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On The Wind Flow Around A Tall Building

By

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Abstract

Local strong wind in the vicinity of the tall building is a serious problem for pedestrians and other structures around it, and the characteristics of the wind flow must be investigated. Observations of the wind flow at the base of full scale tall buildings will be significant for knowing the characteristics of the flow. We performed some measurements of the wind speeds on the plaza of an existing tall building, Kobe Shoko Boeki Center Building. Wind flow around this building was understood considerably through the wind observations. This paper describes the results of the observations.

1. Introduction

A tall building often brings the strong local wind problems to pedestrians and other structures around it. The characteristics of such strong winds are wished to be known before the construction of the building. A wind tunnel test is an available and convenient method for estimating the wind flow and many wind tunnel tests were performed in order to study such problems in various cases.

However, it is difficult to make the wind in wind tunnels to represent all of the characteristics of the natural wind flow, and the similarity law between the results of wind tunnel tests and full scale measurements has been solved insufficiently. On the other hand some researchers have tried to understand such problems by measuring the wind flow around full scale tall buildings. We performed the wind flow observations around an existing tall building, "Kobe Shoko Boeki Center Building". This paper describes the results of those observations.

2. Description of the measurements

The Kobe Shoko Boeki Center Building is situated in the central part of Kobe City. This building is 107 meters high with a square section of 37 meters×37 meters. The site plan around this building is shown in Fig. 1. Another building, Sanbo Hall, is standing close to this tall building, and it was concerned before that strong winds blew often along the strip area between two building.

Observations were performed on June 17th of 1974 and on January 17th of 1975. The wind speeds were measured at various points on the plaza of this building, and six 3 cup anemometers and five Gill anemometers were used. All of the anemometers

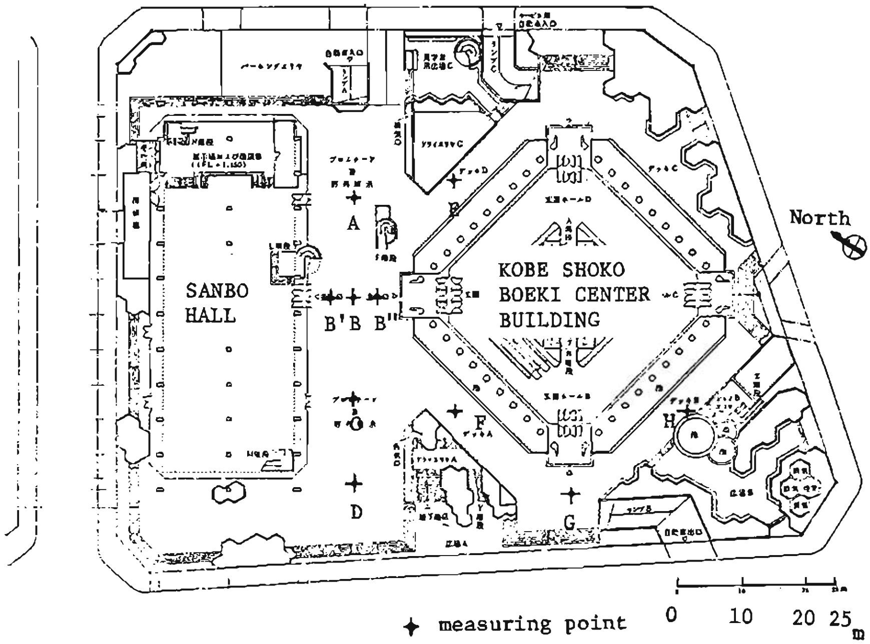

Fig. 1 Site plan around the Kobe Shoko Boeki Center Building.

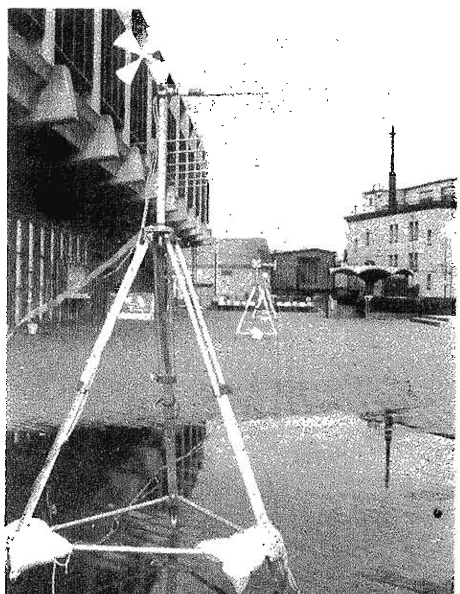

Photo 1 Anemometers set on a tripod.

