perhaps by lowering the percentage of the dead wall, which is by increasing the opening area, could lower the T within the main prayer hall for *Jemaah* to feel comfortable and peace during their religious congregations and other activities.

ACKNOWLEDGEMENT

This research was partly supported by the MINISTRY OF SCIENCE TECHNOLOGY AND INNOVATION MALAYSIA under SCIENCEFUND 1001/PAWAM/6013607 (06-01-05-SF0766) grant and the EACAR Innitiatives.

REFERENCES

Abdullah, F.H., Majid, N.H.A., and Othman, R. 2016. Defining issue of thermal comfort control through urban mosque façade design. *Procedia-Social and Behavioral Sciences* 234: 416-423.

Al-Tamimi, N.A.M. & Syed Fadzil, S.F. 2010. Experimental and simulation study for thermal performance analysis in residential buildings in hot-humid climate (Comparative Study). *Journal of Science & Technology* 15(1): 17-25.

Al-Tamimi, N.A.M., Syed Fadzil, S.F., & Wan Harun, W.M. 2011. The effects of orientation, ventilation, and varied WWR on the thermal performance of residential rooms in the tropics. *Journal of Sustainable Development* 4(2): 142-149.

DOSH. 2010. Department of Occupational Safety and Health. Industry code of practice on indoor air quality. Malaysia: Ministry of Human Resources 1-39.

Elbayoumi, M., Ramli, N.A., & Md Yusof, N.F.F. 2015. Spatial and temporal variations in particulate matter concentrations in twelve schools environment in urban and overpopulated camps landscape. *Building and Environment* 90: 157-167.

Ibrahim S.H., Baharun A., Nawi, M.N.M. & Junaidi, E. 2014. Assessment of thermal comfort in the mosque in Sarawak, Malaysia. *International Journal of Energy and Environmental* 5(3): 327-334.

MS. 2014. *Malaysian Standard. MS 1525:2014. Energy efficiency and use of renewable energy for non-residential buildings - Code of practice* (Second revision). Malaysia: Department of Standards Malaysia.

Yang, T. and Clements-Croome, D.J. 2013. Natural ventilation in built environment. *Sustainable Built Environments* : 394-425.

Nur Baitul Izati Rasli
Environmental Assessment and Clean Air Research (EACAR).
School of Civil Engineering, Engineering Campus,
Universiti Sains Malaysia (USM), 14300 Nibong Tebal,
Penang, Malaysia.
Email: nurbaitulizati@gmail.com

Nor Azam Ramli, (Ph.D)
Professor
Environmental Assessment and Clean Air Research (EACAR).
School of Civil Engineering, Engineering Campus,
Universiti Sains Malaysia (USM), 14300 Nibong Tebal,
Penang, Malaysia.
Email: ceazam@usm.my

Mohd Rodzi Ismail, (Ph.D)
School of Housing Building and Planning,
Universiti Sains Malaysia (USM),
11800 USM, Penang, Malaysia
Email: rodzi@usm.my

Submitted: 4 June 2019
Accepted: 25 Oktober 2019