©Journal of Applied Sciences & Environmental Sustainability 3 (8): 34 - 42, 2017
e-ISSN 2360-8013

Research Article

The Effect of Vegetation in Enhancing the Performance of Courtyard in Buildings of Tropical Climate

Modi S. Zango[1,2]*, Dilshan R. Ossen[1], Doris H. C. Toe[1], Pontip S. Nimlyat[1], Oluwagbemiga P. Agboola[1], Bobai J. Luke[1]

[1] Department of Architecture, Faculty of Built Environment, Universiti Teknologi, Malaysia, 81310 Skudai, Johor Bahru, Malaysia.

[2] Department of Architecture, Nuhu Bamalli Polytechnic, Zaria, Kaduna, Kaduna State, Nigeria.

Email: lbyeo2@live.utm.my

ARTICLE INFO

Article history
Received: 15/07/2017
Accepted: 05/08/2017

Courtyard, Vegetation, Air Temperature, Building Envelope, Sky view Factor.

Abstract

Vegetation and Built environments usually have a relationship in terms of air temperature mitigation, However, courtyard buildings, as a microclimate modifier is rarely assessed. The study examines the courtyard air temperature difference of the atmospheric condition in Chinese shop-house in Malacca, Malaysia. Advocacy, utilizing field measurement and centring on the difference in air temperature of the courtyard with 69% vegetation and courtyard with 18% vegetation under the same state of courtyard Area and height. The Microsoft Excel was used as the Statistical tool throughout the Analysis. The outcomes demonstrate that there exists a difference of 3-degree centigrade in the courtyard with 69% vegetation and courtyard with 18% vegetation. The results demonstrate that vegetation regulates the air temperature within the courtyards.

1. Introduction

The courtyard is defined as the internal space within the building that is open to the sky. Traced back to the pre-historic period courtyards are utilized extensively in China and Morocco. The functions of the courtyard are to prevent/protect the occupants from the harsh weather and provide environmental activities such as ventilation and lighting (27). The form of a courtyard, affected by the climate conditions of the region, in China the form reduces from the north to south. In general, the design and size of the courtyard have a greatly influenced by its performance (27). According to (27), the courtyard can be divided into; fully enclosed, semi-enclosed, and semi-open courtyard. Fully enclosed courtyard is attributed to elongate buildings as such comfortable spaces could be introduced to the core of the building through the courtyard.

©Journal of Applied Sciences & Environmental Sustainability 3 (8): 34 - 42, 2017
e-ISSN 2360-8013

The performance of the courtyard can be optimized by considering the building shape and the heat gain control devices. The forms of the courtyard have taken functional forms other than the quadratic forms of traditional ideas (1). The creation of new and modern forms typified as; U, L, T, or Y. The previous studies on courtyard houses though limited, but some of them focused on ventilation related ;(2), (3), (4),(5), (6),(7), (8), and (9). Others work on the effect of the courtyard on indoor thermal environments see ;(1), (10), and (11); ventilation effects of the courtyard; (7), (12), (13), (14). Several studies are developed on passive strategy by courtyards, e.g., (6). Energy assessment was conducted out by, for example, (10). Thermal performance of courtyard was analysed ;(15), (16), (17), (8), (13), (18), (19), whereas vegetation effects of courtyards were analysed in some studies; (20), (21), (22)(23), and (24). Courtyard houses are commonly found in China or Southeast Asia as well as in numerous different region of the universe (2). Past studies was directed on courtyard houses and their warm impacts, yet the majority of these studies were led in hot, dry atmospheres(25);(9), and a few studies were led in hot, sticky atmospheres. A part of the studies that were led in tropical atmospheres incorporate (13), (14) and (6). For instance, (13) researched the potential utilization of a courtyard for inactive temperature reduction in a solitary story thick-walled building situated in the ardent, moist atmosphere of Colombo, Sri Lanka. These findings gave huge knowledge into courtyard plan in tropical regions. Yet a large portion of them concentrated on isolated houses, which are not the same as Chinese Shop House column houses. Not at all like segregated houses, a lengthened column house normally just has a couple of openings, and in this way, its indoor warm conditions are essentially diverse. However, virtually many of the above subject were made in hot-dry climates and moderates climates and there are few studies that discuss the performances of vegetation within the courtyard houses in hot-humid climatic conditions. This research discourses the effects of vegetation on the courtyard air temperature in a Chinese shophouse in Malacca, Malaysia based on the findings of field measurements.

