ANALYSIS OF THERMAL ENVIRONMENT NEAR WINDOWS USING AIR BARRIER TECHNIQUE

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ABSTRACT

The air barrier technique is to apply the special airflow through window fan to improve the thermal environment near the windows in winter and summer, and especially in winter, to simplify the air conditioning system of perimeter zone of office building and avoid condensation on the surface of window. By using numerical simulation, the paper analyzed the thermal environment of the office building, both applied the air barrier technique or not. The paper also compared the two different methods in winter and summer respectably. According to the results, we may obtain the key control strategy of this technology. It can be validated that the air barrier technique, instead of heating-supply in the perimeter zone of office building, can simplify the machine plant and the duct system of air conditioning. It can also be concluded that, by using the air barrier system, condensation symptom in winter can be avoided and the thermal environment near the windows is improved.

KEYWORDS

Air barrier technology, thermal environment, Numerical simulation, PMV

INTRODUCTION

"Glass building" not only have advantages for the user, such as improving the work environment and making effective use of the outside light, but also popular from a design point of view. Generally, there are 3 types of air-conditioning systems for the perimeters of buildings: a fan coil system that blows up hot or cold air between the glass and the blind, an air-flow window system that uses double-layered windows and sucks out the air between them from the top and air barrier system that creates the air flow between the glass and the blinds (by either blowing air up from the bottom and sucking it out at the top, or the reverse) (Takenaka Corporation, 2000).The Air barrier system has attracted the designers in recent years for its unique potential application in improvement of thermal environment, low cost and energy saving (Furukawa, Koori, 2000).

Air barrier technique can be used in various forms (Huang 2005; Fan 1997).This paper introduces one of the systems as shown in Figure 1. A fan is located inside the windowsill and an exhaust fan is installed in the ceiling above the window. These two parts compose an air barrier. In winter, the fan, which located inside the windowsill with heating coil (or electric heater), supplies hot airflow to decrease the load of surroundings of the building and to avoid condensation on cold glass surface in winter by controlling the supply air parameters.

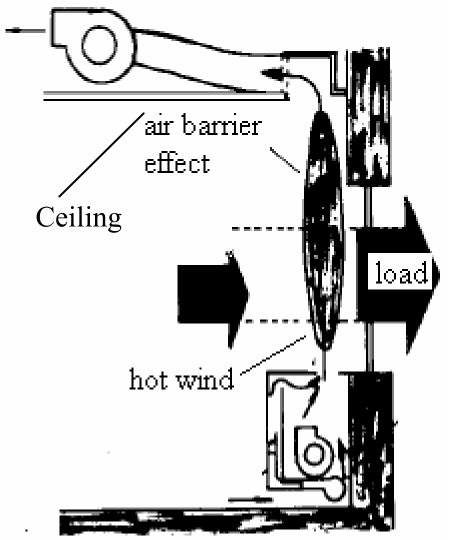

Figure 1 Air barrier system

This paper chiefly concerns the indoor thermal environment near the windows from the aspect of

Table 1 Building structure, supply and exhaust air parameters for Figure.2

ITEM	**MATERIAL**	**HEAT TRAN COFFIENT/** W/(m^2·K)	**THICKNESS**/ mm	**AREA**/m^2
Surrounding structure	Glass window	1.8	19	2×2.55
	Wall	2.05	400	0.5×2.8
ITEM	**AIR VOLUME** m^3/h	**AIR INLET AREA/** m^2	**TEMPERATURE/** ℃	**Remark**
Supply air	900	0.14×2	23	
Exhaust air	330	—	—	

Table 2 Supply and exhaust air parameters for Figure.3

ITEM	**AIR VOLUME** /m^3/h	**SUPPLY OPENING AREA**/m^2	**EXHAUST AREA**/m^2	**SUPPLY TEMPERATURE**/℃
Supply air	300	0.02×2	0.19×2	25
Exhaust air	330	—	0.15×2	—

Table 3 supply and exhaust air parameters in summer condition

ITEM	**AIR VOLUME** /m^3/h	**TEMPERATURE**/℃	**HUMIDITY**/g/kg	**AREA**/m^2 (free air ratio is 0.5)
Supply opening 1	900	16.2℃	9.9g/kg	2×0.14
Supply opening 2,3	160	16.2℃	9.9g/kg	0.6×0.07
Recycle opening	300	—	—	2×0.02
Exhaust	330	—	—	2×0.15

All models have the same building structure PMV, temperature and velocity distribution of the area near windows. By using the software Airpak, this paper compared the indoor thermal environment of the office which created by air barrier system and center air-conditioning system.

