© 2018 IJSRSET | Volume 4 | Issue 9 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Cooling Effects of Vegetated Courtyard of Mid-Rise Buildings of Tropical Climate

Modi Sule Zango*[1,2], Abimaje Joshua[1,3]

*[1]Department of Architecture, Faculty of Built Environment, Universiti Technologie Malaysia, Johor, Malaysia

[2]Department of Architecture, School of Environmental Studies, Nuhu Bamalli Polytechnic, PMB1061, Zaria, Kaduna State, Nigeria

[3]Department of Architecture, Federal Polytechnic Idah, Kogi State, Nigeria

ABSTRACT

This document Passive design strategies within the microclimate regarded as crucial. Previously, the heat in the courtyard has recorded but not much attention given to the cooling effect of the vegetated courtyard of mid-rise buildings. However, evapotranspiration and shading effects of vegetation in courtyard considered as alternatives for mitigating the Air Temperature, Mean Radiant Temperature, surface temperature. Vegetation is the sources of coolants for the microclimate of the surrounding area. Other researchers opined that the vegetation within the courtyard represents the most efficient passive manner of cooling building or urban spaces. This study examines the cooling effects of the vegetated courtyard of mid-rise buildings of tropical climate through simulations. Envi-met is a software that simulates the plant-air-atmosphere with the environment and it was used in this study after validating the software. Simulations were conducted under different vegetation scenario using a model. The result shows that there is a positive significance in the performance of the vegetated courtyard. These demonstrate that vegetation affects the thermal indices within the courtyard of the mid-rise building.

Keywords: Vegetated courtyard, a Mid-rise building, Envi-met software, Tropical climate, Surface temperature, Mean radiant temperature, air temperature.

I. INTRODUCTION

Vegetation can play an important role in the topo-climate of towns and the microclimate of buildings too. It is different according to the macroclimatic circumstances, but in any case, vegetation can give a significant contribution to the climatic conditions. [1]

In a recent study,[2] conducted an experiment to study the impact of a ventilated inner courtyard on the thermal performance of a single-family house in a hot–arid region. Numerical investigation of data noted during the summer of 1997 was conceded out. The results show that the courtyard gives great efficiency in providing cool indoor air with cross ventilation. In another research,[3] an assessment between different geometries of courtyards in expressions of wind flow structures and indoor air speed is implemented centered on the validation of Computational Fluid Dynamics (CFD) simulations with 2D dispersed wind-tunnel experiments. In addition, assessment of thermal comfort is made inside a number of selected apartment rooms in front of different courtyard geometries. It is proven that rooms with cross ventilation have higher indoor air speed figures and accordingly, an improved thermal comfort than with single-sided ventilation. The courtyard measurements, the location of the room and the orientation are important features controlling the indoor air speed and thermal comfort. In their research,[4] discover the prospect of a courtyard for passive cooling in a single story high mass building in a warm humid climate. From the findings of thermal dimensions, a significant correlation between wall surface temperatures and indoor air temperatures is obvious. A reduction of indoor air temperature lower the levels of ambient is seen as a role of heat exchange between the indoor air and high thermal mass of the building cover. However, this behaviour is affected by indoor airflow forms, which are organized through the pattern between building fenestrations and the courtyard of the building. From a computational exploration, several airflow forms are recognized. A temperately better indoor thermal modification is seen when the courtyard acts as an air funnel discharging indoor air into the sky than the courtyard performs as a suction zone inducing air from its sky opening. The former form is stimulated when the courtyard is ventilated through openings originate in the building form. The passive cooling effects of a courtyard of a small building were calculated statistically by[5] in their paper, using energy-analysis software well-known for that purpose. The passive cooling structures well thought-out were the shading paraphernalia of courtyard walls and two large trees (of various shapes) planted carefully next to the south wall of the structure, the existence of a pool, a lawn and flowers in the yard, and the wind shading effects of the walls and trees. It was established that these buildings alone could not endure thermal comfort during the hot summer hours in Tehran, but lessening the cooling energy necessities of the building to some extent. They have an aggressive consequence of increasing the heating energy requirements of the building slightly. The same savings in cooling energy requirements of the structure can be developed through many buildings such as wall and roof insulation, double-glazed windows, and special sealing adhesive tape to decrease penetration. They all sheltered on heating energy necessities as well.