2. Methodologies

In The field mensuration was done in a 2 no. two storeys Chinese shophouse from 15/10/2014 to 22/10/2014. These shophouses are located in the central part of the heritage zone in Malacca, Malaysia. (2.2 0 N and 102.2 0 E), as showed in figure 1 & 2. The justification for selecting Malacca is because of significant of that Chinese shophouse as it originates from china. The shophouse peculiar because of the presence of the deep courtyard in which is common among the Malaysia traditional building. The two shophouses is located in the same area in the central row with a shallow frontage and along the deepness. This shophouse earlier built between the 1600s and 1800s with the solid mold of the Dutch Architecture. Malaysia has a closely consistent climate condition end-to-end of the year, for instance, the mean monthly

air temperature at Malacca weather station ranged from 26.50 C -27.8 0 C for a small variant of 1.30 C over the last thirty years.

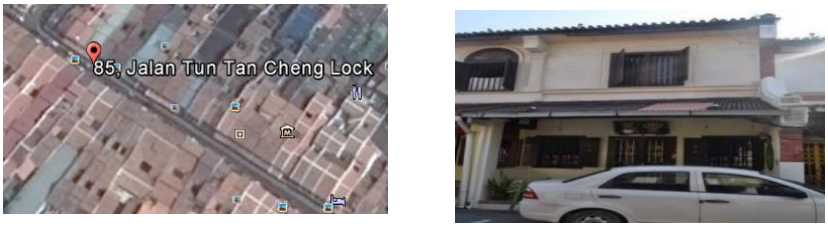

Fig. 1. Case study shophouse 1 (a) Location (source: google earth, retrieved on 34th October, 2014); (b) Front exterior view

Fig. 2. Case study shophouse 2 (a) Location; (source: google earth, retrieved on 24th October, 2014); (b) Front exterior view

Figure 3 & 4 shows floor plans of the case study. The two shophouse are located in almost the same location, as shown, the shophouses have three each deeply atrium-type courtyards at front (CY1), centre (CY2), and the rear (CY3) of the extended structure. In this case, CY1 of the first, and the CY3, of the second courtyard were selected, and they are almost in the same area (15 square metres). The sky view factor for the CY1 for the first shophouse was measured at 4.7% while CY3 the sky view factor for the CY3 of the second shophouse was measured at 7.4%.

©Journal of Applied Sciences & Environmental Sustainability 3 (8): 34 - 42, 2017
e-ISSN 2360-8013

Fig. 3. (a) Floor plans of case study Chinese shophouse 1 and (b) views of the three courtyards

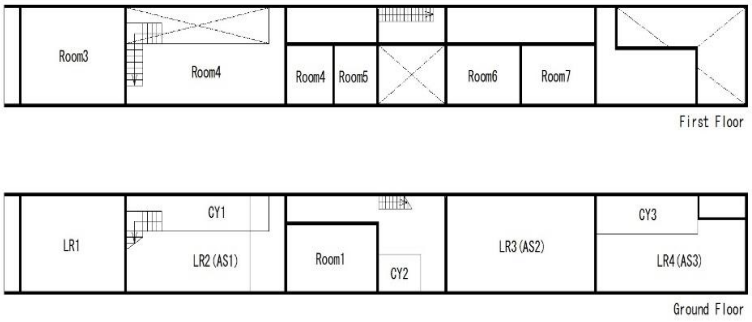

Fig. 4. (a) Floor plans of case study Chinese shophouse 2 and (b) views of the three courtyard

The thick clay tiles were applied for roofing without ceiling and thermal insulation while the wooden boards were adopted for the ceiling. On the first floor, wooden boards were also applied to the floor on the first floor, meanwhile, on the first floor was tiles. Windows and doors were created of wooden stuff without glass in. Floor materials for the CY1 were marble tiles while that of the CY3 was concrete.CY1 was covered with about 18% of potted plants, while the case of CY3, about 69% was covered with potted plants. The defined space height at first floor was almost 3.7m for CY1 and for the CY3, 3m. A veranda with a depth of 2m was located in front of the first shophouse while a depth of 1.8m was recorded in the second shophouse. The first shophouse is located at 85, Jalan Tun Tan Cheng Lock while the second shophouse is

located at 18, Jalan Tukang Emas. Both the shophouses are open to the street and it's used for commercial purposes. The building in use during the measurement and is occupied by only three people. The air conditioner did not install at all. Air temperature and relative humidity at 1.5m above floor were mensural at the centre of the two courtyards (T & D TR- 72), at the interval of ten minutes. Surface temperatures of roofs near the courtyards were calculated. The measurement takes about seven days, meanwhile, outdoor air temperature, relative humidity, and atmospheric pressure were measured at the veranda (see fig. 3 & 4), whereas a weather station (Daris vantage pro 2) was placed in a small space located about 500m away from the measurement site (at 4m above the ground). The measurement was recorded at two courtyards CY1 and CY3 of the two shop houses.

