WIND ENVIRONMENT EVALUATION IN NEIGHBORHOOD RESIDENTIAL AREAS IN MALAYSIA

A Case Study of Johor Bahru Metropolitan City

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Abstract

This paper discusses planning guidelines at the neighborhood residential areas in consideration of wind flow in Malaysia. It aims to reduce the energy consumption particularly from the usage of home air conditioners. Natural wind flow is one of the most effective methods to help achieve the energy saving objectives in large cities especially under the tropical climate like Malaysia. This paper presents the results of several wind tunnel tests on selected neighborhood residential areas in the Johor Bahru Metropolitan City. Moreover, the wind environment evaluation of the selected case study areas under the climate conditions of the city was carried out. The results of the evaluation shows that the mean wind velocities at 1.5m height of some of the Malaysian terraced houses cases were in the comfort zone particularly during the northeast monsoon period. Nevertheless, both in the southwest monsoon period and the inter monsoon period, although the mean values of wind velocity ratio of the Malaysian terrace houses had been slightly higher than the trend line of the Japanese apartment houses, the mean wind velocities in all the cases in the Johor Bahru City and Japan did not reach the required comfort zones.

Keywords; Energy saving city, Residential neighborhood, Wind environment evaluation, Wind flow, Wind tunnel tests

1.Introduction

The need for energy saving in cities is increasingly recognized in Malaysia. The world trade crude oil price has been continuing increase recently. Since more than 60 per cent of the electricity is generated by gas, which price is related to the crude oil price, it is believed that the electricity tariff may be raised soon in Malaysia (the New Strait Times, 2004). Therefore, in order to maintain a stable economic growth, the government must consider the ways to reduce the dependence on fossil fuels and promote every saving initiation.

In addition, the Kyoto Protocol on global climate change, which urges signatories to cut their greenhouse gas emissions, is expected to come into force from early 2005 since Russia, one of the major contributors to green house gas, has approved rectification. Although currently the protocol refers only for the developed nations, which have huge amount of greenhouse gas emissions, it can be predicted that the developing countries including Malaysia will be required to consent to the protocol in the near future. Thus, it is very important and effective to examine the energy saving means to reduce the green house gas in the course of its economic development.

The last three decades has seen tremendous growth of urban population in Malaysia. Its percentage has increased from 27% in 1970 to 62% in 2000. This indicates that the current energy consumption in the urban areas has become considerable percentage and expected to further rise in the near future. The present final energy demand is almost 5 times larger than that of 1980’s (Malaysia, 2002). Therefore, it is essential for efforts to attain the energy saving objectives in the urban areas in every way.

This paper mainly focuses on the energy consumption from air conditioners usage in the urban residential areas. It aims to discuss planning guidelines at the neighborhood level in consideration of wind flow in order to reduce its usage in Malaysia. Natural wind flow is one of the most effective methods to help achieve the energy saving objectives in the cities especially under the tropical climate like Malaysia.

Past literatures on wind studies illustrate that wind velocity distribution around buildings (Hagishima et al., 2000; Horikoshi et al., 2003). However, most of these studies have been focused on surrounding or some blocks of buildings. Thus, it is evident that there are relatively few studies of wind flow in larger areas such as residential areas, particularly at the neighborhood level.

The present authors have conducted several researches in order to examine planning methods of neighborhood areas in consideration of wind flow in Japan (Kubota and Miura et al., 2000, 2002). These studies have presented the results of the wind tunnel tests on selected residential areas and examined the relationship between the housing patterns and the mean wind velocity at the neighborhood level.

The present study is based on the above research. The idea is to apply those methods that have been developed in Japan into Malaysian tropical climate conditions. This paper presents the results of several wind tunnel tests on selected neighborhood residential areas in the Johor Bahru Metropolitan City. Moreover, the wind environment evaluation of the case study areas under the climate conditions of Johor Bahru City was carried out.

