

## **MEASUREMENT OF THE WIND FLOW IN RESIDENTIAL AREAS OF JOHOR BAHRU METROPOLITAN CITY Toward Planning Guidelines for Energy Saving City in Malaysia**

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### **Abstract**

Most cities in Malaysia experience hot and humid climate during most part of the year. In large metropolitan cities such as Johor Bahru, the use of air conditioners to cool dwelling units has been increasing sharply partly due to continuing rise in disposable income brought about by recent high economic growth. This has resulted to significant rise in non-renewable energy consumption, thus does not contribute toward sustainability.

Natural wind flow is one of the most effective energy-saving methods to improve the thermal environment at the neighborhood level. This paper presents the results of several wind tunnel tests on selected residential areas in Johor Bahru Metropolitan City. By comparing the average of wind velocity of each case studies, the paper discusses the planning guidelines at the residential neighborhood level area in order to create sufficient wind flow and help achieve energy saving and sustainability objective.

**Keywords:** Energy saving city, Wind flow, Wind tunnel tests, Residential neighborhood, Sustainability, Planning guidelines

### **1. Introduction**

Most cities in Malaysia experience hot and humid climate during most part of the year. In large metropolitan cities such as Johor Bahru, the use of air conditioners to cool dwelling units has been increasing sharply partly due to continuing rise in disposable income brought about by recent high economic growth. This has resulted to significant rise in non-renewable energy consumption, thus does not contribute toward urban sustainability.

The aim of this study is to discuss the various planning guidelines at the neighborhood residential areas toward the attainment of energy saving city objective in Malaysia. Several approaches may be adopted in order to achieve the objective of energy saving. However, this study focuses the discussion on wind flow effects of the neighborhood residential areas. Natural wind flow is one of the most effective energy-saving methods to cope up with high temperature and humidity and to improve the thermal environment at the neighborhood level of large cities. Moreover, wind flow plays an important role to reduce the heat and air pollution at the city level. Therefore, this paper presents the results of several wind tunnel tests on selected residential areas in Johor Bahru Metropolitan City. The main purpose of the wind tunnel tests is to examine the methods to create sufficient wind flow and help achieve energy saving and sustainability objectives at the neighborhood level.

Several studies have been conducted in the past that use various planning methods to achieve energy saving objective at the city level (e.g., Cook G.D. 1994). However, in regard to studies on the wind effects, although there are many studies in inside and surrounding of

buildings (e.g., Lawson et al. 1975, Murakami et al. 1980), there are few studies for the residential area, particularly at the neighborhood level. Therefore, there are some building guidelines that have been taken into account of wind effects, but the planning guidelines of residential areas in consideration of wind flow is very limited.

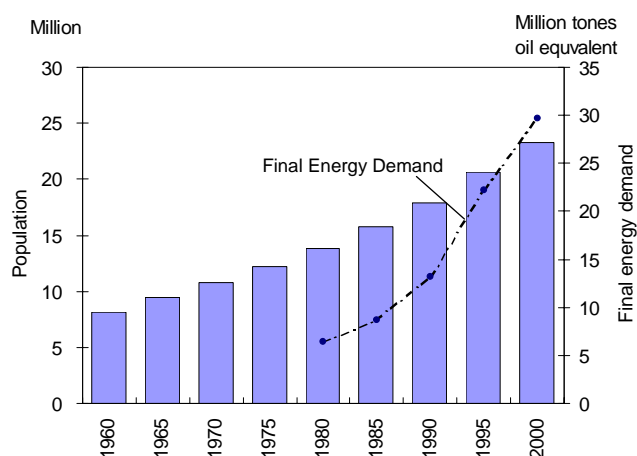
Gandemer (1975) has examined and classified effects of buildings on wind environment in neighborhood areas. He has identified five major effects, i.e. the channel effect and the venturi effect etc. The channel effect means that the wind tends to blow higher along the street formed like a gully by the set of the row of buildings. The venturi effect is a funnel phenomenon caused by two separate buildings whose axes make an acute or right angle. Since terraced houses, which basically consist of row of buildings, are one of major housing patterns in Malaysia, it is predicted that especially this two effects, the channel effect and the venturi effect, would occur.

