WIND EFFECTS ON PEDESTRIANS

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ABSTRACT

Unpleasant strong winds in pedestrian areas are frequently encountered in built up cities like Hong Kong. Depending on the characteristics of the wind including mean magnitude, uniformity, ambient temperature, etc., the level of disturbance to users of pedestrian areas can be different. To evaluate whether the disturbance induced by wind is unacceptable or, more severe, dangerous to the users of pedestrian areas, various criteria had been suggested by different researchers while no unique criteria were agreed universally. This note describes the typical wind comfort criteria in respect to gust wind speed, the typical locations of pedestrian areas with frequent occurrences of strong wind and the general wind speed reduction measures. The pedestrian wind comfort study at the Hong Kong TVB City was used as a case study.

KEYWORDS

pedestrian level wind, wind induced discomfort, wind comfort criteria, wind speed reduction measures

INTRODUCTION

In highly built up cities such as Tokyo, Hong Kong, Toronto, Paris, unpleasant strong wind can be frequently encountered in many pedestrian areas. The extent of discomfort to pedestrian varies from inducing slightly unpleasant feeling to producing a falling down hazard. Two of strong wind events in pedestrian areas encountered in Hong Kong recently were those occurred in the Sea Crest Villa in Sham Tseng (Figure 1) and the Movie City in Tseung Kwan O (Figure 2).

強風下浪翠園途人跌倒受傷

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受到強烈季候風影響，本港多處刮強風，位於深井青山公路青龍頭後的浪翠園，有三人在強風下跌倒受傷。

天文台指，本港吹偏北強風，平均風速每小時超過四十公里。陣風間中達烈風程度。在強風下，浪翠園有三名居民抵受不住跌倒，被送往仁濟醫院治理。

Figure 1: Strong Wind Event at Sea Crest Villa (Extracted from Ming Po)

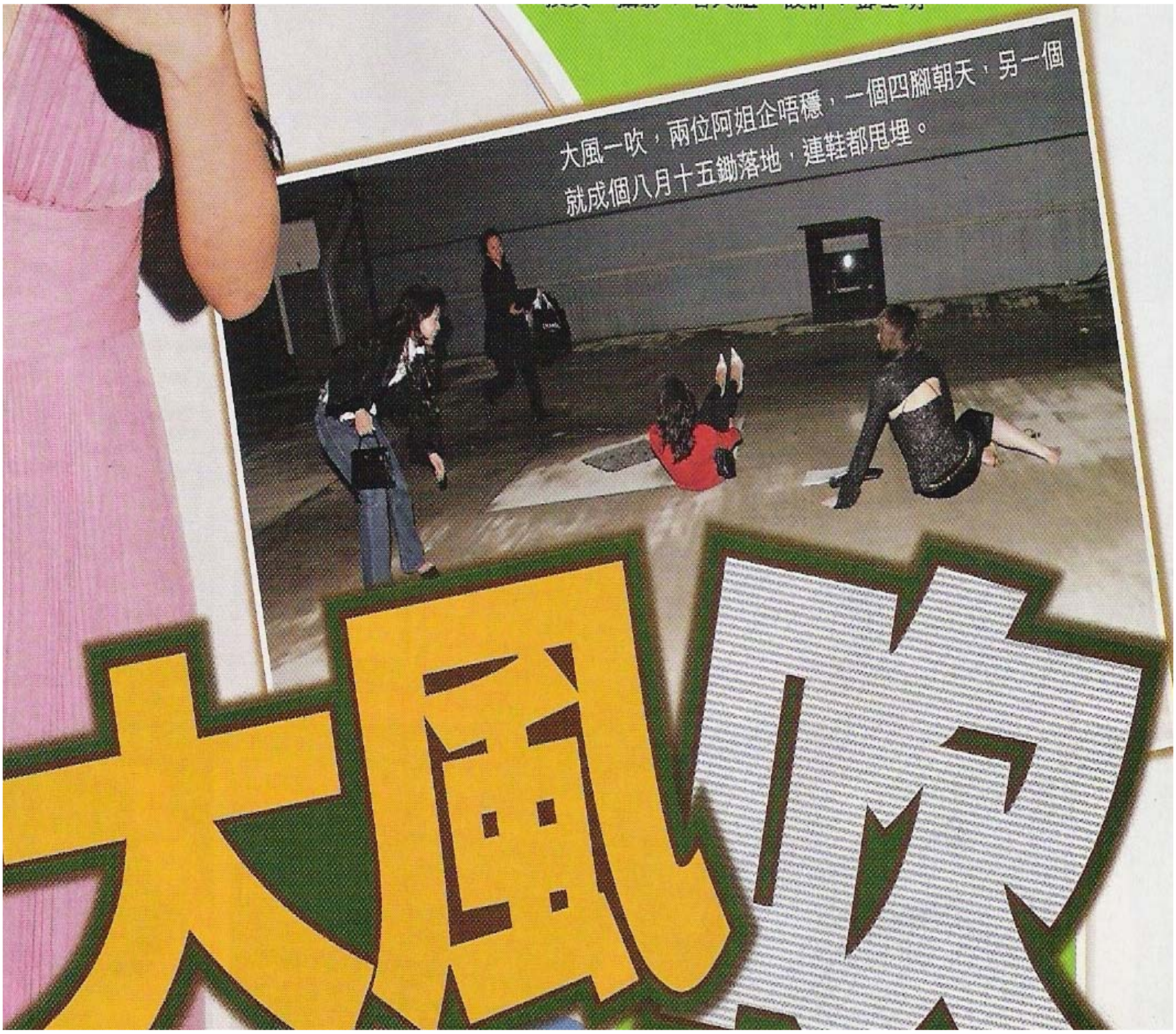

Figure 2: Strong Wind Event at Hong Kong Movie City (Extracted from Next Magazine)

Generally speaking, the cause of frequent occurrences of strong wind at pedestrian area is primary related to the configuration of building structures and/or topography in the vicinity of the pedestrian area. Depending on the characteristics of the wind including magnitude, uniformity, ambient temperature, etc., the level of disturbance to users of pedestrian areas can be different. This literature note is to describe the typical wind comfort criteria, the typical locations of pedestrian areas with frequent occurrences of strong wind and the general wind speed reduction measures. The pedestrian wind comfort study at the Hong Kong TVB City is used as a case study.

WIND COMFORT CRITERIA

Wind Characteristics and Human Discomfort

There are several wind characteristics related to human discomfort including speed, uniformity or turbulence level, ambient temperature, etc. Amongst them, the primary wind characteristics that can induce discomfort, inconvenience and even dangerous occurrences to users of pedestrian areas are primary the mean wind speed and the uniformity or turbulence level. The effect of these two characteristics on people can be studied in term of a gust wind speed V defined as follows:

$$V = \overline{V} + k\sqrt{V'^2} \quad (1)$$

where $\overline{V}$ is the mean speed, $\sqrt{V'^2}$ is the root mean square speed used to determine the turbulence level of the wind and k is a constant reflecting to the significance of fluctuation part in the gust wind speed. Typically, the mean speed means hourly (or sometimes 10-minute) averaged speed and the gust speed means the 3 second averaged speed. In addition, according to the studies conducted by E.C. Poulton, et. al. (1975) and J.C.R. Hunt, et. al. (1976), the appropriate value of k is about 3.0.

Based on the study conducted by A.D. Penwarden (1973), the effects of different gust wind speeds are tabulated in Table 1. It needs to point out that the wind effect on people will be more severe under a wind with a larger fluctuation part than under a wind with a smaller fluctuation part, even though their gust speeds are identical. Besides, the wind effect on people will be more severe if the wind flow is highly non-uniform in space.

TABLE 1

EFFECTS OF DIFFERENT GUST WIND SPEEDS

Beaufort Number	Description of Wind	Speed (m/s)	Description of Wind Effects
0	Calm	Less than 0.4	No noticeable wind
1	Light airs	0.4-1.5	No noticeable wind
2	Light breeze	1.6-3.3	Wind felt on face
3	Gentle breeze	3.4-5.4	Wind extends light flag, Hair is disturbed, Clothing flaps
4	Moderate breeze	5.5-7.9	Wind raises dust, dry soil, and loose paper, Hair disarranged
5	Fresh breeze	8.0-10.7	Force of wind felt on body, Drifting snow becomes airborne, Limit of agreeable wind on land
6	Strong breeze	10.8-13.8	Umbrellas used with difficulty, Hair blown straight, Difficulty to walk steadily, Wind noise on ears unpleasant, Windborne snow above head height (blizzard)
7	Moderate gale	13.9-17.1	Inconvenience felt when walking
8	Fresh gale	17.2-20.7	Generally impedes progress, Great difficulty with balance in gusts
9	Strong gale	20.8-24.4	People blown over by gusts

Human Comfort Criteria

A number of research studies were undertaken to suggest different human comfort criteria [e.g. W.H. Melbourne, et. al. (1971), A.D. Penwarden (1973) , L. W. Apperley, et. al. (1974), A.D. Penwarden et. al. (1975), N. Isyumov (1975) and J.C.R. Hunt, et. al. (1976)]. Even though no unique criteria are agreed universally to evaluate the comfort level of pedestrian level wind, the following findings for the effects of different gust wind speeds on people are generally agreed in the above studies.

