PEDESTRIAN WIND COMFORT: WIND TUNNEL APPROACH AND CFD

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1. Introduction

The quality of open urban spaces has received a lot of attention in recent years. There is a broad recognition that microclimatic conditions contribute to the quality of life in cities, both from the economic as well as from the social viewpoint. Consequently, universities and other research organizations, municipal and other government forms, as well as construction and architectural companies have expressed significant interest and allocated resources to examine microclimatic conditions, particularly the effect of wind, on the outdoor human comfort. This task is quite complex because, contrary to the more or less controllable indoor comfort conditions, outside human comfort in an urban climate is generally affected by a wide range of variables such as wind speed and direction, air temperature, solar radiation, possible precipitation in various forms and the like.

In Europe, a 3-year (2001-2004) EU-funded project with extensive surveys carried out at different open spaces, has finished after completing approximately 10,000 interviews, which will eventually be uploaded on the internet (http://alpha.cres.gr/ruros). The project aims to produce an urban design tool that provides architects, engineers, urban planners and other decision makers with means to assess effectively the construction of new buildings and the development of cities from the economic, psycho-physiological and sociological perspective of human comfort, air temperature, relative humidity, solar radiation, air quality, human activity.

Work has also been carried out within the auspices of the European Action C14 dealing with *Impact of Wind and Storm on City Life and Built Environment*, with a working group interested in the effects of wind on pedestrians, their assessment and comparisons, as well as the parameters they influence human comfort and its evaluation. Results have appeared in the 2002 Workshop in Nantes, e.g. Westbury et al. (2002) and in the International Conference in Urban Wind Engineering and Building Aerodynamics organized by Von Karman Institute for Fluid Dynamics in May 2004. In addition, the American Society of Civil Engineers (ASCE) has put out a pertinent state-of-the-art document (2003) which was developed with input from the European Action C14.

The present lecture notes will describe the aerodynamics of the urban environment and the reasons causing high wind speeds at sidewalks and, consequently, potential discomfort to pedestrians; they will address the experimental and computational evaluations of the wind on people in the urban environment and will focus on the state-of-the-art of the development of human outdoor comfort criteria by considering a wide range of parameters, including wind

speed, air temperature, relative humidity, solar radiation, air quality, human activity, clothing level, age and the like.

2. Aerodynamics of the Urban Environment

Strong winds are usually accelerated at the pedestrian level within the urban environment, say around tall buildings, due to particular aerodynamic configurations generally associated with tall buildings. In the case of a simple rectangular tall building, it is the boundary layer flow that causes descending flows towards the street level due to the pressure differences created by the velocity differences between higher and lower levels. This downflow is significant due the pressure proportionality to the square of the velocity (Bernoulli equation) and its strength increases with the building height. Figure 1 demonstrates this effect, which is termed in the literature as *downwash*. Clearly, downwash is diminished drastically in the absence of boundary layer flow and this explains the lack of adequate representation of wind effects in the building environment for simulations carried out in the past using aeronautical wind tunnels for building aerodynamics applications.

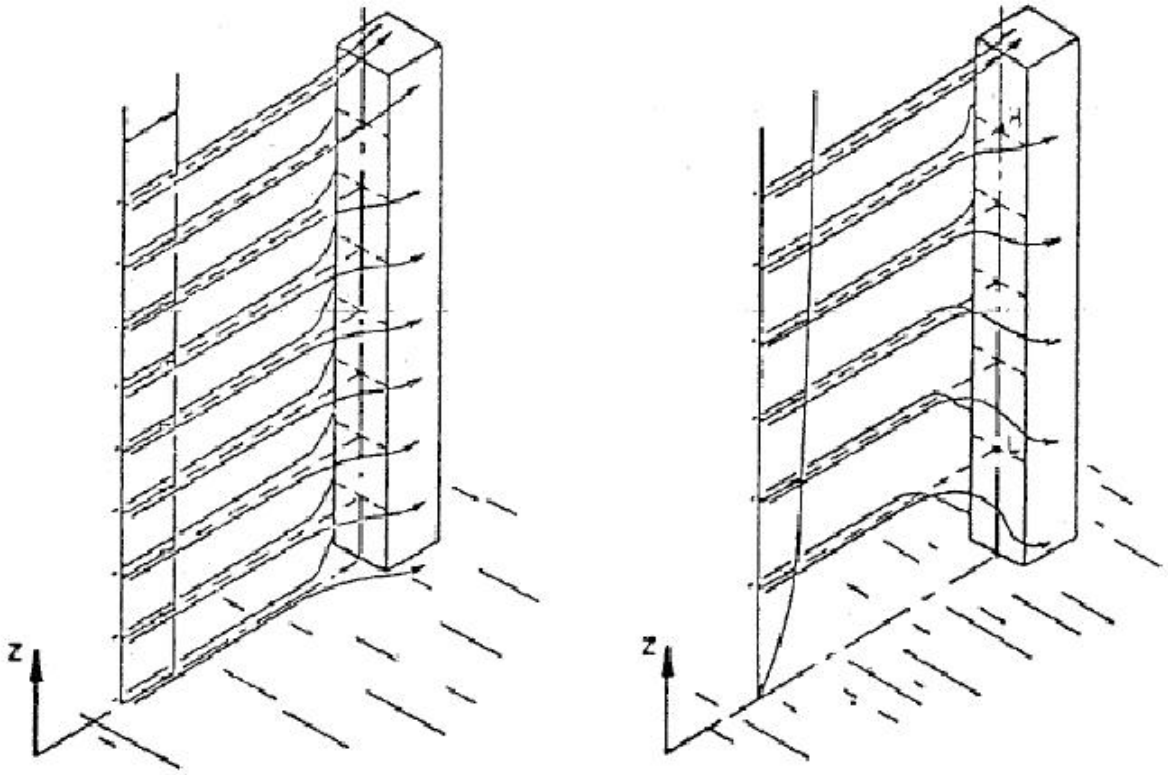

Figure 1. Uniform and boundary layer wind flow around a tall rectangular building

In general, buildings will only induce high wind speeds at lower levels if a significant part of them is exposed to direct wind flows. It is actually the direct exposure to wind rather than building height alone, which causes the problem. This is shown diagrammatically in Figure 2. Another type of pedestrian-level winds is formed when high speed winds pass through openings between high-pressure air on the windward wall and low pressure regions on the