Table 1

Measuring Points	Anemometers	
	1974. 6. 17	1975. 1. 17
A	3-cup	3-cup
B	Gill (3-dimen.)	Gill
B′	3-cup	
B″	3-cup	
C	3-cup	Gill (2-dimen.)
D	Gill (2-dimen.)	Gill (2-dimen.)
E	3-cup	3-cup
F	3-cup	3-cup
G		3-cup
H		3-cup

Table 2

The First Observation

Time	Wind Speed	Wind Direction
15h55m	6.3 m/s	ESE
16hoom	5.9	E
05m	5.8	E
10m	5.8	E
15m	6.0	ENE
20m	6.0	E
25m	6.5	ENE
30m	6.8	E
35m	8.0	ESE
40m	9.7	E
45m	11.6	E
50m	11.7	E
55m	11.3	E

(The above values are averaged during 1 minute.)

The Second Observation

Time	Wind Speed	Wind Direction
16h20m	7.0 m/s	SW
25m	7.0	SW
30m	6.5	SW
35m	6.2	W
40m	6.0	W
45m	8.5	W
50m	11.0	W
55m	10.4	W
17h00m	9.8	W
05m	8.9	W
10m	9.2	W
15m	8.3	W

(The above values are averaged during 5 minutes.)

were set on the eight tripods with 2 meters height. (Photo 1) Arrangements of the anemometers were different in both observations, and the measuring points and the arrangements of anemometers are shown in Fig. 1 and Table 1. Output voltages from all of the anemometers were recorded on magnetic tapes of a 14 channels data recorder. A propeller type anemometer was installed on a pole 10 meters above the penthouse. The wind speed and wind direction through this anemometer were recorded on paper charts. Some examples of the traces of wind speed and wind direction during the both observing periods are shown in Fig. 2, and the mean wind speeds and main wind directions in the analysed periods are shown in Table 2. The dominant wind direction was easterly on June 17th and was westerly on January 17th, and the mean wind speeds were ranged 5 to 12 m/s. Analog data on magnetic tapes were converted to digital data on paper tapes, and were processed by an electronic computer (NOVA Model-1).

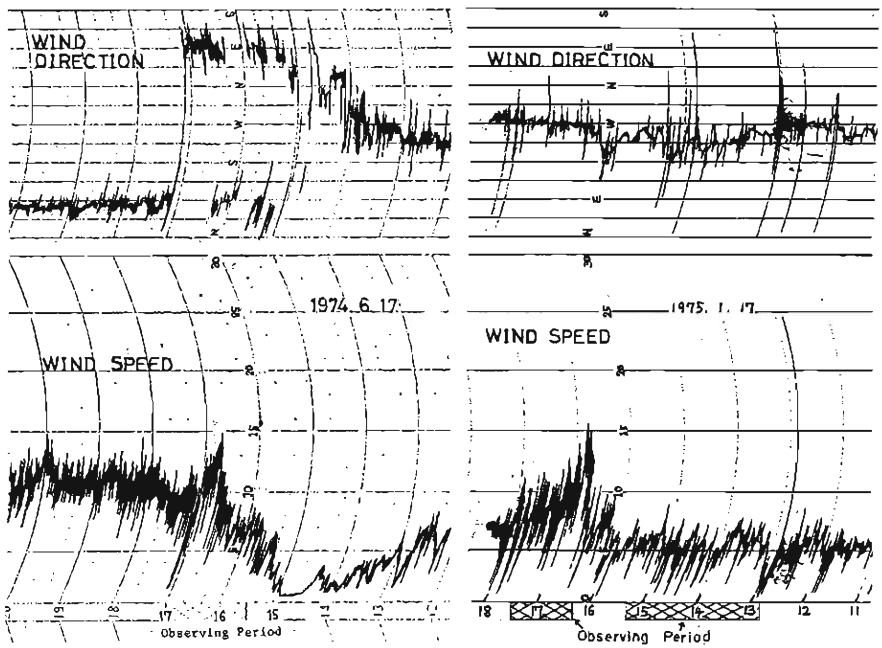

Fig. 2 Traces of the wind speeds and the wind directions in the observing periods.

