Analysis of the Window Side Thermal Environment Formed by Air Barrier Technique in Winter Conditions and Its Economy

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Abstract: The air barrier technique applies airflow through a window fan to decrease the heat load of a window surface and avoid dewfall in winter and decrease heat radiation from the window surface in summer. This paper uses numerical simulation to predict the energy-saving potential and thermal comfort of the air barrier technique used in office buildings. It also analyzes the surface temperature of the window by using the simulation software Airpak. According to the results, we can obtain the key control strategy of this technology. It can be found that the air barrier technique, instead of the heating-supply around outside-zone for office building, can avoid dewfall in winter and decrease the cold radiation, which has a great effect on thermal environment around the window. Characteristics such as outer air temperature, indoor load, thermal characteristics of structure, and air-supply parameters through window fans are analyzed in detail to measure their effects on energy consumption, window side environment and *PMV* values. The paper provides theoretical reference and technical guidance for applying air barrier technology correctly, improving the window side environment and reducing energy consumption.

Key words: air barrier technology; window side environment; numerical simulation; energy saving

1. INTRODUCTION

With the increasing of large-area glass buildings, how to predigest air-conditioning system, improve the environment of window side area, avoid the dewfall in winter become the key concerns of the designer when design air-conditioning systems for large office building. The Air barrier technique has attracted the designers in recent years for its unique potential application in the problem mentioned before.

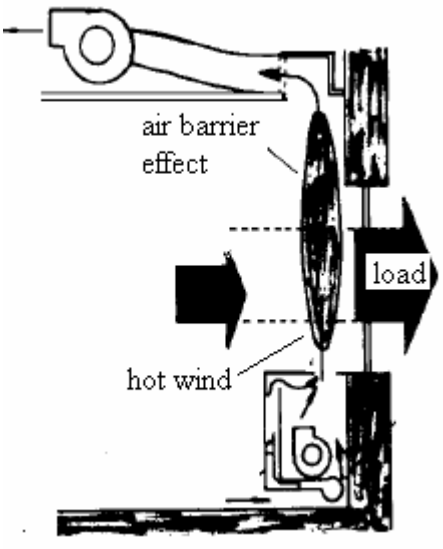

Fig.1 Air barrier system

Air barrier technique can be used in various forms[1].This paper introduces one of the systems as shown in Fig.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), supply hot airflow to decrease the load of surroundings of the building and to avoid dewfall on cold glass surface in winter by controlling the supplyair parameters. This paper chiefly concerns the relationship between indoor thermal environment and improvement of dewfall problem, economy, comfort and energy-saving potential.

Tab. 1 building structure and supply air parameters

Item	Material	Heat tran coff/ 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/m^2	Exhaust/m^2	Remark
Supply air parameter	300	0.02×2	0.19×2	300W power
Exhaust air parameter	330	—	0.15×2	

2. STUDY METHORD

2.1 Object

As shown in Fig.2, take one cell of the office outside-zone as the standard room we 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 stander cell and the hall. The designed indoor temperature is 22℃ and relative humidity is 40%. 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. The building structure data and supply air parameters are listed in Table 1.

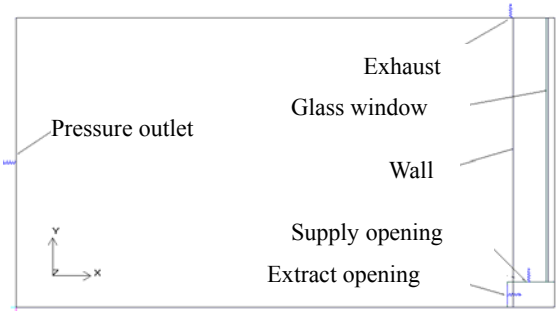

Fig.2 Office model with air barrier

2.2 Solution

By using numerical simulation software Airpak, we simulated the environment of window side area, dew point temperature on surface and energy consumption. In the calculation, the third king of boundary condition and the RNG K-ε model were used. The grid of the objects and the boundary layer is defined; the number of the total grid is 202449 and 180170 respectively (with and without air barrier technology).

