

Wind Environment Evaluation of Neighborhood Areas in Major Towns of Malaysia

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Abstract

This paper discusses planning methods of neighborhood residential areas in Malaysia, focusing on the effect of wind flow. This study aims to determine strategies that reduce energy consumption at the neighborhood scale, targeting especially a reduction in the use of air-conditioners. For naturally ventilated buildings, the wind flow around the structure strongly affects the air change rates within the building. This paper presents the evaluations of the wind environment in selected case study areas, under the respective climatic conditions in major Malaysian towns. The evaluations in towns on the west coast and inland of Peninsular Malaysia showed results that, the majority of terraced house cases did not meet the required criteria, under the respective local climatic conditions. This was mainly due to the weak wind conditions in these towns. It was considered that the location of towns was a key factor in determining such weak wind conditions. High-rise housing was suggested as an effective means of utilizing stronger winds at elevated floor levels in urban Malaysia.

Keywords: wind flow; wind environment evaluation; energy saving; residential neighborhood; natural ventilation

1. Introduction

The Kyoto Protocol on climate change came into effect in February 2005. This required the signatory nations to reduce emissions of greenhouse gases below 1990 levels, by 2012, as part of an attempt to achieve a more sustainable global environment. Only developed countries have been required to set greenhouse gas reduction targets, to date. However, energy-saving strategies are also important for developing countries.

The last three decades have seen tremendous growth of urban populations in Malaysia. The percentage of people living in urban areas has increased from 27% in 1970 to 62% in 2000. Current energy consumption in urban areas is therefore a very significant percentage of total energy consumption in the country and it is expected to rise further in the near future. The present nationwide final energy demand is almost five times larger than it was in 1980 (Malaysia, 2002a). Thus, it is essential to introduce energy-saving strategies to urban areas wherever possible.

Greenhouse gases caused by the use of air-conditioners in residential areas contribute substantially to emissions. Maximizing the use of natural ventilation can significantly reduce the reliance on air-conditioners and therefore emissions. Recent recognition of the need to save energy has been the catalyst for a reassessment

of the importance of natural ventilation. A number of studies related to natural ventilation in buildings can be seen over the last few decades. For example, Backer and Standeven (1996) summarized results of comfort monitoring surveys, with the aim of developing comfort criteria specifically for naturally ventilated buildings. In addition, three teams conducted field surveys on the thermal comfort offered by naturally ventilated buildings: in the UK by Raja *et al.* (2001), in Singapore by Wong *et al.* (2002) and in Indonesia by Karyono (2000).

For naturally ventilated buildings, the wind flow around the structure strongly affects the air change rates within the building. Thus, if a wind environment that generates sufficient wind speed is designed at a neighborhood scale, the energy consumption of air-conditioners in the area can be significantly reduced. In addition to the benefits stated above, wind flow also plays an important role in diffusing air pollution and heat at an urban scale as well as a neighborhood scale. However, although many studies examine natural ventilation in and around individual buildings, there are relatively few studies on wind flow in these larger areas.

The following authors, in several studies, examined planning methods of neighborhood areas in Japan, paying attention particularly to the effect of wind flow (Kubota, Miura, Tominaga and Mochida, 2000, 2002). Furthermore, the present authors addressed similar subject matter in studies conducted in Malaysia (Kubota and Supian, 2004, 2005).

The present study continues the research mentioned above and, in particular, discusses planning methods of neighborhood residential areas in Malaysia, focusing

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on the effect of wind flow. The study aims to determine strategies that reduce energy consumption at the neighborhood scale, targeting especially a reduction in the use of air-conditioners. This paper presents the evaluations of the wind environment in selected case study areas, under the climatic conditions in major Malaysian towns, using data from the wind tunnel tests conducted previously.