3. Results and Discussions

(1). The First Observation

The first observation was performed on June 17th of 1974 as stated before, and the main object of the observation was to measure the wind flow in the strip area between the Kobe Shoko Boeki Center Building and Sanbo Hall. The measuring points were A, B, B′, B″, C, D, E and F shown in the Fig. 1. Three of Gill anemometers were set on the point B, and detected the three components of the wind speed; the horizontal direction along the line of ABCD, the another horizontal component across the line of ABCD in right angle and the vertical component. Othe Gill anemometers were set on the point D to measure two horizontal components of the wind speed. Six 3 cup anemometers were set on other measuring points A, B′, B′′, C, E and F.

The mean wind speeds were estimated from one hour analog data, and those mean values are averaged over 1 minute period at the intervals of five minutes. To

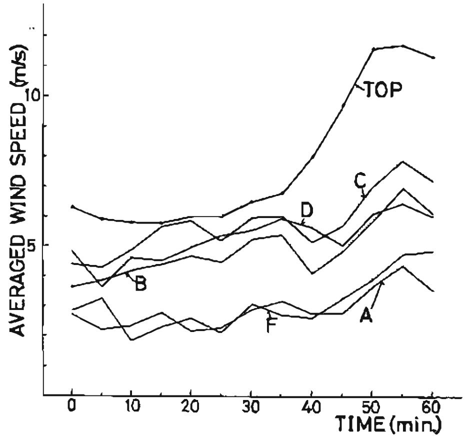

Fig. 3 Variations of mean wind speeds. (1st Observation)

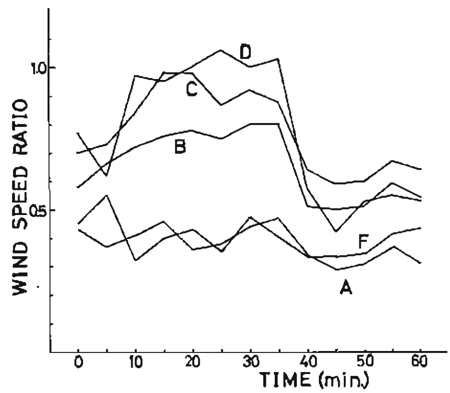

Fig. 4 Ratios of wind speeds to the reference wind speed.

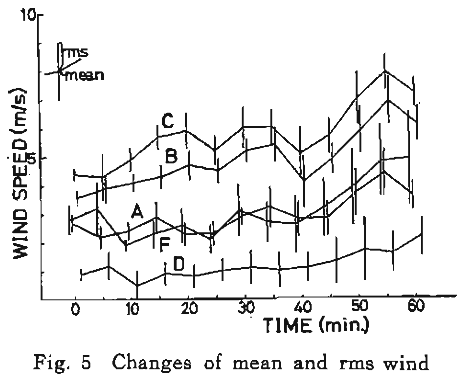

Fig. 5 Changes of mean and rms wind speeds.

compute mean and rms values, the analog data were sampled at the intervals of 0.1 second. Fig. 3 shows parts of the calculated results of the variations of mean wind speeds. The wind speed at the top of the building is illustrated to be refered to other wind speed values in the figure. The wind speeds at the points A and F are remarkably smaller than those at the points B, C and D. The main wind direction at the top of the building was almost easterly, and the wind blew through between two buildings from the point A to the point D. The wind speeds of the points B, C and D are larger than that of the point A, or the wind speed is fastened at the location where the distance between two buildings is smallest and the increased wind speed decrease gently. The ratio of the wind speed of the point A to those of the points B, C and D were calculated, and the mean ratios are 1.7, 2.0 and 1.9 at the points of B, C and D. The differences between the wind speeds of the point B and those of points B′ and B″ are not remarkable and the wind speeds at the points B′ and B″ are slightly larger than the value at the point B.

With the increase of the wind speed at the top of the building, the wind speeds on the measuring points at the base of the building increase. Wind speed values at the points A and F seems to be increased in proportion to the wind speed at the top of the building. However, the wind speed ratios of the wind speeds of other points B, C and D to the wind speed at the top is varied. The wind speed at the top may not be reduced largely by the building, and it is reasonable that the wind speed is regarded to be a reference wind speed. Fig. 4 shows the ratios of wind speeds at various points to the reference wind speed. The ratios of wind speeds at the points A and F to the reference wind speed are not seriously changed. However, wind speeds at the points B, C and D is not proportional to the reference wind speed. In other words, when the standard wind speed exceeds 7 m/s, the wind speeds at the points B, C and D do not increase in proportion to the standard wind speed. In this case, the wind speed ratios are 0.5 to 0.65 at the points B, C and D, and 0.3 to 0.4 at the points A and F.

