EFFECT OF PARTITION LOCATION ON THE AIR AND CONTAMINANT MOVEMENT IN A ROOM

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ABSTRACT

The ventilation engineer's plan at the design stage could be influenced by many factors. It may also be different from the requirements for the final users of the spaces. In case of open-space design, which is getting popular due to its flexibility, it is more difficult to provide adequate ventilation to control the indoor air quality. Specially, when partitioning of the space is employed.

The partition configurations, including the gap height from the floor and the location in the room, and the contaminant source location in the space are the factors concerning this study. Physical model tests were conducted to study the effect of partitioning on the airflow and the contaminant movement in the room. The test conditions were also numerically simulated by using Computerized Fluid Dynamics (CFD).

It was found that the partition location and its gap affect the air distribution in the room, in terms of the room mean age of air, although there is no obvious trend. The contaminant source location also affects the ventilation performance, in terms of the ventilation effectiveness. The results imply that there exist optimal configurations, i.e. the partition location, the gap height, and the contaminant source location, for maximum ventilation performance. If these are correctly applied, the air quality in the space could be improved.

KEY WORDS

CFD; Chamber Study; Mixing Ventilation; Tracer Gas; Ventilation Effectiveness

INTRODUCTION

Recently, Sandberg and Claesson [1] studied the effect of blockage on the air distribution in a room and showed that the blockages could affect the air distribution in their tests. Nielsen et al. [2] investigated the influence of office furniture on the air movement in a room with mixing ventilation, and found that the furniture affected the air movement in the lower part of room, but not in the upper part. Bauman et al. [3] investigated a wide range of partition configurations and environmental parameters to study the comfort and ventilation conditions in workstations. Their conclusions, based on model tests using conventional ceiling supply and return ventilation system, were that the effect of office partitions on the air circulation or ventilation efficiency was insignificant. Halliwell et al. [4] studied the effect of partition numerically using CFD and concluded that introducing a partition into a room created a highly polluted zone.

Lee and Awbi [5] have studied the effect of interior partitions on the air movement in a room with mixing ventilation. The height of partition and the gap between the partition and the floor were tested experimentally and numerically using CFD. They found that the interior partition could affect the airflow and the contaminant movement and implied the existence of an optimal gap height for contaminant movement control between the supply and exhaust zones. The potential of energy reduction by improving ventilation effectiveness was also reported [6].

In this study, interior partitioning, as the main interior structure separating two zones, is investigated by conducting scale-model tests and CFD simulations. The effect of partition configuration on the airflow and contaminant movement, including its location in the room and the gap between the partition and the floor, has been examined. The effect of contaminant source location (CSL) is also investigated. The concept of ventilation effectiveness and age of air are used to evaluate these effects.

MODEL TESTS AND CFD SIMULATIONS

The location of an interior partition and its gap between the floor in a model room were varied to study their effect on the airflow and the contaminant movement in the model room. Figure 1 shows the experimental setup used in the model tests. A scale-model, 1.6^{m} (L) x 0.8^{m} (W) x 0.7^{m} (H), has been used with a supply and an exhaust ceiling-mounted openings for ventilation. A variable-speed axial fan supplied the airflow into the model room. A Multichannel Flow Analyzer, Dantec Model 54G301 and 54N10, was used to measure the velocity at the supply opening to achieve the desired airflow rate. A partition height, 70% of the room height, was placed in the middle (0.5L) and moved towards the supply zone (0.4L) and the exhaust zone (0.6L). Three different gap heights, 0%, 5%, and 10% of model height (H), were tested simultaneously.

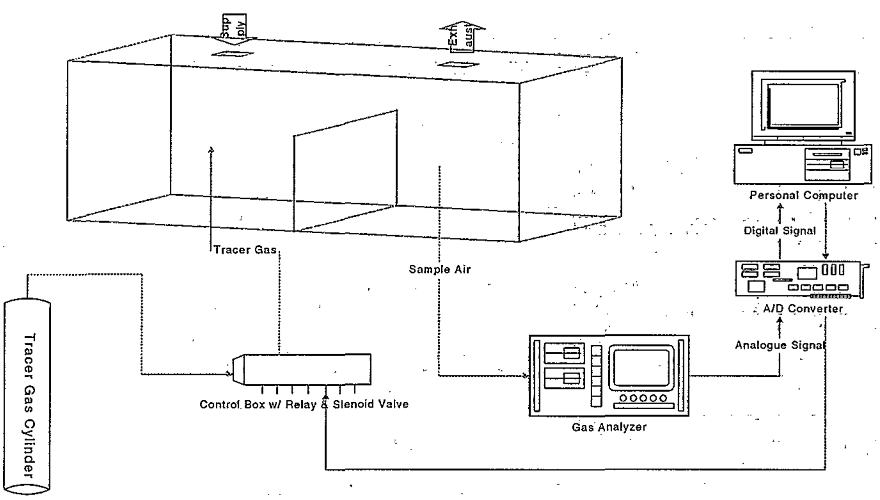

Figure 1. Experimental setup for model tests.