$V \le 5m/s$	No human discomfort induced
$5m/s < V \le 10\ m/s$	Human unpleasant feeling induced and performance affected
$V > 10m/s$	Strong human unpleasant induced and performance seriously affected

Apart from gust speed, the frequency of occurrences of strong wind is also widely adopted as a parameter to evaluate whether the wind environment at a pedestrian area is desirable for people since almost every open area will be unavoidable to encounter strong wind when signals of strong seasonal wind or typhoon are hoisted. The comfort criteria with consideration of both gust wind speed and frequency of occurrences proposed by L. W. Apperley, et. al. (1974) is presented in Table 2 as example. In addition to the criteria, A.D. Penwarden et. al. (1975) suggested a much simple criterion that it was desirable for pedestrian areas to encounter strong wind of gust speed greater than 5m/s with frequency of occurrences not exceed 10% of the time.

TABLE 2

HUMAN COMFORT CRITERIA FOR DIFFERENT PEDESTRIAN AREAS

Criterion	Area Description	Limiting Wind Speed	Frequency of Occurrences
1	Plazas and Parks	Occasional gusts to about 6 m/s	10%of the time or about 1000h/yr
2	Walkways and other areas subject to pedestrian access	Occasional gusts to about 12 m/s	1 or 2 times per month or about 50 h/yr
3	All of above	Occasional gusts to about 20 m/s	About 5 h/yr
4	All of above	Occasional gusts to about 25 m/s	Less than 1 h/yr

Note: Under gust speed of 25 m/s, persons are easily knocked down.

Since universally agreed human comfort criteria are not yet developed, in practice, the criteria adopted for a site will generally depend on the activities carried out in the site and the decision of the site owners.

TYPICAL LOCATIONS OF STRONG WIND IN BUILT UP AREAS

Based on Emil Simiu, et. al. (1996), strong wind occurrences at pedestrian areas often occur at the three regions shown in Figure 3 and are associated with the three types of flow accordingly as follows:

Type I Vortex flow near the ground level space between buildings (i.e at region A),

Type II Descending air flows passing around windward buildings corners (i.e. at region B), and

Type III Air flows passing through the covered corridors at the ground level connecting the windward side to the leeward side of buildings (i.e. at region C)

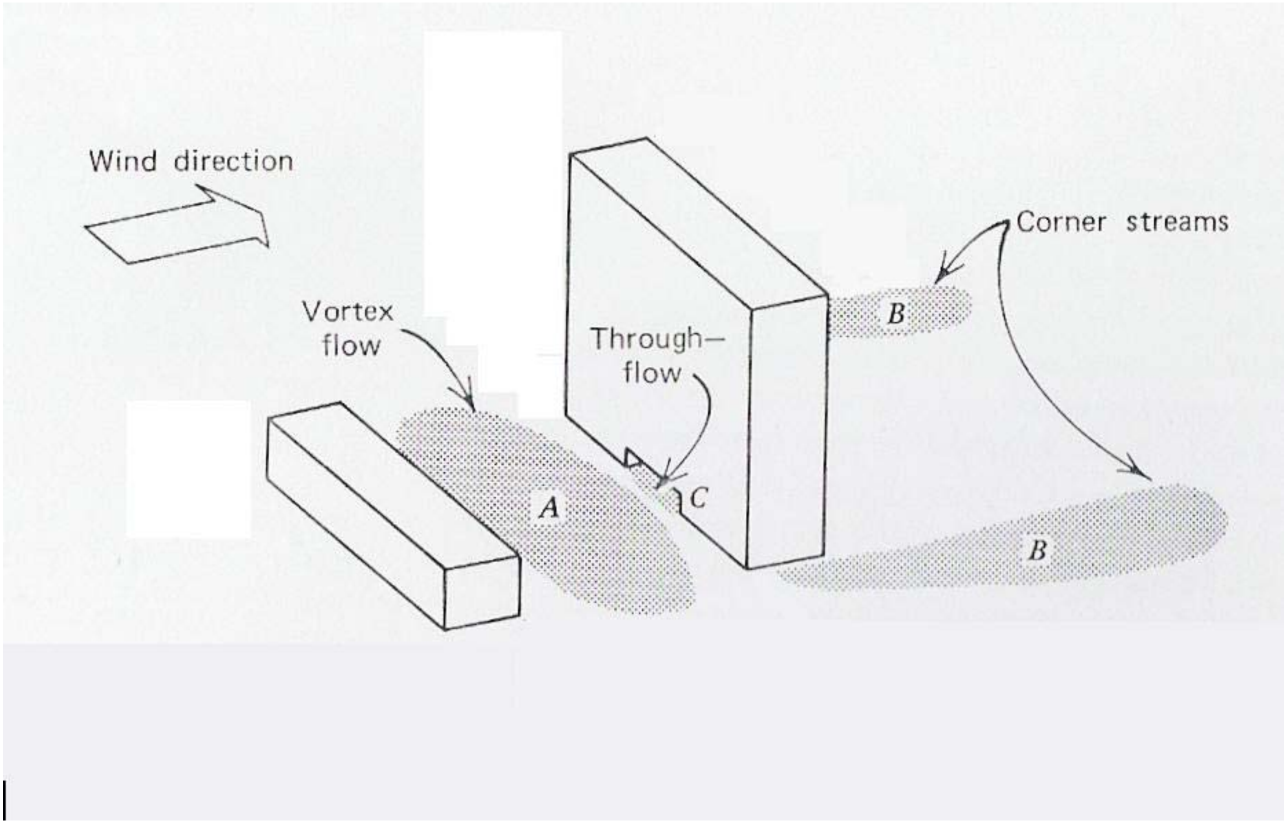

Figure 3: Typical Regions of Strong Surface Wind in Built up Area

Visualization of flow in the three regions in wind tunnel by injecting smoke in the upstream air flows are illustrated in Figure 4 and Figure 5. As shown in these figures, part of the strong wind at higher level defected downward by the tall building either forms a vortex sweeping the ground at region A (Type I flow) or sucks into the opening at ground forming a high speed through-flow sweeping the corridor at region C (Type III flow). Another part of the strong wind is accelerated around the tall building corners and forms jets sweeping the ground at region B (Type II flow).

All of the above three types of air flow can bring the strong wind at higher elevation towards the ground level and thus, intensify the wind speed at the pedestrian areas and induce unpleasant feeling to the users of the areas. In particular, the speed of the through-flow in the corridor is accelerated by suction effect and can be higher than that at the higher elevation and cause serious discomfort to the users. These three types flow are also encountered in the case study described later.