Rms values of wind speeds were also calculated and shown in Fig. 5. Rms values are less than 1.0 m/s at the points of A, B, C and D but often exceeds 1.0 m/s at the point F. Mean wind speeds of the points A and F are nearly equal to each other but the rms values are different. Intensities of turbulence are 0.1 to 0.4 at the point F, and about 0.1 at the point C. The point F is close to the leeward surface of the building, and the intensity of turbulence there shows that the flow behind the building is more turbulent.

Gust factors are important for considering such kinds of wind problems because gusty winds produce troubles for pedestrians and car drivers. Gust factors were estimated from the wind speed records by the Gill anemometers at the points B and D which show the horizontal components along the line of ABCD. The gust factor is defined to be the ratio of the gust speed to the 10 minute averaging wind speed, and it is varied by changing the averaged period of gust speed. Estimated gust factors are 1.1 to 1.2 for the 60 seconds averaged period and 1.5 for the 1 to 3 seconds period.

(2) The Second Observation

The second observation was performed on January 17, 1975. In this observation, 3 cup anemometers were set at the points of A, E, F, G and H in Fig. 1. Gill anemometers were installed at the points B, C and D, and the two anemometers were set in order to measure the two horizontal components at the points C and D. The dominant wind direction at the top of the building was almost westerly, and the wind blew from point D to point A. The point F was near the windward surface of the building, and the points E and H were near the sideward surfaces.

A 1 hour record was analysed and the mean wind speed variations are estimated.

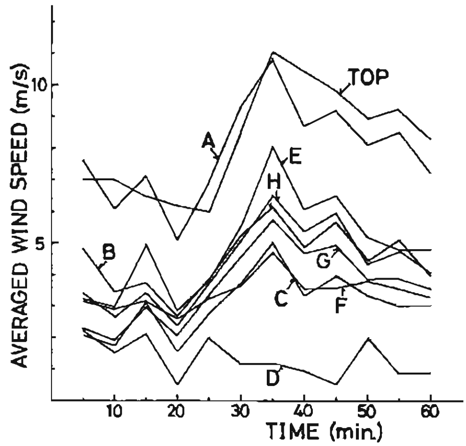

Fig. 6 Variations of mean wind speeds. (2nd Observation)

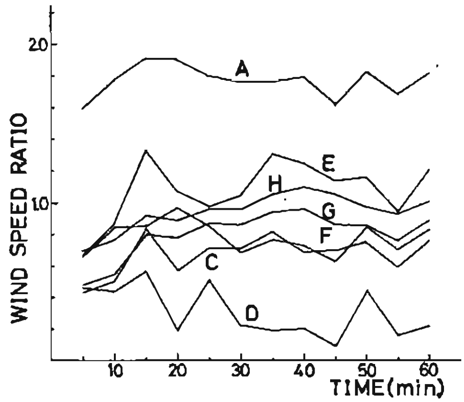

Fig. 7 Ratios of wind speeds to the wind speed on point B.

The mean wind speeds were averaged over 5 minutes period in this observation and those values are shown in Fig. 6. In this figure, the wind speed of the point A is highest and that of the point D is lowest. It is obvious that the wind speed were accerelated at the area between two buildings. The ratios of wind speeds on the measuring points to the wind speed on the point B are shown in Fig. 7. The ratio for the point A is ranged between 1. 6 and 1. 9. The mean ratios for the points A, C and D are 1. 78, 0. 67 and 0. 31. In the first observation, the mean ratios for points A, C and D are 0. 64, 1. 18 and 1. 16. The distance between points A and B is equal to that between the points B and C, and the ratio (A/B=0. 64) on June 17th is nearly equal to the ratio (C/B=0. 67). As the wind directions are opposite to each other in both observations, it is reasonable that the ratios are equal. However, the ratio (C/B) in the first observation is different from the ratio (A/B) in the second observation. In the second observation, the wind strikes against the west surface of the building, and blows down in the area of the points B, A, E and H and the most

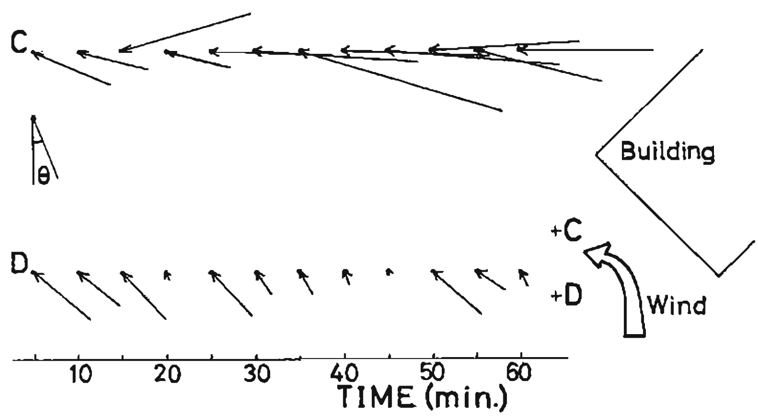

Fig. 8 Wind direction changes on points C and D.