In another studies, [6]an experimental field study was piloted to examine three dynamic courtyard design selections including orientation, dimensions and proportions, as well as dense (walls) and transparent surfaces (windows), in fourteen valued traditional houses in five ancient cities located in the BS climate of Iran. Consequences of this numerical study consented that in Iranian traditional central courtyards were planned centered on a careful thoughtfulness to orientation and geometrical properties regarding the physical and natural contemplations to act as an effective passive cooling system. In conclusion, all data sets were merged to endorse a physical–environmental design model for central courtyards as a valued passive strategy that can be overall for the broader use of environmentally sustainable design philosophies in future practice concerning courtyards for buildings in BS climate.

However,[7] piloted an experimental and theoretical archetypal for the assessment of courtyards as a passive approach for internal space conditioning. Two expressive case studies, in a refurbished pre-elementary school building in Mendoza, were selected. Findings show that in semi-dry areas with a massive number of clear sky days, the shading condition of the courtyard is the approach that most importantly affects the thermal and energy conditions in classrooms.

Subsequently,[8] studied three urban heat modification approaches that moderate the microclimate of the courtyards: varying the albedo of the facades of the urban blocks, with water ponds and encompassing urban vegetation. The outcomes showed that a north-south canyon orientation offers the shortest and the east-west direction the longest length of direct sun at the centre of the courtyards. Moreover, increasing the albedo of the facades really enhanced the mean radiant temperature in a closed urban plan such as a courtyard. In comparison, using a water pond and urban vegetation cooled the microclimates; providing extra validation of their potential as strategies for cooling cities. The outcomes are validated through a field measurement and calibration.

[9] Posited that air temperatures in internal courtyards can be elucidated using the sky view factor, the height of the courtyard and the change in the heights of the building and walls that form the courtyard. Meanwhile,[10] reiterated that central courtyard buildings in UTM were intended based on a careful attention to orientation and configurations to improve their operative passive cooling potentials.

Vegetation can play a significant role in the topo-climate of towns and the microclimate of buildings too. It is diverse according to the macroclimatic conditions, but in any case, vegetation can give an important contribution to the climatic situations. [1] Though,[11] and [12], examine six landscape approaches, using varied arrangements of trees, grass, and a directly above shade mesh. The effects of these behaviour were established during the summer season in two semi-enclosed courtyards located at an urban settlement in the arid Negev Highlands of southern Israel. Compared to a non-vegetated exposed courtyard, which on average get an extreme air temperature of 34 ◦C in mid-afternoon. A connected courtyard conserved with shade trees and grass acknowledged a daytime temperature drop of up to 2.5 K, however shading the courtyard with a material shading mesh, counter-intuitively, caused a comparative rise of almost 1 K. Unshaded grass was found to cause only a small air temperature decrease and had the highest water requirement. Nevertheless, when the grass was shaded, either by the trees or by the shade mesh, a synergic result created more cooling as well as a decrease of more than 50% in total water use.

Also in another study[13], to assess the cooling efficacy from vegetation planted in a public park, using three pavilions and complimentary green areas are added to the simulations, and the results establish that there is an improved cooling effect in the park with a greater coverage ratio. In the contextual studies of the vegetated courtyard in the tropical climate, not much has been done, and there is a need for a study to be conducted in this aspect. Therefore, the aim of this study is to assess the cooling effects of the vegetated courtyard of the mid-rise building of tropical climate.

II. METHODS

The methods applied in this research are sectioned into two; the field measurement and simulations experiment.

Field Measurement in Malacca

The climate data collection was conducted between 15/10/2014 to 22/10/2014 in a two-story Chinese shop-house sited at the central part of the heritage zone in Malacca, Malaysia (2.2°N and 102.2°E) as illustrated in figure 1.

Figure 1. (a) Floor plans of case study Chinese shop-house 1 and (b) views of the three courtyards

Malacca was selected based on its historical and heritage significant, as the shophouse originates from China. The main purpose of the climate documentation was to make available an initial data for air temperature, relative humidity, wind speed, wind direction. Actually most of the courtyard surveyed during the data collection are rectangular and deep, constructed between 1600"s and 1800"s with features of Dutch Architecture. This shophouse is located at 85, Jalan Tun Tan Cheng Lock, as accessed from the street. The hottest day was selected as data for the simulation. The simulation was done to validate the Envi-met software, to ascertain it suitability for other simulations. The validation process is shown in figure 2 and 3.