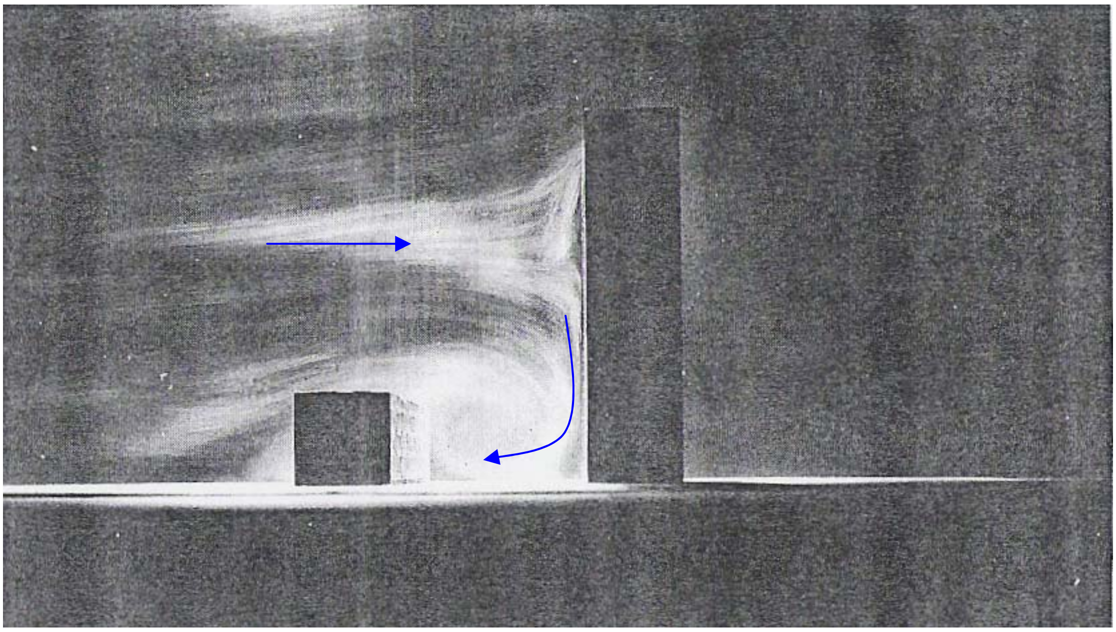

Figure 4: Air Flow at Region A

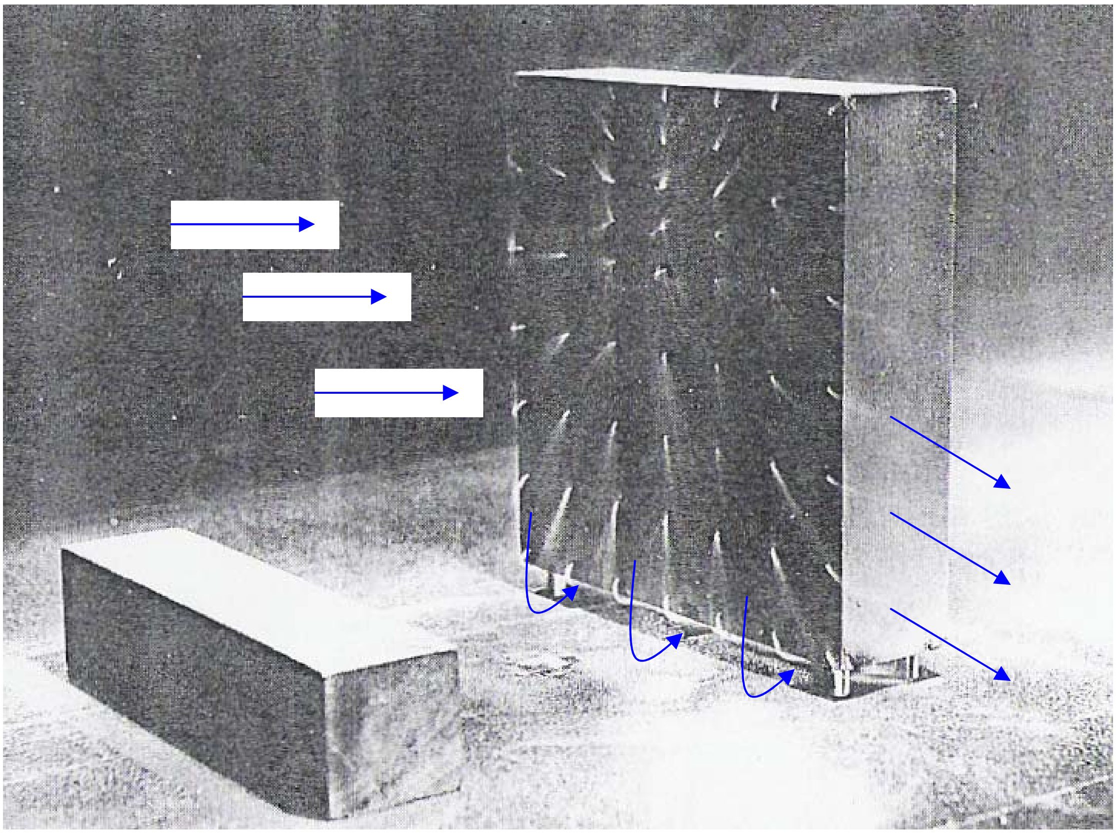

Figure 5: Air Flow at Regions B and C

TYPICAL WIND SPEED REDUCTION MEASURES

If the wind speeds at certain pedestrian areas are considered unacceptably high to the users, appropriate mitigation measures should be sought to improve the wind environment by reducing the wind speeds in those areas or otherwise protect the users from unpleasant wind effects.

If the concerned sites are still under design stage, the development layout such as heights and shapes of the buildings should be reviewed and physical model of the revised design should be tested in wind tunnel to evaluate whether the adopted wind comfort criteria can be satisfied. Otherwise, feasible wind reduction measures should be considered and tested in wind tunnel to evaluate their effectiveness.

Typical mitigation measures to reduce the wind speed at pedestrian areas including:

(i) roofs over appropriate areas (Figure 6),
(ii) solid or porous screens at suitable locations (Figure 7 and Figure 8) and
(iii) airtight transparent corridors (Figure 9).

Figure 6: Transparent Solid Roofs

Figure 7: Transparent Solid Screens

Figure 8: Porous Screens

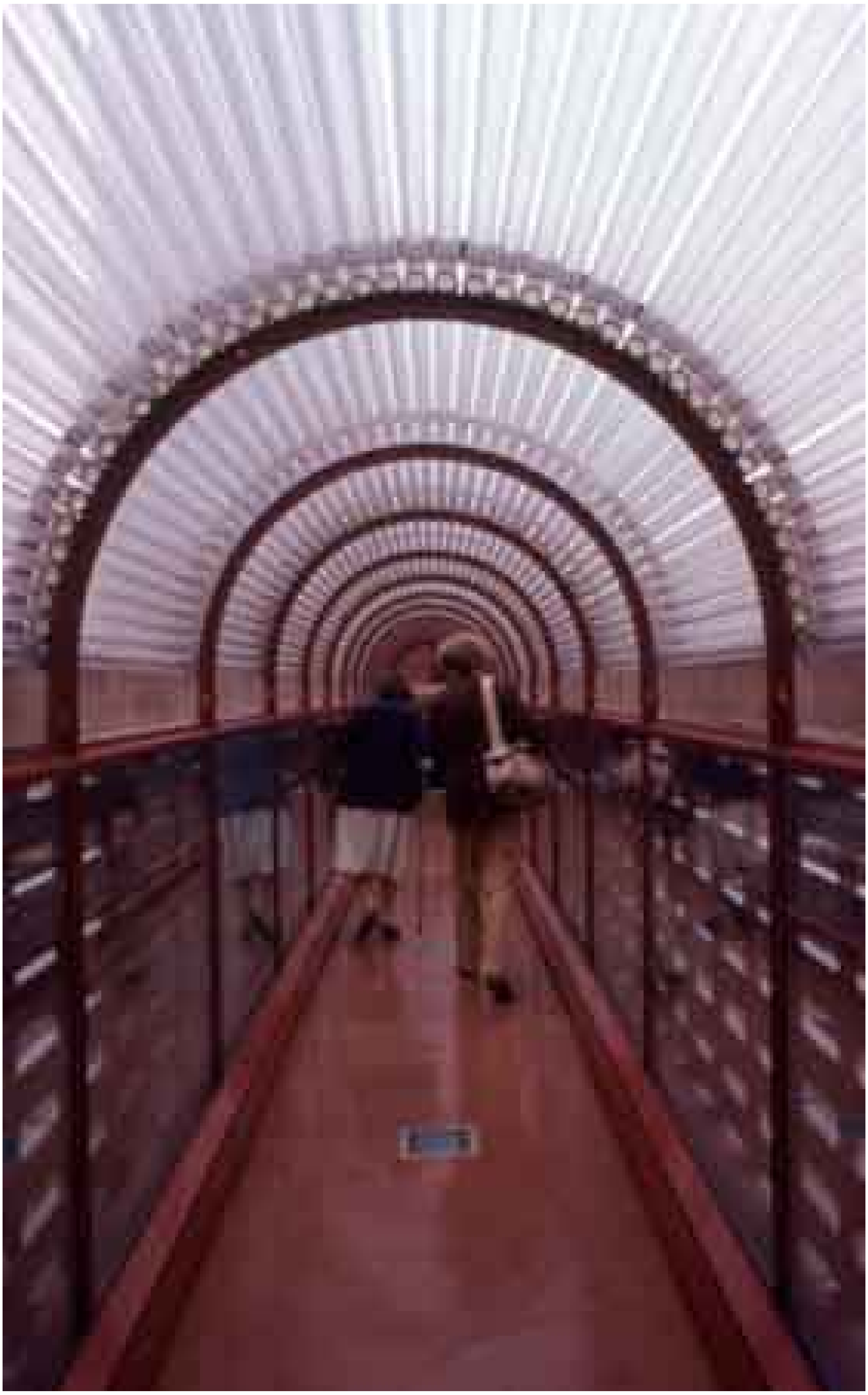
Figure 9: Air-tight Transparent Corridor

CASE STUDY – PEDETSRIAN WIND COMFORT STUDY AT HONG KONG TVB CITY

Study Objectives

The primary objectives of the case study are:

i) to identify pedestrian areas of high wind speed in the TVB City;

ii) to conduct wind tunnel test to investigate the largest wind speeds at the identified pedestrian areas under normal conditions; and

iii) to compare the assessed wind speeds with the adopted comfort criteria, and to find out cost-effective measures to improve the pedestrian level wind environment or otherwise protect pedestrians from unpleasant wind effects.

Identification of Pedestrian Areas of High Wind Speed

Based on a number of site inspections and the information provided by TVB, 11 no. of pedestrian areas in TVB City were identified as the locations of strong winds frequently encountered and of particularly concerned. The layout of TVB City and the eleven strong wind locations (i.e Point B – Point L) are illustrated in Figure 10. To assess the magnification of wind speeds in those locations relative to that in open area, the wind speeds at the car park (i.e Point A) were also assessed in the wind tunnel test and used as reference speeds.

Site visits to the above strong wind locations were conducted to inspect the existing site condition and identify possible causes of occurrences of strong wind, which were essential for considering suitable mitigation measures. Photographs of the existing site conditions of the reference point and the eleven strong wind locations were shown in Figure 11 – Figure 22.