The tracer gas, 0.5% of CO_2, was injected as a pulse into the supply air. The two positions of the tracer injection were at the centerline of the supply and the exhaust openings, i.e. 0.5H under the supply and 0.5H under the exhaust. The data acquisition system (DAS) which has an analogue-to-digital converter, Humusoft Model AD-512, and the control box controlled the injection of tracer gas. A CO_2 analyzer, ADC SB-421, sampled and read the tracer gas concentration at the exhaust opening as the room reference concentration. The signal was read by the DAS at 1Hz sampling rate which was tested and reported in previous work [7]. Matlab, Mathworks Version 5.2.0.3084, was used to control the test procedure and to analyze the results. Further details of the test procedure can be found in Reference [7]. The test conditions in the model room were also simulated using the CFD, VORTEX [8].

RESULTS AND DISCUSSION

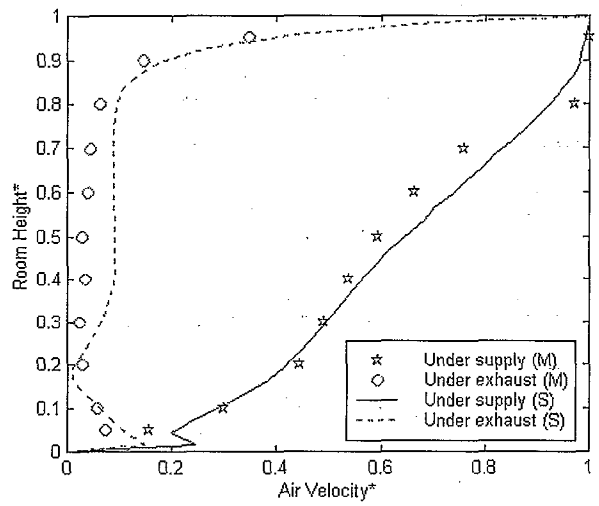

Figure 2. Comparison of measured and simulated air velocity under the supply and exhaust openings in Figure 1. (Note: M=measured, S=simulated)

Model tests and CFD simulations were carried out to study the effect of partition location and the gap between the partition and the floor. The effect of contaminant source location on the contaminant concentration within the model is also investigated. Figure 2 shows a comparison between the normalized measured and simulated air velocities in the model room without partition. There is a good agreement between the results for the supply air jet, although some discrepancy exist in the results for the exhaust zone. The discrepancy between measured and simulated velocities, however, could be due to the low velocities in the exhaust zone which are difficult to measure accurately. Figure 3 summarizes the results of the model tests for the effect of partition location and the partition gap with the source location under the supply opening. The 1st column shows the effect of partition location on the ventilation effectiveness, which is defined by Equation (1), for different partition gap. The x-axis is the normalized distance from the supply zone (*x/L*) which is the left-hand side of the test room in Figure 1. The 2nd column shows the effect of gap height for different partition locations.

$$\varepsilon_{out} = \frac{\textit{Ventilation Rate Measured at Exhaust}}{\textit{Air Supply Rate}} \qquad (1)$$

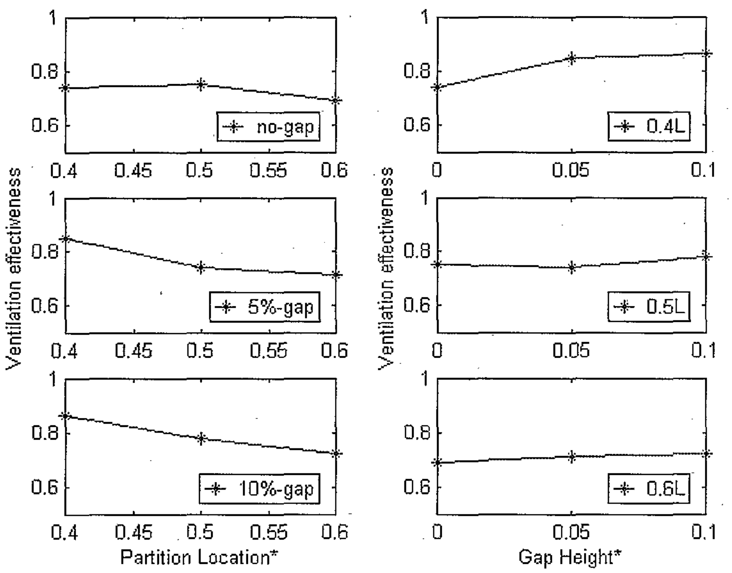

Figure 3. Effect of partition on ventilation effectiveness due to different partition location and its gap underneath. The CSL is located under the supply.