2. Outline of Case Study Areas

The Johor Bahru Metropolitan City is located in the southernmost part of the Peninsula Malaysia. It is the second largest city after Kuala Lumpur and the population size in 2000 is approximately 1 million. Since the majority of housing patterns of the Johor Bahru City are low-rise terraced houses, this case study mainly concentrate on these housing patterns (Fig.1). The selection of the three residential areas was based on the housing density and five neighborhood areas were chosen for the wind tunnel tests (Fig.4). A brief outline of these five cases is shown in Table1.

3. Methods of Wind Tunnel Tests

The boundary layer wind tunnel at *Universiti Teknologi Malaysia* was used for the

Fig.1. Terraced houses residential area

Table1. Brief outline of case study areas for wind tunnel tests

Case	Gross buildings coverage ratio(%)	Gross floor area ratio (%)	Ratio of buildings coverage of each stories(%)	
			1-2	more than 2
1	21.9	43.8	100	-
2	24.5	31.0	93	7
3	28.9	48.9	100	-
4	30.6	55.3	100	-
5	32.5	44.8	100	-

tests (Fig.2). The cross-section of the wind tunnel is 1.4m x 1.4m, with a test length of 9m. The vertical profile of mean wind velocity in the tests was prepared to obey a 1/4 power law by using roughness elements (Fig.3).

The models for the tests are scaled in 1/500. The real scale of each area is 410m x 410m, thus the scale of models becomes 820mm x 820mm. Since the main purpose of the present study is to assess the effects of housing patterns on the wind flow, the models did not take into account the existing trees, setbacks and roof shape of buildings. To cover the whole area, 49 measuring points were placed equally outside of the buildings in each area as Fig.4 and 5. Both wind direction and wind velocity at 1.5m height of each 49 measuring point were measured through the wind tunnel tests in each 16 wind directions, such as the north, north-northeast etc.

4. Results of Wind Tunnel Tests

Fig.4 shows examples of the results on analysis of wind flow in each case. In each figure, the wind direction is arranged in order to agree with a direction towards bottom to top. Thus, the geographical orientation of the sites changes in line with the above arrangement. Each of the wind velocity ratios indicated in the figure were computed by dividing wind velocity at 1.5m height with buildings to wind velocity at the same height measured without buildings. When a measuring wind velocity is the same as the wind velocity without buildings, the wind velocity ratio is “1”. The wind velocity ratio “over 1” means that a measuring wind velocity was increased by the effects of the surrounding buildings.

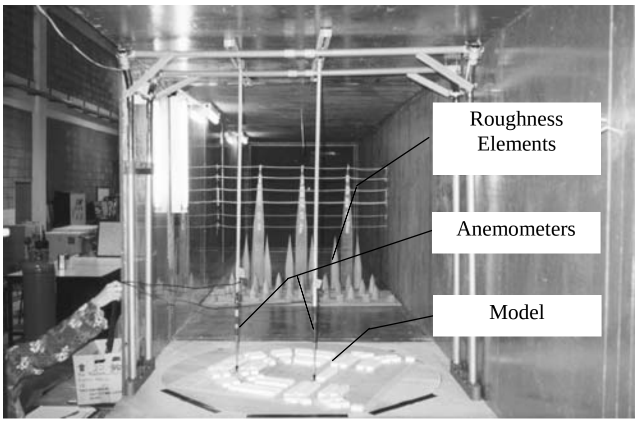


Fig.2. Wind tunnel tests facilities

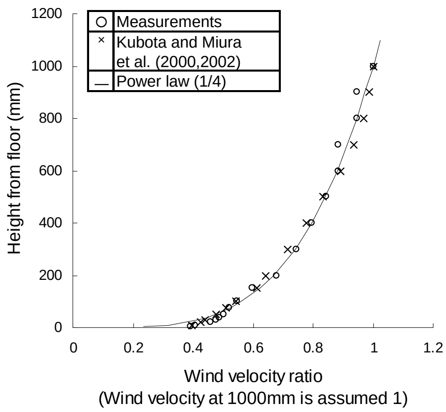


Fig.3. Vertical profile of mean wind velocity

All data that was measured at 49 measuring points in 16 wind directions are summarized in Fig.5. The second column in Fig.5 indicates the mean wind velocity ratio of all measuring points in each 16 wind direction. In order to consider the relationship between housing patterns and each mean values of wind velocity ratio, the site plans and those charts of mean wind velocity ratio are oriented to the same direction. The third column in Fig.5 shows the frequency of all data of wind velocity ratio, which are total data of the measuring points of all wind directions.