2. Results Summary of Previous Wind Tunnel Tests

The previous study (Kubota and Supian, 2005) presented results of wind tunnel tests on selected neighborhood areas in Johor Bahru City, Malaysia. The main aim of the wind tunnel tests was to examine the relationship between the housing patterns and the mean value of wind velocity at a neighborhood scale.

According to the property market report (Malaysia, 2002b), terraced houses accounted for approximately 57% of the total Malaysian existing housing stock in 2002, followed by apartment houses (25%) and detached houses (11%). Thus, the majority of housing types in Malaysia are considered to be terraced houses. For this reason, this study has focused especially on terraced house areas (Fig.1.). Five selected case study areas and the measuring points (1.5m height in the actual scale) in the previous wind tunnel tests are shown in Fig.2.

The results of the above study revealed that there is a strong relationship between the gross buildings coverage ratio and the mean value of wind velocity ratio, which was obtained by averaging values measured at all the points under the conditions from 16 wind directions in each case (Fig.3.). The increase of the gross buildings coverage ratio decreased the mean wind velocity ratio in each housing type, i.e. Japanese apartment houses and detached houses.

Fig.3. also indicates that the mean values of wind velocity ratio in five Malaysian cases were slightly higher than the trend line of Japanese apartment cases. Since the buildings of these Malaysian terraced houses were generally more straight and much longer than those of Japanese apartment houses, the factors influencing the wind speed increases such as the channel effect have occurred more frequently in Malaysian cases. As a result, the mean values of wind velocity ratio in the five Malaysian cases were considered to have become higher.

3. Wind Environment Evaluation

3.1. Methods of evaluation

The following two steps were considered in wind environment evaluations. Firstly, the wind velocity ratios measured in the previous wind tunnel tests, were transformed into the actual wind velocities by using climatic data in selected major Malaysian towns. Secondly, the wind environment in five terraced house cases (Fig.2.) and Japanese cases was evaluated, under the respective local climatic conditions, using the



Fig.1. Terraced House Area



Fig.2. Case Study Areas in Previous Wind Tunnel Tests
Source: Kubota and Supian (2005)

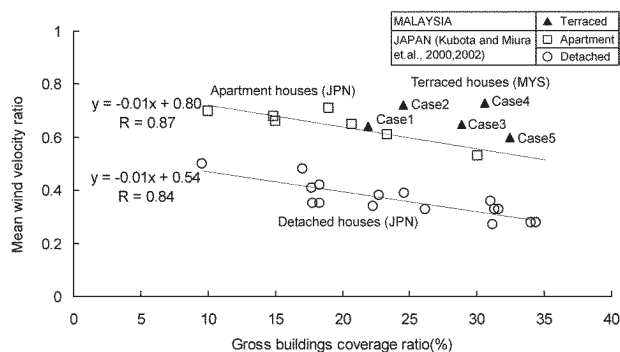


Fig.3. Relationship between Gross Buildings Coverage Ratio and Mean Wind Velocity Ratio
Source: Kubota and Supian (2005), Kubota and Miura *et al.* (2000, 2002)

following criteria.

Many of the criteria to assess problems caused by the strong wind around buildings at the ground level have been proposed by a number of researchers (e.g. Isyumov and Davenport, 1975; Murakami *et al.*, 1986). By contrast, there are few studies on assessment criteria to avoid thermal discomfort during the summer months due to insufficient wind speed.

Murakami and Morikawa (1985) proposed wind velocity ranges for avoiding such thermal discomfort

during the summer months due to insufficient wind speed as well as the problems caused by the strong wind (Appendix A). The present study is aimed at neighborhood areas where the wind velocity is usually reduced by the effects of building density. Moreover, most Malaysian towns experience relatively weak wind as well as hot and humid climate throughout the year as described later. Thus, major problems induced by the wind in Malaysian towns are considered as outdoor thermal discomfort and the lack of natural ventilation in buildings due to insufficient wind speed. Therefore, the above criteria were applied for the evaluations of wind environment shown in the section 3.3.

