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ANALYSIS OF PEDESTRIAN-LEVEL WIND VELOCITY IN FOUR NEIGHBOURHOODS IN KLANG VALLEY

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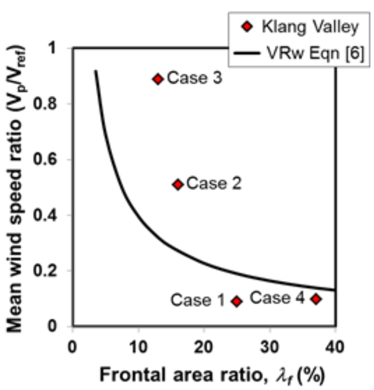
Graphical abstract



Abstract

Urban ventilation is important for the purpose of pollution dispersion, indoor ventilation for free running buildings and urban thermal comfort. In comparison to suburban cities, high-density cities have very low wind speeds at pedestrian level due to the densely built buildings blocking the wind and creating stagnant zones locally. Under this circumstance, field measurements were performed to investigate the performance of pedestrian wind at four major cities in Klang Valley. Mean wind speed was measured using anemometers at 1 minute data interval for 3 hours and the data collection for each case were obtained at pedestrian level. The mean wind speed ratio was plotted against the frontal area ratio and plan area ratio. The result indicates that: (1) the mean wind speed dramatically decreases with the increase of plan area ratio and (2) the mean wind speed exponentially decreases with the increase of frontal area ratio and qualitatively agrees with the power law relationship which is proposed by previous researcher. In addition, the frontal area ratio is considered as a better parameter to evaluate the performance of urban ventilation.

Keywords: Pedestrian wind velocity, plan area ratio, frontal area ratio, wind direction, urban ventilation

1.0 INTRODUCTION

The urban population in Peninsular Malaysia has been rapidly developing whereby the rate of population increased from 54.3% to 67% between the years 1999 to 2009 [1]. This trend is expected to continue as the nation develops and it has been estimate that, within 2010 to 2020 approximately 6 million additional population will live in the urban areas of Peninsular Malaysia [2]. This high rate of increase in population contributes to the increase in density of cities and urban conurbations. Due to the dense urban structure, the pedestrian comfort in the urban area is reduced especially in the locations where the wind flows are obstructed by buildings. A study in the heritage city of Melaka shows that a direct relationship exists between the air temperature and the built-up ratio [3]. Therefore, it is important for city planners and urban designers to design cities for wind especially in hot and humid country like Malaysia.

The objective of this study is to investigate the pedestrian wind environment at four major areas in Klang Valley towards the attainment of a well-ventilated city. Many factors were used to determine the pedestrian wind environment in relevant literature [4-7]. Studies have shown that the relationship between the frontal area ratio (ratio of building frontal area to ground surface area, *hereafter* λ_f) and mean wind speed ratio is more suitable to investigate the pedestrian wind performance compare to the building coverage ratio or plan are ratio (ratio of building roof area to ground surface area, hereafter λ_p) [5, 6, 8].