In Fig.4, arrows and circles are added in order to illustrate the areas in which the wind velocity ratios indicate either relatively high or low values. The mean values of wind velocity ratio were obtained in around 0.6-0.7 throughout the five cases as in Fig.5. Thus, in Fig.4, the areas where the wind velocity ratios are more than 0.7, they are recognized as a main wind flow area in the present study and indicated in arrows in consideration of the measured wind direction at each points; thin arrows indicate around 0.8, thick arrows indicate more than around 0.8. On the other hand, the areas where the wind velocity ratios are less than 0.5, they are recognized as a weak wind flow area and marked with circles in Fig.4.

The points in each case from the figures are summarized as follows.

(1) Case1

When rows of terraced houses are almost parallel to the wind direction, wind velocity ratios between the buildings tend to indicate higher values. This is accelerated by the channel effect (Gandemer, 1975) especially when the long rows are placed parallel. On the other hand, when the angle of rows of terraced houses to the wind direction becomes close to 90 degrees, wind velocity ratios between buildings tend to drop. This is because the space between the rows is placed in a shadow of the buildings. For example, these tendencies are seen when the wind direction is from the northeast in Case1 (Fig.4(1)).

(2) Case2

In Case2, one of the major parts of terraced houses is placed at perpendicular arrangement like Case1 and a row of semi-detached houses is also situated in the southeast direction of the area (Fig.4(2), Fig.5-2). The effects of the semi-detached houses on the wind flow are clearly seen when the wind direction is from the northeast. At the northeast wind direction, the leeward side of the row of semi-detached houses has similar wind velocity ratios as that on the windward side. That is, a wind is blown through the spaces between semi-detached houses from windward side to leeward side (Fig.4(2)).

It is evident that if the row of semi-detached houses were a long row of terraced houses like that of Case3, the wind flow will not be able to reach the upper part. Therefore, in order to avoid the increase of the weak wind flow areas, semi-detached houses would be effective as an alternative housing patterns.

(3) Case3

In Case3, two long rows of terraced houses lie diagonally from west to east in the middle (Fig.4(3), Fig.5-3). These rows have much influence on the whole wind flow. For example, when the wind direction is from the north and the angle of rows to the