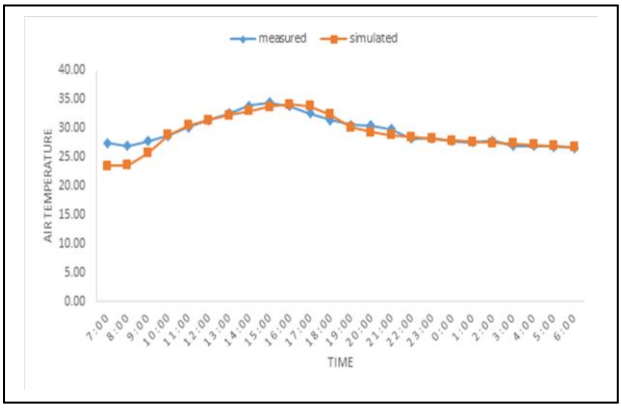

Figure 2. Graph showing the relationship between the measured and simulated air temperature in the Chinese Shophouse.

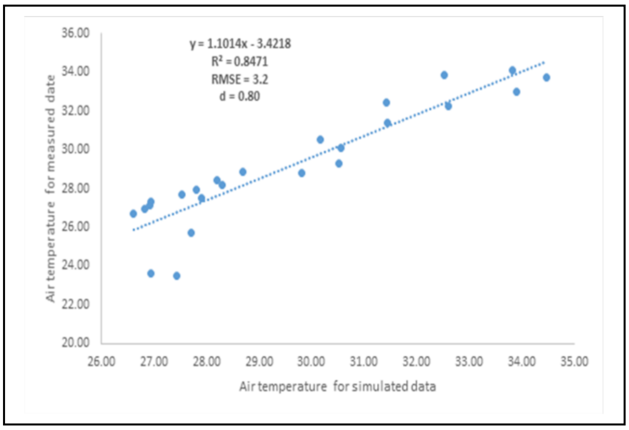

Figure 3. Scatter graph showing the correlation between the simulated and the measured air temperature in the Chinese shophouse.

Simulation Experiment

The significance of this process is to develop the courtyard models that will be used for the simulation experiments. The courtyard ratio is defined as a relationship between the heights, width, and the length of the courtyard. The height that is considered in this context is 15metres as it is within the mid-rise building in Malaysia[14],[15].

A square courtyard was selected as the model and has the dimension of 15m x 15m x 15m with the courtyard ratio of 1:1:1 (H: L: W). The vegetation used are tree and grass in three patterns as shown in Table 1, will be considered. The first model (A) surface covering will be laid with 100% concrete, the second model (B) surface covering will have 100% grass and the third model (C) surface covering will be 6 trees and laid with 100% grass, the tree height is about 10metres each.

Table 1. Table showing the simulations test cases

Mode l	Simulations test		
	Dimension (HxLxW)	**Ratio**	**Surface Covering**
A	15mx15mx15 m	1:1:1	100% concrete
B	15m x 15m x 15m	1:1:1	100% grass
C	15m x 15m x 15m	1:1:1	6trees, 100%grass.

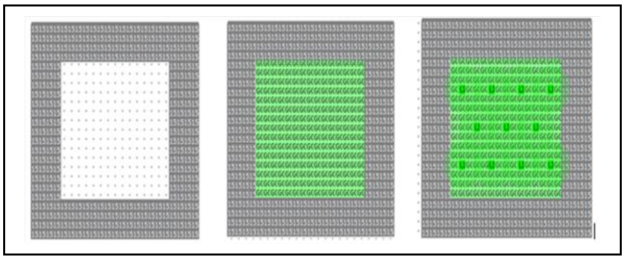

Figure 4: Selected courtyard model and the vegetation pattern to be used for the simulation.

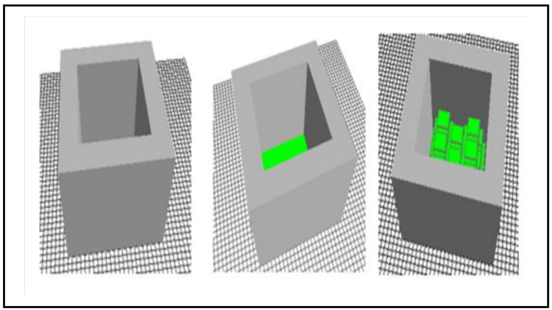

Figure 5. The selected courtyard model showing the vegetation pattern for simulation.

