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Experimental study of the influence of a moving manikin on temperature profile and carbon dioxide distribution under three air distribution methods

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ABSTRACT

The influence of occupants' movements is seldom considered in room air distribution studies. However, sedentary and walking occupants mix in many conditioned rooms, such as in an open plan office. The influence of movements on the room air distribution has been reported. In this paper, series of tests under three air distribution methods (stratum ventilation, displacement ventilation and mixing ventilation) with a moving manikin are conducted. The manikin is moving at speeds of 1.0 m/s and 0.5 m/s, along two moving routes respectively. Velocity, temperature and CO_2 concentration are measured to determine the influence on air distribution. The results show that temperature profile and CO_2 distribution are not influenced significantly by a short-time movement. When the movement lasts for a long time, the moving manikin produces a mixing effect and reduces the ventilation effectiveness. The influence under mixing ventilation is the smallest. The influence under stratum ventilation is smaller than that under displacement ventilation. Stratum ventilation has higher ventilation effectiveness at the occupant's head level than that of the other two air distribution methods. The results show the application potential of stratum ventilation under a condition with frequent movements.

1. Introduction

Nowadays, indoor air quality and energy saving have been taken more seriously in the ventilated room. Many studies have been done and different air distribution methods have been carried out [1,2]. Stratum ventilation, a technically feasible air distribution to accommodate higher room temperature in small or medium rooms, is one of them. Under stratum ventilation, the fresh air is directly sent to the occupant's breathing zone. Therefore, it could provide a better thermal comfort and satisfactory inhaled air quality in the breathing zone with relatively higher room and supply air temperatures [3–5]. As the supply air temperature of stratum ventilation was higher, the temperature of chilled water was higher, which improved the coefficient of performance (COP) of the associated chillers. It contributed to a significant energy saving, 25% and 44% at least when compared with displacement ventilation and mixing ventilation respectively [6]. Considering the different positions and types of contaminant sources, the diffusion of gaseous contaminant under stratum ventilation was smaller than that under displacement ventilation. The contaminant concentration in the breathing zone under stratum ventilation was lower in most of the conditions [7]. The anti-airborne infection performance of stratum ventilation was also better than that under displacement ventilation. The droplet concentration in the breathing zone after a cough is significantly lower than that under displacement ventilation [8].

Although the aforementioned studies show the potential of stratum ventilation, the influence of movements has seldom been dealt with. However, moving can influence the airflow motion in enclosed environments significantly and cause the contaminant transmission risk by the experiment [9]. When a cylinder-shaped manikin did a single movement, it caused laminar horizontal air movements. When it did back-and-forth continuous periodical

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Fig. 1. Test chamber.

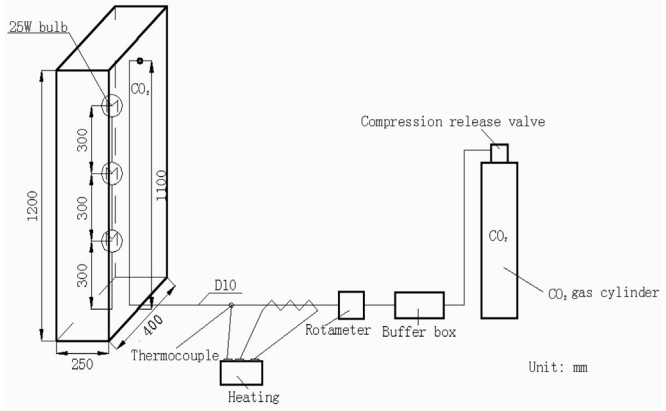

Fig. 2. Configurations of simulated sedentary person and CO_2 releasing system.