THE THERMAL ENVIRONMENT OF OFFICE ROOM IN WINTER CONDITION

Object

Taking one cell of the office perimeter zone as the standard room the paper study, its size is 5.2m×3.0m×2.8m. Consider the hall as the outside environment and there is a zero-pressure opening between the standard cell and the hall. The designed indoor temperature is 22℃, relative humidity is 40% and the paper set it as a constant. The outdoor temperature is given as -4℃. The supply air temperature is determined according to the energy balance between the supply airflow and the load of the building. Figure 2 and Figure 3 have shown the models of different air distribution and the building structure data and supply air parameters are listed in Table 1 and Table 2, respectively.

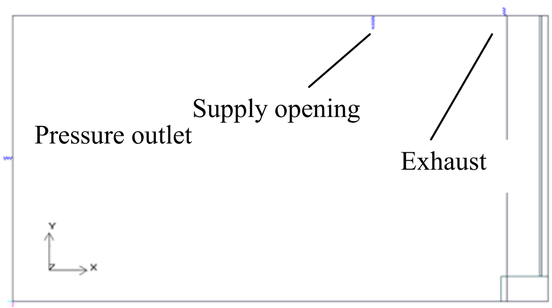

Figure 2 Office model without air barrier

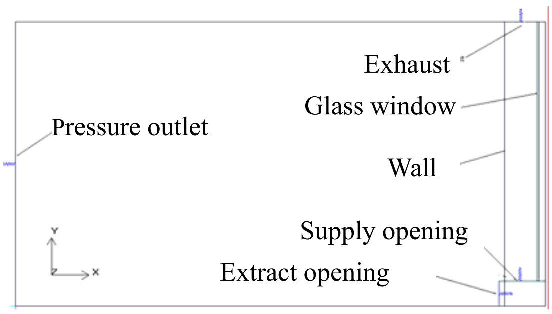

Figure 3 Office model with air barrier

Solution

By using numerical simulation software Airpak, we simulated the environment of window side area. In the calculation, the third kind of boundary condition and the RNG k-ε model were used. For when we take condensation problem into account, we should study the surface temperature of the windows, then heat transfer between indoor and outdoor air becomes an important factor. Also, the RNG k-ε model is more suitable for this calculation because the RNG theory provides an analytically-derived differential formula for effective viscosity that accounts for low-Reynolds-number while the standard k-ε model is a high-Reynolds-number model.

The grid of the objects is well defined. The paper also refined the boundary layer to obtain more accurate results. The number of the total grid is 194778 and 192381 with and without air barrier technology respectively.

Results

In this section, we take the lengthways and middle cut plane(Z = 1.5m) of the room as the study objective.

- PMV Distribution

As is well known, PMV is an important index when we judge the indoor thermal environment. The value range from -3~3 which “-3”means cold, “3” means hot and “0”means comfort. It is mainly influenced by 6 factors: air temperature, relative humidity, air velocity, radiation temperature, clothing value and metabolic rate. The first four factors can be calculated by the software, and the clothing value and metabolic rate are 1.3clo and 1.2 met respectively based on the routine clothing in office.

Figure 4 and Figure 5 shows the PMV distribution of the office without and with air barrier technology.

It can be seen obviously that with no air barrier technology, the PMV distribution is nonuniform, the PMV index of the room is between -0.3~0 in most part, only few parts of the room can reach the value of 0.But with air barrier technology, the PMV distribution is equally, the value is vary from -0.15 to 0.03, the PMV in most part of the room is more closer to the comfort index “0”, and the environment of window side has been improved.

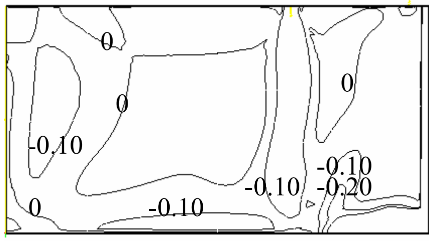

Figure 4 PMV distribution without air barrier

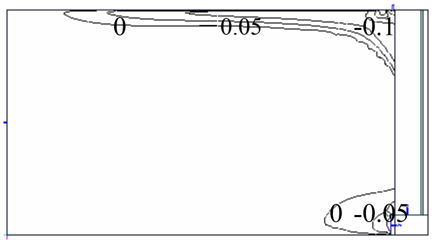

Figure 5 PMV distribution with air barrier

- Velocity Distribution

From Figure 6 and Figure 7 we can find the differences of the indoor airflow in different conditions (with air barrier technology or not).

In Figure 6, there exists reverse flow from the hall to the cell. The distribution of velocity is not uniform enough. The velocity is high than 0.3m/s and it also has visible downdraft along the window surface which may cause discomfort.

In Figure 7, there is no reverse flow in the joint of the hall and cell, the distribution of velocity is highly equal, the average velocity in occupancy area is 0.07 m/s, and the environment of the window side area is more comfortable. By the way, there will be other supply air opening to make the velocity higher than 0.07 m/s in real situation which may create a comfort environment.

