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Experimental study of buoyancy driven natural ventilation through horizontal openings

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1 Introduction

Air flow through horizontal openings is an important issue of mass and energy transfer between different zones in buildings. Horizontal openings occur in staircases, stairwells, ventilation shafts, service shafts and chimneys. Hence mass and energy transfer through them have important implications regarding energy saving, thermal comfort, control of contaminants, micro-organisms and spread of fire and smoke.

This research work is focused on obtaining the air flow rate through the horizontal openings driven by buoyancy. The measurement results can be used in both simple calculation tools to give a rough estimate of the capacity for design of a ventilation system, but also be implemented in more detailed models, especially multizone models, for simulation of the performance of natural ventilation systems.

2 Method

The experiments were carried out in a full-scale test cell which was divided into two rooms, namely a "thermostatic chamber" and a "test room". The thermostatic chamber was 8 m length, 6 m width and 4.7 m height; and the test room was 4.1m length, 3.2 m width and 2.7 m height, respectively. The thermostatic chamber simulated the environmental conditions controlled accurately by an air conditioner. Only one square horizontal opening was located on the roof center of the test room. The higher indoor temperature was produced by heating cables uniformly distributed on the floor inside the test room. CO_2 constant injection tracer gas system was used to measure the air flow rate. Different cases were examined by varying the temperature differences of inside and outside of the test room, the opening area and the opening ratio L/D.

3 Results and Discussion

The full-scale measurement data fit reasonable well with the brine-water scale measurements found in the literature, although significant differences exist between them for certain L/D ratios, see Figure 1. For opening ratios L/D from 0.035 to 0.115, the dimensionless air flow rate, expressed by the Fr number, was found to be about 0.050, which is lower than the constant Fr value 0.055 given by Epstein [6]. The maximum dimensionless air flow rate was found about 0.11 for L/D = 0.59 in stead of L/D = 0.4, and approximately 15% higher than the peak value 0.095 predicted by Epstein. It can also be seen from Figure 1, that only three different flow regimes can be distinguished in this experimental study: Oscillatory exchange flow (Regime I), Bernoulli flow (Regime II), and turbulent diffusion (Regime IV). The combined turbulent diffusion and Bernoulli flow (Regime III) cannot be identified.

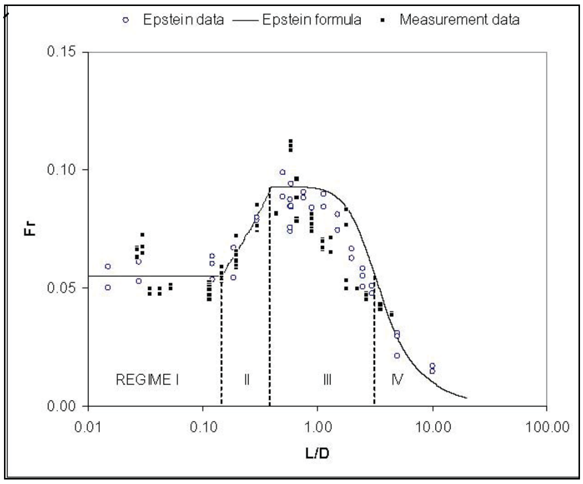

Figure 1. Comparison of full-scale air flow measurement and the Epstein brine-water scale measurement expressed by the Fr number as a function of the L/D ratio.