3. Results and Discussion

Evaluation of Temperature of the courtyard with 69% vegetation (CY1) and courtyard with 18% vegetation (CY3). The purpose of this study is to evaluate the impact of vegetation on the air temperature of a courtyard. Fig. 5 & 6 shows the temporal variables of major thermal variables that were measured in the courtyard at a height of 1.5m above the floor during the seven-day measurement period. The outdoor condition in these figures represents the values that were measured at the veranda located in front of the two shophouses. The veranda space was accompanied by a man-made surface such as asphalt (fig. 1 & 2), and thus reported higher temperature throughout the day. Nevertheless, measurement of the veranda space is representative of the ambient environment.

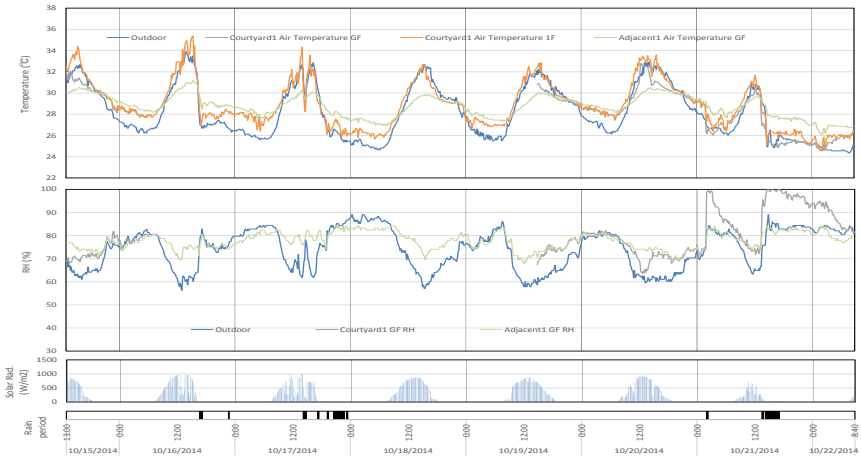

Fig. 5. Temporal variations in shophouse 1 (a) air temperature and (b) relative humidity with the corresponding outdoor conditions.

©Journal of Applied Sciences & Environmental Sustainability 3 (8): 34 - 42, 2017
e-ISSN 2360-8013

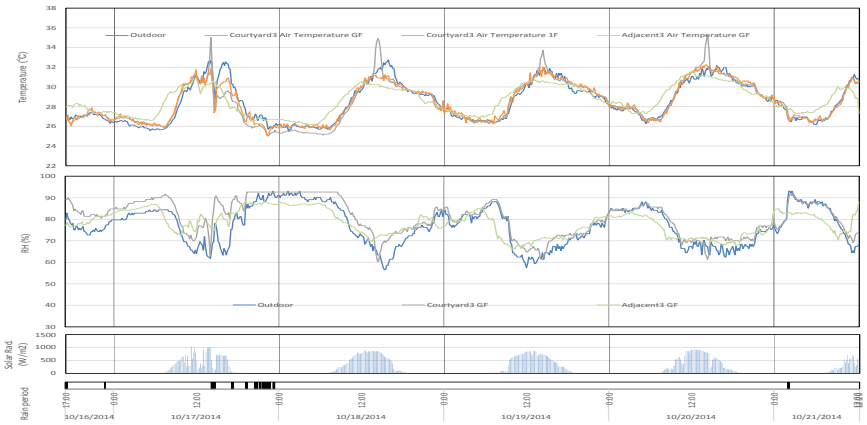

Fig. 6. Temporal variations in shophouse 2 (a) air temperature and (b) relative humidity with the corresponding outdoor conditions

Evaluating the two courtyard CY1, and CY3, the hottest day was selected during the measurement period and the temperature analysis was conducted. It was observed that though the courtyard areas are approximately the same and the height of the courtyard is also the same. The thermal components of the courtyard building in terms of material composition are the same, there is a temperature variation between CY1 and CY3 of 30c between 12.00pm – 2.00pm, implying that courtyard with 69% potted plants performs better in reducing the courtyard air temperature compared to a courtyard with 18% vegetation, as shown in figure 7.