III. RESULTS AND DISCUSSION

All The aim of this research is to assess the cooling effects of the vegetated courtyard of mid-rise buildings of tropical climate through simulation. The variable measured were:

I. Air temperature
II. Mean Radiant Temperature
III. Surface Temperature

Air temperature

The distribution of the air temperature in the three models. The results demonstrate that the model A (figure 6) recorded its maximum air temperature at 16:00hrs and amounting to 31.98°c in the courtyard laid with 100% concrete. By laying on the courtyard with 100% grass (model B), air temperature drop by 0.03°c. Finally, it was observed that a drop in the air temperature of 0.12°c (model C) is recorded when the courtyard is laid with 6 trees with 100% grass. This shows that the model C that has the combination of tree and grass perform better although the air temperature difference is low, it shows that vegetation moderate the microclimate for thermal comfort (Yang et al., 2017).

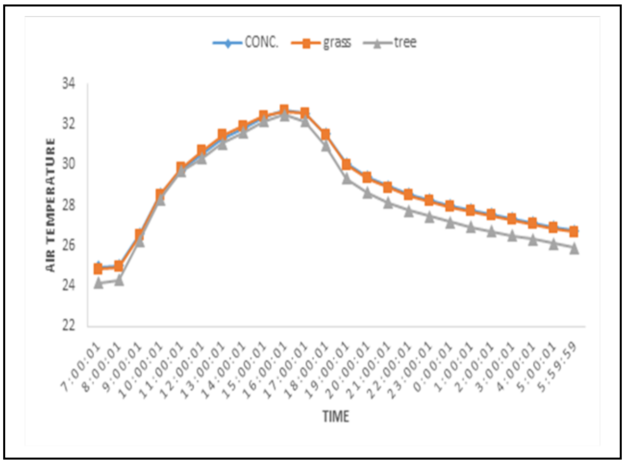

Figure 6. Graph showing the air temperature distribution within the vegetated courtyard

Mean Radiant Temperature (MRT)

The distribution of the Mean radiant temperature, (Tmrt) in the three models thus: it was observed that the Tmrt recorded its maximum at 15:00hrs with a Tmrt value of 61.36°c with the surface covering with 100% concrete(model A). When 100% grass (model C) was laid on the courtyard surface a reduction of 2.75°c, mean radiant temperature is observed. However, 24°c Mean radiant temperature was recorded when the courtyard was laid with 6 trees laying on 100% grass (model C). The mean radiant temperature shows significant differences between the vegetated and non-vegetated courtyard, with a difference of about 24°C. The model that has the combination of tree and grass record the lowest temperature followed by the model that has the 100% grass and the worst is the model that has the 100% concrete.

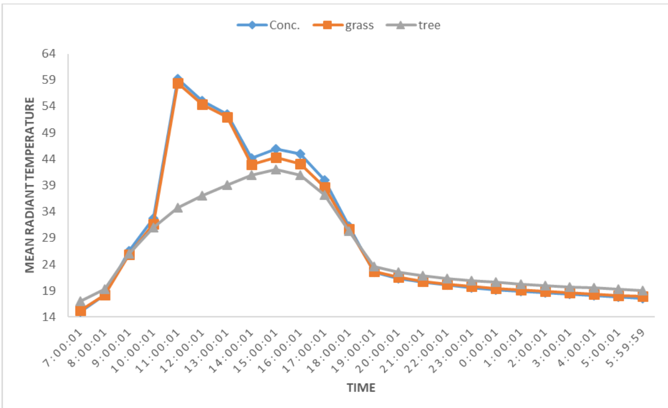

Figure 7. Curves showing the mean radiant temperature distribution within the vegetated courtyard.

The temperature difference is due to the principles of shading and evapotranspiration[16]. The model that has the combination of tree and grass, the tree, in particular, provides shades that prevent the radiation from the sun to have a direct effect on the surface of the courtyard thereby reducing the mean radiant temperature. While the leaves of the tree undergo the process of evapotranspiration that is the combination of evaporation and transpiration. (Process where the leaves transpire by releasing water vapour on the surface of the leaves and then evaporate into the air thereby cooling the air).

Surface Temperature

The surface temperature conceived at the hottest hour, which is 16.00 hrs. As the Leonardo extracts depict that the colour show the surface that has the highest temperature at 1600 hours, is in consonance with the air temperature and mean radiant temperature result. Surfaces of combining the trees and grass show a lower temperature distribution compared to 100%grass and 100% concrete.