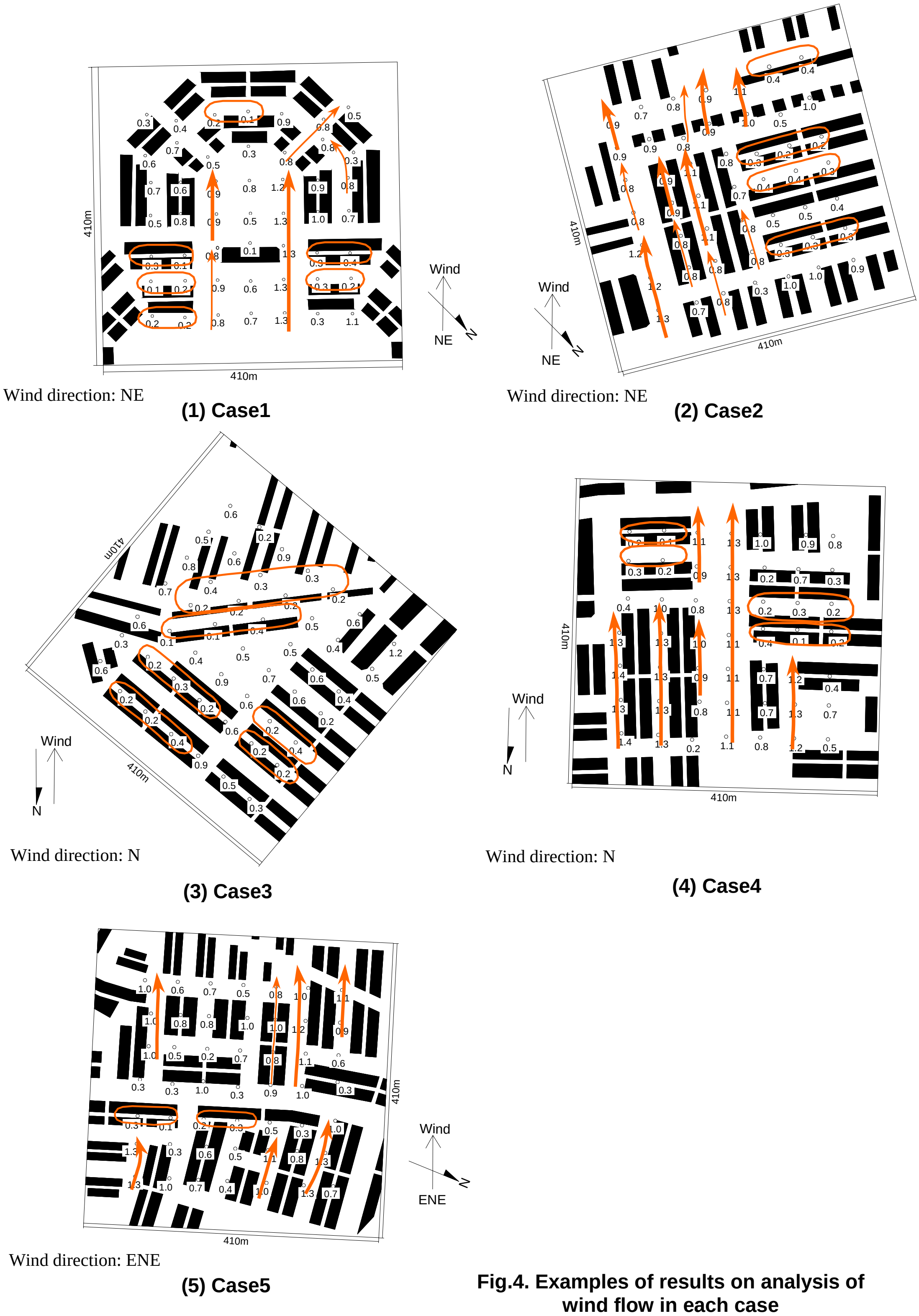


Fig.4. Examples of results on analysis of wind flow in each case

wind direction is around 90 degrees, the values of wind velocity ratio around the two long rows of terraced houses significantly dropped (Fig.4(3)). This is due to the interruption on the wind flow by the two long rows. The lowest value of mean wind velocity ratio is obtained at the north wind direction (Fig.5-3).

(4) Case4

In Case4, a wide road is located in the middle of the area in the north-south axis