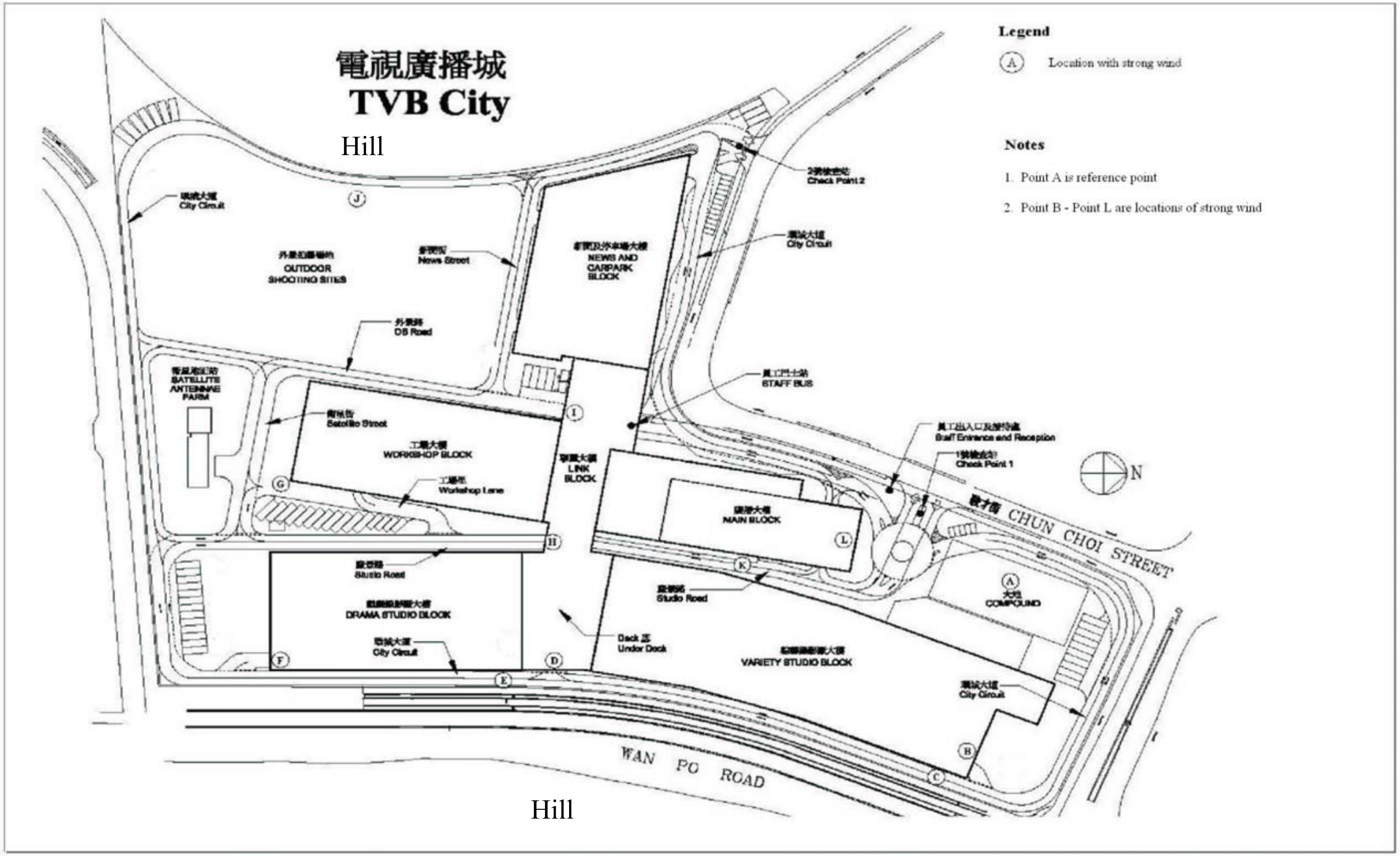

Figure 10: Layout of TVB City and Locations of Strong Winds

Figure 11: Point A

Figure 12: Point B

Figure 13: Point C

Figure 14: Point D

Figure 15: Point E

Figure 16: Point F

Figure 17: Point G

Figure 18: Point H

Figure 19: Point I

Figure 20: Point J

Figure 21: Point K

Figure 22: Point L

Possible Causes of Frequent Occurrences of Strong Wind

Based on the layout of the development and the existing site conditions as shown in Figure 10 – Figure 22, possible causes of frequent occurrences of strong wind at those locations were identified and presented in Table 3.

TABLE 3
POSSIBLE CAUSES OF FREQUENT OCCURRENCES OF STRONG WIND

Location	Possible Causes of Frequent Occurrences of Strong Wind
Point B	Covered through-flow corridor inducing Type III flow
Point C	Buildings and hill in the vicinity forming a narrow through-flow passage (Channelized Effect)
Point D	Covered through-flow corridor inducing Type III flow
Point E	Buildings and hill in the vicinity forming a narrow through-flow passage (Channelized Effect)
Point F	Covered through-flow corridor inducing Type III flow
Point G	Descending air flows passing around the corners of adjacent buildings (Type II Flow)
Point H	a) Wind at higher elevation impacted on windward building inducing Type I flow, b) Covered through-flow corridor inducing Type III flow, and c) Adjacent buildings formed a funnel shape topography significantly magnifying the approaching wind speed
Point I	Covered through-flow corridor inducing Type III flow
Point J	Wind at higher elevation impacted on windward hill inducing Type I flow
Point K	a) Wind at higher elevation impacted on windward building inducing Type I flow, b) Adjacent buildings formed a roughly funnel shape topography slightly magnifying the approaching wind speed
Point L	Covered through-flow corridor inducing Type III flow

Notes:

Type I Vortex flow near the ground level space between buildings,

Type II Descending air flows passing around windward buildings corners, and

Type III Air flows passing through the covered corridors at the ground level connecting the windward side to the leeward side of buildings

In addition, by reviewing the local topography in the vicinity of the TVB City (Figure 23), it was found that the windy environment in TVB City was also probably due to the two hills (Shek Miu Wan landfill site and Fat Tong Chau) located at respectively the east and the west sides of the development creating a channelized effect to magnify the approaching wind speed in a range of directions. Furthermore, the development was located next to sea (Tai Miu Wan) in the south and was not sheltered by other structures. Thus, strong winds from the sea could be encountered in the development.

Test Methodology

To determine the wind speeds at the concerned locations, wind tunnel tests were carried out in the boundary layer wind tunnel of the RED Consultants Limited in Hong Kong. The wind tunnel was 26m long with a test section of 17.5m long, 3.3m wide and 2.2m high. The average wind speed used was 16m/s.

The model of the TVB City with an undistorted scale of 1:300 was placed on the turn table of the wind tunnel (Figure 24). A hot wire anemometer was used to obtain accurate measurement of wind speeds at the test points.

The wind speeds at 6 feet height at each test point were measured at 24 wind azimuths in 15 degree increments. Zero degree denoted wind blowing from north direction and 90 degree denoted wind blowing from east direction.

As the development is located next to sea (Tai Mui Wan), the typical wind profile in open seas derived based on the wind data recorded on Waglan Island was used as the profile of the approaching wind in this wind tunnel test. Details about the wind profile used could be found in the Code of Practice on Wind Effects in Hong Kong 2004.

Assessment Criteria

In this case study, the wind speeds at pedestrian level were regarded as desirable if the 3s gust wind speed was greater than 5 m/s with a frequency of occurrences less than 10% of the time, which was equivalent to the wind comfort criterion proposed by A.D. Penwarden et. al. (1975).

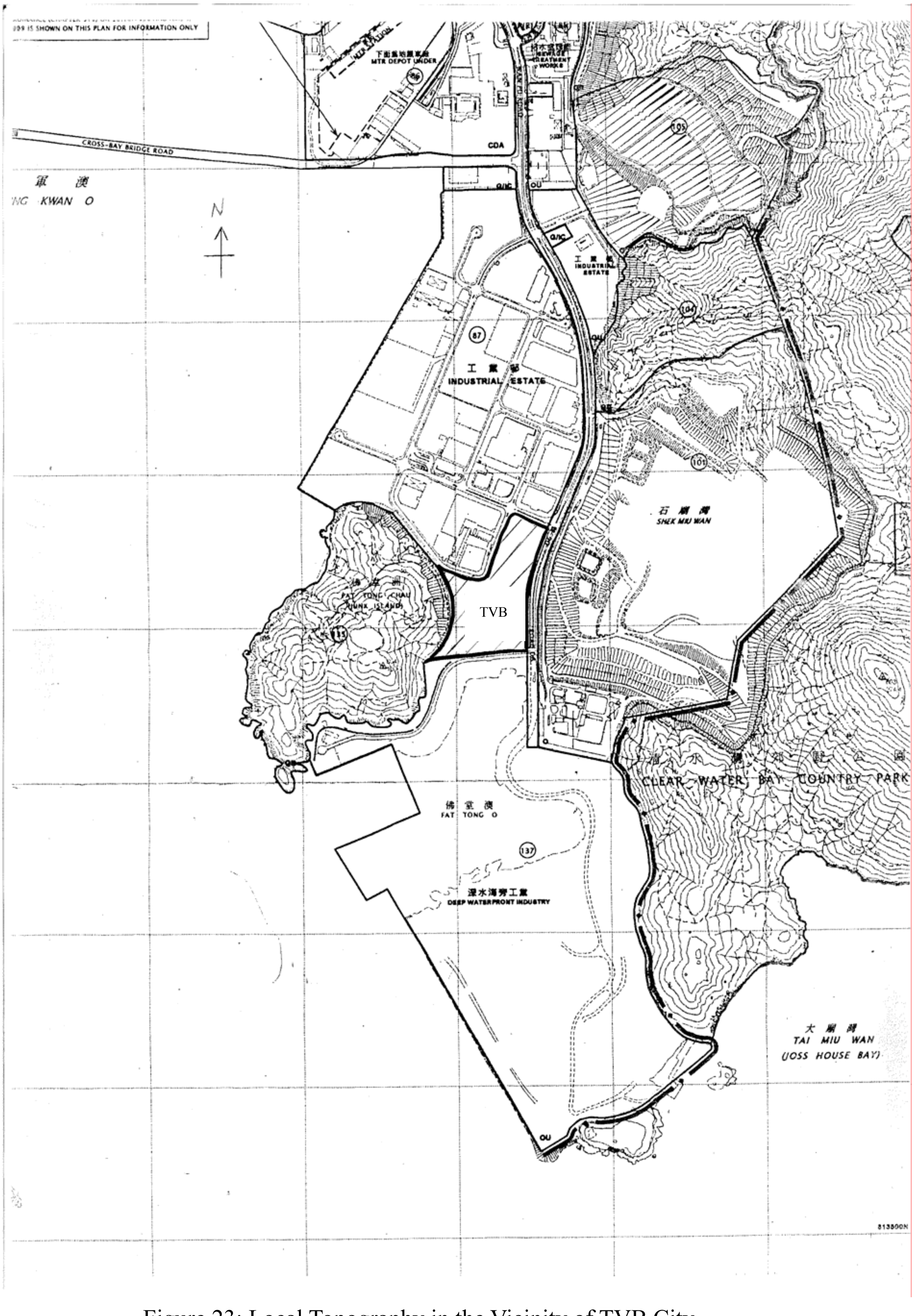

Figure 23: Local Topography in the Vicinity of TVB City

Figure 24: 1:300 TVB City Model

Test Results

<u>Existing Conditions</u>

The wind speeds at the test locations at 6 feet height evaluated based on the wind tunnel test results were tabulated in Table 4. According to the test results, the pedestrian level wind environment of the whole TVB City was windy with the maximum wind speeds at 6 feet height exceeding 5 m/s at all the test locations except Points F and G.

