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# Canadian Building Digest

Division of Building Research, National Research Council Canada

**CBD 174**

## Ground-level Winds Around Tall Buildings

Originally published February 1976.

W.R. Schriever

### Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

Because of the frictional drag of the earth's surface, wind speeds at ground level are much lower than those in the unobstructed flow several hundred feet higher (gradient wind). In general, the rougher or more built up the area, the lower the speed near the ground. There is, however, an exception to the rule. Tall, slab-like buildings tend to deflect wind down into previously sheltered areas. The resulting increased wind speeds near the ground are annoying and at times dangerous to pedestrians. This problem is becoming more widespread with the increasing number of tall buildings. Indeed cities with many tall buildings have become known as "windy cities."

It is the purpose of this Digest to review the effect of wind on people and discuss wind speed changes induced by buildings. Mechanical effects that make it difficult to walk and thermal effects that make a place chillier than it would otherwise be, will be considered.

### Mechanical Effects

The Beaufort Scale of Wind Speeds, prepared in 1806 for use at sea and later extended to use on land by stating the effects of wind on people, trees, etc., serves as a convenient starting point (Table 1). Speeds shown are averages only and may be exceeded by gusts. As winds are usually very gusty between buildings, some of the effects will occur at Beaufort numbers lower than those stated.

The descriptions used in Table 1 come from different sources,<sup>1,2</sup> including the British Building Research Station where staff members have been subjected to *steady* winds in a wind tunnel. Difficulties with *gusty* winds similar to those experienced by pedestrians near the base of tall buildings have been studied in Australia.<sup>3</sup> It was found that with winds gusting to 20 m/sec (45 mph) people had difficulty with balance, particularly if a gust came from the side. For example, if the wind speed rose from 12 to 23 m/sec (27 to 52 mph) in 2 to 3 sec, some people were forced to their hands and knees.

### Table I. Beaufort Scale And Wind Effects On Land

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Beaufort Average

Effects

Number	Speed mph	
1	1-3	No noticeable wind. Smoke rises nearly vertically.
2	4-7	Wind felt on face, leaves rustle.
3	8-12	Hair is disturbed, clothing flaps.
4	13-18	Dust and loose paper raised, hair disarranged.
5	19-24	Force of wind felt on body. Limit of agreeable wind on land.
6	25-31	Some inconvenience in walking.
7	32-38	Difficulty when walking against wind.
8	39-46	Difficulty with balance in walking.
9	47-54	Danger in being blown over.
10	55-63	Trees uprooted, considerable structural damage.

High wind speeds that may be only annoying for the young and fit can be very dangerous for the elderly or infirm, particularly if streets and sidewalks are slippery. In Great Britain during 1972 two elderly people actually died of head injuries suffered in separate accidents in which they were blown over at the corners of tall buildings. As wind speeds tend to be increased by tall buildings, some limitation to that increase should be sought.

### **Thermal Effects**

The thermal (or chilling) effect of wind is also important, but it is more difficult to assess, because of the interaction of air temperature, sunshine, clothing and activity (heat production), quite apart from the fact that people in different climates apparently have different temperature tolerances.

Basically the question of comfort is one of heat loss from the human body. using the limits of "onset of sweating" and "onset of shivering" Humphreys<sup>4</sup> has calculated the conditions that produce thermal comfort. To give an example, a particular metabolic rate (strolling) and solar gain (sunshine) were chosen. Figure 1 shows the strong influence of wind speed on comfort conditions, particularly at lower speeds.