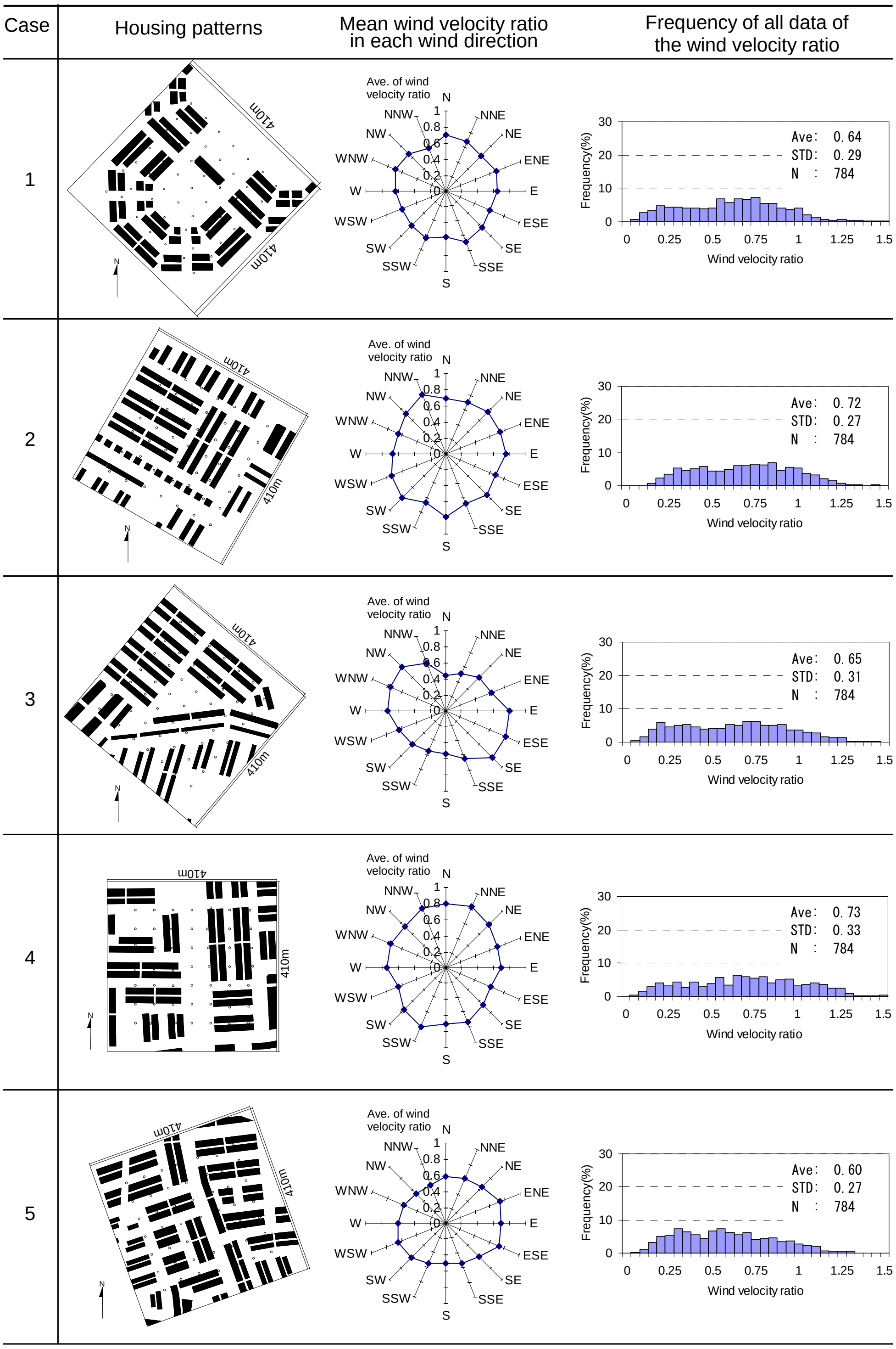


Fig.5. Frequency of wind velocity ratio of all points in 16 wind directions in each case

(Fig.4(4), Fig.5-4). When the wind direction is from the north, high values of wind velocity ratio are obtained and many points indicate values of over 1 within the wide road (Fig.4(4)). The mean value of wind velocity ratio of all data is 0.73; this is the highest value among the cases.