Nevertheless, the criteria proposed by Murakami and Morikawa (1985) do not necessarily evaluate the performance of natural ventilation in dwellings directly. The present study aims to promote natural ventilation within dwellings, as part of an effort to reduce energy consumption of air-conditioners at the neighborhood scale. Therefore, it is also necessary to assess wind environment in the case study areas based upon evaluations of natural ventilation performance in dwellings using another measure such as the air change rate in the future study.

3.2. Climatic conditions in Malaysia

Malaysia consists of the Peninsular Malaysia and a part of Borneo Island. Since the Peninsular has the major population (76%), the present study is aimed on this area. The Peninsular Malaysia is situated between 1°N and 7°N latitude, under the tropical climate (Fig.4.). Most towns in the Peninsular experience high temperature and humidity throughout the year without remarkable variations. However, there is a seasonal climatic change, which is dominated by the monsoons. The monsoons represent significant changes in the wind conditions and rainfalls. The monsoon season can be divided into two monsoon periods and the inter monsoon period; namely, the northeast monsoon period (November to March), the southwest monsoon period (May to September) and the inter monsoon period (April and October) (Fig.4.).

The six towns in the Peninsular Malaysia, Penang, Kuala Lumpur, Johor Bahru, Temerloh, Kota Bharu and Kuala Terengganu were selected as case study towns for the present wind environment evaluations. Fig.4. illustrates the location of six selected towns and general wind directions of each monsoon period. Most major towns in the Peninsular Malaysia are located in coastal areas. Many urbanized towns such as Kuala Lumpur and Penang are on the west coast of the Peninsular. By contrast, many towns located on the east coast such as Kota Bharu and Kuala Terengganu are relatively less urbanized towns.

The climatic conditions of towns dominated by the monsoons are significantly different between the east and west coast of the Peninsular. Penang is located on a small island along the west coast. It is the third biggest town in Malaysia. Kuala Lumpur is the capital city of

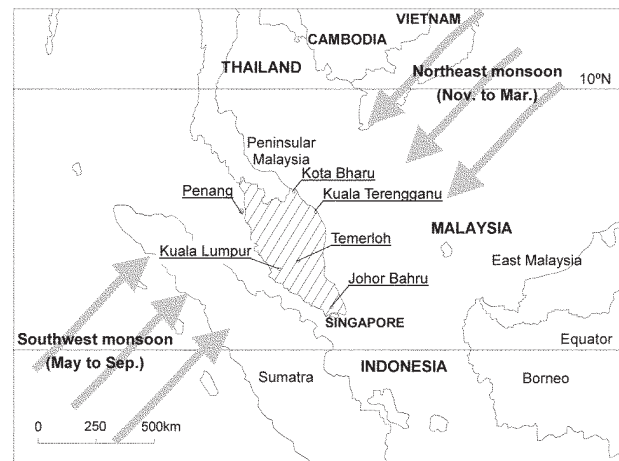


Fig.4. Case Study Towns for Wind Environment Evaluation

Malaysia, which is situated approximately 50km from the coastal line. Johor Bahru is the second largest town after Kuala Lumpur and located at the southernmost part of the Peninsular. Temerloh is one of the medium size towns in the state of Pahang. This town was selected as an example of inland town. Kota Bharu and Kuala Terengganu were chosen as towns on the east coast of the Peninsular. Both of these towns are located along the South China Sea.

Fig.5. indicates the wind roses and summary of climatic conditions over the past 15 years (1988-2002) at respective weather stations in six selected towns. The indicated climatic data was calculated by averaging hourly values at respective weather stations observed by the Malaysian Metrological Service (1988-2002).

As shown in Fig.5., both the mean temperature and the mean relative humidity vary minimally throughout the year. By contrast, the direction and mean wind velocity in respective towns change according to the monsoon periods. The mean wind velocities in the six towns indicate 1-3m/s as shown in Fig.5.