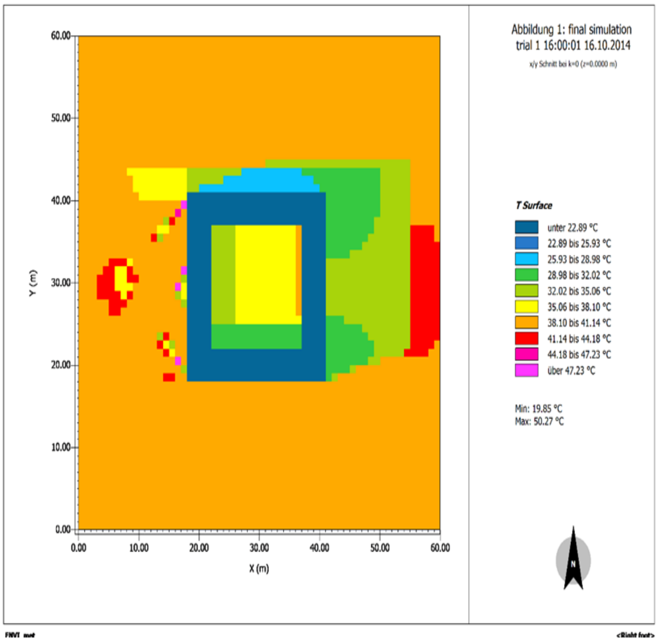

Figure 8. Leonardo figure showing the surface temperature distribution of the courtyard at 100%concrete (model A).

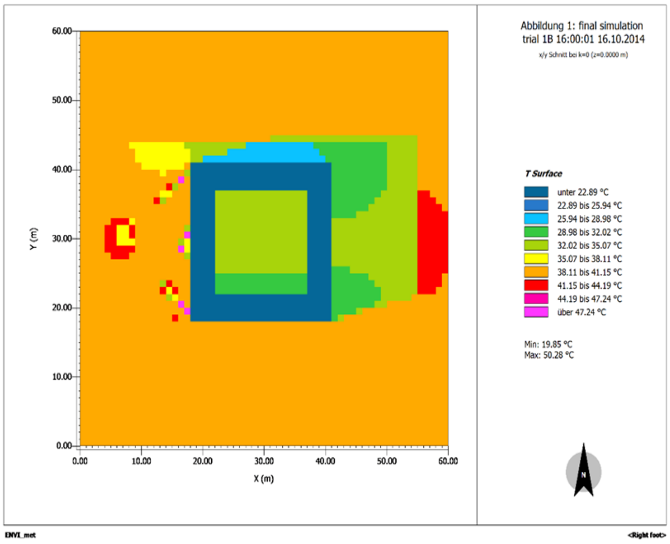

Figure 9. Leonardo figure showing the surface temperature distribution of the courtyard at 100% grass (model B).

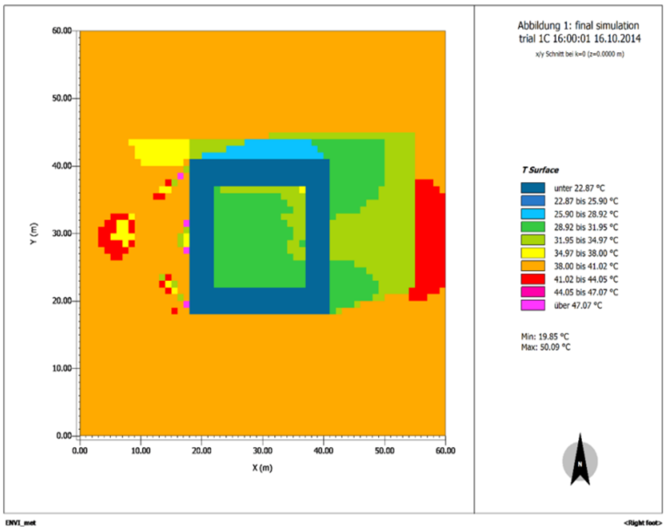

Figure 10. Leonardo figure showing the surface temperature distribution of the courtyard combination of trees and grass (model C).