<u>Proposed Measures</u>

As the maximum wind speeds at points F and G did not exceed 5m/s, no mitigation measures were required at the two locations. Besides, since the maximum wind speed at point J was just marginally greater than 5m/s, no mitigation measures were proposed at that location.

TABLE 4

WIND SPEEDS AT 6 FEET HEIGHT (EXISTING CONDITIONS)

Wind Direction	Point A (Reference Point)	Point B	Point C	Point D	Point E	Point F	Point G	Point H	Point I	Point J	Point K	Point L
0	3.9	7.7	10.0	4.4	4.6	3.1	2.3	3.0	3.9	1.9	6.0	3.3
15	3.5	6.7	9.4	5.0	4.9	3.6	2.3	3.2	4.5	1.7	5.5	3.4
30	3.5	6.1	8.3	6.7	5.7	4.4	2.1	3.3	5.2	1.7	5.0	3.6
45	4.1	3.9	5.0	6.4	5.2	4.5	2.4	3.3	4.8	2.4	6.1	4.6
60	4.7	5.1	6.0	7.2	6.6	4.7	3.0	3.8	3.4	4.0	4.6	4.2
75	5.3	4.9	5.1	3.1	1.6	1.8	2.4	4.0	3.1	5.2	4.3	3.8
90	2.3	2.2	2.3	2.8	1.4	2.3	2.5	2.5	2.2	2.2	2.5	3.1
105	2.5	2.2	2.1	3.0	2.2	3.1	2.2	2.5	4.9	2.7	2.5	3.1
120	5.5	2.4	3.7	4.3	4.0	3.0	2.7	3.0	5.0	2.3	2.5	6.4
135	2.7	2.2	4.2	2.7	1.7	2.1	2.7	10.6	8.4	1.7	2.7	3.0
150	6.4	2.2	3.4	2.9	2.0	2.9	4.0	6.8	7.3	1.9	5.7	3.0
165	6.5	3.0	3.8	2.9	1.8	3.9	2.8	5.8	6.7	2.5	4.6	3.0
180	4.8	2.7	3.3	2.8	1.6	3.0	3.9	7.0	7.5	2.9	2.1	2.8
195	2.2	2.3	2.6	2.7	1.6	2.7	4.7	6.9	7.7	2.3	1.8	2.6
210	1.9	2.0	1.7	2.7	1.5	2.6	4.3	7.0	6.6	2.3	2.4	2.6
225	2.6	2.1	1.5	2.5	1.4	3.0	3.7	6.9	6.3	1.8	2.2	2.8
240	2.7	2.0	1.7	2.8	1.5	1.9	2.9	5.5	6.8	2.3	2.1	2.8
255	2.2	2.2	2.2	4.0	2.1	1.6	3.4	4.5	7.2	2.4	1.8	2.7
270	1.8	2.1	2.2	2.8	1.4	1.8	2.2	2.9	2.2	1.7	2.5	2.7
285	2.4	2.2	5.7	3.0	1.5	1.2	2.3	1.8	3.7	1.6	4.2	4.2
300	2.0	2.7	8.4	3.5	1.7	1.2	3.4	2.1	4.4	2.1	5.3	4.6
315	1.9	4.3	8.5	4.6	2.9	1.2	3.4	1.8	3.9	2.0	6.7	3.2
330	2.7	5.7	8.4	5.9	3.7	2.6	1.8	1.6	3.8	1.9	7.5	3.1
345	3.4	6.4	9.0	3.2	3.0	2.6	1.9	2.0	4.1	2.3	6.2	3.0
Maximum Speed	6.5	7.7	10.0	7.2	6.6	4.7	4.7	10.6	8.4	5.2	7.5	6.4

At points B, C, D, E, H, I, K and L, the wind speeds at 6 feet height were significantly greater than 5m/s which would likely induce considerably unpleasant to the passengers and affect the routine activities of moving large size of properties form scene to scene in the development. Therefore, mitigation measures were essential to reduce the maximum wind speeds at those locations to not exceeding 5m/s at 6 feet height or to suppress the maximum wind speeds as much as possible if the former goal was unlikely to achieve. In this case study, the proposed measures made use of construction of roofs over appropriate areas and erection of solid/porous screens at suitable locations. The function of the roof was to block a portion of the wind blowing from higher levels into the concerned areas while the functions of the solid and porous screens were to block the wind blowing from particular directions and dissipate the energy of the wind blowing from particular directions respectively. The screens would be made of transparent materials to allow the pedestrians and road users looking through the screens to minimize the possibility of occurrences of accidents.

Layouts of the proposed measures at the above 8 locations were shown in Figures 25 – 29. For each location, the wind speeds at critical directions (i.e. the directions where the wind speeds exceeded 5m/s in the existing conditions) after implementation of the proposed measures were presented in Table 5.

Points B and C

At points B and C, the proposed measures included construction of a roof on top of the opening at point B and 2m high transparent porous screens in the vicinity of the points as shown in Figure 25.

According to Table 4 and Table 5, the maximum speeds at points B and C were significantly reduced from 7.7m/s to 4.0m/s and from 10.0m/s to 4.8m/s respectively. Therefore, the proposed measures could effectively suppress the wind speeds at points B and C to not exceeding 5m/s.

Points D and E

Similar to points B and C, the proposed measures at points D and E included construction of a roof on top of the opening at point D and 2m high transparent porous screens in the vicinity of the points as shown in Figure 26.