Kubota and Miura et al. (2000)(2002) have conducted several researches in order to examine the use of planning methods of residential areas in consideration of wind flow in Japan. Both Japanese and Malaysian cases are comparable since both experience hot and humid climate during particular day of the summer month. In Japan, the authors conducted a series of wind tunnel tests on the residential areas selected from Tokyo and examined the planning methods of neighborhood residential areas in consideration of wind flow.

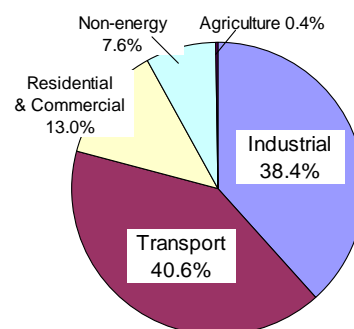
## 2. Overview of Population and Energy Balance in Malaysia

Malaysia is one of the fastest growing economies in South East Asia. Its population has rapidly increased in recent years from 11 million in 1970 to 23 million in 2000 (Fig.1). That is, the population has almost doubled in past 30 years. One of the causes for this rapid increase was the effect of urbanization. Percentage of the urban population was only 27% in 1970, but it has risen to 62% in 2000.

This rapid population increase and recent high economic growth have resulted in the tremendous increase of the demand for energy consumption (Fig.1). The ratio of the residential and commercial sector in the total energy demand is not large so far (Fig.2). However, it is assumed that the energy demand both the residential and commercial sector will rise especially partly due to the increase of the use of air conditioners. As we described,



**Fig.1 Population and Energy Demand in Malaysia**  
 Source: Malaysia Plan, National Energy Balance Malaysia



**Fig.2 Profile of Final Energy Demand in Malaysia (year 2000)**  
 Source: National Energy Balance Malaysia

since most cities in Malaysia have hot and humid climate during most part of the year, it is very important to consider the planning methods to minimize the use of air conditioners in residential and commercial sector by using the renewable energy before they have completed the development of the country.

### 3. Outlines of the Case Study Areas

Johor Bahru Metropolitan City is located in the southernmost part of the Peninsula Malaysia. It is the second largest city in Malaysia and the population is approximately 1 million in 2000. Since the majority of housing pattern of Johor Bahru Metropolitan City is terraced houses, we mainly concentrate on these housing patterns in this study (Photo 1). We selected three neighborhood residential areas in consideration of housing density and five areas among them were chosen for the wind tunnel tests (Fig.3). The outlines of these five case study areas are shown in Table 1.

Case1 is in a new residential area located in the outskirts of Johor Bahru City. The main features of this residential area are unique housing patterns and large area of open spaces. In the site including Case1, several parallel rows of terraced houses are arranged to surround a large community park, which is located in center of the area.

Both Case2 and Case3 are middle class neighborhood residential areas located approximately 6km from the center of the city. It was developed from the late 1970's. This residential area is composed of some housing patterns along with the development units. Case2 is the area that mainly consists of terraced houses and semi-detached houses. One of the blocks of terraced houses is arranged at right angles to another blocks. Case3 is the area that mainly consists of terraced houses. Mainly two arrangement types of parallel rows of terraced houses are seen in this area. They are placed against each other by an angle of almost 90 degrees and another two rows of terraced houses are located between them, in middle of the area.

Both Case4 and Case5 are situated in north of the city center; it is one of the expanded residential areas of Johor Bahru City. The development of this area has been started in the 1990's. In Case4, a wide road is located in center of the area. However, since the housing density of the whole area is relatively high, the gross buildings coverage ratio is higher than the former cases. Case5 is an area whose density is the highest among this case study.

