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Evaluating and modelling the response of an individual to a sudden change in wind speed

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Abstract

The response of an individual to a sudden increase in wind velocity is important in terms of wind comfort and wind safety. This paper is concerned with the latter issue and outlines a series of physical and numerical experiments undertaken in order to evaluate the response of an individual to a sudden change in wind speed. The physical experiments were undertaken in the dynamic circuit of the Jules Verne Climatic Wind Tunnel at CSTB in Nantes, France and subjected 31 people to wind speeds up to 20 m/s. In all cases the wind speed increased from a mean value of zero to the target value in approximately 0.2 s. The wind speed required to cause loss of balance is shown to be a function of orientation and weight.

In an attempt to understand the influence that gust frequency and mean velocity exert on wind safety criteria, a simple numerical model has been developed. The model is shown to agree reasonably well with the data pertaining to the physical experiments. Furthermore the model has been used in a predictive sense to evaluate response of a 50th percentile child to sudden changes in wind speed. It is shown that such a child is potentially very wind sensitive, with 30% reduction in the wind velocity required to cause loss of balance when compared to the 50th percentile adult male.

Keywords: Wind comfort; Wind stability

1. Introduction

In recent years there has been a renewed interest in the response of pedestrians to local meteorological factors. Stathopoulos [1] illustrated that the comfort of an individual is a complex function of a number of different parameters including air temperature, humidity, solar radiation and wind speed. While it is not always possible to control the environmental conditions, through careful town planning, architecture and engineering it is possible to influence the local wind field in certain locations. Numerous techniques can be employed to ensure that the probability that a wind speed exceeds a threshold level is low, or at least corresponds to an acceptable level, related in part to a set of comfort criteria. The actual threshold value adopted will vary from location to location, since over time local inhabitants will adjust to the prevailing environmental conditions and what is acceptable in one country may or may not be acceptable in another country. Such an issue was debated at length in the European Concerted Action COST C14 "Impact of Wind and Storm on City Life and Built Environment" and led to a comparative case study where a common experimental model of a virtual urban environment was tested by five research institutions for a given set of climatic conditions [2]. Each institution was asked to evaluate the pedestrian level comfort using there own, well-established set of comfort criteria. The results of the project demonstrated that even in a relatively simple urban environment the level of assessed comfort varied widely between each institution.

Of perhaps greater importance than pedestrian comfort and a parameter that should not vary significantly between individuals of the same age group who possess similar relevant biological parameters (e.g. gender, weight, height etc.) is the threshold wind speed relating to safety, i.e. what

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wind speed corresponds to a safe level of statistical risk? This paper outlines a series of full scale physical and numerical experiments that were undertaken in order to establish the response of an individual to sudden changes in wind speed and to provide an insight into the acceptable level of wind speed which could be used for safety criteria. Section 2 of the paper reviews the previous work that has been undertaken in this area, while Section 3 outlines the physical experiments undertaken. Section 4 of the paper presents a simplified model of the response of an individual while Section 5 comments on the findings of the paper as a whole and presents conclusions which it is hoped that those involved with the design of the built environment will find useful.

2. Related work

For the purposes of simplicity we will assume that a safe wind speed is considered to be one which does not cause a person to loose their balance. Durov [3] defines losing balance as when a person's initial posture is changed, e.g. by taking steps or moving the legs, so as not to fall. The early experiments in this field were undertaken by Penwarden [4], Penwarden et al. [5], Hunt et al. [6] and Murakami and Deguchi [7]. In [4] a few individuals were observed while walking and standing in a wind tunnel or in the natural wind, and were found to have difficulty in walking steadily from a wind speed of 10.8 m/s and above. Hunt et al. [6] examined the effects of turbulence on individuals and measured their ability to undertake simple tasks such as walking, putting on a raincoat or pouring water. These experiments found that turbulence and wind velocity gradients can have a significant impact on the response of an individual. Penwarden et al. [5] measured the drag force and projected area on a number of individuals either standing facing into the wind or side on to the wind, with a wind speed of 8.5 m/s. Murakami and Deguchi [7] also measured drag force and their experiments involved four females wearing skirts and four males, used three wind speeds, and tested individuals when facing the wind or side on to the wind. The projected area of an individual facing the wind was found to decrease slightly with increasing wind speed, this was because an individual bent forward as the wind speed increased. The drag coefficient for both standing orientations decreased with increasing wind speed.

Table 1 is a collection of quoted wind speeds at (and above) which people are in danger of falling over. It should be noted that many of these values were obtained from subjective responses to experimental conditions and that

Table 1
Summary of critical wind speeds for human stability

Reference	"Blowing over" wind speed (m/s)		Additional information
	Gusty wind	Steady/mean wind	
Melbourne [10]	23		
Pendwarden et al. [5]		15–20	Unpleasant, $U = 8$–10 m/s Discomfort, $U = 5$ m/s
Hunt et al. [6]	20 (gust wind[1]) 13–20 (non-uniform wind[2])	13–15 (steady wind[3]) 20–30[4]	[1] $U < 9$ m/s [2] U varies by 70% over 2 m [3] For ease of walking [4]For safety of walking
Lawson [14]		17.2 (hourly average)	Actually specified as Beaufort Scale > Range 7 (14.1–17.2 m/s)
Soligo [13]	22–27.8 (gust)	11.9–15 (mean wind speed)	From modified Beaufort Scale at 1.5 m above the ground
Bottema [11]	20[5] 15[6]	10	[5] For young people [6] For elderly people
Durov [3]			From Beaufort Scale "difficult to walk"
Peters [15]	12.5–20		Depending on gust duration
BRB [16]	17[7] 11[8]		Used on the J.N.R [7]For personnel, trackside [8]For passengers on platform
Freys (quoted in [15])		11	German railway criteria. Forbidden for passengers, nuisance for personnel
London underground (quoted in [15])		8 (long periods)	For personnel
NS-Holland Railconsult Best (quoted in [15])		11	Passengers on the platform