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Effect of internal partitions on the performance of under floor air supply ventilation in a typical office environment

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ABSTRACT

This paper presents a case to investigate the effect of partitions in an office on the performance of under floor air supply ventilation system via computational fluid dynamics. The assessment is in terms of thermal comfort and indoor air quality with the use of a validated computer model. The results indicate that the partitions may significantly affect airflow and performance of a under floor air supply ventilation system. In particular, the presence of a gap above the partition wall is able to improve air distribution owing to less air re-circulation in the upper zone. Its effect on thermal comfort and indoor air quality indicators are evaluated.

1. Introduction

The use of mechanical ventilation in buildings has become increasingly inevitable as the average size of buildings increases. The conventional design uses the mixing ventilation (MV) system, with the supply inlets and the exhaust outlets commonly located at the ceiling level. In the last 30 years, displacement ventilation became increasingly popular as an alternative with the supply inlets located at or near the floor. The displacement system was initially pioneered in Scandinavia for industrial applications [1]. This system is more complicated and its performance is affected by many room design factors, such as air supply velocity, air temperature, cooling load and room height. A thorough discussion on the effect of these variables was given by Yuan et al. [2]. They concluded that internal partitioning considerably affects the performance of an under floor air supply ventilation system.

In modern office environment, internal partitions are often used to divide office space. The effect of these partitions on airflow and ventilation systems is often a subject of interest. Cao and He [3] found that cross ventilation could be significantly affected by the position of internal partitions. However, as compared to traditional full solid wall partitions, the use of floor-to-false-ceiling internal low partitions is able to improve airflow distribution and hence thermal comfort.

Full-scale model tests were conducted by Bauman et al. [4] to study the various effects of office partitions on air movement and thermal comfort in separate office spaces. The investigation was based on conventional MV mode. They found that the height of internal partitions had insignificant effect on thermal comfort. This was also true for the partitions with gaps at the bottom end. Partitions were also the focus of a series of experiments conducted by Chow and Tsui [5] to study the airflow characteristics of ventilated spaces. They studied both the optimal height of partitions to produce separate ventilation conditions for segregated work-spaces. Both sidewall and ceiling diffusers were investigated.

Recently Lee and Awbi [6] looked into partitioning of office spaces for MV system. Indoor air quality was evaluated by changing various partition parameters, including the location and geometry relative to the contaminant source.

The above studies clearly showed the importance of partitions in ventilation performance. However, it was also clear that all the above studies focused purely on MV. The flow patterns of displacement mode and mixing mode are known to be very different. A thorough literature review by the authors of this paper revealed that so far no study had delved into under floor air supply ventilation with partitions. The effect of partitions on under floor air supply ventilation performance is not deducible based on existing literature. The current study is therefore justified.

2. Numerical modeling

2.1. Validation of CFD model

The two main approaches in studying pollutant dispersion and indoor airflow are experimental tests and CFD studies. In this

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study, a validated RNG $k-\varepsilon$ model based on the commercial program of CFX is used to perform the analysis [7]. The movement of air may be predicted from the solution of the discretized mass, momentum and energy equations. For offices, shops and classrooms, this model has been tested extensively under the conditions of MV, displacement ventilation and stratum ventilation [8,9], Relevant contents are recapitulated to demonstrated the validity of the model to this study:

The experimental data reported by Yuan et al. [10] were used to validate the CFD model. Validation was conducted by comparing the flow patterns, vertical profiles of temperature, concentration, velocity, and turbulence intensity between measurement and computation for an individual office and a section of a large office. The configuration and specification of both cases are shown in Fig. 1 and Table 1, respectively.

2.1.1. Individual office

Figs. 2–4 present, respectively, measured (markers) and computed (lines) temperature, SF_6 concentration and velocity in the office. The horizontal axes are dimensionless elevation normalized by room height ($Z = 0$ is the floor and $Z = 1$ is the ceiling). The vertical axes are dimensionless measured parameters.