The effects of the northeast monsoon are relatively stronger than those of the southwest monsoon in the Peninsular. This is mainly because of the geographical location of the Sumatra Island of Indonesia (Fig.4.). In all the selected towns except for Kuala Lumpur, the mean wind velocities in the northeast monsoon period indicate higher values than those in the southwest monsoon period (Fig.5.). Especially on the east coast of the Peninsular, the northeast monsoon strongly affects its regional climate. Fig.5. also shows that values of mean wind velocity in the inter monsoon period are similar with those in the southwest monsoon period in respective towns.

Moreover, in Malaysia, since the solar radiation is very strong throughout the year, land-sea breeze is one of the most significant weather phenomena to affect the local climate particularly in coastal areas.

The weather station in Penang is located on the south coast of the Penang Island, facing the Strait of Malacca. Therefore, the influences of the sea breeze

(the south-southwest wind) can be seen throughout the year (Fig.5.(1)). The effects of the sea breeze in Kuala Lumpur (the west wind) are not remarkable compared to Penang as indicated in Fig.5.(2). This is mainly due to location of the city, i.e. distance from the coastal line. The mean wind velocity in Kuala Lumpur is only 1.4m/s in the northeast monsoon period and 1.6m/s both in the southwest monsoon period and the inter monsoon period (Fig.5.(2)).

In Johor Bahru, the mean wind velocity in the northeast monsoon period (1.8m/s) is slightly higher than that of Kuala Lumpur, and the wind velocities both in the southwest monsoon period and the inter monsoon period (1.1m/s) are a little lower than those of Kuala Lumpur (Fig.5.(3)).

The wind in Temerloh is extremely weak, mainly because the town is situated inland. The percentage values for the calm conditions indicate 16.2% in the northeast monsoon period, 25.2% in the southwest monsoon period and 28.3% in the inter monsoon period as shown in Fig.5.(4). The calm condition indicates that the mean wind velocity was equal or less than 0.3m/s. These values in Temerloh were very high compared to the other case study towns. The mean wind velocities in the town are less than 1m/s throughout the year (Fig.5.(4)).

On the east coast of the Peninsular, the wind direction of the daytime sea breeze corresponds to those during the northeast monsoon period. Thus, in Kota Bharu and Kuala Terengganu, the wind directions observed during the northeast monsoon period prevail and the mean wind velocities exceed those in other case study towns as indicated in Fig.5.(5)(6)-a. The mean wind velocities during the northeast monsoon period in both these towns are 2.7m/s.

3.3. Results and discussion

The actual wind velocities at 1.5m height at all measuring points were calculated by using the above climatic data. The methods of this calculation are described in the Appendix B. Verifications of the methods have been made in the previous researches (Kubota and Miura *et al.*, 2002).

Fig.6. shows results of calculations. Y-values in Fig.6. indicate the mean wind velocities of five terraced house cases and Japanese cases, under the local climatic conditions in the respective six towns. Each plot in figures corresponds to the mean wind velocity for each case. For example, the mean wind velocity in Case 1 was 0.79m/s in Fig.6.(1)-a. This means that the actual mean wind velocity in Case 1 will be 0.79m/s, if it is situated under the climatic conditions in Penang during the northeast monsoon period.

According to Murakami and Morikawa (1985), the wind velocity range of 0.7-1.7m/s allows a reasonable wind environment under the daily mean temperature of more than 25°C (Appendix A). These required wind velocity ranges for facilitating a reasonable wind environment are indicated as hatch areas in Fig.6.