IV. CONCLUSION

This study assessed the cooling effect of the vegetated courtyard of the mid-rise building of tropical climate. Simulations were conducted on three models of the courtyard with a different pattern of vegetation, and the following variables were measured, air temperature, mean radiant temperature, and surface temperature. The results prove that vegetation has a strong influence in mitigating the high air temperature, mean radiant temperature and surface temperature, thereby improving the microclimate. There is an about 24°C reduction of mean radiant temperature, and 0.18°C of the air temperature, and a significant difference in surface temperature.

V. REFERENCES

[1]. I. S. Zonneveld, "The land unit - A fundamental concept in landscape ecology, and its applications," Landsc. Ecol., vol. 3, no. 2, pp. 67–86, 1989.

[2]. N. A Al-Hemiddi and K. a Megren Al-Saud, "The effect of a ventilated interior courtyard on the thermal performance of a house in a hot–arid region," Renew. Energy, vol. 24, no. 3–4, pp. 581–595, Nov. 2001.

[3]. A. Tablada and B. Blocken, "The influence of courtyard geometry on air flow and thermal comfort: CFD and thermal comfort simulations," PLEA2005 - 22nd Conf. Passive. Low Energy Archit., no. November, pp. 13–16, 2005.

[4]. I. Rajapaksha, H. Nagai, and M. Okumiya, "A ventilated courtyard as a passive cooling strategy in the warm humid tropics," Renew. Energy, vol. 28, no. 11, pp. 1755–1778, 2003.

[5]. H. Safarzadeh and M. N. Bahadori, "Passive cooling effects of courtyards," Build. Environ, vol. 40, no. 1, pp. 89–104, 2005.

[6]. F. Soflaei, M. Shokouhian, and S. M. M. Shemirani, "Investigating of Iranian Traditional Courtyard as Passive Cooling Strategy (A Field Study on BS climate)," Int. J. Sustain. Built Environ, vol. 5, no. 1, pp. 99–113, 2015.

[7]. M. A. Canton, C. Ganem, G. Barea, and J. F. Llano, "Courtyards as a passive strategy in semi dry areas. Assessment of summer energy and thermal conditions in a refurbished school building," Renew. Energy, vol. 69, pp. 437–446, 2014.

[8]. M. Taleghani, M. Tenpierik, A. van den Dobbelsteen, and D. J. Sailor, "Heat in courtyards: A validated and calibrated parametric study of heat mitigation strategies for urban courtyards in the Netherlands," Sol. Energy, vol. 103, pp. 108–124, 2014.

[9]. T. Kubota, M. A. Zakaria, S. Abe, and D. H. C. Toe, "Thermal functions of internal courtyards in traditional Chinese shophouses in the hot-humid climate of Malaysia," Build. Environ. vol. 112, pp. 115–131, 2017.

[10]. M. Bulus, M. B. Hamid, and L. Y. Wah, "Courtyard as a Passive Cooling Strategy in Buildings," vol. 4, no. 1, pp. 48–55, 2017.

[11]. L. Shashua-Bar, D. Pearlmutter, and E. Erell, "The cooling efficiency of urban landscape strategies in a hot dry climate," Landsc. Urban Plan, vol. 92, no. 3–4, pp. 179–186, 2009.

[12]. L. Shashua-Bar, D. Pearlmutter, and E. Erell, "The influence of trees and grass on outdoor thermal comfort in a hot-arid environment," Int. J. Climatol., vol. 31, no. 10, pp. 1498–1506, 2011.

[13]. A.-S. Yang, Y.-H. Juan, C.-Y. Wen, and C.-J. Chang, "Numerical simulation of cooling effect of vegetation enhancement in a subtropical urban park," Appl. Energy, vol. 192, pp. 178–200, 2017.

[14]. T. G. Farea, D. R. Ossen, and A. D. Isah, "Common Configuration of Light-Well in High-Rise Residential buildings in Kuala Lumpur," 4th Int. Netw. Trop. Archit., no. DECEMBER, pp. 1–8, 2012.

[15]. S. N. A. Saruddin and F. M. Nazri, "Fragility curves for low- and mid-rise buildings in Malaysia," in Procedia Engineering, 2015, vol. 125, pp. 873–878.

[16]. M. F. Shahidan, M. K. M. Shariff, P. Jones, E. Salleh, and A. M. Abdullah, "A comparison of Mesua ferrea L. and Hura crepitans L. for shade creation and radiation modification in improving thermal comfort," Landsc. Urban Plan, vol. 97, no. 3, pp. 168–181, 2010.