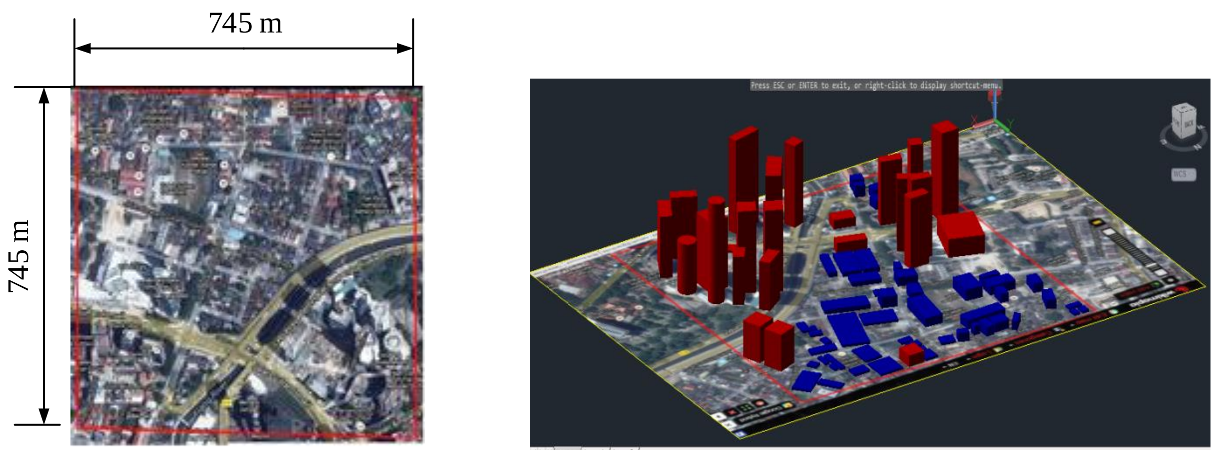
Most of those studies were based on Computational Fluid Dynamics (CFD), thus it is important to notice that there are relatively few studies on mean wind speed ratio through wind tunnel or field study. Hence, Kubota and Ahmad [9] had performed a wind tunnel experiment and proposed a relationship between housing pattern (λ_p) and mean wind speed ratio for selected low-rise terraced house areas in Johor Bahru Metropolitan City. The study revealed that the mean wind speed ratio decreases linearly with λ_p and the mean wind speed ratio of this study was found to be slightly higher than Japanese apartment houses which used the same methodology (see Figure 3). Recently, Arkon and Özkol [10] selected Izmir Bay area for their field measurement and they found that the uniformity of building heights has negative effect on enhancing pedestrian-level wind speed. In addition, the upwind direction has important effect on the lower wind speed at pedestrian level when it is perpendicular to the canyon and the result is similar with Kubota and Ahmad [11].

The present study is based on field measurement of four locations in Klang Valley namely Kampung Baru (Case 1), Taman Keramat (Case 2), Pantai Dalam (Case 3) and Mont Kiara (Case 4). The idea is to apply the exponential equation developed by Abd Razak *et al*. [6] based on the idealized building to the real urban structure.

2.0 DESCRIPTION OF FIELD MEASUREMENT

The mean wind speed at pedestrian level, wind direction and mean wind speed above the canopy layer were measured by using anemometers (WatchDog 2550 Weather Station) and the wind measurement was fixed to one minute interval to ensure the accuracy and it was placed on the sites for the duration of 3 hours to collect data each case. To determine the wind direction and mean velocity, the refence anemometer was placed 2m above the rooftop of the taller building in each case. Next, the data for pedestrian mean wind speed was measured at 1.5m height from the ground level.

The selection of the field study consists of high rise buildings and they are surrounded by the low rise building or residential buildings. An area of 745m x 745m was chosen as case area because of wide coverage of buildings has satisfied the required characteristics (see Figure 1). Case 1 (Kampung Baru) is located in the city center of Kuala Lumpur and consists of low-rise residential building, shop lot and high-rise commercial building. Case 2 (Taman Keramat), Case 3 (Pantai Dalam) and Case 4 (Mont Kiara) are located approximately 9km from city center. High-rise and low-rise building for Case 2, 3 and 4 are composed of apartment and terraced house. The details of urban building layout, wind direction and frequency of mean wind speed are shown in Figure 2.



(a) (b)

Figure 1 (a) Image of Kampung Baru capture using WikiMapia viewer and (b) 3D image of building in Kampung baru