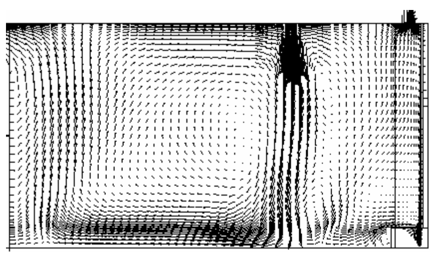

Figure 6 Velocity distribution without air barrier

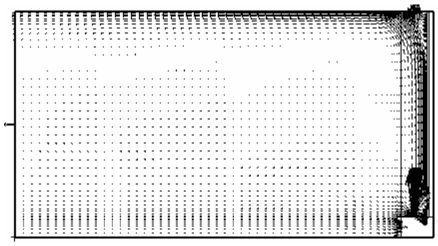

Figure 7 Velocity distribution with air barrier

- Temperature Distribution

Figure 8 and Figure 9 describe the temperature distribution of the office formed by two different airflow patterns (with air barrier technology or not).

In Figure 8, temperature of the window side area changes obviously due to the cold radiation of the window. The temperature of the left part of the room is less than 22℃, it cannot meet the design requirement.

In Figure 9, most parts of the office have the same temperature of 22℃, thanks to the air barrier technology.

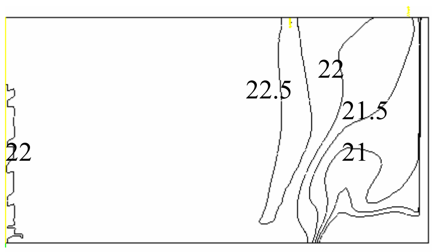

Figure 8 Temperature distribution without air barrier

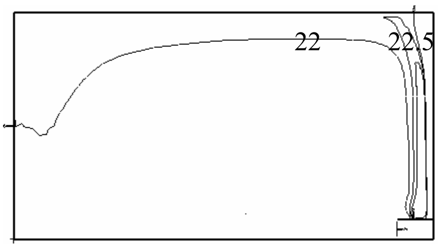

Figure 9 Temperature distribution without air barrier

STUDY THE THERMAL ENVIRONMENT OF OFFICE IN SUMMER CONDITION

Object

Also, we take one cell of the office outside-zone as the standard room, its size is 5.2m×3.0m×2.8m. Consider the hall as the outside environment and there is a zero-pressure opening between the standard cell and the hall. The designed indoor temperature is 24℃, relative humidity is 55% and the paper set it as a constant. The outdoor temperature is given as 34℃. The supply air parameters are equal to the indoor air parameters, other supply and exhaust air parameters are listed in Table 3. The heat source of the room is 2882W, heat flux of the window is equal to the heat load of solar radiation. Figure 10 and Figure 11 have shown the models of opening distribution from different orientation.

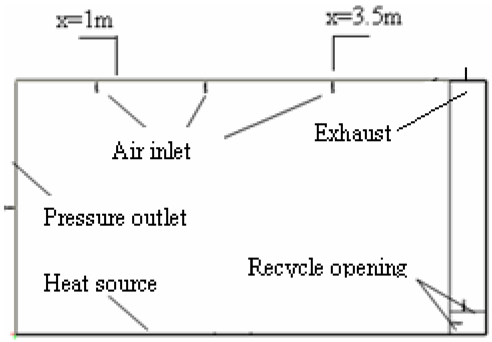

Figure 10 Office model

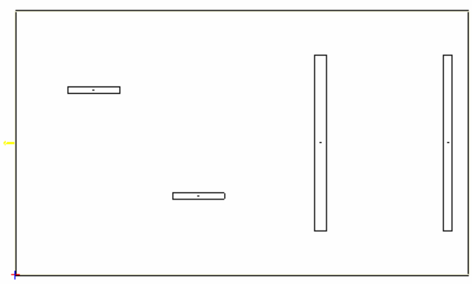

Figure 11 opening distribution

Solution

By using numerical simulation software Airpak, we simulated the environment of window side area. In the calculation, the second kind of boundary condition is a good choice according to the solar radiation in summer., and the K-ε model were used because we do not need to consider the viscosity of the windows. The grid of the objects and the boundary layer is defined; the number of the total grid is 57851 and 38491 with and without air barrier technology respectively.

Results

In this section, we also take the lengthways and middle cut plane(Z＝1.5m) of the room as the study objective.

- PMV Distribution

Figure 12 and Figure 13 shows the *PMV* distribution of the office without and with air barrier technology. The clothing value and metabolic rate are 0.5clo and 1.2 met respectively based on the routine clothing in office.

Comparing the two figures, we can draw some conclusions:

1） The PMV value near the windows of the office is higher than that far away from the windows no matter whether the air barrier technology is applied.