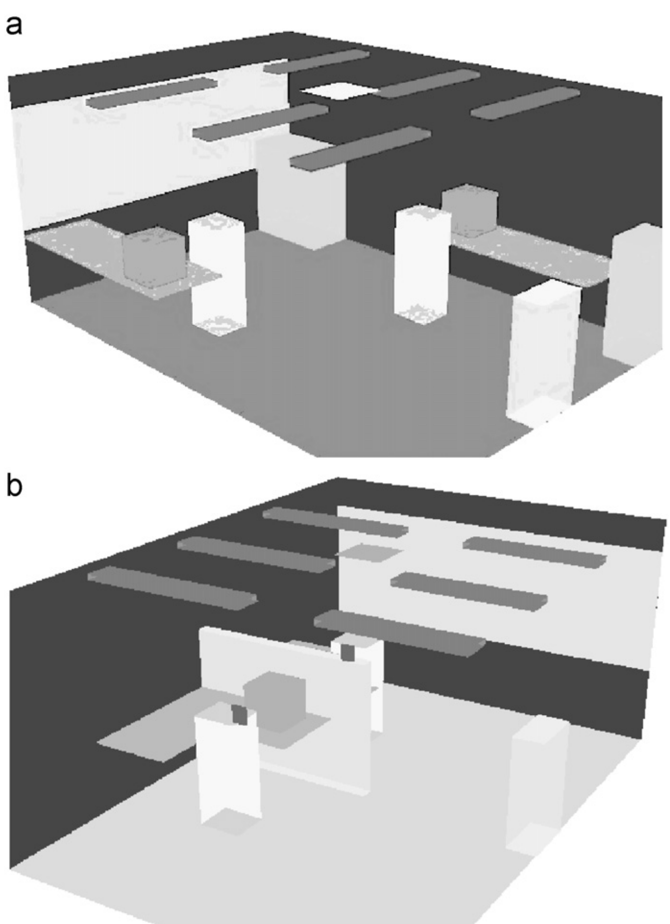

Fig. 1. Space layouts: (a) individual office and (b) section of large office.

Fig. 2 clearly shows that the displacement ventilation system created temperature stratification. The temperature gradient in the lower part of the office is much larger than the one in the upper part, because most heat sources (occupants and computers) are located in the lower part of the room. Since occupants stay in the lower part of the room, the temperature stratification represents a potential risk of draft. One important criterion in design of displacement ventilation system is to ensure the temperature difference is sufficiently small between the head and foot levels. The agreement between the computed temperature and measured data is good.

Fig. 3 shows the tracer-gas concentration profiles in the room. The tracer-gas sources were introduced at the head level of the two occupants. The SF_6 concentration in the occupied zone is much lower than that in the upper zone. The concentration increases rapidly between Z of 0.4 and 0.5, which can be considered as the stratification height. There are discrepancies between the computed concentration profile and the measured data. Since the tracer-gas is a point source and re-circulating flow exists in the upper part of the office, the tracer-gas concentration in the upper part is not uniform and very sensitive to position and boundary conditions. Nevertheless, the accuracy of the computation is acceptable.

Fig. 4 illustrates that the velocity in most of the space, except near the floor, is lower than 0.05 m/s. The magnitude is so low that the hot-sphere anemometers may fail to give accurate results. Nevertheless, the measured velocity is close to that observed through the use of smoke, and the computed results agree well with the data.

Fig. 5 compares the computed and measured age of air in the mid-section of the office. It further shows that the computed age of air is 10% smaller than the measured one. The age of air is younger in the lower part of the office than that in the upper part.

2.1.2. Large office

Figs. 6 and 7 present the computed and measured results for a section of the large office, which are in the same format as those for the individual office. Again, very similar results were obtained as those for the individual office.

2.2. Boundary conditions

The inlet is defined as an opening with a uniform velocity. Outlet boundary conditions are set as the Neumann boundary condition, i.e., mass flow boundaries are specified to ensure that the mass flow rate out of the domain is the same as the mass flow rate into the flow domain [11]. Toluene, formaldehyde and CO_2 concentrations in supply air are calculated based on the mass balance of the air circulation. Constant heat flux conditions are applied for the external walls and windows, respectively. The values of heat flux and air circulation are calculated using "Carrier E20-II Programs" [12]. The heat generated by each occupant determined according to Chapter 29 of ASHRAE Fundamentals

Table 1
Case specifications for experimental measurements

Case	Occupant (number)	Equipment (W/m^2)	Lighting (W/m^2)	Internal load (W/m^2)	Ventilation rate (ACH)
Individual office	2	14.9	10.8	33.7	4
Section of large office	2	14.9	10.8	33.7	8