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Application of exceedance probability based on wind kinetic energy to evaluate the pedestrian level wind in dense urban areas

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ABSTRACT

In the present study, assessment of wind environment within the pedestrian level domains of highly populated areas is carried out. Three typical models of a dense urban area are considered and numerically simulated in order to examine the effects of the geometry of such models on wind flow characteristics within the pedestrian domain of a street canyon located within this area. The calculated flow fields are employed to estimate the exceedance probabilities within the study domain using a new approach: average wind kinetic energy. The study is applied to Tokyo, Japan; based on its mean wind velocity data. The results demonstrate that the exceedance probability analysis of the pedestrian wind environment could be a valuable tool for assessing urban areas. Also, the calculated probabilities demonstrate substantial dependence on both the geometry of building arrays and the wind conditions of the considered domain.

1. Introduction

High-density building arrays can affect wind flow characteristics at pedestrian level, which in turn affects the acceptability of the wind conditions for pedestrian use. Consequently, demonstration of a satisfactory wind environment at the pedestrian level of such areas is required to ensure a reasonable level of comfort for inhabitants. From this perspective, the present research sheds light on how to analyze pedestrian wind environments within dense urban areas through the application of exceedance probability to assess the wind conditions of such areas.

Many researchers have studied wind conditions in urban areas and used the exceedance probability analysis to assess the safety and regular wind discomfort in such areas. Most of these studies focused on pedestrian level winds. Melbourne [7] studied assessment of prospective environmental wind conditions regarding a proposed building development in Australia. He described a method for predicting the probability of occurrence of a given wind speed at a particular location. Murakami [10] constructed criteria for assessing wind conditions on the basis of wind speed and survey of residents' opinions over a long period of time. They used the exceedance probability analysis based on the Weibull distribution to describe their criteria, and they applied such criteria in evaluating the wind conditions in a typical city center area. Ohba et al. [12] carried out actual field measurements in order to study wind conditions at ground level around a redevelopment area in Tokyo. They used 17 measurement points to assess whether the wind conditions were acceptable or not based on three published criteria: Murakami [10], Melbourne [6] and Isyumov N and Davenport AG [7]. Their study results demonstrate that Murakami's criterion is midway between those of Melbourne and Davenport. Similar to the previous study, Ratcliff and Peterka [14] carried out wind tunnel measurements of pedestrian wind speeds for nine building projects to evaluate five different criteria using exceedance probability. Visser and Cleijne [18] carried out wind tunnel experiments and full scale measurements to predict the wind climate around two buildings through the application of the exceedance probability approach. Murakami [9] conducted observations of wind flow at ground level over a period of 2 years around a high-rise apartment building in a built-up area in Tokyo. They derived approximation of the exceedance probability for mean wind velocity and gust wind velocity at ground level by the Weibull distribution and they concluded that the approximation by the Weibull distribution becomes more accurate if the wind data for each wind direction is approximated separately and then those distributions are summed up. As an overview of previous studies, Stathopoulos [16] addressed experimental and computational evaluations of the wind on people in an urban environment and focused on the development of human outdoor comfort criteria by considering a wide range of parameters, including wind speed, air temperature, relative humidity, solar

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