In Penang, since the local mean wind velocity was relatively high during the northeast monsoon period as shown in Fig.5.(1)-a, all the five terraced house cases fall within the required wind velocity range (Fig.6.(1)-a). The calculated mean wind velocity in the northeast monsoon period indicates 0.79m/s in Case 1, 0.87m/s in Case 2, 0.71m/s in Case 3, 0.93m/s in Case 4 and 0.74m/s in Case 5, respectively. All these values are more than 0.7m/s, which is the lower limit of wind velocity for facilitating a reasonable wind environment in the proposed criteria. On the other hand, both in the southwest monsoon period and the inter monsoon period, the calculated mean wind velocities in all the five cases do not meet the required criteria (Fig.6.(1)-bc). Yet the mean values of wind velocity ratio in five terraced house cases had been higher than the Japanese cases in the previous wind tunnel tests. The calculated mean wind velocities in five cases during both these periods range over 0.5-0.7m/s.

In Kuala Lumpur, since the local mean wind velocity in the northeast monsoon period was lower than that of Penang as indicated in Fig.5.(2), the calculated mean wind velocities in all the five cases do not meet the required criteria throughout the year; the mean values range over 0.4-0.6m/s (Fig.6.(2)).

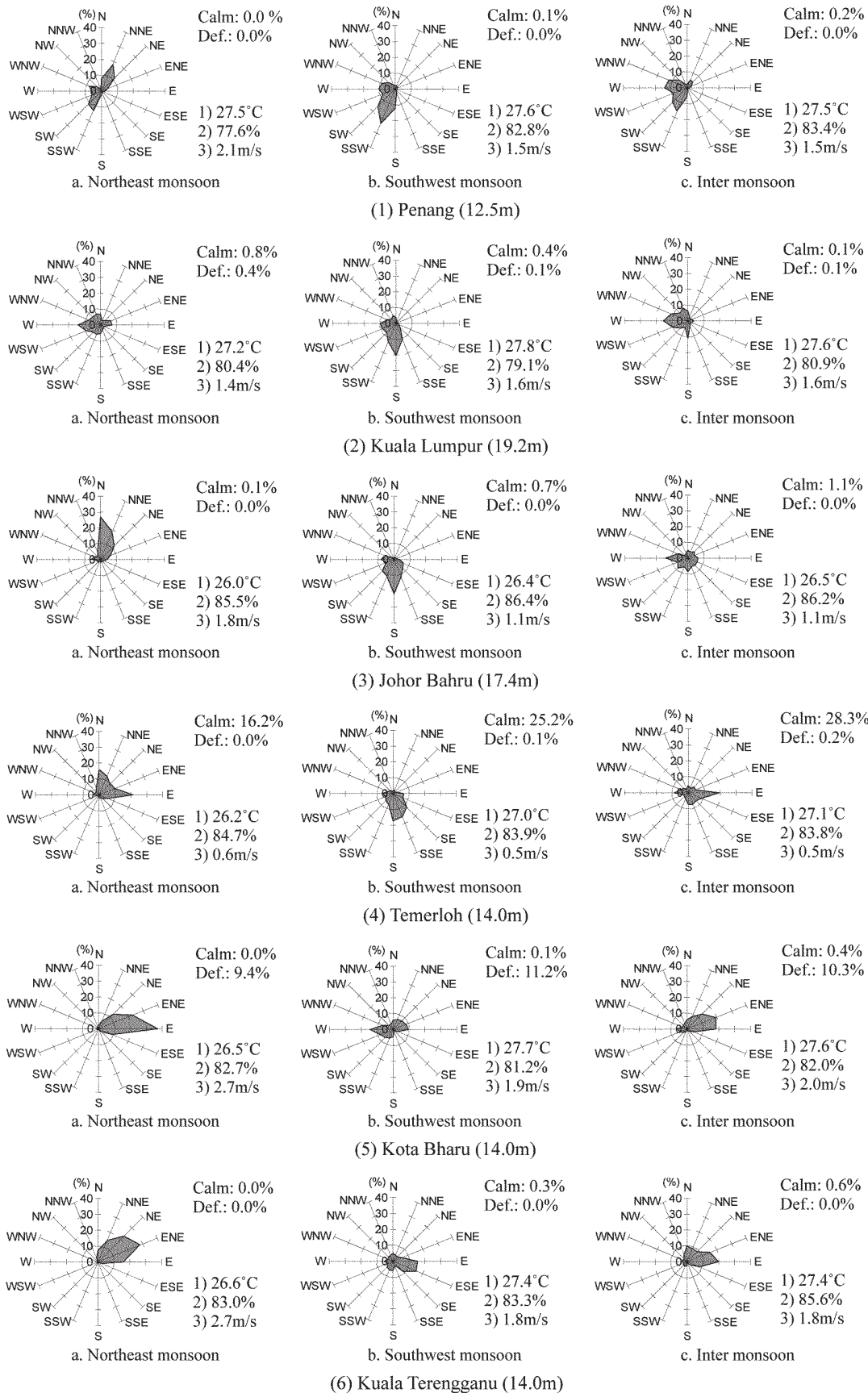
The results in Johor Bahru were similar with those in Kuala Lumpur. Except for Case 4 in the northeast monsoon period, the calculated mean wind velocities in all the five cases do not meet the required criteria throughout the year; the mean values range over 0.3-0.7m/s (Fig.6.(3)).