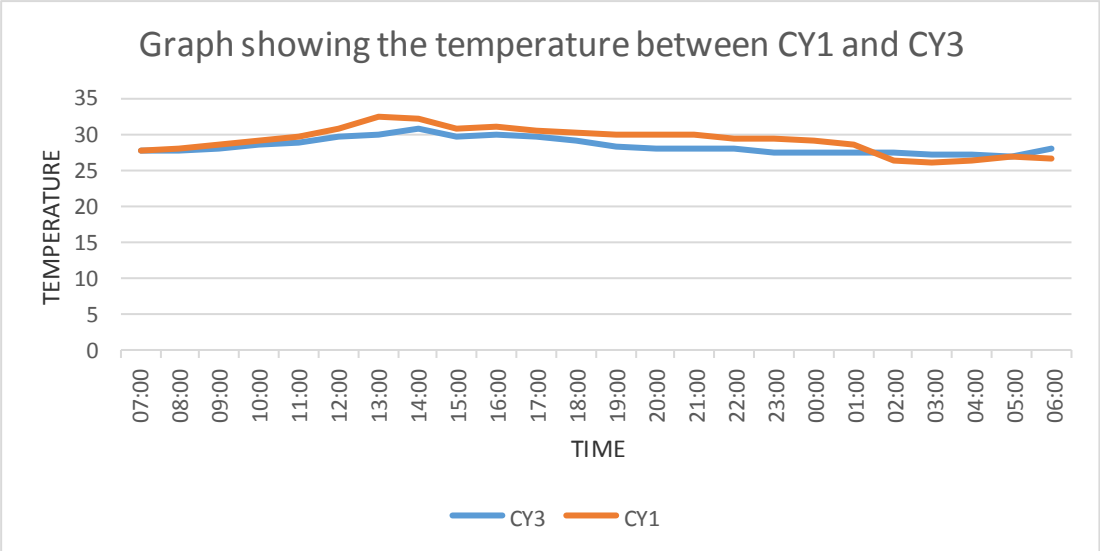

Fig. 7. Graph showing the temperature difference between CY1 and CY3

4. Conclusion

The findings of the field measurement demonstrate that the temperature of the courtyard with 69% vegetation CY1 and the courtyard with 18% vegetation CY3 have a 30c in courtyard air temperature difference between 12.00 pm - 2.00pm. The result verified that vegetation within the specified area affects the microclimates, most especially the temperature, in the context of the tropics. Another reason for the temperature is due to evapotranspiration and Photosynthesis activities of the plants. In the case of Evapotranspiration vapour is released into the surrounding to reduce the temperature.

References

1. Muhaisen AS. Shading simulation of the courtyard form in different climatic regions. Build Environ. 2006;41(12):1731–41.
2. Zakaria MA, Kubota T. Environmental Design Consideration for Courtyards in Residential Buildings in Hot-humid Climates : A Review. 2014;1(1):45–51.
3. Kubota T, Hooi D, Toe C, Ossen DR. Field Investigation of Indoor Thermal Environments in Traditional Chinese Shophouses with Courtyards in Malacca Malaysia , using field measurements and focuses on the cooling effects of courtyards . The results indicate. 2014;(January):2–9.
4. Almhafdy A, Ibrahim N, Ahmad SS, Yahya J. Analysis of the Courtyard Functions and its Design Variants in the Malaysian Hospitals. Procedia - Soc Behav Sci [Internet]. Elsevier B.V.; 2013;105:171–82. Available from: http://www.sciencedirect.com/science/article/pii/S1877042813043930
5. Sadafi N, Salleh E, Haw LC, Jaafar Z. Evaluating thermal effects of the internal courtyard in a tropical terrace house by computational simulation. Energy Build [Internet]. Elsevier B.V.; 2011;43(4):887–93. Available from: http://dx.doi.org/10.1016/j.enbuild.2010.12.009
6. Dili AS, Naseer MA, Zacharia Varghese T. The influence of internal courtyard of Kerala traditional residential buildings in providing a comfortable indoor environment. Int J Earth Sci Eng. 2010;3(1):2–5.
7. Jamaludin AA, Hussein H, Mohd Ariffin AR, Keumala N. A study on different natural ventilation approaches at a residential college building with the internal courtyard arrangement. Energy Build [Internet]. Elsevier B.V.; 2014;72:340–52. Available from: http://dx.doi.org/10.1016/j.enbuild.2013.12.050
8. Meir IA, Pearlmutter D, Etzion Y. On the microclimatic behavior of two semi-enclosed attached courtyards in a hot dry region. Build Environ. 1995;30(4):563–72.
9. Berkovic S, Yezioro A, Bitan A. Study of thermal comfort in courtyards in a hot arid climate. Sol Energy [Internet]. Elsevier Ltd; 2012;86(5):1173–86. Available from: http://dx.doi.org/10.1016/j.solener.2012.01.010