(5) Case5

The gross buildings coverage ratio of Case5 is 2% higher than that of Case4, and the highest of all cases. In Case5, there is neither large open spaces like Case1 nor

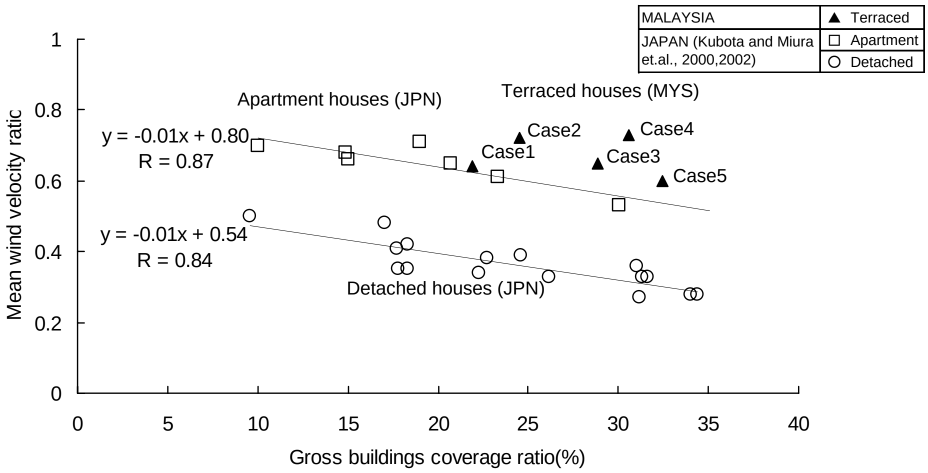


Fig.6. Relationship between gross buildings coverage ratio and mean wind velocity ratio of cases
Source: Japanese cases quoted from Kubota and Miura et al.(2000,2002)

wide roads like Case4 (Fig.4(5), Fig.5-5). The highest value of mean wind velocity ratio is given when the wind direction is from the east-northeast.

Each five cases in the present study mostly consist of long rows of low-rise terraced houses. The perpendicular arrangements are seen in all cases and this seems to be one of the typical housing patterns of terraced houses in Malaysia. Throughout all cases, it is found that the wind velocity ratio between the buildings tend to indicate higher values when rows of terraced houses are almost parallel to the wind direction. However, because of the perpendicular arrangements of terraced houses, some other rows of terraced houses are placed at an angle of almost 90 degrees to the wind direction at the same time and the wind velocity ratios between the buildings drop. Therefore, it can be considered that the perpendicular arrangement of terraced houses is one of the significant causes of reduction of the average wind flow in the neighborhood residential areas.

5. Discussions

Fig.6 shows the relationship between the gross buildings coverage ratio and the mean value of all data of wind velocity ratio of the cases. In Fig.6, the results of the Japanese cases (Kubota and Miura el al., 2000, 2002) are also indicated as white marks. According to the above study, both in the areas of detached houses and the apartment houses of Japan, the increase of the gross buildings coverage ratio tended to decrease the mean wind velocity ratio. Further, this figure indicates that the mean wind velocity ratio in Japanese apartment houses is higher than that of Japanese detached houses.

At the beginning of the present study, it was predicted that since housing layout of the terraced houses in Malaysia has some resembled of the Japanese apartment houses, the mean wind velocity ratio also must be similar to that of the Japanese apartment houses. However, as Fig.6 shows, the mean wind velocity ratios of the Malaysian cases are slightly higher than the trend line of the Japanese apartment houses. It is considered that since the housing patterns of these Malaysian terraced houses are more straight and much longer than that of the Japanese apartment houses, the factors of increases, such as the channel effect, occurred more frequently in the Malaysian cases. Thus, the mean wind velocity ratios become higher as a result. However, whether or not this explanation is true would not be known until further study is carried out.

6. Wind Environment Evaluation in Johor Bahru City

The wind environment evaluation was carried out based on the results of the wind tunnel tests. The wind velocity ratios, which measured in the wind tunnel tests, were transformed into the actual wind velocities by using the climate data of Johor Bahru City and the wind environment of the selected case study areas were evaluated under the same climate conditions by using the existing criteria for wind environment.

(1) Climate conditions in Johor Bahru City

The climate data of Senai station from 1988 to 1999 were used for this analysis. The Senai station is the nearest weather station from the center of Johor Bahru City located approximately 10-20km inland from each selected case study areas. In Malaysia, although temperature and humidity are generally high throughout a year, there is a seasonal climatic change, which is dominated by the monsoon. Thus, a year can be divided into three different periods; the northeast monsoon (Nov-Mar), the southwest monsoon (May-Sep), the inter monsoon (Apr, Oct).