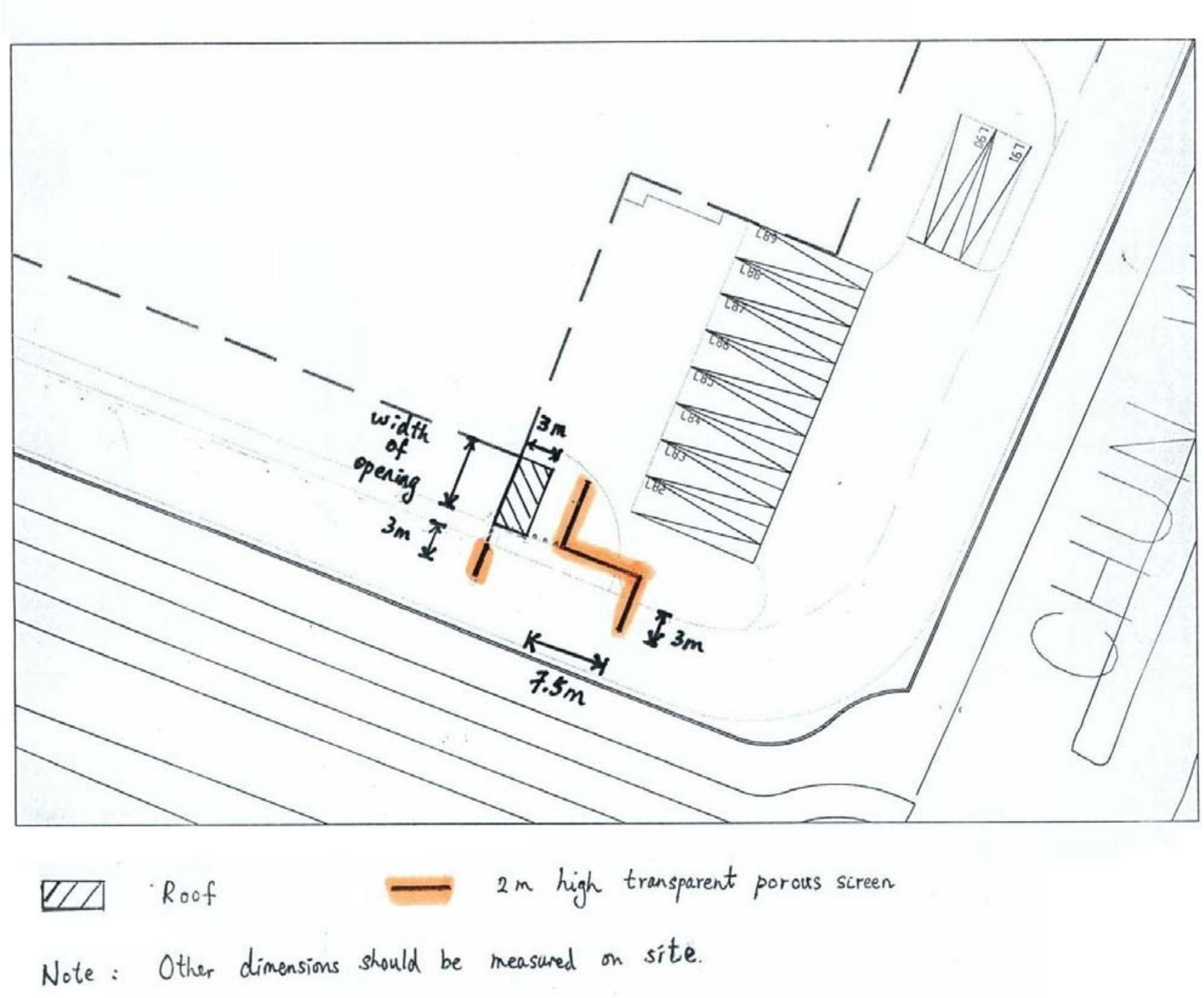

Figure 25: Proposed Measures at Points B and C

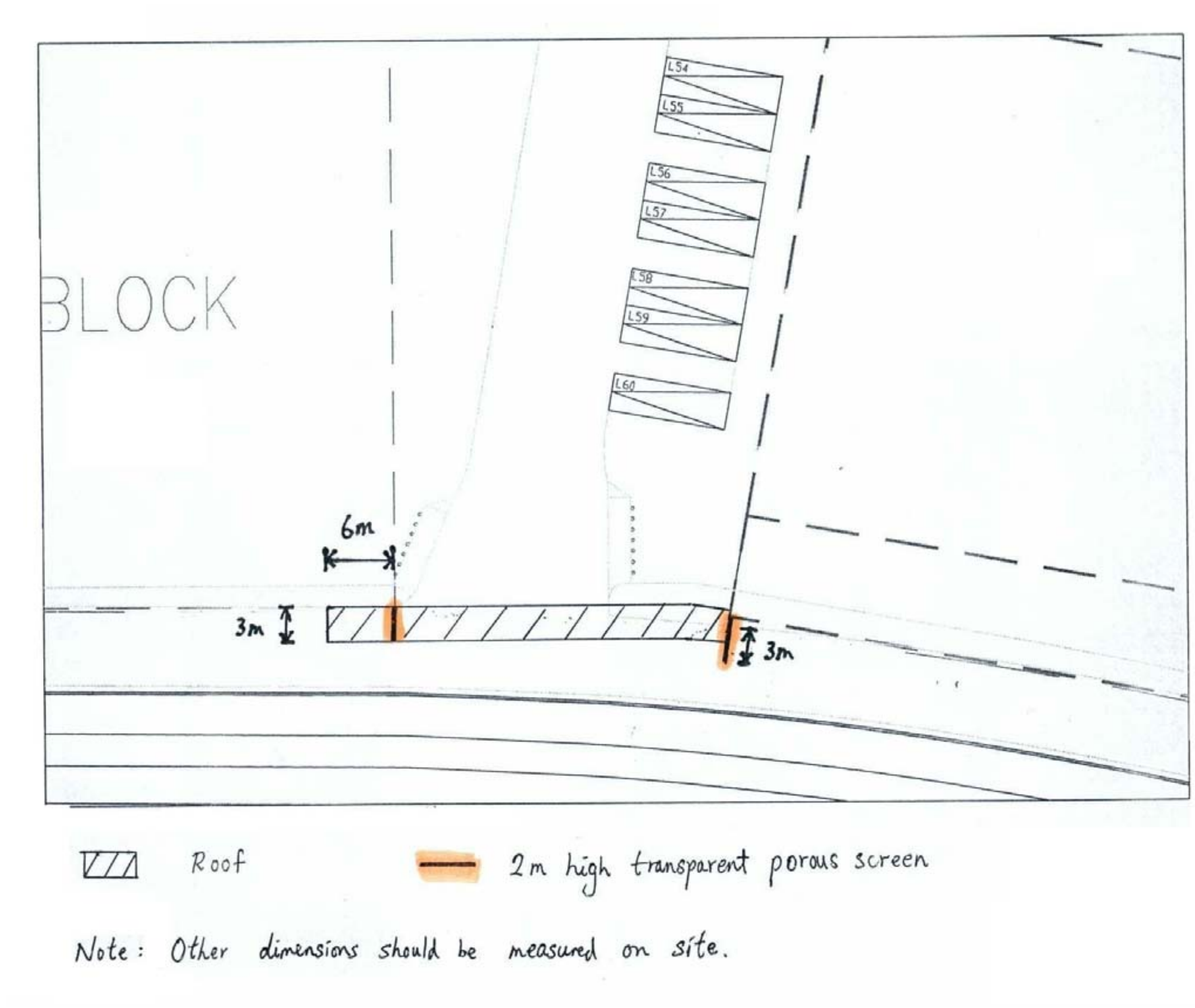

Figure 26: Proposed Measures at Points D and E

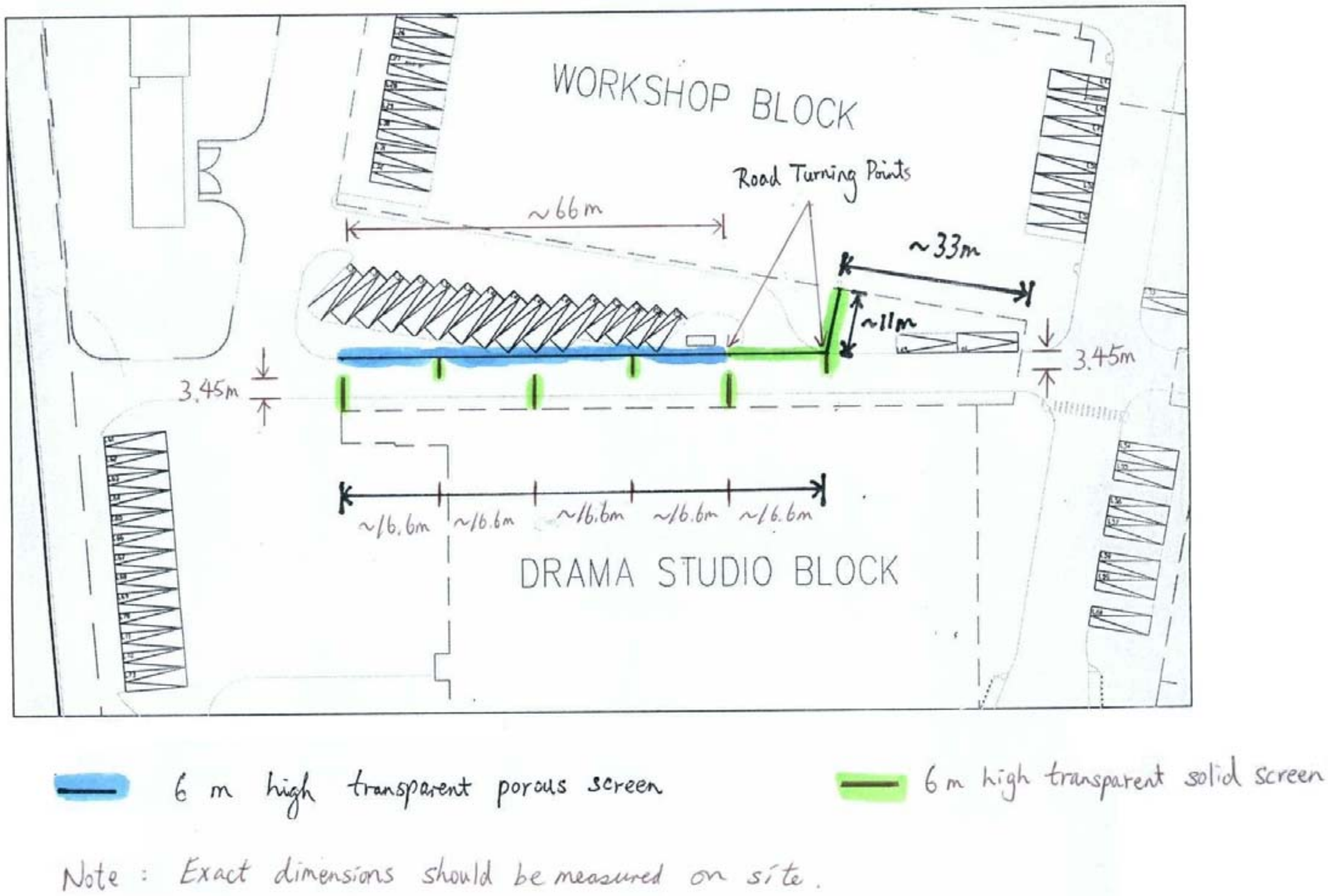

Figure 27: Proposed Measures at Point H

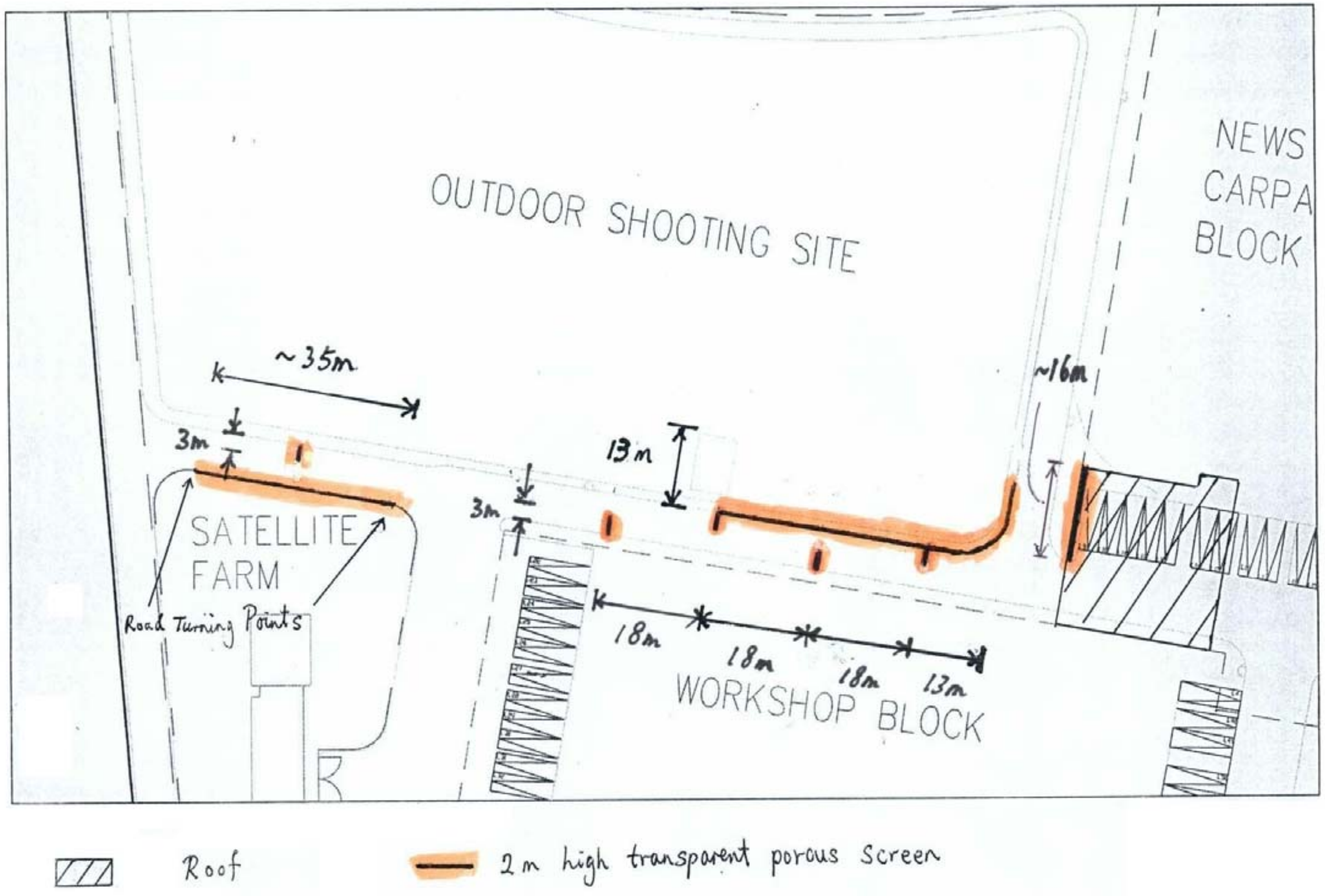

Figure 28: Proposed Measures at Point I

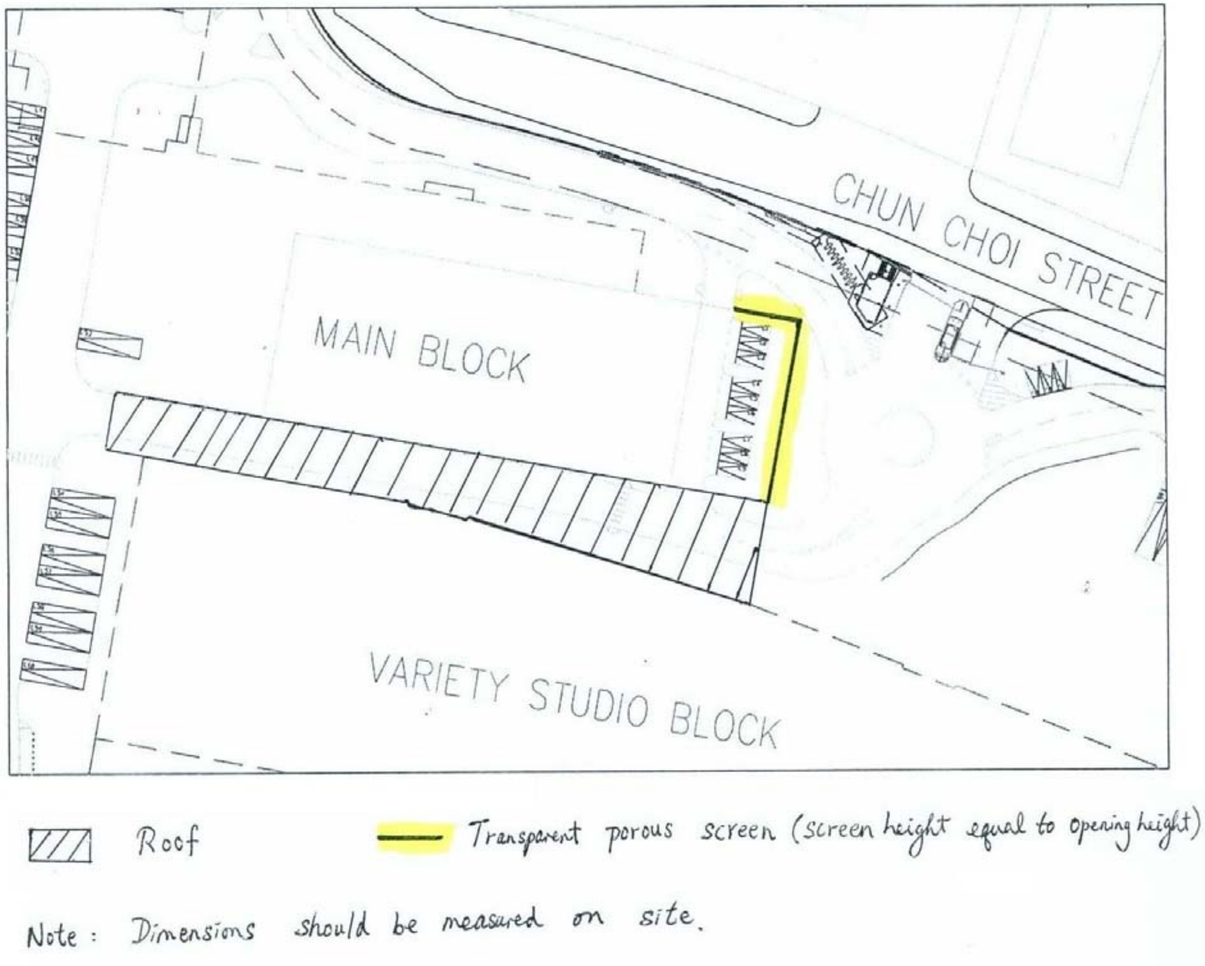

Figure 29: Proposed Measures at Points K and L

TABLE 5

WIND SPEEDS AT 6 FEET HEIGHT (WITH PROPOSED MEASURES)

Wind Direction	Point B	Point C	Point D	Point E	Point H	Point I	Point K	Point L
0	3.9	3.6	-	-	-	-	3.8	-
15	4.0	3.8	3.2	-	-	-	3.7	-
30	3.7	4.8	4.2	2.9	-	3.7	-	-
45	-	3.5	4.9	3.0	-	-	3.4	2.0
60	3.7	4.7	4.2	3.1	-	-	-	2.0
75	-	2.6	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-
105	-	-	-	-	-	-	-	-
120	-	-	-	-	-	3.4	-	1.2
135	-	-	-	-	5.9	4.7	-	-
150	-	-	-	-	4.9	4.5	2.4	-
165	-	-	-	-	4.2	4.5	-	-
180	-	-	-	-	4.0	4.5	-	-
195	-	-	-	-	3.8	4.3	-	-
210	-	-	-	-	3.9	3.4	-	-
225	-	-	-	-	3.9	3.5	-	-
240	-	-	-	-	3.8	3.8	-	-
255	-	-	-	-	-	4.4	-	-
270	-	-	-	-	-	-	-	-
285	-	2.1	-	-	-	-	-	4.2
300	-	3.0	-	-	-	-	3.2	4.2
315	-	3.3	-	-	-	-	3.5	-
330	2.4	3.5	1.9	-	-	-	3.6	-
345	2.9	3.5	-	-	-	-	3.7	-
Maximum Speed	4.0	4.8	4.9	3.1	5.9	4.7	3.8	4.2

Note: Only the wind speeds at the critical directions (i.e. the directions where the wind speeds exceeded 5m/s in the existing conditions) were measured.

According to Table 4 and Table 5, the maximum speeds at points D and E were significantly reduced from 7.2m/s to 4.9m/s and from 6.6m/s to 3.1m/s respectively. Again, the proposed measures could effectively suppress the wind speeds at points D and E not exceeding 5m/s.

Point H

The proposed measures at Point H included erection of 6m high transparent solid and porous screens on the footpath and vehicular road as shown in Figure 27. In particular, the entrance/exit of the car park in the south of the point would be completely blocked by the screens.

According to Table 4 and Table 5, the maximum speed at point H was reduced from 10.6m/s to 5.9m/s. Unlike the situations at points B to E, the maximum wind speed at this location could only be suppressed to about 6m/s after implementation of the proposed measures. The strong wind at that point was likely due to the funnel-shape passage between the buildings that significantly magnifying the speed of the wind blowing from south-east to south-west directions. As this strong wind magnification effect appeared unable to be completely eliminated by typical cost-effective measures while the proposed measures were already capable to largely reduce the maximum wind speeds to about 6m/s which was slightly greater than 5m/s, it was considered that no further mitigation measures were required to further reduce the maximum wind speed to not exceeding 5m/s.