10. Canton MA, Ganem C, Barea G, Llano JF. Courtyards as a passive strategy in semi-dry areas. Assessment of summer energy and thermal conditions in a refurbished school building. Renew Energy [Internet]. Elsevier Ltd; 2014;69:437–46. Available from: http://dx.doi.org/10.1016/j.renene.2014.03.065
11. Ratti C, Raydan D, Steemers K. Building form and environmental performance: Archetypes, analysis, and an arid climate. Energy Build. 2003;35(1):49–59.
12. Sharples S, Bensalem R. Airflow in courtyard and atrium buildings in the urban environment: A wind tunnel study. Sol Energy. 2001;70(3):237–44.
13. Rajapaksha I, Nagai H, Okumiya M. A ventilated courtyard as a passive cooling strategy in the warm humid tropics. Renew Energy. 2003;28(11):1755–78.
14. Tablada A, Blocken B. The influence of courtyard geometry on air flow and thermal comfort: CFD and thermal comfort simulations. PLEA2005 - 22nd Conf Passive Low Energy Archit [Internet]. 2005;(November):13–6. Available from: http://www2.asro.kuleuven.be/asro/english/home/fdt/FrankDeTroyer_files/p182-v1-t01.pdf
15. Aldawoud A. Thermal performance of courtyard buildings. Energy Build. 2008;40(5):906–10.
16. Muhaisen AS, Gadi MB. Effect of courtyard proportions on solar heat gain and energy requirement in the temperate climate of Rome. Build Environ. 2006;41(3):245–53.
17. Moonen P, Dorer V, Carmeliet J. Evaluation of the ventilation potential of courtyards and urban street canyons using RANS and LES. J Wind Eng Ind Aerodyn [Internet]. Elsevier; 2011;99(4):414–23. Available from: http://dx.doi.org/10.1016/j.jweia.2010.12.012
18. Safarzadeh H, Bahadori MN. Passive cooling effects of courtyards. Build Environ. 2005;40(1):89–104.
19. Muhaisen AS, Gadi MB. The shading performance of polygonal courtyard forms. Build Environ. 2006;41(8):1050–9.
20. Shashua-Bar L, Pearlmutter D, Erell E. The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. Int J Climatol. 2011;31(10):1498–506.
21. Park M, Hagishima A, Tanimoto J, Narita K ichi. Effect of urban vegetation on the outdoor thermal environment: Field measurement at a scale model site. Build Environ [Internet]. Elsevier Ltd; 2012;56:38–46. Available from: http://dx.doi.org/10.1016/j.buildenv.2012.02.015
22. Mangone G, van der Linden K. Forest microclimates: Investigating the performance potential of vegetation at the building space scale. Build Environ [Internet]. Elsevier Ltd; 2014;73:12–23. Available from: http://dx.doi.org/10.1016/j.buildenv.2013.11.012

23. Hassan AM, Lee H. A theoretical approach to the design of sustainable dwellings in hot dry zones: A Toshka case study. Tunn Undergr Sp Technol [Internet]. Elsevier Ltd; 2014;40:251–62. Available from: http://dx.doi.org/10.1016/j.tust.2013.10.017

24. Taleghani M, Tenpierik M, van den Dobbelsteen A. Energy performance and thermal comfort of courtyard/atrium dwellings in the Netherlands in the light of climate change. Renew Energy [Internet]. Elsevier Ltd; 2014;63:486–97. Available from: http://dx.doi.org/10.1016/j.renene.2013.09.028

25. Al-Hemiddi NA, Megren Al-Saud KA. The effect of a ventilated interior courtyard on the thermal performance of a house in a hot-arid region. Renew Energy. 2001;24(3-4):581–95.

26. Edwards, B., SIibley, M., Land, P. Courtyard Housing: Past, Present, & Future. Taylor and Francis, New York. (2006)

27. Hyde, R. Climate Responsive Design A study of buildings in moderate and hot humid climates.E & FN SPON, New York (2000)