2） The PMV value near the windows is lower and more acceptable when there applied the air barrier system. People may feel hot in half parts of the room if there is not air barrier system. Use the air barrier can improve the environment of window side obviously.

3） The air barrier has less effect on the PMV distribution far away from the window side.

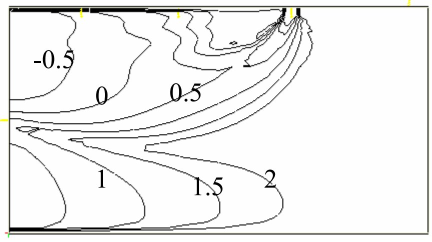

Figure 12 PMV distribution without air barrier

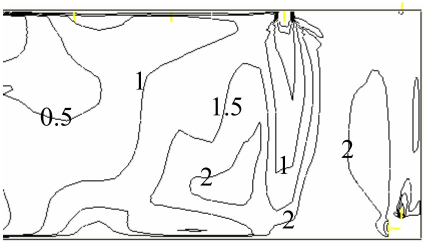

Figure 13 PMV distribution with air barrier

- Velocity Distribution

Figure 14 and Figure 15 have shown the velocity distribution of the office formed by two different airflow patterns (with air barrier technology or not).

From the two Figures 14 and 15, we can find our some rules:

1） There is a deflection when the airflow go into the office for the solar radiation is high and the velocity distribution is out-of-order when we do not apply air barrier system. Velocity of the air in the bottom part is larger than 0.3m/s which cannot meet the design requirements.

2） The velocity distribution is more uniform and reasonable when there exits a air barrier, and the average velocity of the room is smaller.

3） Taking air distribution pattern into account, the air barrier has effect on the thermal environment of the office.

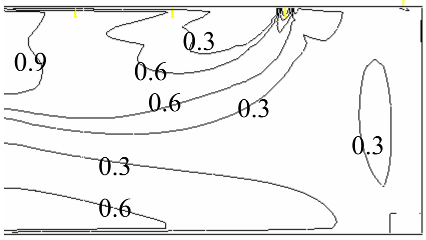

Figure 14 Velocity distribution without air barrier

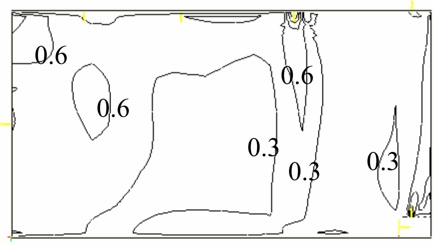

Figure 15 Velocity distribution with air barrier

- Temperature Distribution

Figure 16 and Figure 17 have shown the temperature distribution of the office formed by two different airflow patterns (with air barrier technology or not).

From the two figures, we can also draw the conclusions:

1） The air barrier can improve the temperature distribution near window side evidently because the extract fan under the window mixes the indoor air and supply air sufficiently.

2） Reasonable use of air barrier can reduce the heat radiation efficiency.

3） Temperature distribution of the place far away from the window side can also be affected by the air barrier.

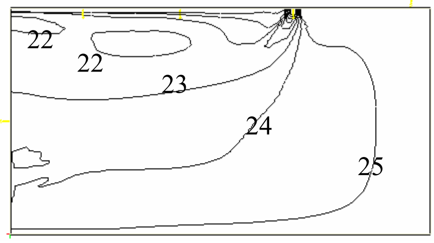

Figure 16 Temperature distribution without air barrier

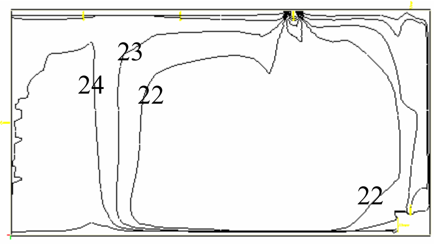

Figure 17 Temperature distribution with air barrier

CONCLUSION

Compared with the system without air barrier technology, using air barrier system cannot only improve the environment of the window side and thermal comfort of the office, but also make the airflow distribution more reasonable. It can also deal with the load near the source, which reduces the complication of system. But it is hard to tell whether the air barrier system is better than others on energy saving potential and economy. The key point in our further study is to find a balance among the comfort, economy and energy saving.

REFERENCES

Takenaka Corporation. 2000. http://www.takenaka.co.jp/takenaka_e/news_e/pr0009_01.htm

Furukuwa, Koori, and Takai. Research on heat performance of windows for perimeter-less air-conditioning. 2000:151-152

Chen Huang. 2005. Built Environment. Beijing: China Machine Press.

Cunyang Fan. “Improvement of window side thermal environment and energy saving in office buildings,” HV&AC, 1997(4):18-25.

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