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Research Article

Effect of indoor buoyancy flow on wind-driven cross ventilation

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Abstract

Designing for wind-driven cross ventilation is challenging due to many factors. While studies have focused on the difficulty of predicting the total flow rate and measuring opening characteristics of cross ventilation, few have investigated the impacts on the distribution of indoor air. This paper provides insights on how local heat sources can generate significant buoyancy driven flow and affect indoor mixing during wind-driven cross ventilation scenarios. Measurements of air distribution were conducted by a tracer gas method for a multi-zone test building located in Austin, Texas, USA, along with cross ventilation flow at the openings. A computational fluid dynamic (CFD) model was also developed for this test building, which utilizes the measured flow properties at the openings as boundary conditions. Resulting air distribution patterns from the CFD model were then compared to the experimental data, validating the model. Further parametric analyses were also conducted to demonstrate the effect of interior heat loads in driving internal air mixing. Key findings of the investigation suggest a local heat source smaller than 35 W/m^2 can increase the indoor mixing during cross ventilation from less than 1 air exchange to as high as 8 air exchanges per hour. This result also suggests a typical occupancy scenario (people and electronics) can generate enough heat loads to change the indoor air mixing and alter the effect of cross ventilation.

Keywords

natural ventilation,
cross ventilation,
CFD,
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buoyancy

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1 Introduction

Energy efficient buildings have been the goal for architects, building engineers, and policy makers in recent years. While adding energy generation onsite, such as photo-voltaic panels, can substantially decrease a building's power draw from the electrical grid, reducing a building energy consumption is a more economical solution (Parker 2009). One approach to limit building energy consumption is to design buildings with natural ventilation. While the two components of natural ventilation, buoyancy- and wind-driven flows, have been studied as driving forces for ventilation, few researchers have covered their combined effects on the distribution of indoor air.

The complexity of wind and buoyancy combined natural ventilation is well documented. Hunt and Linden (1999) showed that in the case of simple displacement cooling scenarios, wind and buoyancy can work together in a predictable manner to increase ventilation rates. However, others have shown that the combined effect is significantly more complicated. For example, Li et al. (2001) showed that even with simplifications, natural ventilation involving wind and buoyancy is complicated and unstable and a given external condition could produce multiple scenarios of natural ventilation with various ventilation flow rates. Additionally, Lishman and Woods (2009) showed that combined natural ventilation flow regimes could be described by multiple steady states where each state is dominated by either wind or buoyancy force. More importantly, one state can transition to another if the change in external wind or temperature condition is sufficient. Furthermore, Yuan and Glicksman (2007, 2008) showed how wind fluctuations and temperature changes could result in completely different flow regimes for a building with natural ventilation. These findings suggest that the wind and buoyancy combined indoor flow regime must be treated as a complex phenomenon and can be affected easily over time due to varying external conditions.

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