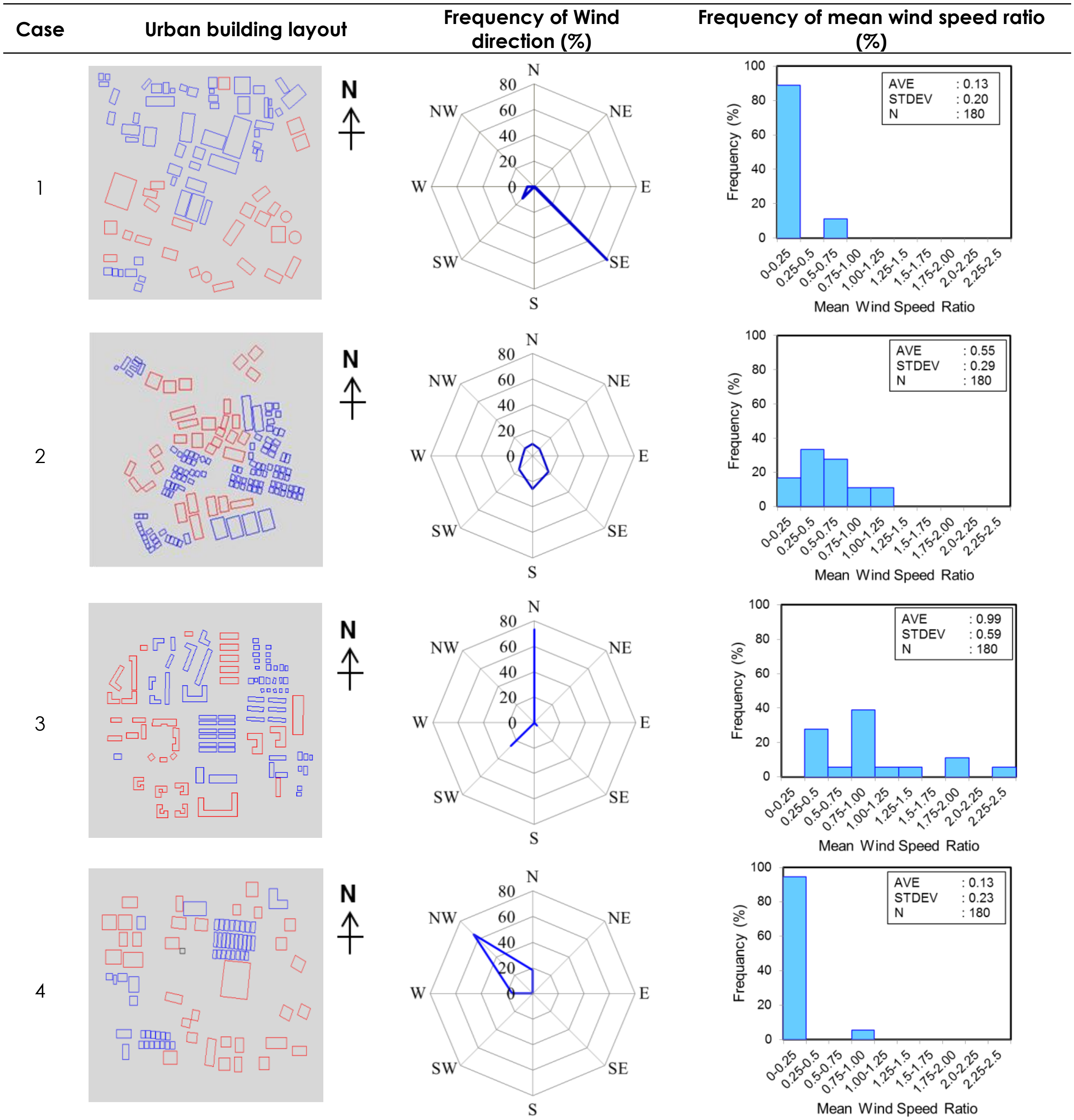


Figure 2 Frequency of mean wind speed ratio and wind direction at selected area

Table 1 Brief outline of field study

Case	Location	Plan area ratio, λ_p (%)	Frontal area ratio, λ_f (%)
1	Kampung Baru	21	25
2	Taman Keramat	18	16
3	Pantai Dalam	13	13
4	Mont Kiara	19	37

Table 1 shows a brief outline of the field study in terms of λ_p and λ_f and the values of those ratio were calculated based on 3-D image that was extruded from the WikiMapia viewer image. The values of λ_p were calculated based on the ratio of projected building roof area to the ground surface area, and the values of λ_f which is defined as the ratio of building surface area normal to the upwind to the ground surface area were also calculated using the same approach.

3.0 RESULTS AND DISCUSSION

Figure 3 shows a firm correlation between the λ_p and the mean wind speed ratio of the heterogeneous building in Klang Valley. Interestingly, the mean wind speed ratio for Klang Valley dramatically decreases as the λ_p increases. However, this trend line is slightly differ as compare to the trend line that was produced by Kubota and Ahmad [9]. This shows that the mean wind speed at pedestrian level is significantly influenced by the building morphology such heterogeneous building height, building orientation, building arrays and building aspect ratio and not only dependent on λ_p.