### 4. Methods of the Wind Tunnel Tests

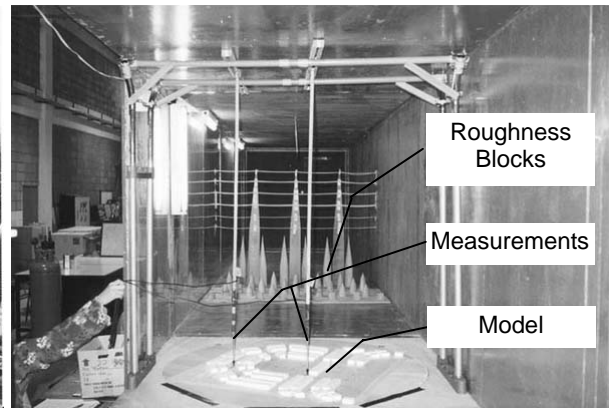
The large boundary layer wind tunnel in Universiti Teknologi Malaysia was used for the

**Table1 Outlines of Case Study Areas for the Wind Tunnel Tests**

Case	Gross buildings coverage ratio(%)	Gross floor area ratio (%)	Ratio of buildings coverage of each stories(%)	
			1-2	more than 3
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	-



**Photo1 Terraced Houses Residential Area**



**Photo2 Wind Tunnel Tests Facilities**



**Fig.3 Site Plan of the Case Study Areas**

tests. A cross-section of the wind tunnel is 1.4m x 1.4m, with a test length of 9m. The vertical profile of wind velocity in the tests was prepared by using roughness blocks etc in order to simulate the natural wind in urban areas (Photo 2). In general, it is known that this vertical profile agrees with a power law. In this study, 1/4 is used as the value of coefficient of the power law.

The models for the tests are scaled in 1/500. Since the real scale of each area is 410m x 410m, the scale of models becomes 820mm x 820mm. Measuring points of 49 are placed equally in outside of buildings in the whole of each area as in Fig.4 and Fig.5. Both wind direction and wind velocity at 1.5m heights of each 49 measuring point were measured in

each 16 wind directions, such as North, North-North-East etc, through the wind tunnel tests.

## 5. Results of the Wind Tunnel Tests

Fig.4 shows some examples of the results on analysis of wind flow in each case. In each figure, the wind direction is arranged to agree with a direction from below of the paper to above. Each of wind velocity ratios indicated in the figure were computed to divide a measuring wind velocity at 1.5m heights by a wind velocity at the same height in the flat model with no buildings. When a measuring wind velocity is the same as this standard wind velocity with no buildings, the wind velocity ratio is "1". Besides, the wind velocity ratio "over 1" means that a measuring wind velocity was increased by the effects of the surrounding buildings.

In the figures of wind velocity ratio, main wind flows, where the wind velocity ratios are more than 0.7, were drawn as arrows in consideration of the measurement of wind direction. On the other hand, wind velocities become weak in backside of the buildings against the wind direction. Those weak wind velocity zones, where wind velocity ratios are less than 0.5, were marked with circles in the figure.

All data that was measured at 49 measuring points in 16 wind directions are summarized in Fig.5. The second column in Fig.5 shows the average of wind velocity ratio of all measuring points in each 16 wind direction. Since the direction of site plans, which are shown at left side of the figure, is same as the right figures, the site plans will help understand the relationship between the housing arrangement and the average value in each wind direction.

The third column in Fig.5 indicates the frequency of all data of wind velocity ratio, which are total data of the measuring points of all wind directions. The important points in each case from the figures are summarized as follows.