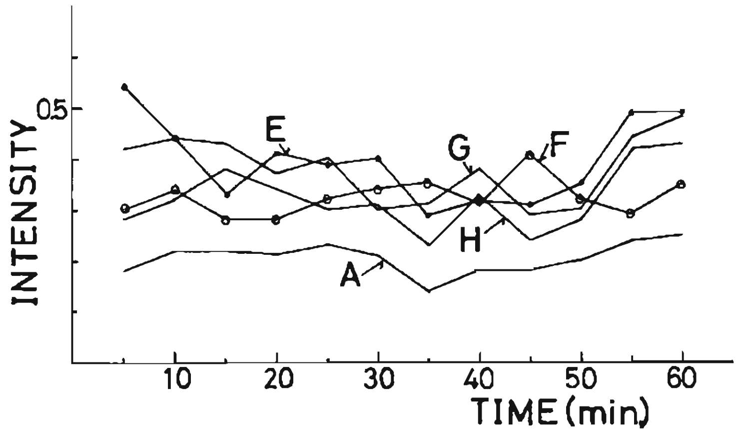

Fig. 9 Changes of intensity values.

strong wind blows at the point A. In the second observation, the point D is situated in front of the building for wind, and the wind speed is not large. The mean wind direction estimated roughly from two horizontal components at the points C and D is shown in Fig. 8. When θ is defined as an angle as shown in Fig. 8, θ at the point D is varied 9 to 56 degrees and θ at the point C is varied from 73 to 96 degrees. The wind direction at the point C intersects the line of ABCD at nearly right angle. The fact means that the wind flow is distorted by the building in the windward region of the building. The wind speeds of the points E and H near the sidefaces are slightly larger than those of the F and G near the windward surface.

Estimated rms values exceed 1 m/s in most of the examples, and are larger than the results in the case of June 17th. The intensities were calculated and the values are shown in Fig. 9. They are varied 0. 3 to 0. 5 at the points E, F, G and H but those values at the points A and B are varied 0. 2 to 0. 3.

The spectra of wind speeds were also calculated, and spectral peaks were found in some cases. The meaning of their peaks is uncertain and is not described in this paper.

4. Concluding Remarks

The results of the observations showed some of the flow characteristics on the ground level of the Kobe Shoko Boeki Center Building. The wind speed at the leeward point between two buildings in the second observation is largest and nearly equal to the speed at the top of the building. The result shows that strong winds blow near the windward corners of the building, and this feature is consistent with the results of the wind tunnel tests by others. As the Sanbo Hall is close to the Kobe Shoko Boeki Center Building, the wind between two buildings is increased. The fact was proved by the observed wind speed values on the four points in the strip area between the buildings. Increased ratios to the wind speed at the windward measuring point are 1. 7, 2. 0 and 1. 9 at each point along the wind direction in the first observation, and are 1. 5 and 2. 7 in the second observation. In the first observation, the measuring points were situated behind the leeward surface of the building, and the contracted effect only seems to be ramarkable. The wind attacks the windward surface of the building, and the wind is increased near a windward corner. This effect is considered to be superimosed to the cotracted effect, and increased ratios in the second observation are larger than those of the first observation. This fact is also prooved by the estimation of the wind directions at the windward measuring points in the second observation. Considering the wind speed at the top of the building as a reference wind speed, the ratios of the wind speeds at various points for the reference wind speed are estimated. The wind speed distribution around this tall building is understood by the results of the wind speed ratios in the latter half of the first observation and the second observation. The wind speed on the point where the distance between two buildings is shortest, is about 0. 55 times of the wind speed at the top of the building in both observations. The value at the point near the windward surface in the second observation is 0. 43, and the values at the points near the sideward surfaces in the second observation are 0. 59 and 0. 52.

Intensity values are varied from 0. 1 to 0. 5 at various measuring points. Gust factor is recommended to be 1. 5 for considering such problems.

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