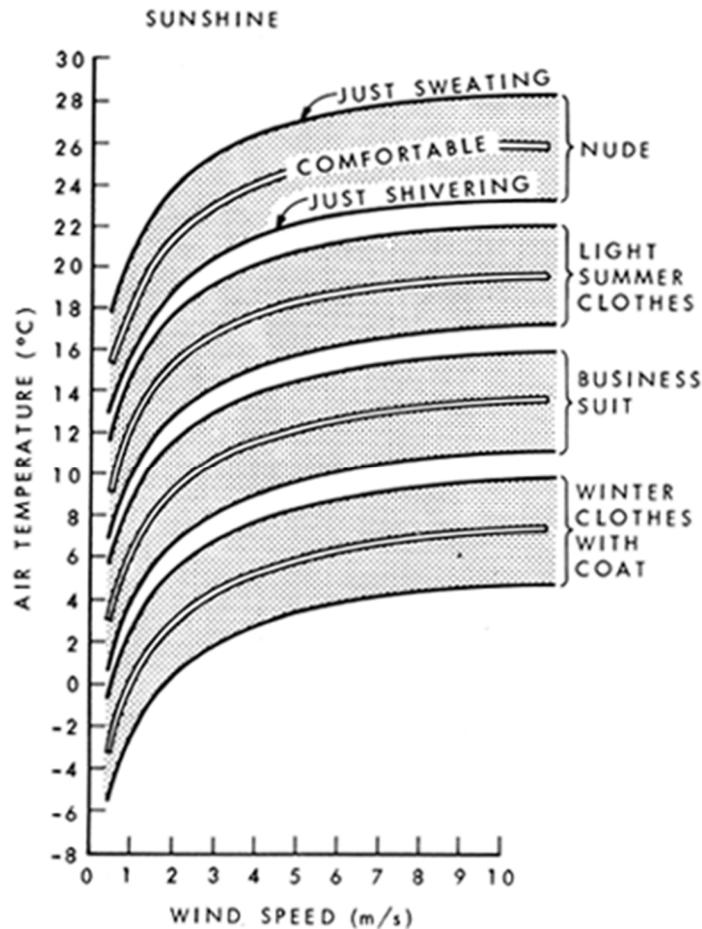


Figure 1. Comfort conditions for strolling in full sun, as a function of air temperature, wind speed, and clothing. (Crown copyright. Reproduced by permission of the Director, Building Research Establishment, U.K.)

**Shelter Around Buildings** The effect of buildings on wind speeds at pedestrian level can be expressed by the ratio:

$$R = \frac{\text{wind speed at pedestrian level, with buildings}}{\text{wind speed at the same level, no buildings}}$$

In suburban areas where there are only low buildings pedestrian areas generally experience wind speeds with ratios, R, in the range 0.5 to 0.7.<sup>1</sup> When wind encounters a single tall slab-like building a different flow pattern emerges (Figure 2). The wind divides at about three quarters of the building height (stagnation region). Above this, the air flows up the face of the building and over the roof; below, it flows down to form a vortex in front of the building before rushing round the windward corners. This results in increased wind speeds in regions A and B, where R maybe as high as 1.5 and 2.0, respectively.

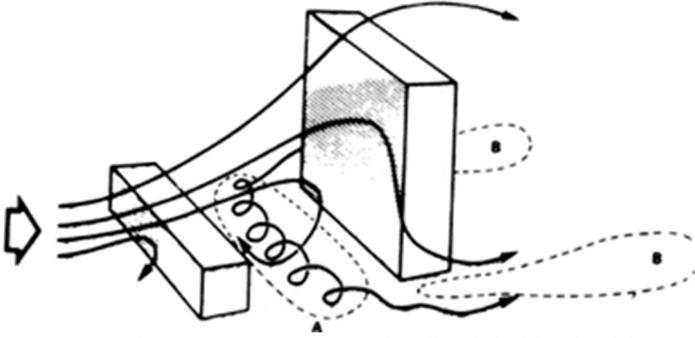


Figure 2. Flow patterns around tall, slab-like building. Note areas of increased wind speeds at pedestrian level. (Crown copyright. Reproduced by permission of the Director, Building Research Establishment, U.K.)

Wind speeds around a particular building are dependent on various factors, but in part on the height and width of building.<sup>5</sup> The values quoted are for a slab-type structure four or more times the height of those surrounding it. When height is less than twice that of surrounding buildings,  $R$  does not generally exceed 1.0.<sup>1</sup> The distance downwind over which increased wind speeds will be experienced depends on the configuration of the neighbouring buildings, but it can be expected to be roughly equal to the height of the tall one.

As the higher wind speeds are produced mainly by downward deflection of the flow, solutions to the problem generally attempt to prevent this flow from reaching the ground. For example, if a tall building is placed on a large podium, the affected areas can be confined to the roof of the podium (Figure 3).

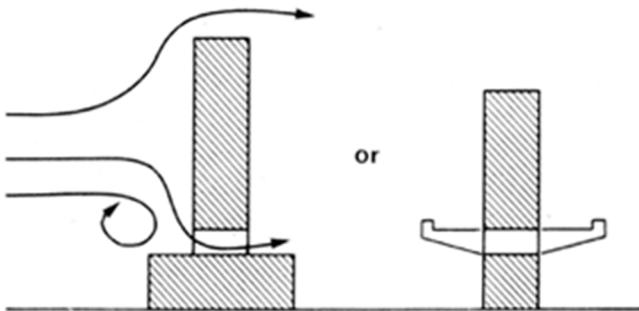


Figure 3. Use of a podium or canopy to remove areas of increased wind speeds from street level. (Crown copyright. Reproduced by permission of the Director, Building Research Establishment, U.K.)

### Wind Frequency

An important question is how frequently certain wind speeds induced by a proposed new building should be allowed to occur in areas where wind speed is affected by a new building. Wind conditions must necessarily be described in statistical terms. Figure 4 is a statistical representation of mean wind speed at gradient level for Toronto for the spring, the windiest part of the year. The contours indicate the relative fraction of time during which wind speeds exceed certain values. The frequency with which winds occur at gradient level is often unavailable, but corresponding plots can be derived from wind speeds and directions measured at a height of 30 ft (10 m) at weather stations of the Atmospheric Environment Service.

