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Assessment of the Environmental Condition of Fully Enclosed Courtyard in Hot Humid Tropics

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Abstract: The solution to the issue of climate change focused on finding effective passive strategies to bring down the energy demands of buildings. The outcome of this step that the designers became more aware of traditional strategies that depend on non-mechanical methods, in order to improve the comfortable atmosphere. For an example in hot-dry and hot-humid zones cooling is a priority than heating, for this demand many elements support natural techniques applied in these buildings for many decades, such as courtyards, mashrabiyya, wind towers and ventilation tunnel. This study, therefore, assessed the courtyard environmental conditions through field measurement in order to establish the fact that the courtyard is an element to support natural technique. From the field measurement result, the courtyard environment was able to reduce the air temperature by 2.25°C and relative humidity by 1.2% compared with the outdoor environment. The study shows that the courtyard improves the environmental condition of the building, and therefore, there is a need for further study on the effect of vegetation on the thermal performance of the courtyard for midrise building in Tropical climate of Malaysia.
Keywords: Courtyard, Passive Strategy, Air Temperature, Relative Humidity, Hot Humid tropics

I. Introduction

It is essential to note that the quantity of solar radiation inside the courtyard affected by the dispersed and redirected radiation as well as the uninterrupted solar radiation. [1]The performance of the courtyard, acts as a radiation trap by the enclosed wall, which re-direct the solar radiation according to their albedo.
The proportions of the courtyard also have an influence on its microclimate, as seems from a study that is piloted in India. [2]The study equated a variety of traditional courtyard houses with different courtyard sizes. It was established that as the size of the courtyard increases, the thermal performance of the courtyard inclined to decrease; [3].
Shading of courtyards can be considered in two ways: the first - self-shading of the courtyard by the neighbouring walls, and the second - shading the courtyard's space by an added shading means. Concerning the first, [4], studied the influence of self-shading by the surrounding built-up space on courtyards with various sizes. He used thermal simulation software to forecast the yearly essential cooling and heating loads in two circumstances: with solar shading deliberated and deprived of solar shading considered. It is indicated that the shading effects more considerably on increasing the constant heating load in winter than on decreasing the cooling load in summer. This translates that the susceptibility of heating load to the gained solar radiation is more than that of cooling load to shaded areas. Therefore, in their opinion, it is more dangerous to acquire solar radiation in winter than to obtain it in summer. A study piloted in Tucson, Arizona, examined significant variances between surface temperatures for shaded and non-shaded walls. It revealed that heavy shading reduced solar heat gain on windows and impervious features. For example at 08:00h surface temperature difference between shaded and non-shaded eastern wall was as high as 24°C [5]. The influence of shading the courtyard has similar results throughout the season. [4], indicated that the shading influence on increasing the cooling load could be more important than the heating load. Thus, it might be more difficult in some places to attain solar radiation than barring it.
Shading the courtyard by additional shading strategies can increase thermal conditions, as was shown by [6]. In a study conducted in a hot, dry climate centers on the influence of a ventilated internal courtyard on the thermal performance of a house an investigational house observed in six stages; each stage represented an altered ventilation approach (opening of an inner or outer window through the day or night, removing the

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courtyard's protection at night, a swimming pool with or without water). One of the altering features within the courtyard was a white cotton tent covering the courtyard's space and the swimming pool. The shading by the cover decreases the normal temperatures. Nevertheless, eliminating the cover at night reduced the courtyard air temperature and the water temperature through the night. Therefore, the most exceptional performance was while the cover was detached at night and ventilation amongst the outdoors and the courtyard was tolerable during the night only. Removing the cover at night permits long wave radiation to release from the courtyard's planes to the clear sky and night. This illustration that changeable shading devices, which avoid solar heating through the hot hours and permits long-wave emittance during the cold hours, can result in better thermal conditions inside the courtyard.

However, in the context of hot and humid climate, shading is preferable compared to orientation, as an orientation only have little signs on the courtyard thermal conditions.[7] examined the thermal effects of the courtyard in a terraced house in Malaysia hot, humid climate. Their findings indicated that there is a significant reduction in the indoor temperature when the roof cover is raised that prevent heat gain from direct solar radiation. [8] and [2], also obtained similar findings with the application of courtyard verandah and the canopy of trees. Another study by [9], indicated that the effect of stack effect is applied when there is an increase in cross ventilation flow of a high thermal mass house with a courtyard in Sri Lanka. [10] Examine the cooling effects of courtyards in Chinese Shophouse in Malaysia. Their findings show that there exists a relationship between the air temperature and the sky view factor measured in the courtyard. [11], concludes that the exposure of courtyard to the diffused solar radiation, in a hot humid climate, affect the heat gain. Also, the orientation of the building could be less significant related to direct shading or sky exposure.