Moving the partition toward the exhaust zone decreases the ventilation effectiveness because it changes the airflow structure which are shown in Figure 4. The presence of contaminant source in the exhaust zone achieves higher ventilation effectiveness overall. This is substantiated by the simulated resulted shown in Figure 4.

The results obtained from the CFD simulations with the partition located in the middle of the room, 50% L, are shown in Figure 4. The arrows show the resultants of the calculated velocity vectors and the gray fill

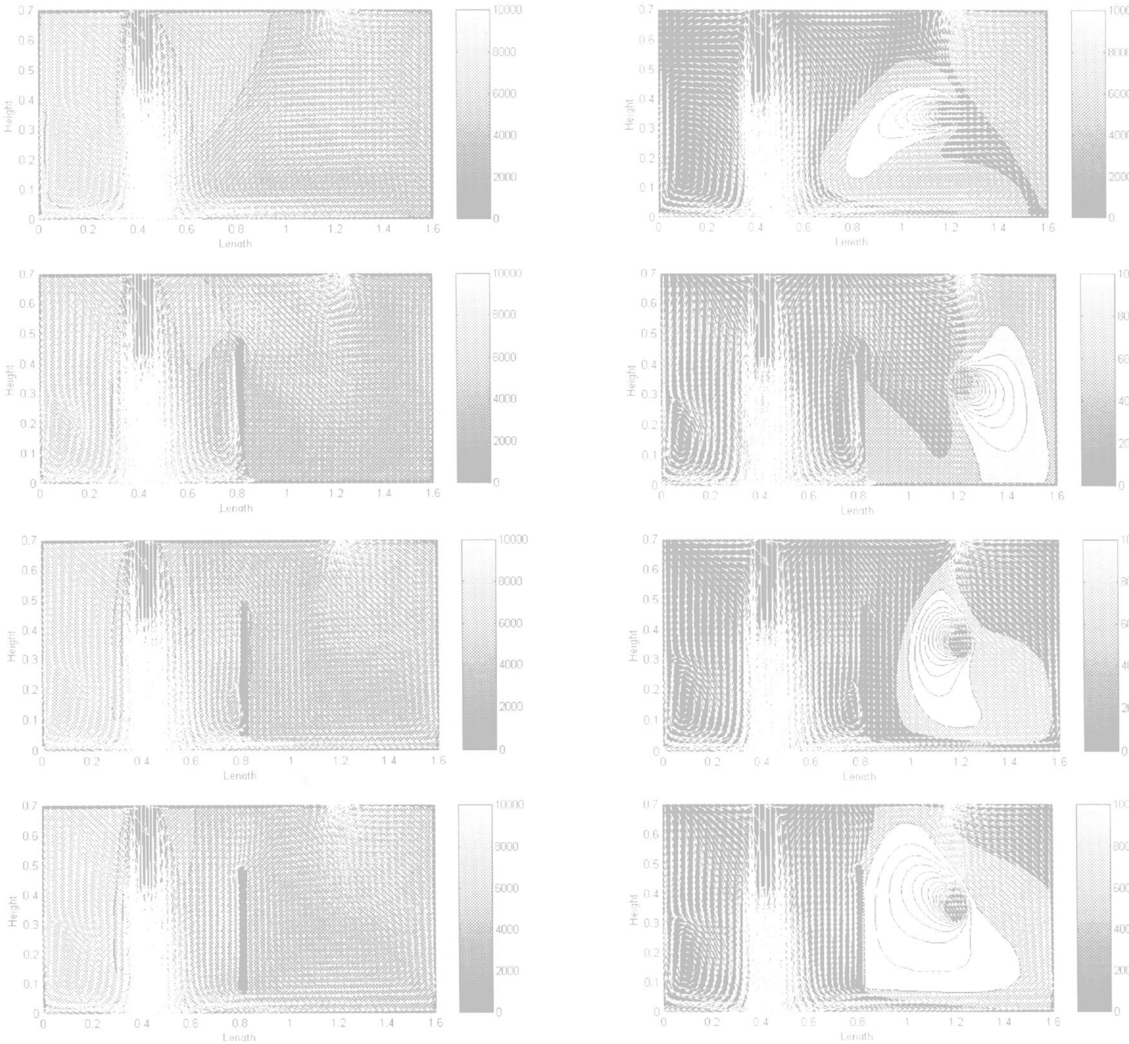

Figure 4. Effect of partition on contaminant movement due to different source location and partition gap. (Note: the 1st column for CSL at 0.5H in supply zone, the 2nd column for CSL at 0.5H in exhaust zone; 1st row for no-partition, 2nd row for no-gap, 3rd row for 5%-partition, and 4th row for 10%-partition.)

shows the concentration.

