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Wind tunnel investigation on influence of fluctuating wind direction on cross natural ventilation

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ABSTRACT

The performance of wind driven natural ventilation is influenced significantly by the boundary conditions set for the wind. In real conditions the wind direction is fluctuating constantly so it is important to consider this fluctuation in experiments and simulations. This paper investigates the influence of fluctuating wind direction on cross-ventilation using wind tunnel experiments with the aim of improving the evaluation accuracy for natural ventilation. A periodically fluctuating wind direction was designed and reproduced in the experiment. Rapid Response FIDs (Flame Ionization Detector) were used to monitor the concentration of tracer gas. An index named diluting flow rate (DFR) is introduced to evaluate the ventilation performance of this kind of experiment. The results indicate that the DFRs of fluctuating cases are approximately 65–100% of the maximum airflow rate and DFR is influenced by the wind speed, the opening size and the wind direction fluctuation. Informed by the experimental data the mechanism of this combined influence is discussed in this paper.

1. Introduction

Natural ventilation is a passive ventilation method for buildings for removing contaminated air away from an indoor space and because of its passive components it consumes less energy compared with mechanical ventilation [1]. Natural ventilation can also provide a high level of thermal comfort [2]. Application, designing and study of natural ventilation have become increasingly common in recent years [3–5].

Numerical Simulation and experiment are two prevalent tools used to study natural ventilation [6,7]. There are mainly two driving forces in natural ventilation: stack pressure and wind pressure [8]. To evaluate the efficiency of wind pressure driven natural ventilation, the setting of the boundary conditions for wind is very important. However, in experiments and simulations it is usual for wind to be modeled as an airflow that has a changeless mean velocity and fixed direction whereas the actual wind direction and velocity is varying all the time [9–12]. It is necessary to consider the fluctuation of wind to get more accurate results.

Over many years CFD tools have been improving significantly and applied to study ventilation more than ever [13]. LES model and other more accurate turbulent models can be applied to simulate the effect from the variability of wind on ventilation now as a result of development in computer hardware. Yi Jiang and Q.Y. Chen studied this effect by CFD method using the LES model and unsteady calculation [14]. N.G. Wright studied natural ventilation by using DES model and testified the validity of DES model, which can capture the unsteady cross-ventilation [15]. Cheng-Hu Hu et al. used LES model to analyze the cross-ventilation and studied the unsteady flow [16]. The CFD method has its own limitations with the turbulent models used and different turbulent models are only suitable for different issues [6,17,18]. Validation is often required before using a turbulent model [19].

Reproducing a fluctuating wind in a wind tunnel is difficult [20]. Wind tunnel experiment on natural ventilation is often used [21,22]; however the wind tunnel investigation with fluctuating wind direction is rare. W. Etheridge carried out many works, considering the unsteady characters of natural ventilation and proposed several experimental techniques to evaluating the effect of natural ventilation [23–26]. However, these studies did not generate fluctuating wind direction in the wind tunnel experiment.

It is important to evaluate the performance of natural ventilation accurately. The index of air change rate, ACH (Air Change per Hour) [27], is often used. Although this index clearly indicates the ratio of the volume of airflow to the volume of indoor space, it can only be applied to small spaces in which air is well mixed. For huge or complex spaces, it will cause a considerable error. Lars Davidson

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