Fig.7 shows the wind rose of the Senai station in the three periods. As shown in Fig.7, although both temperature and humidity are almost constant throughout the year, the direction and velocity of the prevailing wind are different between them. The wind velocities are relatively higher in the northeast monsoon period, but the mean wind velocity is not so high; the daily mean velocity is only 1.8m/s (Fig.7(a)).

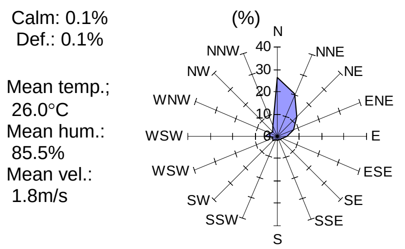
(2) Methods of evaluation

The actual wind velocities at 1.5m height in all measuring points were calculated by using the above climate data of Senai station, not only in Case1-Case5 but also in the previous Japanese cases. Fig.8 shows the results of the above calculations. It indicates that the mean wind velocities of each case study areas under the climate conditions of Senai station as the y-value. For example, the mean wind velocity of Case1 in Fig.8(a) is 0.65. This means that the actual mean velocity of Case1 will be 0.65m/s, if it is situated under the climate conditions of Johor Bahru City.

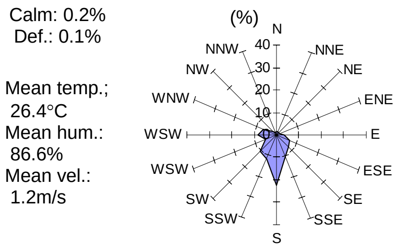
Studies on comfort zones for wind environment have been carried out by a number of researchers. Murakami et al.(1985), for example, suggested the comfort zones of daily mean wind velocity taking account of the daily mean temperature. According to Murakami, wind velocity range of 0.7-1.7m/s is the suitable zone for wind environment under the daily mean temperature of 25°C or more.

(3) Results of evaluation

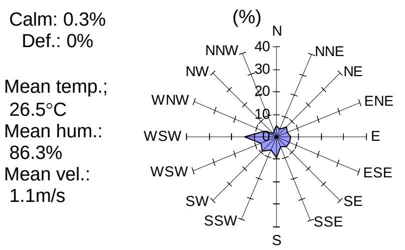
The comfort zones are indicated as hatch areas in Fig.8 according to the above criteria. The mean wind velocities at 1.5m height of some cases including Malaysian terraced houses of Case2, 4 are in the comfort zone during the northeast monsoon period (Fig.8(a)). Nevertheless, both in the southwest monsoon period and the inter monsoon period, although the mean values of wind velocity ratio of the Malaysian



(a) Northeast monsoon (Nov-Mar)

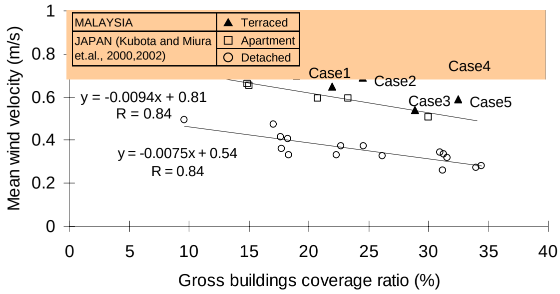


(b) Southwest monsoon (May-Sep)

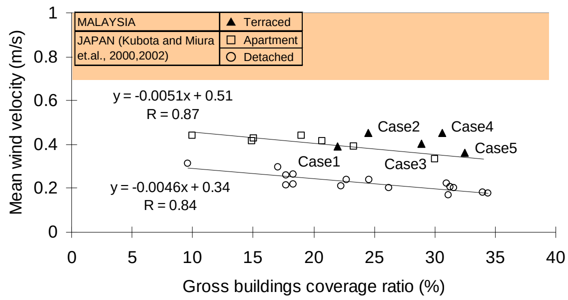


(c) Inter monsoon (Apr, Oct)