Temerloh obtained much lower mean wind velocities. All the five cases are far from the required wind velocity ranges throughout the year (Fig.6.(4)). The calculated mean wind velocities in five cases range over 0.2-0.3m/s.

The above results suggest that, for the west coast and inland towns on the Peninsular, the majority of terraced house cases did not meet the required criteria, under the respective local climatic conditions, the only exception being for the northeast monsoon period in Penang. This is mainly due to the weak wind conditions in these towns. It is considered that the location of towns is a key factor in determining such weak wind conditions.

Therefore, it can be concluded that, in general, when considering wind flow at a neighborhood scale, terraced housing is not a suitable option for towns located on the west coast and inland of the Peninsular. Since sufficient wind is unlikely to occur at the pedestrian level in these towns, high-rise housing is suggested as an effective means of utilizing stronger winds at the elevated floor levels in urban Malaysia.

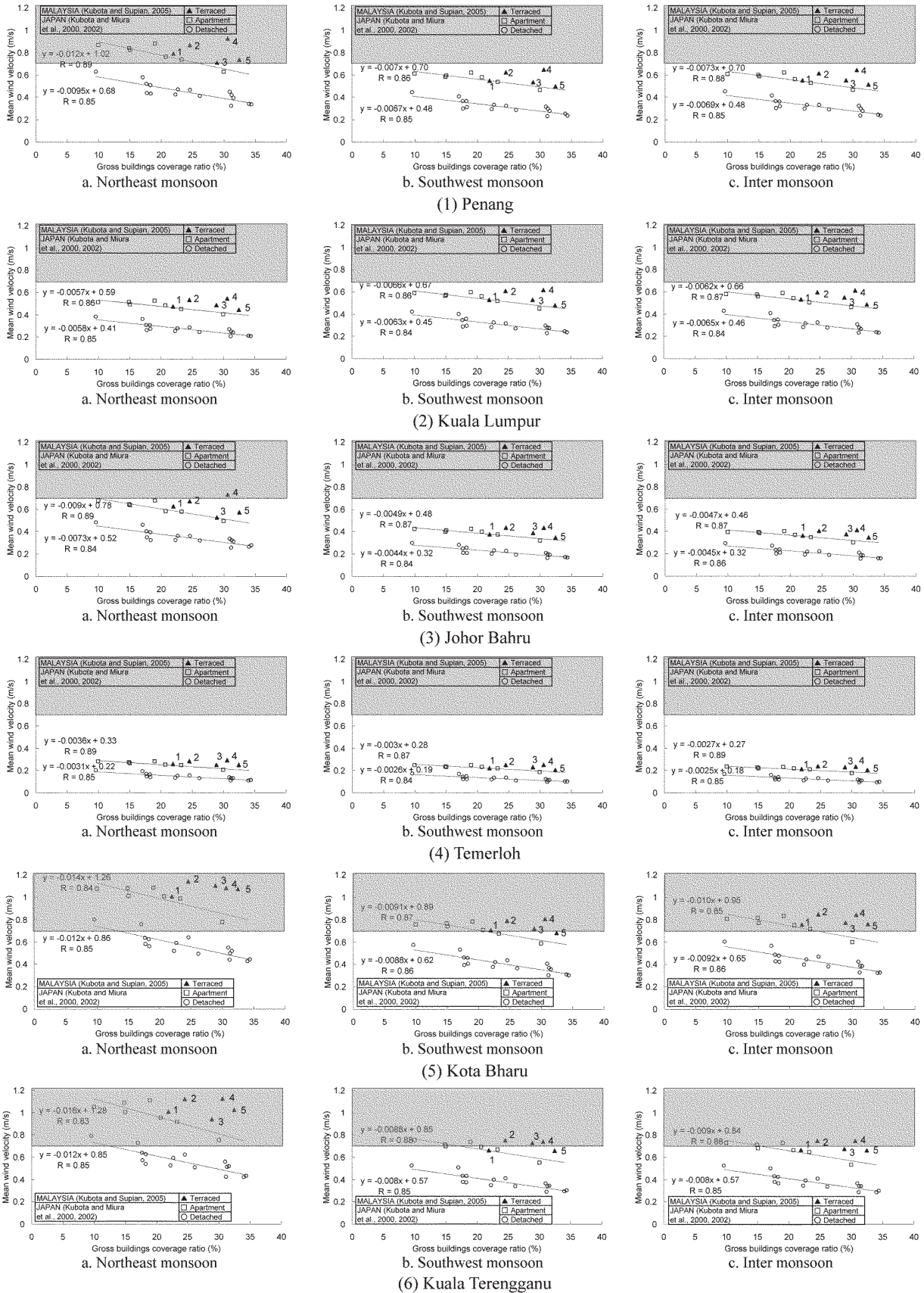
The local mean wind velocities in Kota Bharu and Kuala Terengganu were relatively high throughout the year (Fig.5.(5)(6)). Thus, the results in these towns show that many terraced house cases fall within the required wind velocity ranges throughout the year.



Note: 1) Daily mean temperature, 2) Daily mean relative humidity, 3) Daily mean wind velocity.

Figures in brackets after the name of towns indicate the height of anemometer above the ground level.

Fig.5. Wind Rose and Climate Summary in Respective Case Study Towns (1988-2002)