movements across the room, it caused a complex turbulent flow field. And the influence on air velocity field caused by movements was irrelevant to the temperature stratification in a room [10]. The shape of manikin could cause some difference, but the qualitative results were the same [11]. Under displacement ventilation, a moving manikin could make the vertical temperature gradient small. Higher moving speed led to a smaller local air exchange index in the occupied zone [12]. Different kinds of movements resulted in different influences under displacement ventilation and mixing ventilation. The effect on local concentration distribution caused by movements under displacement ventilation was more significant than that under mixing ventilation. However, on average, displacement ventilation was still more effective than mixing ventilation [13]. When the influence of movements and human breathing was combined, it was found that the effect on the

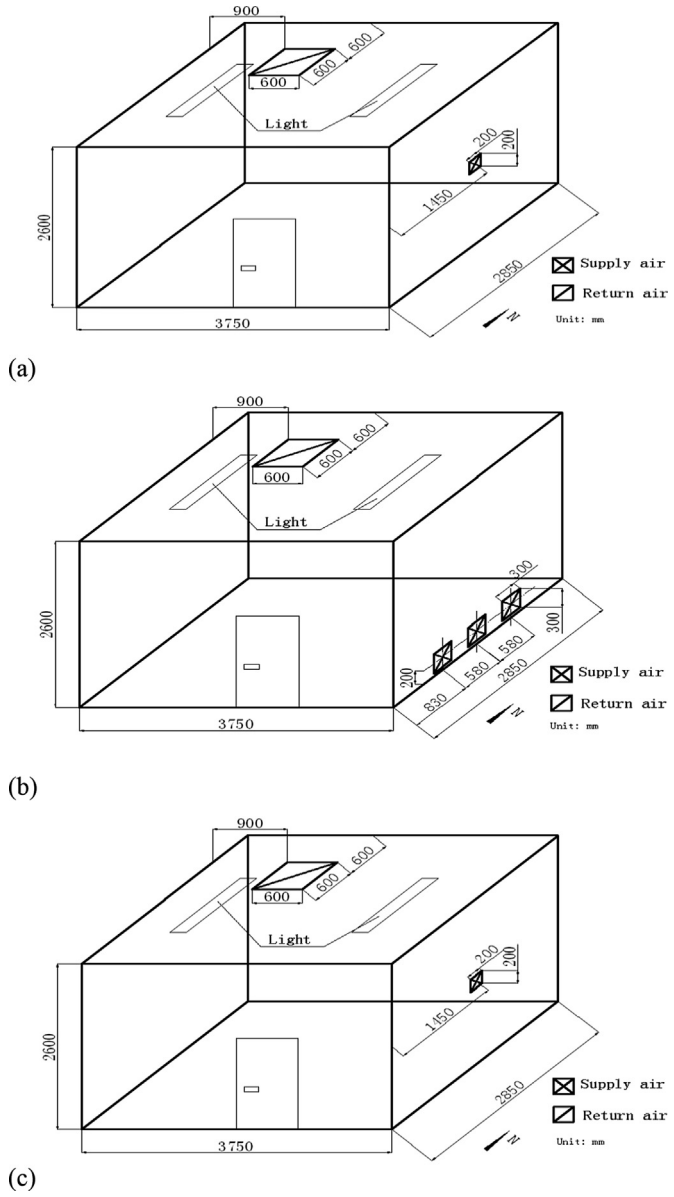

Fig. 3. Layouts of air terminals under (a) stratum ventilation, (b) displacement ventilation and (c) mixing ventilation.

vertical contaminant distribution caused by movements was significant. And the higher the moving speed, the less the stratification was [14]. And some numerical simulation also shows the human walking affects the air distribution in the room [15–20].

In reality, in many air conditioned rooms, there is a mixture of sedentary and walking occupants. More or less, from time to time, the occupants move around, especially for spaces like open plan offices. Therefore, this paper studies the influence of movements on

Table 1
Internal heat sources.

Item	Heat (W)
Sedentary occupant	75
Lights	72 × 2 = 144
Total	219

Table 2
Condition of three ventilation methods.

Ventilation method	Supply air temperature (°C)	Airflow rate (ACH)
Stratum	21	5
Displacement	19	5
Mixing	19	5