Building and Environment 46 (2011) 911–921

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Wind-induced ventilation performances and airflow characteristics in an areaway-attached basement with a single-sided opening

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ARTICLE INFO

Article history:
Received 6 August 2010
Received in revised form
18 October 2010
Accepted 18 October 2010

Keywords:
Areaway
Basement
Single-sided natural ventilation
Wind tunnel experiment
Large-eddy simulation
Homogeneous emission rate

ABSTRACT

In the present study, we performed both wind tunnel experiments and numerical simulations on a scale model with the focus on wind-driven natural ventilation in an areaway-attached basement with a single-sided opening. In the experiments, the mean value of the effective ventilation rate, purging flow rate (*PFR*) was measured for nine wind incidence angels based on the homogeneous emission rate method. The experimental results were used to validate two numerical approaches: Reynolds averaged Navier–Stokes (RANS) modeling and large-eddy simulation (LES). The influences of inflow turbulent fluctuations for LES modeling were also examined. The comparisons between the experiment and the numerical simulation indicate that LES can provide more accurate results than RANS and the inflow turbulent fluctuations should be taken into account for LES modeling. Based on LES with the inflow turbulent fluctuations, the mean airflow patterns within and around the areaway-attached basement were further studied for different wind incidence angles to investigate the influence of wind direction on ventilation performance in the areaway space. Furthermore, the relationships between the effective ventilation rate and the kinetic energy in the basement space were analyzed for three wind directions: 0°, 90° and 180°. A close correlation was found between the mean values, whereas the corresponding time variations showed large discrepancies. Finally, we compared the effective ventilation rate obtained using the homogeneous emission rate method and the airflow rates through the opening using two integration procedures. The effective ventilation rates were found lower than the airflow rates through the opening.

1. Introduction

Ongoing urbanization during the last decades has resulted in serious energy and environmental problems as well as the increasing demands for more hand uses [1]. In the case of urban residential areas of some countries, given the presence of strict law restrictions on building height, people tend to build their houses with basements for residential purposes rather than for mere storage purposes to meet the increasing demands for more extra spaces. Nonetheless, despite many acclaimed benefits, subterranean living in basements is often accompanied with some environmental constraints, among which indoor air quality is the most concern. Natural ventilation can be a cost-effective solution to this problem without the necessity of mechanical means, which should be well integrated into building design, such as through windows and louvers. It should also be noted that inducing natural ventilation by wind in basements is not as easily achieved as in above-ground rooms. An applicable example is the use of an areaway space as shown in Fig. 1, which is a sunken patio with a top opening facing upwards and with doors or windows linked to an adjacent basement. The presence of such a space can act as a buffer zone to moderate local microclimate in the adjacent basement by allowing the ambient clean air to dilute the contaminated air inside.

Areaway spaces, including some similar architectural forms, such as sunken courtyards beneath the ground level, have been widely adopted throughout the world. They can be found in both vernacular and contemporary buildings, residential and public types. Despite the ubiquity, only a few quantitative investigations have been performed on natural ventilation in areaway-attached basements. For example, Liu and Han [2] carried out field measurements and surveys in four cave dwellings in a rural area of Gongxian, China and tested seven designs to improve ventilation performance. They found that providing openings at both the back and front of the caves was the best means to improve ventilation, followed by constructing a vertical tunnel at the back of the caves. Nevertheless as for basements in urban residential dwellings, there are many circumstances in which cross ventilation and stack ventilation are restricted due to limited space. In the present study, the attention is focused on wind-driven single-sided natural

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doi:10.1016/j.buildenv.2010.10.019