II. Methods And Material

Raja Zarith Sofiah Library, Universiti Teknologi Malaysia (UTM) located at 2.2°N, 102°E and oriented to NE-SW direction was selected for field measurement. The Tunku Temenggong of Johor, Tunku Idris Iskandar Ibni Sultan Ibrahim, officially launched this library on 30th September 2014. Raja Zarith Sofiah library UTM is a four-storey building with the capacity to accommodate 2000 people at one time. The building has a central courtyard that is more than 400 square meters (m2). This is a characteristic of most buildings that have courtyard around the study area, due to the following reasons: 86

i. The Building is a practical example of a fully enclosed courtyard building with the height of 15 metres that has courtyard as suggested.
ii. The courtyard is big enough to validate the proposed models that will be used in the current study for simulations.
iii. Raja Zarith Sofiah Library UTM is planned in an unobstructed space, and thereby have an advantage in conducting field measurements.
iv. The courtyard in Raja Zarith Sofiah Library UTM is fully enclosed courtyard building that is an advantage to the study, as the study focuses on the enclosed courtyard.

In order to validate the Envi- met software, site survey and field measurement of climate data was conducted. The site survey includes building height, courtyard dimensions, courtyard ratio/configuration, courtyard finish material, shape and height of the trees if any. The significance of gathering data related to the courtyard finish material, vegetation, tree height, canopy, courtyard dimension and configurations was to be used as input data for validating the site model with the real contextual influence.

The courtyard inventory confirms that the height of the building is about 15 metres, the length of courtyard connotes 15 metres, and the width is 15 metres portraying that the courtyard is cube. Therefore the courtyard ratio/configuration (h x l x w) connotes 15m x 15m x 15m.

The material finish of the courtyard was mostly grass on loamy soil, partly finished with walkway covered with concrete tiles covering about 45% as shown in Figure 3.11. There are six trees spaced about 5 metres distributed within the courtyard, the height of this tree is about 15 metre, almost the same height as the building. There are four concrete slaps, finished with tiles meant for sitting, with a height of about 1 metre.

Three positions were selected, (1) middle, (2) left and (3) right of the courtyard (as shown in figure 3.8) for HOBO Pro v2 data loggers U23 to be positioned for field measurement. A weather Station was placed nearby the Raja Zarith Sofiah Library, UTM about 500 metres away from the measurement site were used in the courtyard as mentioned above. The data were collected for seven days from 11th to 17th July 2017. The reason for selecting these days was that the sky was prevalent sky type, no rain, with high radiation. The instruments used in the field measurement are shown in Figure 3.12 and classification was identified in Table 1

1(a) 1(b)

Figure 1(a) and 1(b) External view of the case study building and the layout of the case study building courtyard respectively.

Field measurement are shown in Figure 3 and the classification of measuring instrument was identified in Table 1

Table 1
Classification of the measurements instruments

Variables	Instruments	Accuracy	Sensor Height
Air temperature and Relative Humidity	HOBO Pro v2 data loggers U23.	Average ±0.21°C to 50°C	1.5m

III. Results And Discussion

Assessing the environmental conditions of the courtyard, field measurement on the courtyard was carried out; this is intended to compare between the outdoor conditions and the courtyard microclimate to establish the fact that courtyard microclimate is better than the outdoor environment. Figure 3 shows the variation in air temperature between the outdoor and the courtyard environment.

There is a significant variation in the air temperature differences of the outdoor environment and the courtyard environment. The significant differences can be seen throughout the days of the measurement. There is a consistency in the temperature rise from 7:00 and set at 19:00. The most significant temperature differences can be seen during the afternoon hours between 13:00 to 17:00 when the temperature reaches its peak. A temperature difference between the outdoor and the courtyard environment is up to 2.25°C from 12:00 to 15:00, and therefore comfortable range was achieved in the courtyard as compared with outdoor.

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The hourly relative humidity decreased between the outdoor and the courtyard environment for seven days period, as shown in Figure 3. It can be observed that the relative humidity increase pattern is correlated with the air temperature pattern presented in Figure 4. The highest temperature differences create a higher decrease in relative humidity starting from 8:00 hour to the peaks at 15:00 to 17:00 and reducing gradually at night time. Relative humidity differences between the outdoor and the courtyard environment were up to 1.2 %. (at 15.00).