Even though the proposed measures could suppress the wind speeds substantially, it would also induce significant disturbance to the road users and pedestrians including blocking the entrance/exit of the car park and occupying a considerable part of the footpath and the vehicular road. Under this circumstance, an alternative option of measures (Figure 30), which would induce much less disturbance to road users and pedestrians while the maximum wind speed could only be suppressed to about 7m/s, was proposed for the development owner's consideration.

Point I

The proposed measures included construction of a roof on top of the opening at point I and erection of 2m high transparent porous screens on the footpath and vehicular road as shown in Figure 28.

According to Table 4 and Table 5, the maximum speed at points I were reduced significantly from 8.4m/s to 4.7m/s. Even though the proposed measures could effectively suppress the wind speeds not exceeding 5m/s, it would also induce significant disturbance to the road users as it would occupy a considerable part of the vehicular road. Under this circumstance, an alternative option of measures (Figure 31), which would induce much less disturbance to the road users and required fewer construction cost while the maximum wind speed could be suppressed just marginally greater than 5m/s (the maximum wind speed with this option of measures was 5.4m/s), was proposed for the development owner's consideration.

Points K and L

The proposed measures at these points included construction of a roof on top of the corridor at point K and 2m high transparent porous screens entirely covered the concerned openings as shown in Figure 29.

According to Table 4 and Table 5, the maximum speeds at points K and L would be significantly reduced from 7.5m/s to 3.8m/s and from 6.4m/s to 4.2m/s respectively. Therefore, the proposed measures could effectively suppress the wind speeds at these locations not exceeding 5m/s.

SUMMARY

The typical wind comfort criteria in respect to gust wind speed, the typical locations of pedestrian areas with frequent occurrences of strong wind and the general wind speed reduction measures are briefly described. Application of appropriate mitigation measures with consideration their effectiveness in wind speed reduction and disturbance to the users of the pedestrian areas are demonstrated via the case study.

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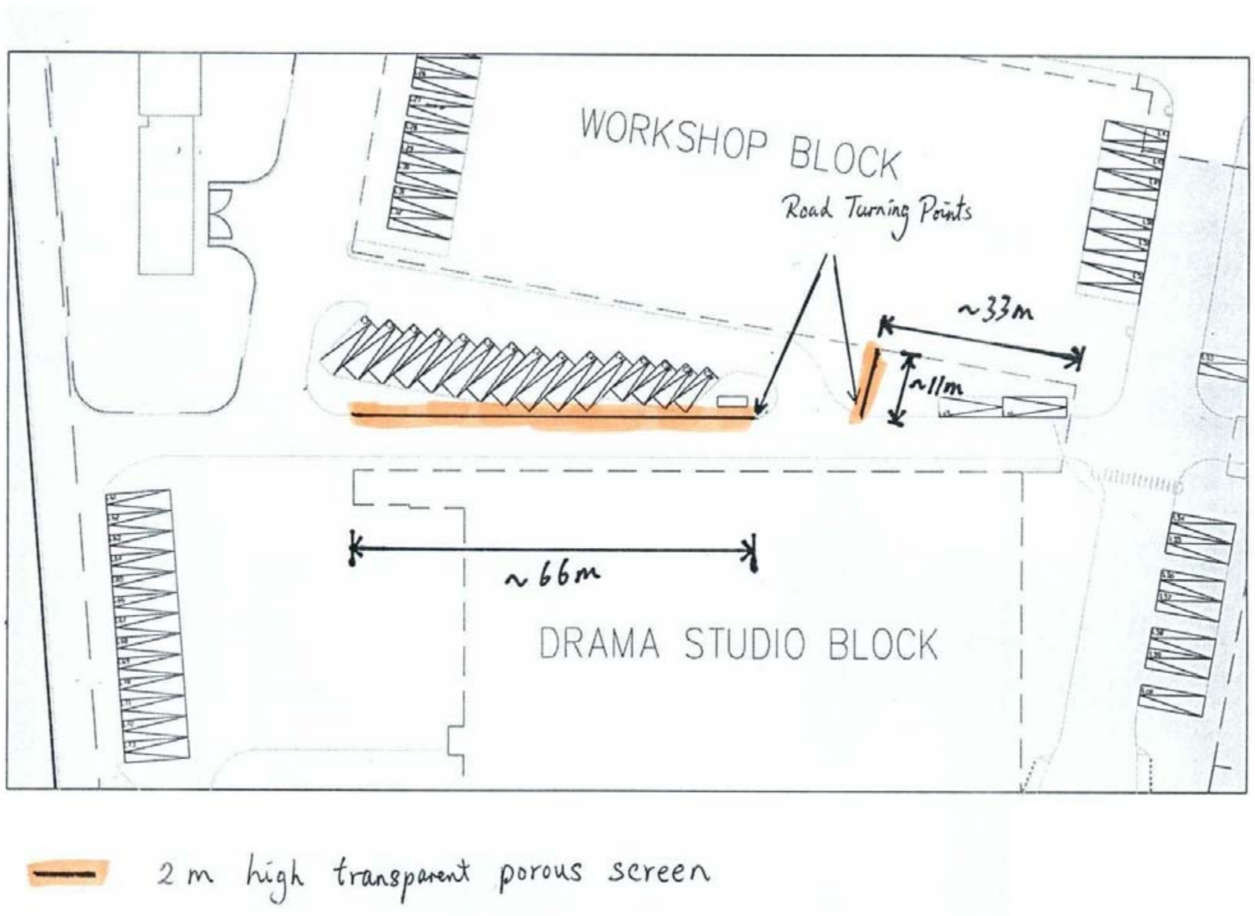

Figure 30: Alternative Option of Proposed Measures at Point H

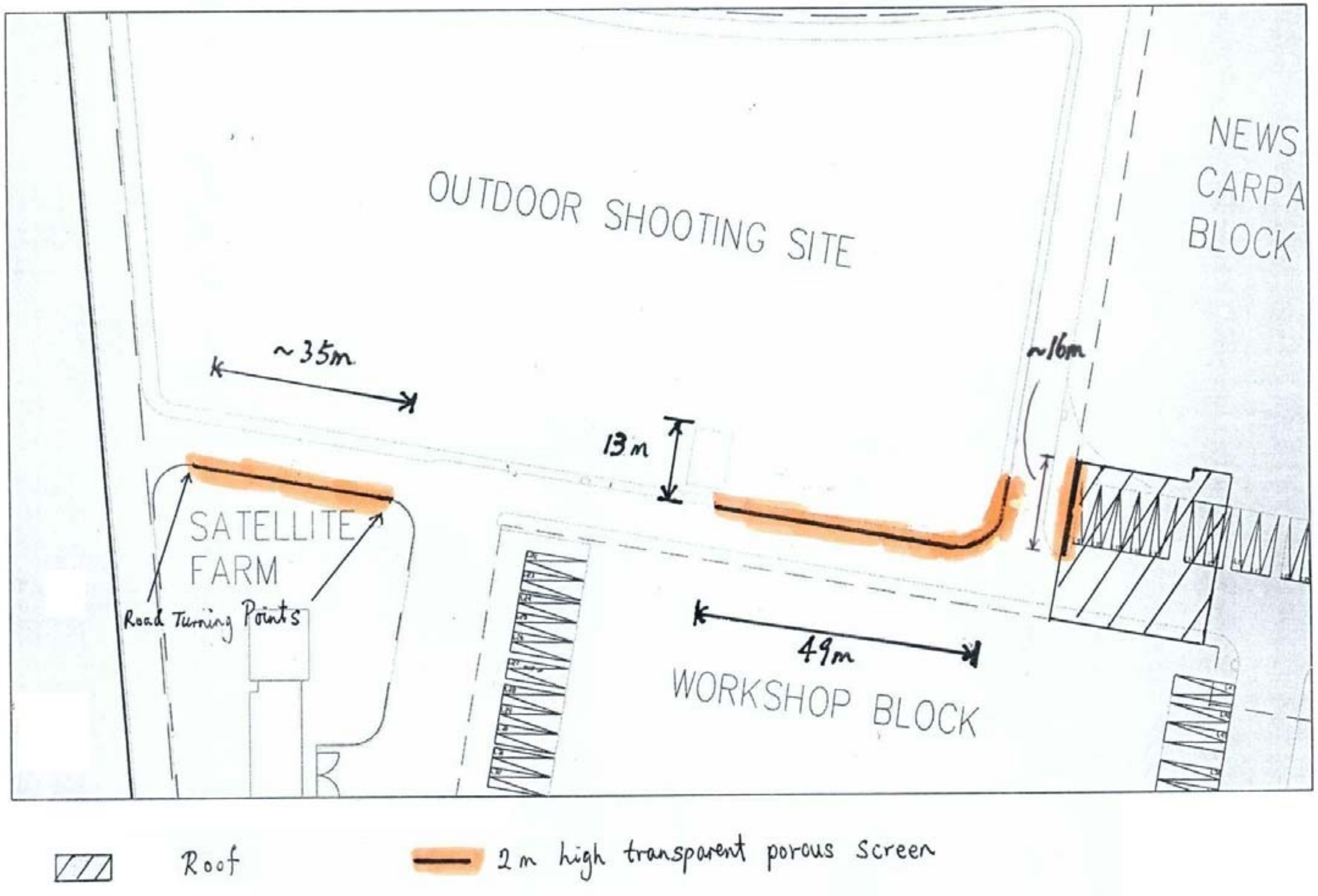

Figure 31: Alternative Option of Proposed Measures at Point I