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Indoor air quality control in case of scheduled or intermittent occupancy based building: Development of a scale model

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A B S T R A C T

When a building is used only for intermittent occupancy, continuous operation of ventilation system is not necessary for achieving good indoor air quality during the occupation periods. Such buildings have a great energy saving potential which is not harnessed enough yet. Indeed, energy loss can be avoided by promoting natural means and managing mechanical ones. Therefore, control strategies based on time and/or occupancy scheduled ventilation associated to pre-purge ventilation constitute a key for an energy efficient ventilation system.

The purpose of this paper is to demonstrate the robustness of an experimental scale model that can be used to provide recommendations on the management and the control of ventilation systems in case of intermittent occupancy. Thus, several surveys and experimentations were carried out using both ENTPE classrooms and an experimental apparatus in order to characterise existing ventilation systems and to test a number of control strategies, which have been developed and tuned using a simulation tool (HYBCELL) based on finite differences and pressure air flow models.

1. Introduction

At present, there is a great interest in ventilation systems as an energy efficient way to achieve thermal comfort and indoor air quality. To reach those targets and manage complex ventilation systems such as hybrid ventilation, intelligent control of ventilation is needed. In addition, several studies have shown the potential of ventilation control for occupants' productivity improvement [1,2]. Recent French surveys on energy consumption in buildings subject to variable occupancy (intermittent occupancy) published by the French Energy Agency (Agence de l'Environnement et de la Maîtrise de l'Energie) in 2005 [10] have highlighted a great potential of energy saving in such buildings. Those surveys have also shown that educational buildings (21% of French buildings) represent 166.4 million m^2 of heated area and an annual heating energy consumption of more than 26 TWh. Given that ventilation has a major impact on the global performance of buildings, in terms of energy consumption as well as regarding indoor climate, the energy benefits of a well-managed ventilation system for intermittently occupied buildings are clear [3].

The aim of the work described in this paper was to test the performance of basic ventilation control strategies for indoor air quality. For this purpose, an experimental device representing a prototype of a classroom equipped with controlled ventilation system has been developed. This work aimed also to assess the robustness of this device. Indeed, this prototype will serve to provide recommendations on the management and on the control of ventilation systems in case of intermittent occupancy instead of using a real classroom. The methodology adopted to reach this target consisted on a retroactive approach based on experimental and numerical studies. To begin with, several indoor air quality in terms of CO_2 concentration surveys have been carried out at the ENTPE school (Lyon, France) in order to assess the performance of the existing mechanical ventilation system. Then, as previous studies held at the ENTPE/DGCB/LASH showed that the simulation tool "HYBCELL" could be used to predict the performances of ventilation systems [4], this numerical model has been used to model the ENTPE classroom. It was also used in a further phase of the study to develop and to assess several control strategies for ENTPE mechanical ventilation systems.

Finally, an experimental device representing a scale model of the ENTPE classroom has been designed and used both to calibrate the HYBCELL pollutants' model and to experimentally test and validate developed control strategies.

2. Experimental setup and numerical model

A classroom at ENTPE and a device developed at the ENTPE/LASH laboratory were experimentally monitored.

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Fig. 1. ENTPE classroom view.

2.1. The ENTPE classroom

The classroom that was used to carry out the experimental monitoring and to test the mechanical control strategies is a single zone at the lower floor of a two-storey building. It is 7.5 m long, 6.2 m wide and 3.10 m high (Fig. 1), and has a large glazed facade oriented East-north. The classroom is equipped both with a natural ventilation system (two openings and one door) and a double-flow mechanical ventilation system. This classroom was chosen on account of its occupancy pattern which was of typically intermittent type.

2.2. The scale model

An experimental device has been developed at the ENTPE/LASH laboratory (Figs. 2 and 3) in order to adjust the numerical model, and to develop and to assess control strategies for ENTPE mechanical ventilation system. The experiment setup developed for this study represents a scale model of an ENTPE classroom. It is a Plexiglas parallelepiped volume (3 m long, 1 m wide and 1 m height) and can also be used as wind tunnel to characterise openings' behaviour.

Three CO_2 sensors have been used. Two of them have been installed inside the scale model and the third being placed near the air inlet so as to take outdoor conditions into account (Fig. 2). In order to simulate occupants' breathing CO_2 (18 l h^{-1} per person) and water vapour (0.1 kg h^{-1} per person) have been injected, using two mass flow controllers. In addition, an electric heater has been used to simulate metabolic heat of occupants. The experimental device can simulate up to six occupants. A very low pressure fan has been placed near the point of injection of the CO_2 to ensure the homogeneity of the air inside the scale model, in terms of CO_2 concentration. Preliminary experimentation using smoke injection showed that the actual apparatus avoids ventilation flow shortcut and presents a good mixture of indoor air.

The experimental setup has been provided with a mechanical inlet and natural outlet. In order to improve the indoor air homogeneity and to avoid air shunts, two honeycombed grilles have been placed 1 m and 2 m far from the inlet. In addition, a conic baffle has been placed on the first grille to create laminar flow.

An air velocity sensor placed in the middle of the calibrated outlet duct allows the measurement of air flow [7] according to formula (1):

$$Q = 0.9\pi\frac{d^2}{4}v \quad (1)$$

with Q the air flow (m^3 s^{-1}), d the outlet radius (m), and v the air velocity (m s^{-1}).

The data acquisition system is made up from a USB NI module (Fig. 3) and the whole experimental device is supervised by a laptop. Fig. 2 gives the location of sensors and actuators in the scale model.

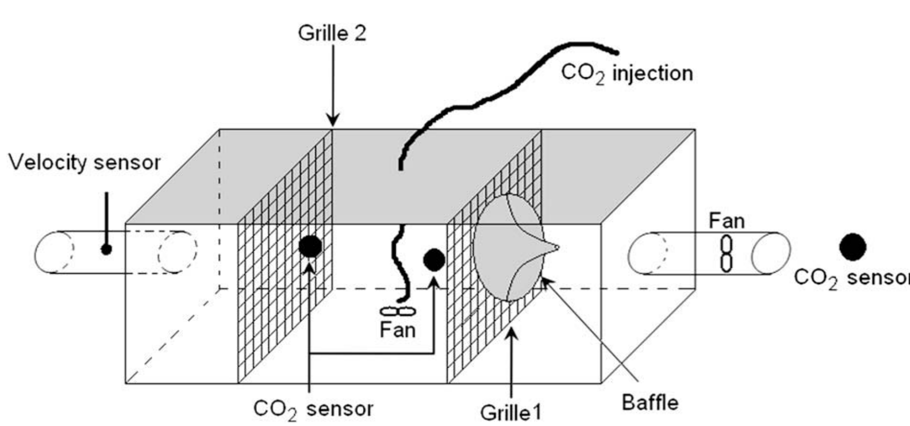

Fig. 2. Scale model apparatus.