The contaminant source was placed at 0.5H under the supply opening and then at 0.5H under the exhaust opening to study the effect of source location on the contaminant movement. The plots in the 1st column are for the contaminant source location under the air supply, and the plots in the 2nd column are for the source location under the exhaust opening of the room. The effect of partition configuration on the contaminant movement is insignificant for the case of the CSL under the supply. This is because the generated contaminant is mixed with the supplied air before the partition changes the airflow pattern. However the effect of partition becomes more significant for the cases of the CSL under the exhaust. For the same airflow of the plots in the 1st column, the generated contaminant is transported in different pattern. The direction of airflow in the exhaust zone is completely changed by the presence of partition. The partition gap also has significant effect on the airflow and affects the contaminant movement significantly. This implies the existence of optimal configuration of the interior partition, as has been reported by the author's [5].

Table 1 and 2 summarize the results of the CFD simulations. The local mean age of air indicates the time required for the supply air to reach a point in the room and a low value is

$$\varepsilon_{room} = \frac{C_{room} - C_{in}}{C_{exhaust} - C_{in}} \times 100[\%] \qquad (2)$$

more desirable [9]. The ventilation effectiveness, defined by Equation (2), indicates the degree of contaminant removal by ventilation, and a high value is desirable.

Table 1. Effect of partition location and its gap on the mean age of air in the model computed and normalized with the value at the exhaust opening. (Note: the location indicates the distance from the side-wall in the supply zone to the opposite wall in exhaust zone.)

Gap / Location	No-gap	5% H	10% H
0% L	0.8910	-	-
40% L	0.8445	0.8739	0.8808
50% L	0.9115	0.8304	0.8563
60% L	0.9672	0.9076	0.8440

Table 2. Effect of partition location and its gap on the computed ventilation effectiveness in the model. (Note: the location indicates the distance from the side-wall with supply zone to the other in exhaust zone.)

Gap	No-gap		5% H		10% H	
Location	Supply CSL	Exhaust CSL	Supply CSL	Exhaust CSL	Supply CSL	Exhaust CSL
0% L	111.3	156.1	-	-	-	-
40% L	119.5	215.3	114.7	130.2	119.5	156.8
50% L	120.2	141.9	116.6	170.6	116.9	146.6
60% L	117.3	174.3	118.3	181.0	115.8	174.1

The results in Table 1 show the effect of the partition on the mean age of air for the room. The presence of a partition changes the mean age and this increases as the partition moves towards the exhaust zone which is clearly un-desirable. In the case of a partition with 10%-gap, however, the movement towards the exhaust zone decreases the mean age, which is an improvement of the ventilation performance. For a particular location of the partition in the room, the gap height improves the computed mean age of air, although no significant relationship of the effect of the gap can be deduced.

The results in Table 2 show the effect of partition for the two CSL's on the ventilation effectiveness as defined by Equation (2). The CSL under the exhaust is more desirable as it achieves higher ventilation effectiveness for the space as a whole. The ventilation effectiveness results in Table 2 have a similar trend to those for the mean age of air shown in Table 1. However, by moving the source location, an improvement in the ventilation performance can also be expected [10]. For instance, the case for the partition with 5%-gap, located in the middle of the room (50%L), gives the best results when considering both ventilation performance parameters.

CONCLUSIONS

There is a correlation between the results of the model tests and the CFD simulations. The following conclusions can be made from this study.

- The measured velocities in the model room are well correlated with the CFD results.
- The partition location in the room, the partition gap and the source location can individually influence the ventilation performance.
- The effect of partition on the airflow in the room has no obvious trend, although there are clear effects of partition on the air movement. For example, the results with 60%L show that a greater gap height improves the room mean age of air, i.e. the air distribution index.
- The contaminant source location has been shown to influence the ventilation effectiveness. In general, the source location within the exhaust zone is beneficial in achieving better ventilation performance. This implies that the ventilation performance could be improved by re-locating the source within the same airflow field, even with the presence of the same partition.

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