EFFECT OF INTERIOR PARTITIONS ON THE AIR MOVEMENT AND AIR QUALITY IN A ROOM WITH MIXING VENTILATION

Heekwan Lee¹ and Hazim B. Awbi²

The University of Reading, Reading, UK
¹ heekwan.lee@rdg.ac.uk
² h.b.awbi@rdg.ac.uk

ABSTRACT
Working spaces in modern buildings are easily formed by interior partitions because these buildings have been designed and constructed as open spaces for flexibility. This could lead to an indoor environment which might be different from the intended design.

In this study, the effect of partition on the indoor air quality in a model room has been investigated with different configurations such as the height of partition and the gap between partition and floor. A small-scale model room with a data acquisition system has been used to monitor the tracer gas concentration with different test conditions in mixing ventilation. In addition, CFD simulations, using Vortex-2, have been carried out for the same conditions as for the model experiments. It is found that the height of partition influences the ventilation effectiveness in the model room. However, the gap under the partition has more significant effect than the partition height.

KEYWORDS
Ventilation Effectiveness, Indoor Air Movement, Mixing Ventilation, Tracer Gas, Model Experiments.

INTRODUCTION
Modern offices are normally designed as open spaces for flexibility, and divided by various interior partitions for practical usage that may be different for different users. The air distribution systems for such spaces are often designed without consideration for the effect of such partitions on the air movement, temperature and contaminant distribution in the space. In practice, this could lead to an indoor environment that is quite different from the original design specifications.

Many studies investigating the effect of partition have been carried out for different ventilation systems. Nguyen (1990) and Cao (1994) have investigated the effect of partition with natural ventilation system and found that the partition configuration can affect the interior airflow distribution.

Other studies (Shaw et al. 1992, 1993 a, b; Ziang et al., 1993, 1997; Haghighat et al., 1996) dealt with workstations, with many partitions, in displacement ventilation. Besides the partition configuration and the workstation arrangement, other environmental parameters have been tested and their effects were discussed. It has been concluded that, in general, the partition has an influence on the air movement but that was minimal in the case of workstations.

Using numerical simulation, Plett et al. (1993) studied the effect of partition on the air movement with mixing ventilation. Kolokotroni et al. (1995) studied the application of space partitioning to minimize the migration of tobacco smoke.
In this study, a small-scale model has been used for conducting physical and numerical experiments using CFD. The effect of partition configuration, such as its height and the gap between the partition and floor, has been examined by using tracer gas techniques. The ventilation effectiveness is introduced to evaluate the effect of partition on the air quality in the space.

**METHOD**

To investigate the effect of partition under controlled environment, a small-scale model room has been constructed and tested experimentally and numerically. The effects of different partition configurations on the air movement and contaminant distribution have been assessed by using a tracer gas technique and that is expressed in terms of local ventilation effectiveness, $\varepsilon_{\text{local}}$, which is defined as the ratio of local ventilation rate to room ventilation rate as follows:

$$
\varepsilon_{\text{local}} = \frac{\text{Local Vent Rate}}{\text{Room Vent Rate}} \times 100[\%] \quad (1)
$$

Figure 1 shows the model experiment system which includes the model room, a tracer gas, a controller, a gas analyzer, and a data acquisition system (DAS) with an analogue-to-digital converter, AD512, Humusoft, Czech Republic. The room, 1.6m x 0.8m x 0.7m H, has ceiling-mounted supply and exhaust openings. An axial fan with a speed controller supplies ventilation air. The partition has been placed in the middle of the box and the heights used were 50%, 60%, 70%, and 80% of the room height. In the model experiments, the gap between the partition and floor was 10% of the room height. Mixing ventilation system has been used in this study.

The tracer gas (CO$_2$) source was placed under the supply opening at mid-height. During tests, the contaminant source location (CSL) has been kept at the same position and the duration of CO$_2$ injection, 5min, was controlled by the DAS. The CO$_2$ gas analyzer, SB-421, ADC, UK, using non-dispersive infrared method (NDIR), was used for monitoring.
Considering mass conservation on a control volume in indoor space in Figure 2 gives the equation as follow:

\[ Q_{\text{out}} C_{\text{out}} + S dt - Q_{\text{in}} C_{\text{in}} = V d C_{\text{in}} \]  

where

- \( Q_{\text{out}} \) = ventilation rate supplied into control volume, m\(^3\)/sec
- \( C_{\text{out}} \) = contaminant concentration in supply air, mg/m\(^3\)
- \( t \) = time, sec
- \( S \) = intensity of tracer gas generation, mg/sec
- \( Q_{\text{in}} \) = ventilation rate leaving control volume, m\(^3\)/sec
- \( C_{\text{in}} \) = contaminant concentration of the air leaving, mg/m\(^3\)
- \( V \) = control volume, m\(^3\)

Equation (2) is rewritten as Equation (3) in terms of time, \( t \). The time-serial tracer gas measurement at a certain point in the model room can be used to obtain the local ventilation rate at the point as follows:

\[ Q_{\text{local}} = - \frac{V}{t} \ln \left( \frac{C(t) - C_{\text{out}}}{C(0) - C_{\text{out}}} \right) \]  

Figure 2 Mass conservation on a control volume in indoor space.

VORTEX-2, which is a CFD code developed for airflow, heat transfer and concentration of species predictions in buildings, has been used to simulate the experiments numerically (Awbi, 1996).

In order to correlate the physical experiment with the numerical simulation, two low velocity transducers, 54R01, Dantec, Denmark, measured the air velocities under the supply and exhaust openings. All of the measurements and the simulations were carried out under isothermal conditions.