Note: Hatch areas in figures indicate wind velocity ranges for facilitating a reasonable wind environment (Murakami and Morikawa, 1985)

Fig.6. Results of Wind Environment Evaluation in Respective Case Study Towns

Especially during the northeast monsoon period, all the five cases as well as the Japanese apartment cases fall within the required range as indicated in Fig.6.(5)(6)-a. The calculated mean wind velocities during this period in Kota Bharu and Kuala Terengganu indicate around 1.0-1.1m/s in the respective five cases.

Therefore, although it was considered that, in general, when considering wind flow at a neighborhood scale, terraced housing was not a suitable option for towns located on the west coast and inland of the Peninsular, it may be acceptable especially for towns located on the east coast of the Peninsular.

4. Conclusions

We have discussed throughout this paper planning methods of neighborhood areas in Malaysia, focusing on the effect of wind flow. The main findings are summarized as follows:

(1) The climatic data in six selected towns across Peninsular Malaysia were analyzed. The results showed that both the mean temperature and the mean relative humidity varied minimally throughout the year. By contrast, the direction and mean wind velocity in respective towns changed according to the monsoon periods.

(2) On the east coast of the Peninsular, the wind direction of the daytime sea breeze corresponded to those during the northeast monsoon period. Thus, in Kota Bharu and Kuala Terengganu, the wind directions observed during the northeast monsoon period prevailed and the mean wind velocities exceeded those in towns located on the west coast and inland of the Peninsular.