### (1) Case1

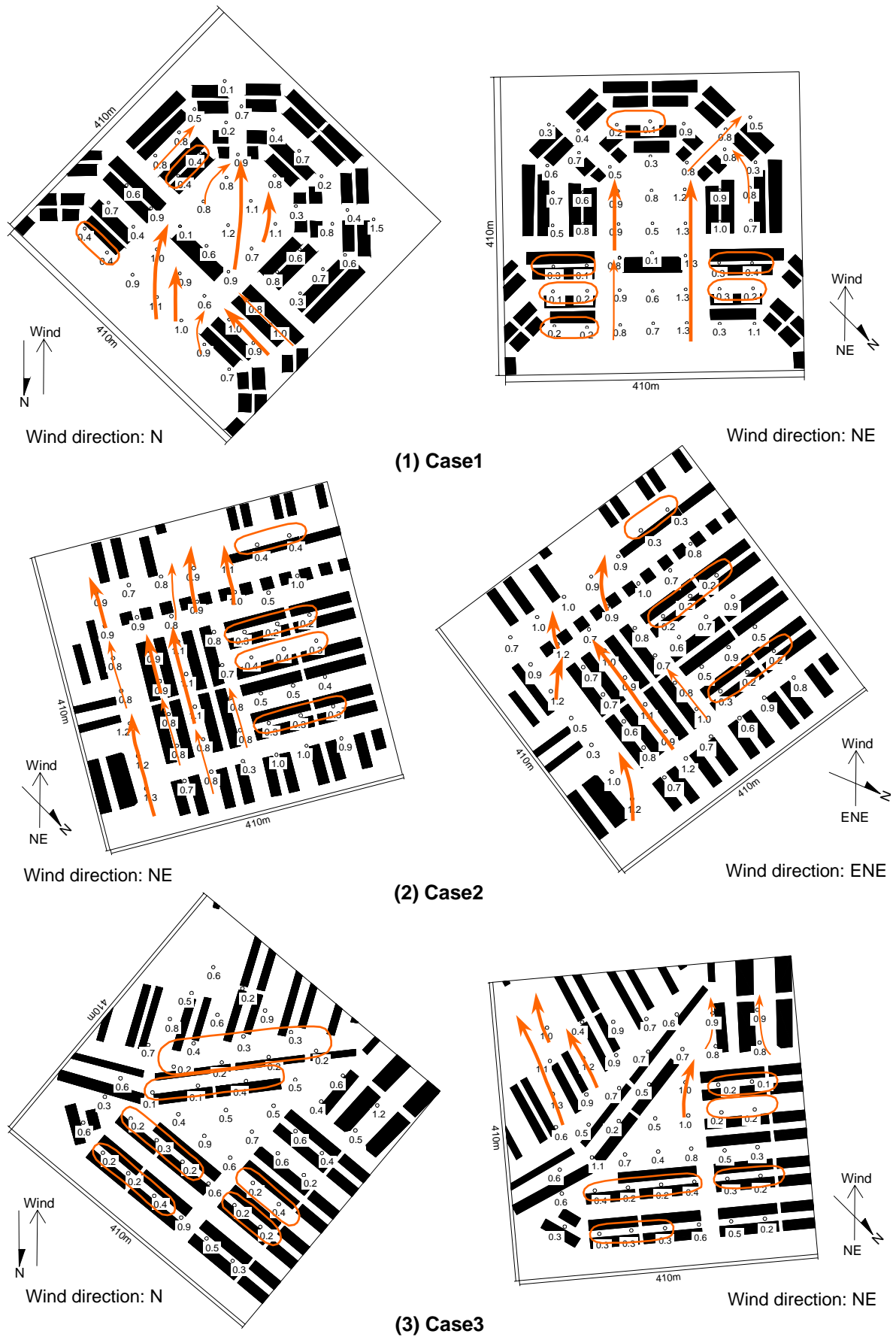
In this Case1, the average wind velocity is the highest, when the wind direction is N. In case of this wind direction, although there are a few weak wind velocity zones, wind blows sufficiently especially in the central park. However, when the wind direction becomes NE, though wind velocities in the central park are still sufficient, wind velocities between the buildings at an obtuse angle to the wind direction on both sides of the area become low (Fig.4).

When rows of terraced houses almost agree with the wind direction, wind velocities between the buildings will be higher. That is called the "Channel Effect", as we have stated in Chapter 1 (Gandemer 1975). On the other hand, when the angle of rows of terraced houses to the wind direction becomes close to 90 degrees, wind velocities will become lower. When the wind direction is NE in Case1, this tendency is seen very clearly.

That is, even if some rows agree with the wind direction and wind velocities in there increases, another rows will be directed at an angle of 90 degrees to it and wind velocities in there will decrease at the same time. Therefore, it is thought that this kind of housing arrangement is not so suitable from a viewpoint of the average wind flow.