RESULTS AND DISCUSSION

The effect of partition on the air movement and tracer gas distribution was investigated experimentally and numerically using CFD.

Figure 3 Comparison of measured and simulated velocities at the centerline of the supply and exhaust openings.

Figure 3 shows the correlation between the velocity measurement in the model and the results from the CFD simulation. The velocity on the x-axis is normalized by the velocity at the supply jet and the height on the y-axis is normalized.
by the room height. The measured velocities are the resultant values from omni-directional velocity sensors used. Similarly the CFD velocity represents the resultant velocity. The agreement between the measurement and the simulation in the lower and upper zones of the model is good, although some discrepancy exists in the middle. Under the air supply zone, the supply air velocity decreases linearly until the jet impinges onto the floor. Along the centerline of the exhaust opening, the velocity away from the opening is very low until the exhaust opening is reached. Figure 4 is a 2-D vector plot of a airflow simulation in the model room under the same conditions as for Figure 3. The supply air jet hits floor and then it spread over the floor. In the exhaust side of the room, there is a reverse flow in the horizontal direction towards supply side.
In Figure 5, the ventilation effectiveness at two points along the centerline of the exhaust is shown for 10%-gap and no-gap at the partition. One point is located at the exhaust which is a reference for the whole room, and the other is at the mid-height of the model under the exhaust. The x-axis is the partition height in the room (Note: 0% means no partition). The local ventilation effectiveness on the y-axis is defined as in Equation (1).

For the condition without partition, $\varepsilon_{local}$ at exhaust is lower than that at the mid-height, which means that the ventilation rate at the exhaust is lower than that at mid-height. The results without partition gap indicate that the higher the partition, the bigger the difference in ventilation effectiveness between the two points. At exhaust, the effectiveness increases with the partition height and shows the maximum effect at 70% height. At mid-height, the effectiveness for 70% and 80% height is much lower than those for 50% and 60%, which implies quite different mixing in the exhaust zone with different partition height. The difference in the ventilation effectiveness disappears when 10%-gap is added to the partition.

A Vortex-2 simulation result in Figure 6 explains this phenomenon. There is not much difference in the supply zone between Figure 4 and Figure 6. In the exhaust zone, however, the partition creates a large stagnant area. It also shows that most of the supply air passes through the gap under the partition, rather than goes over the partition. In this case the partition height has small effect on the air movement in the model room.

Figure 6 CFD simulation for 70% partition height with 10%-gap.
Figure 7 Effect of partition on room ventilation effectiveness (CFD simulation).

Figure 7 shows the results of the partition effect from CFD simulations. The x-axis is the same as that for Figure 5, but the y-axis represents the room ventilation effectiveness defined as:

$$\varepsilon_{\text{room}} = \frac{C_{\text{ex}} - C_{\text{in}}}{C_{\text{room}} - C_{\text{in}}} \times 100 \, \%$$

(4)

where

- $C_{\text{ex}}$ = concentration at the exhaust opening, ppm
- $C_{\text{in}}$ = concentration at the supply opening, ppm
- $C_{\text{room}}$ = mean concentration in the room, ppm

The room ventilation effectiveness increases with partition height for the cases without gap and with 10% gap. For the case of partition without gap, it shows a similar trend to the local ventilation effectiveness from physical experiment at exhaust; although the effectiveness is still increasing with 80% partition height.

With 10%-gap at the partition, the ventilation effectiveness is lower than that for the case without partition gap. The CFD predictions show a drop in the effectiveness at 70% partition height with the presence of 10%-gap.

Finally to investigate the effect of gap height on ventilation effectiveness, which is given previously in Figure 5 and Figure 7, different gap heights between 0% and 10% were simulated. The result shown in Figure 8 reveals that 4%-gap gives the highest ventilation effectiveness. These results imply that the ventilation effectiveness can be improved by selecting different gap height.

Figure 8 Effect of gap height on ventilation effectiveness for the case of 70% partition height.

CONCLUSION

This paper shows that a room partition and its configuration such as the height and the gap at the base has a major influence on the air movement and air contaminant distribution in a model room ventilated by mixing ventilation. In this study, two definitions of ventilation effectiveness have been used; one for the experimental data and the other for numerical simulation data.

The major conclusions from this work are as follows:
- With partition in the model room, the ventilation effectiveness at mid-height under the exhaust is higher than at the
exhaust opening, which is the reference for the room. It implies that the mid-height point does not perceive the ventilation air as much as the exhaust. Due to the mixing of ventilation air and contaminant, it is expected that the local ventilation effectiveness in a room with a partition will be dependent on the location.

- The effect of partition without a gap is such that the local ventilation effectiveness at the exhaust increases with the partition height peaking at 70% height. The effectiveness at mid-height is low compared with that at exhaust. In addition, this gets worse as the partition height increases, peaking at about 70%~80% partition height.
- The effect of gap is such that the 10%-gap diminishes the effect of partition on the ventilation effectiveness without partition because the gap at the partition lets most of the ventilation air pass through with the contaminant, as in Figure 6. This means that the gap has more significant influence on the air movement than the height of partition.
- The CFD simulations show similar effect of the partition on the ventilation effectiveness as the measurement results, although some difference exists in the case of 10%-gap. These results show that the partition gap affects the ventilation effectiveness negatively. This is due to the difference in the definition of ventilation effectiveness in each case.
- The results for 70% partition height with different gap heights show a peak effectiveness at 4%-gap and implies that improvement in ventilation effectiveness can be achieved by changing the gap height under the partition.

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**REFERENCES**


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