(3) The wind environment evaluations in case study areas were carried out, under the climatic conditions in six selected towns on the Peninsular. The evaluations in Kota Bharu and Kuala Terengganu showed results that, in the main, many terraced house cases fell within the required wind velocity ranges for facilitating a reasonable wind environment throughout the year. On the other hand, for the west coast and inland towns on the Peninsular, the majority of terraced house cases did not meet the required criteria, under the respective local climatic conditions, the only exception being for the northeast monsoon period in Penang. This was mainly due to the weak wind conditions in these towns. It was considered that the location of towns was a key factor in determining such weak wind conditions.

(4) Based on the above results, it can be concluded that, in general, when considering wind flow at a neighborhood scale, terraced housing is not a suitable option for towns located on the west coast and inland of the Peninsular.

Over the past few decades, towns, especially on the west coast of Peninsular Malaysia, have seen the development of numerous mass-residential areas. These developments have not taken wind flow into

account. Further research is required to determine planning guidelines that will allow a reasonable wind environment to be maintained throughout the year, especially under weak wind conditions. Since sufficient wind is unlikely to occur at the pedestrian level in these towns, high-rise housing is suggested as an effective means of utilizing stronger winds at elevated floor levels in urban Malaysia.

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Appendix A. Criteria for assessing wind-induced discomfort considering temperature effect (Murakami and Morikawa, 1985)

Murakami and Morikawa (1985) proposed the wind velocity ranges to avoid thermal discomfort during the summer months due to insufficient wind speed as well as the problems caused by the strong wind in and around buildings. In their proposal, both upper and lower limits of wind velocity are changed according to the increase of the daily mean temperature. The proposed criteria are indicated in Table 1.

Their criteria were examined based on the long-term social surveys and the weather observations in Tokyo. The criteria represent comfort and discomfort of human subjects induced by the wind in and around buildings.

Table 1. Criteria for Assessing Wind-Induced Discomfort Considering Temperature Effect
Source: Murakami and Morikawa (1985)

(at 1.5m height)	Daily mean temperature (°C)		
	<10	10-25	>25
Daily mean wind velocity that result in weak wind-induced discomfort.	-	-	0.7m/s
Daily mean wind velocity that is transferred from the comfort range to strong wind-induced discomfort range.	1.3m/s	1.5m/s	1.7m/s
Daily mean wind velocity that begins to result in strong wind-induced discomfort.	2.0m/s	2.3m/s	2.9m/s

Appendix B. Methods on calculations of actual wind velocities

The methods used in the calculations were as follows. Firstly, we assumed that the vertical profile of mean wind velocity in the respective case study towns corresponded with a 1/4 power law. Then, the wind velocities in a wind tunnel at the height of respective weather stations (U_h) were calculated by:

$$U_h / U_\infty = (z_h / z_\infty)^{1/4} \quad (1)$$

Where U_h is the wind velocity in a wind tunnel at the height of respective weather stations (m/s); U_∞ is the reference wind velocity above boundary layer in a wind tunnel (m/s); z_h is the height in a wind tunnel, which corresponds with that of the weather station (mm); z_∞ is the reference height above boundary layer in a wind tunnel (mm).

Secondly, the actual wind velocities in each measuring point in the respective case study towns at 1.5m height ($V_{1.5}$) were calculated by:

$$V_{1.5} / V_h = U_{1.5} / U_h \quad (2)$$

Where $V_{1.5}$ is the actual wind velocity in the respective case study towns at 1.5m height (m/s); V_h is the mean wind velocity based on the climatic data (m/s); $U_{1.5}$ is the mean wind velocity measured by the wind tunnel tests (m/s).

The above calculations were made at all measuring points in every 16 wind directions. And then, the mean wind velocities in the respective measuring points were calculated in consideration of wind roses.

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