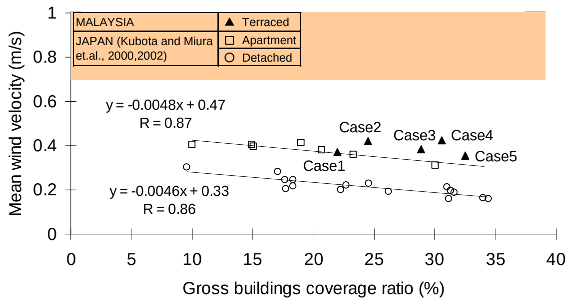
Fig.7. Wind rose in Senai station
Source: Monthly abstract of meteorological observations (1988-1999)



(a) Northeast monsoon (Nov-Mar)



(b) Southwest monsoon (May-Sep)



(c) Inter monsoon (Apr, Oct)

Fig.8. Results of wind environment evaluation in Johor Bahru City

terrace houses were slightly higher than the trend line of the Japanese apartment houses, the mean wind velocities in all the cases including Japanese cases do not reach the comfort zones (Fig.8(b)(c)). That is, both in the southwest monsoon period and the inter monsoon period in the Johor Bahru City, even if the Japanese detached houses, the Japanese apartment houses or the Malaysian terraced houses are chosen as a housing pattern, the mean wind velocity at the neighborhood level does not become suitable since the prevailing wind is low.

7. Conclusion

This paper has presented the results of several wind tunnel tests on selected neighborhood residential areas in the Johor Bahru Metropolitan City. In addition, the wind environment evaluation of the areas under the climate conditions of the city was carried out. The summary of the findings is as follows.

As a result of the wind tunnel tests, it could be considered that the perpendicular arrangement of terraced houses was one of the significant causes to have reduced the average wind flow in the neighborhood residential areas.

At some wind directions of Case2, it was seen that a wind was blown through the spaces between semi-detached houses from windward side to leeward side. Accordingly, it was stated that in order to avoid the increase of the weak wind flow areas, semi-detached houses would be effective as an alternative housing patterns.

The mean wind velocity ratios of the Malaysian cases were slightly higher than the trend line of the Japanese apartment houses. It was considered that since housing patterns of these Malaysian terraced houses were more straight and much longer than that of the Japanese apartment houses, the factors of increases, such as the channel effect, occurred more frequently in Malaysian cases. Thus, the mean wind velocity ratios became higher.

The results of the wind environment evaluation in the Johor Bahru City showed that the mean wind velocities at 1.5m height of some of the Malaysian terraced houses cases were in the comfort zone during the northeast monsoon period. Nevertheless, both in the southwest monsoon period and the inter monsoon period, although the mean values of wind velocity ratio of the Malaysian terrace houses had been slightly higher than the trend line of the Japanese apartment houses, the mean wind velocities in all the cases including Japanese cases did not reach the required comfort zones.

Therefore, it is necessary to examine the planning methods to maintain the comfort wind environment under the low wind conditions like Johor Bahru City, not only in the particular period but also throughout the year in the future research. High-rise housing can be one of the effective ways to utilize the higher wind at the elevated floor level.

Acknowledgements

We would like to express our sincere gratitude to Mr. Abdul Jalil Talisman, an assistant director of planning of Johor Bahru City Council, for providing useful information. We also would like to thank Assoc. Prof. Dr. Ho Chin Siong for his comments. We are particularly grateful to the Aero Laboratory of UTM for lending us the support for the wind tunnel experiments.

This research was supported in part by the Short Term Research Project Grant from RMC of UTM. Further, one of the authors, Tetsu Kubota, was supported under the UTM Post Doctoral Fellow scheme by the MOSTE in 2003-2004 and the JSPS Postdoctoral Fellowships for Research Abroad by the Japan Society for the Promotion of Science in 2004-present.

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