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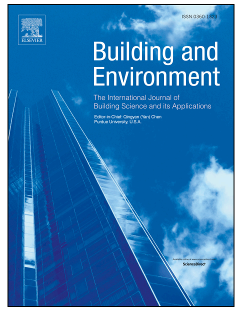

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Numerical simulation of wind-driven natural ventilation: effects of loggia and facade porosity on air change rate

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Abstract

Building envelope geometry has an important impact on cross-ventilation performance. Presence of external architectural structures (e.g. a loggia), and opening surfaces can all affect ventilation performances. All these factors lead to deviation in the wind-driven ventilation rates predicted by semi-empirical models (correlations). Thus, this study is focused on the effects of a loggia and window opening size on cross-flow ventilation rates estimated by Computational Fluid Dynamics (CFD). CFD has been validated on field measurements in a low-rise building, with a steady-state Reynolds-Averaged Navier-Stokes (RANS) model. Ventilation performance is evaluated for buildings with or without a loggia with different opening sizes and various wind conditions. We find the presence of the loggia reduces the average air change rate by 27%, except for one wind direction at which a vortex is formed in the loggia and directs the airflow into the opening. However, the empirical models based on the orifice equation fail to precisely predict the ventilation rate for large windward-side windows. Large windows should be installed on the façade exposed to the prevailing wind, so as to enhance ventilation performance.

1 Introduction

Natural ventilation is an efficient strategy to reduce building energy consumption and improve occupant satisfaction and indoor air quality [1]. Natural ventilation is driven by wind- and/or buoyancy-induced pressure differences [2-4]. Due to its complex mechanism, ventilation performance prediction remains a primary concern [5-13] and how to integrate it into the heating, ventilation, and air conditioning (HVAC) control system of a building is a hot topic [14-15].

Among Building Energy Simulation tools, a common approach is to use natural ventilation correlations derived from semi-empirical models. Semi-empirical ventilation models, usually based on orifice equation and Bernoulli's principle, are simple ways to involve the turbulence effect in to calculation of air change rate or air change per hour (ACH). The two types of ventilation, single-sided ventilation and cross-ventilation, are often treated separately [16-17]. On one hand, when conventional empirical models are used to deal with single-sided ventilation, the main difficulties are the entering and leaving air circulations at the same opening and the interaction between wind and buoyancy effects. Caciolo et al. combined experimental study and numerical parametric analysis to figure out a correlation that involves the main turbulence effects [18]. On the other hand, the mechanism of cross-ventilation is relatively simple because the major driving force is the wind effect, and therefore, the form of cross-ventilation correlations