### (2) Case2

Also in this Case2, one of major parts of terraced houses is placed at an angle of 90 degrees to the others. On the other hand, one of the points in terms of housing arrangement



**Fig.4 Examples of the Results on Analysis of the Wind Flow in Each Case**





**Fig.4 Examples of the Results on Analysis of the Wind Flow in Each Case (continued)**

in this Case2 is about semi-detached houses. For example, when the wind direction is NE, a row of semi-detached houses lies from left to right, on upper part of the area (Fig.4). The point is that wind flow blows through the row of semi-detached houses from lower side to upper part. 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 weak wind velocity zones, semi-detached houses would be effective as alternative housing pattern.

The difference of the average of wind velocity ratio in each wind direction is not large. The average of all data of wind velocity ratio is 0.72; this is higher than Case1 and Case3 (Fig.5).

### (3) Case3

In this Case3, two of long rows of terraced houses lie from west to east in the middle. These rows have much influence on the whole wind environment. When the wind direction is N, since the angle of the rows to the wind direction is around 90 degrees, this influence becomes very clear. The two long rows of terraced houses disturb wind flows in large part of

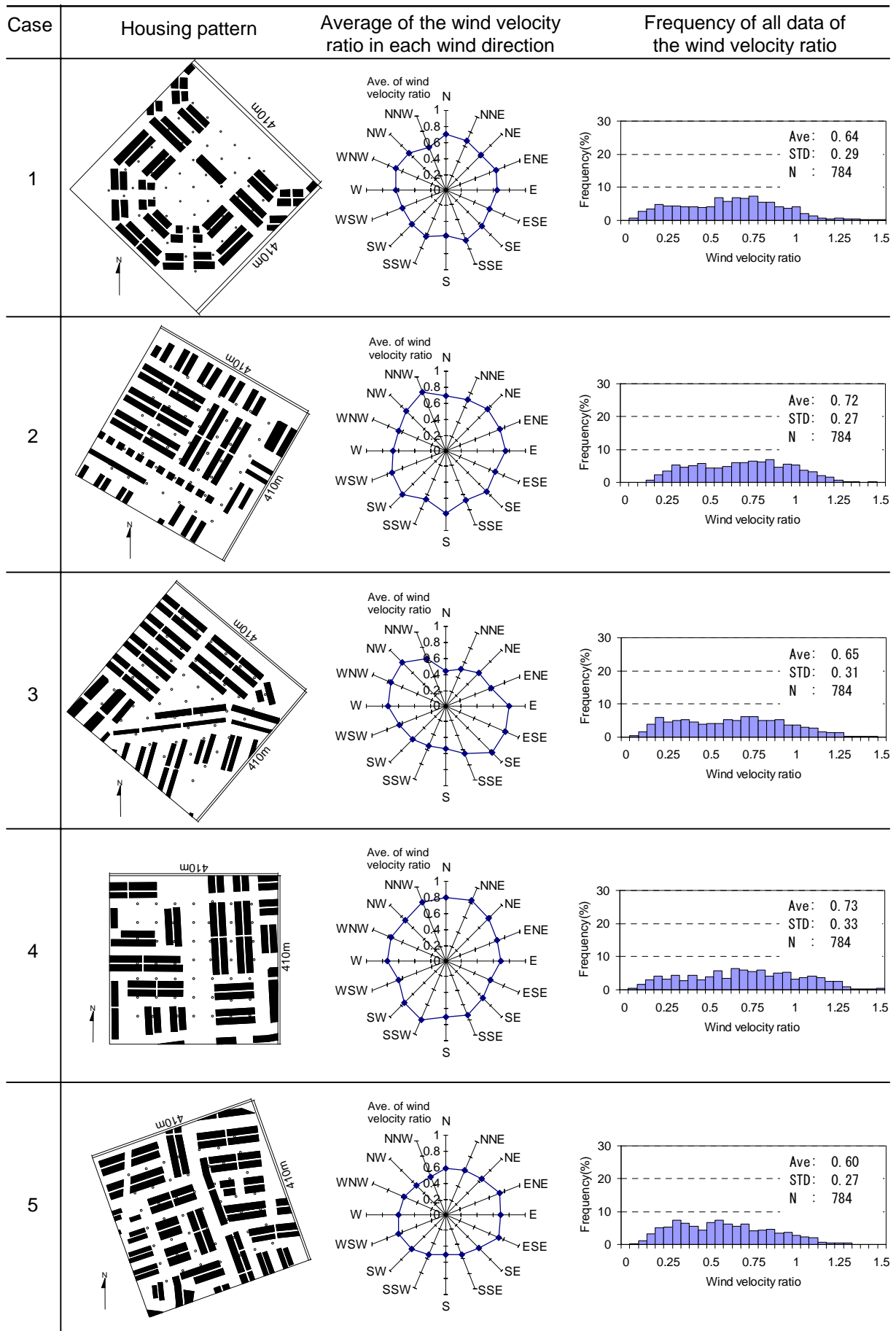


Fig.5 Measurements of All Points in 16 Wind Directions in Each Case



middle of the area. Thus, the average wind velocity in this wind direction N is the lowest as in Fig.5.