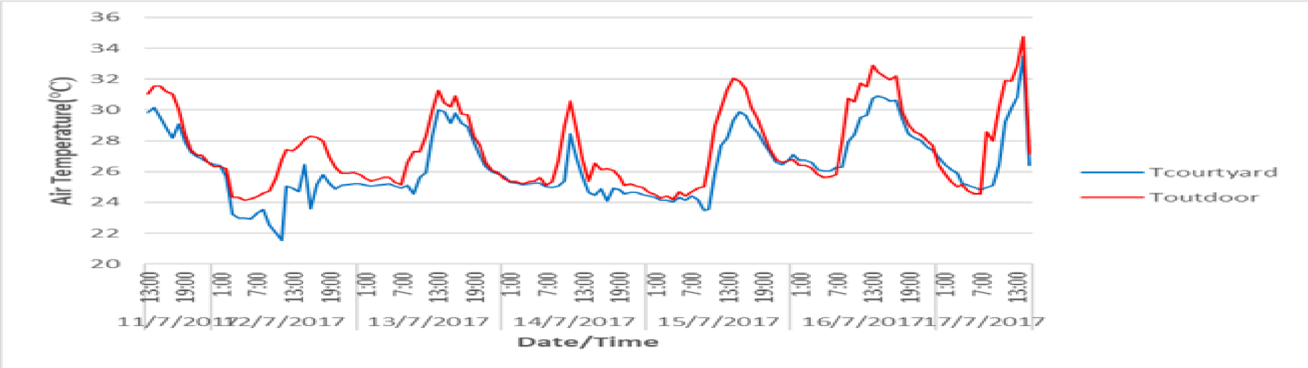

Figure 3 Air temperature variation between the courtyard and the outdoor of the library building on the 16th July 2017.

The environmental function of the courtyard in this context is shading. The courtyard environment provides self-shading thereby reducing the air temperature and increasing the relative humidity. Another possible reason is when the courtyard acted as air funnel by discharging indoor air to the sky, and by receiving air from outside thereby moderating the courtyard microclimate. This is also attributed to the fact that the trees in the courtyard reduce the effect of solar radiation by shading. In addition, the surface finishes in the courtyard absorbed the solar radiation, as about 60% of the courtyard surface is covered with grass.

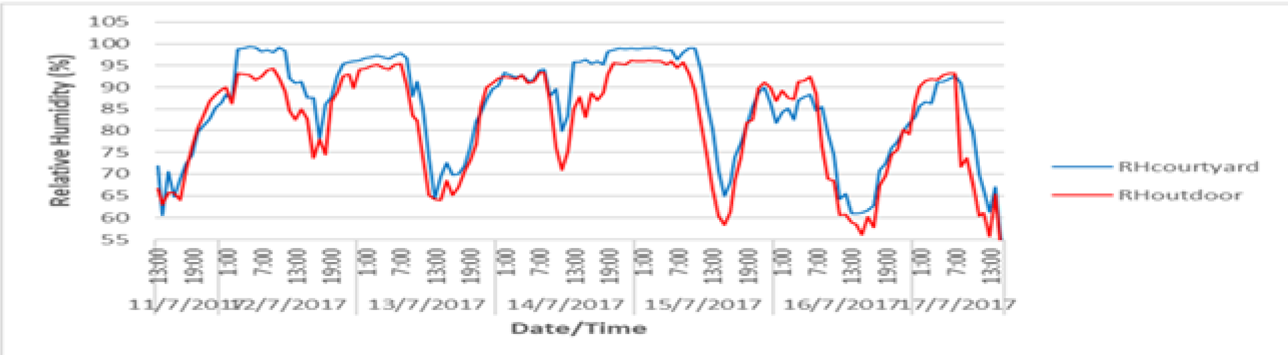

Figure 4 Relative humidity variation between the courtyard and the outdoor of the library building on the 16th July 2017.

IV. Conclusion

Courtyard microclimate has the potential to moderate the microclimate. This is demonstrated in the literature findings. Most of these findings confirmed that the courtyard improved the environmental conditions of the mid-rise building. It is revealed that courtyard reduces the air temperature between 2°C-8°C compared to the outdoors. In agreement with these findings, the field measurement conducted in this study confirmed the findings. From the measurement result, the courtyard environment was able to reduce the air temperature by 2.25°C and relative humidity by 1.2% compared with the outdoor environment. There is a need for further study on the effect of vegetation on the thermal performance of the courtyard for midrise building in Tropical climate of Malaysia.

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