The frontal area ratio, λ_f, is another important parameter for evaluating urban ventilation indices [6] and Figure 4 shows the relationship between the mean wind speed ratio and the λ_f. It is clearly recognized that the mean wind speed ratio exponentially decreases as the value of λ_f increased regardless of any type of urban morphology. This result qualitatively agrees with simple power law equation introduced by Abd Razak *et al.* [6] especially the high value of c. According to the Ng [12], the nature of urban morphology of higher density cities have tall buildings and bulky which lead to a high frontal area ratio. For the case of low λ_f, the mean wind speed ratio slightly over estimates as compare to the power law equation. This is due to the effect of channel which is required to have further investigation by collecting more spatially average data.

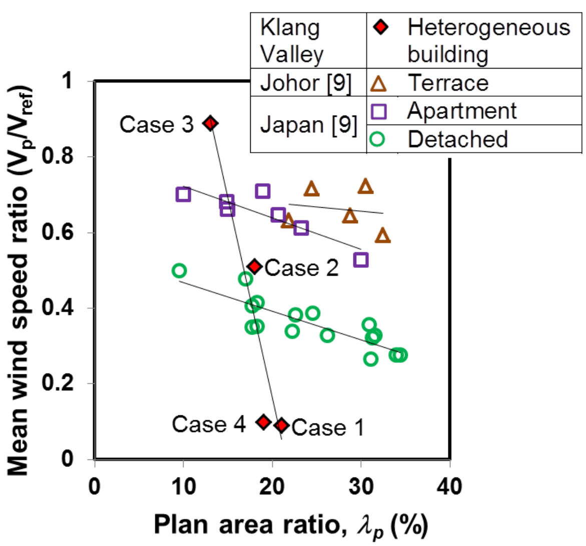


Figure 3 Relationship between λ_p and V_p/V_{ref}

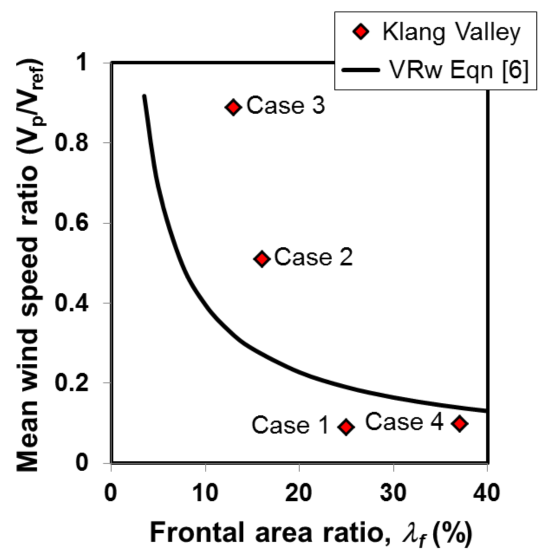


Figure 4 Relationship between λ_f and V_p/V_{ref}

4.0 CONCLUSION

The conclusion of this paper can be summarized as follows:

i. The air velocity at pedestrian level is greatly affected by the urban morphology. High density cities produce low mean wind speed and this situation contributes to the higher pollutant concentration at pedestrian level [7]. This becomes a serious issue for compact cities with higher building coverage ratio (or λ_p) like Hong Kong or Tokyo with λ_p which generally ranges from 25% to 40% [13].

ii. The relationship between the mean wind speed ratio and the λ_f is more suitable to explain the ventilation rate of the urban area as compare to the λ_p. Wong *et al.* [14] explains the λ_f as a good indicator for investigating the corridor ventilation, despite the randomness building geometry such as various aspect ratios, heterogeneity in building height and various building orientation.

iii. Information on overall pedestrian wind environment cannot be attained by classifying the urban built form into cluster of dwelling or height variability such as detached housing and apartment housing [9]. The entire urban morphology consists of mixed buildings geometry and characterized as heterogeneous and complex.

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