When the wind direction become NE, the weak wind velocity zones around the two long rows disappear, however, in right part of the area, the angle of terraced houses becomes 90 degrees to the wind direction and wind velocities in there are becoming low. From the wind direction ENE to ESE, the angle of the two long rows agrees with the wind direction, and the wind flow blows higher between them as a result of the Channel effect and the Venturi effect.

The average of all data of wind velocity ratio in Case3 is 0.65, is almost same as Case1 (Fig.5). In this Case3, it is found that the two of long rows of terraced houses have much influence on the whole wind environment. This is mainly caused by the length of the rows of terraced houses, and the arrangement of them. These influences are seen in the distribution of the average of wind velocity ratio in each wind direction in Fig.5.

#### **(4) Case4**

In this Case4, a wide road is located in middle of the area. When the wind direction is N, wind flows become higher in there and wind velocity ratios in many points reach over 1. Even when the wind direction reaches to NE, the wind velocities in the wide road are still high. This is mainly caused by the wide width of the road. The average of all data of wind velocity ratio is 0.73; this is the highest among the cases.

#### **(5) Case5**

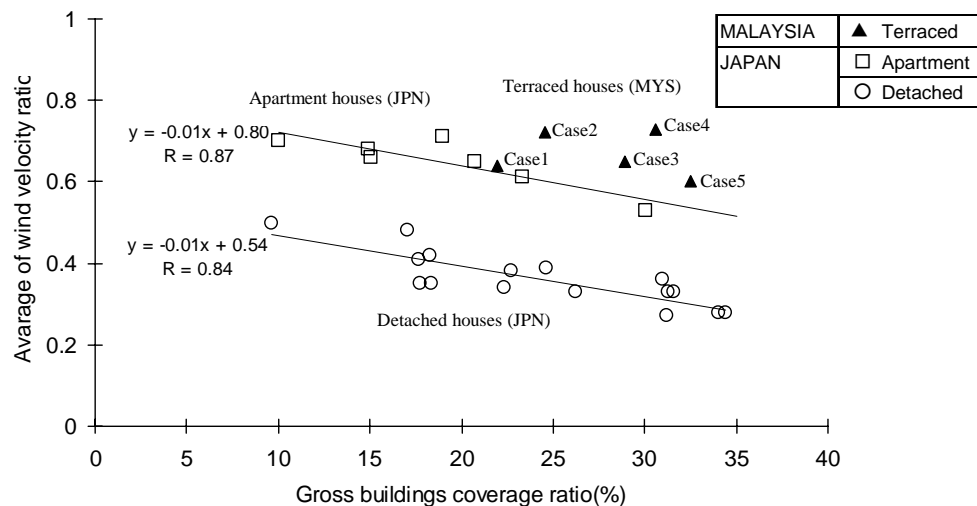
The gross buildings coverage ratio of this Case5 is 2% higher than Case4, and the highest of all cases. In this Case5, there is neither large open spaces like Case1 nor wide roads like Case4. The average of wind velocity ratio is the highest when the wind direction becomes ENE. In this wind direction, since most of rows of terraced houses agree with the wind direction, the wind flow blows well in many points.