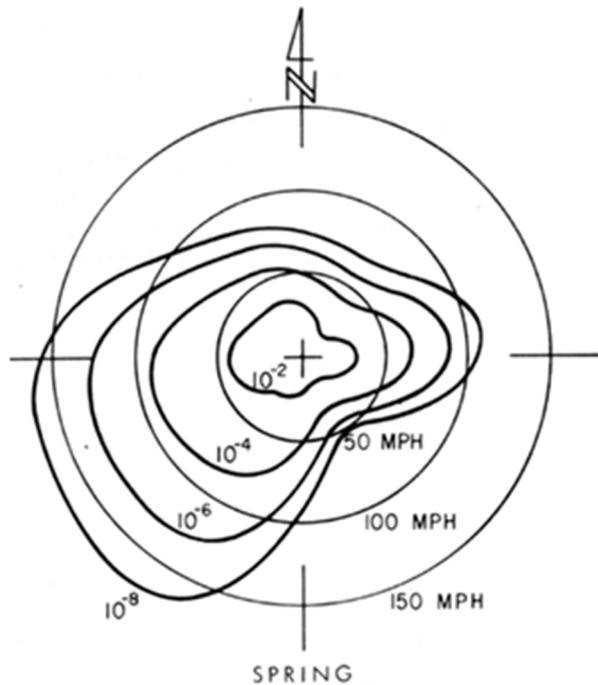


Figure 4. Example of seasonal probability distribution of mean hourly gradient wind speeds, Toronto. (Courtesy, A.G. Davenport.)

The estimation of air flow at street level is difficult because of the interaction of groups of buildings and can usually be achieved only by studying in a wind tunnel an accurate scale model of the building in question as well as its surroundings. For such studies it is essential to use a type of wind tunnel that is capable of simulating the important properties of the real wind, i.e., the variations of wind speed with height and its turbulence or gustiness, for example those at the University of Western Ontario and NRC's National Aeronautical Establishment. By rotating the model and its surroundings on a turntable it is possible to measure street-level wind speeds for different wind directions.

The results can be summarized for each measuring position in the form illustrated by Figure 5, which shows the ratio of the wind speed measured at street level to that at the reference gradient level above the city, and indicates that surface winds are highly dependent on wind direction.

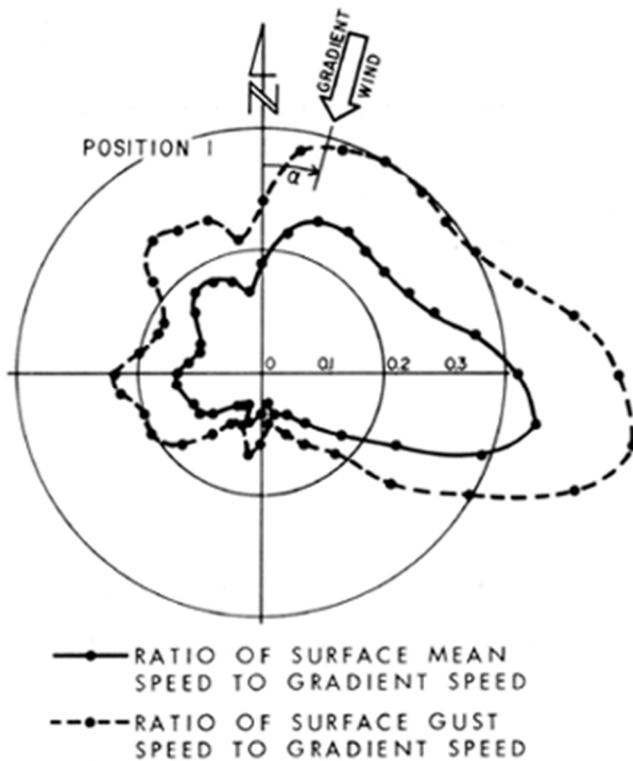


Figure 5. Example of variations of surface mean and gust speeds for winds from different directions. (Courtesy, A.G. Davenport.)

### Guidelines

The degree of comfort considered desirable varies with activity, i.e., walking, strolling, or sitting. Although temperature is a prime factor, windiness of a particular location is also important and is more subject to modification - good or bad - by the design and grouping of buildings.

Using statistical procedures, information of the type shown in Figure 4 and Figure 5 can be combined for estimating the relative frequency with which winds of certain strength will occur and for comparing the results with suggested criteria of acceptable frequencies of wind speeds for different activities (Table 2). These limits<sup>6</sup> have been slightly modified by the author and should be considered only as a guideline to be used with discretion, based on local conditions. A more detailed treatment of this subject has recently been published by the British Building Research Establishment.<sup>7</sup>

**Table II. Possible Limits For Windiness of Pedestrian Areas**

Units: Beaufort Numbers

Activity	Areas applicable	Conditions will be			
		<i>pleasant</i>	<i>unpleasant</i>	<i>annoying</i>	<i>dangerous</i>
		if wind speed exceeds			
Walking fast	Sidewalks	4	5	6-7	8
Walking	Entrance areas	3	4	5	8
Strolling,	Plaza areas,	2	3	4	8

sitting	shopping				
-short	malls				
exposure					
Sitting	Outdoor				
-long	restaurants,	1-2	2-3	3-4	8
exposure	bandshells				
			<i>not more frequently than</i>		
		-	once/week	once/month	once/year

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Although it is impractical to eliminate all occurrences of unacceptable wind conditions, such occurrences should be sufficiently infrequent as to permit the desired function of the pedestrian areas.

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