Since most of rows of terraced houses lie directed from west to east, the average of wind velocity ratio is slightly different among the wind direction (Fig.5). The average of all data of wind velocity ratio in this Case5 is 0.60; this is the lowest of all cases.

### **6. Discussions**

The relationship between the gross buildings coverage ratio and the average of all data of wind velocity ratio is shown in Fig.6. In this figure, the results of the Japanese cases (Kubota and Miura et al. 2000,2002) are also indicated as white marks.

At the beginning of the study, the authors predicted that since the plans of housing patterns of Malaysian terraced houses a little resembled that of the Japanese apartment houses, the average of wind velocity ratio also must be similar to that of the area of Japanese apartment houses. However, as in Fig.6, the averages of the wind velocity ratio of this Malaysian cases are slightly higher than the trend line of Japanese apartment cases as a whole. It is considered that since the housing patterns of these Malaysian cases were more straight and much longer than that of Japan, the factors of increases, such as the Channel effect or the Venturi effect, occurred more frequently in the Malaysian cases, and as a result, the average wind velocity became higher. However, whether or not this explanation is true would not be known until further study is carried out.



**Fig.6 Relationship between Gross Buildings Coverage Ratio and the Average of Wind Velocity Ratio of the Cases**

Source: Japanese cases quoted from Kubota and Miura et al.(2000)(2002)

## 7. Conclusion

This paper presented the results of several wind tunnel tests on selected residential areas in Johor Bahru Metropolitan City. The main purpose of the wind tunnel tests was to examine the methods to create sufficient wind flow and help achieve energy saving and sustainability objectives at the neighborhood level. The summary of the results is as follows.

Five cases for the tests mostly consisted of long rows of terraced houses. In those cases, wind velocities tended to be high at several points between the terraced houses by effects of the "Channel effect" and "Venturi effect". However, when rows of terraced houses were placed at an angle of around 90 degrees to the wind direction, wind velocities between them were low. Almost of the cases, major part of the terraced houses was placed at an angle of 90 degrees to the others. Thus, it was considered that even if some rows agree with the wind direction and wind velocities in there increase, another rows would be directed at an angle of 90 degrees to it and wind velocities in there would decrease at the same time. Therefore, it was thought that this kind of housing arrangement is considered not so suitable from a viewpoint of the average wind flow.

In one of the cases, some parts of the area consisted of semi-detached houses. In this case, it was shown that the wind flow blew through the row of semi-detached houses from one side to another side. It was stated that if the row of semi-detached houses were a long row of terraced houses, the wind flow would not be able to reach the upper part. Therefore, in order to avoid the increase of weak wind velocity zones, semi-detached houses would be effective as alternative housing pattern.

The relationship between the gross buildings coverage ratio and the average of all data of wind velocity ratio was shown. Also, results of the previous Japanese cases were compared with them. The averages of wind velocity ratio of the Malaysian cases were slightly higher than the trend line of the Japanese apartment cases as a whole. It was considered that since housing patterns of these Malaysian cases were more straight and much longer than that of the area of Japanese apartment houses, the factors of increases, such as the Channel effect or the Venturi effect, occurred more frequently in Malaysian cases, and as a result, the

average wind velocity became higher. However, whether or not this explanation is true would not be known until further study is carried out.

Some findings of the wind tunnel tests are summarized above and it is evident that further research is required. In particular, it is necessary to clarify both the usage of energy and the resident's consciousness to energy saving in residential areas through social surveys. This kind of survey would be useful not only for collecting the required data but also for enhancing the resident's awareness toward energy saving. It is very important to help change the resident's mind-set in order to achieve energy saving objectives especially in the country that has just started to consider it.

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