3. STUDY OF COMFORT

3.1 *PMV* Distribution

As we all known, *PMV* is an important index when judge the indoor thermal environment. It is mainly influenced by 6 factors: air temperature, relative humidity, air velocity, radiation temperature, clothing value and metabolic rate[1], the first four factors can be calculated by the boundary conditions, the clothing value and metabolic rate are 1.3clo and 1.2 met respectively based on the routine clothing in office.

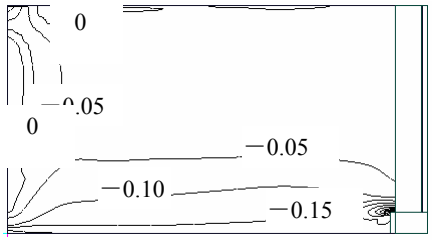

Fig.3 *PMV* distribution without air barrier

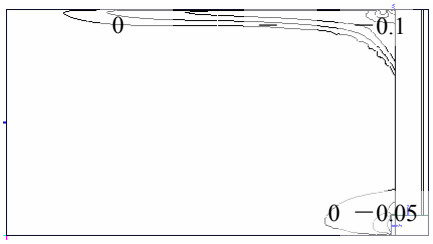

Fig.4 *PMV* distribution with air barrier

Fig.3 shows the *PMV* distribution of the lengthways middle cut plane(Z＝1.5m)without air barrier technology while Fig.4 shows the *PMV* distribution of the lengthways middle cut plane(Z＝1.5m)with air barrier technology.

It can be seen obviously that with no air barrier technology, the PMV distribution is layered, the lower part of the room is a little cold, the PMV in most part of the room is between 0~-0.2,the max value is 0.03 and the minim value is -0.5.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", the environment of window side has been improved.

3.2 Velocity Distribution

From Fig.5 and Fig.6 we can find the differences of the indoor airflow in different conditions (with air barrier technology or not).

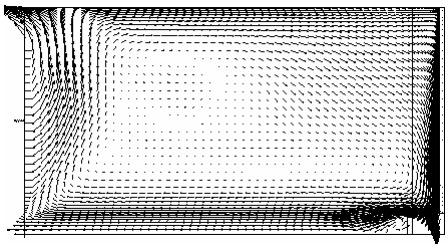

Fig.5 Velocity distribution without air barrier

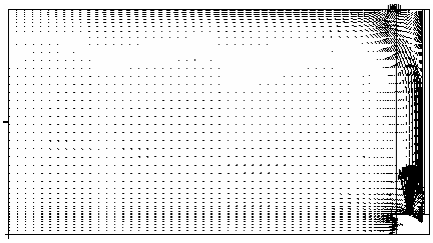

Fig.6 Velocity distribution with air barrier

In Fig.5, there exists reverse flow from the hall to the cell; the distribution of velocity is not equally enough. There also has visible downdraft along the window surface and the velocity near the window surface even reach to 0.26m/s.

In Fig.6, 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, the environment of the window side area is more comfortable.

4． DISCUSSION ON DEWFALL

4.1 Surface Temperature Distribution

When the air temperature is 22□, relative humidity is 40%，the dew point temperature of the glass window surface is 7.8□. Fig.7 and Fig.8 tell the surface temperature distributions under different conditions (with air barrier technology or not).In Fig.7, the surface temperature becomes lower from top to bottom; the lowest temperature is 10□, higher than the dew temperature. In Fig.8, we can find that the use of air barrier can increase the average temperature of the surface. The temperature of the lower and higher parts of the surface is high because of the influence of the hot airflow, but the temperature of the middle part of the surface is lower than 7.8□, which may cause dewfall.

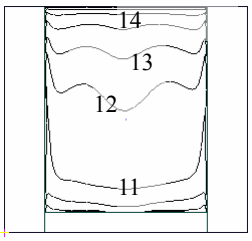

Fig.7 Temperature distribution without air barrier

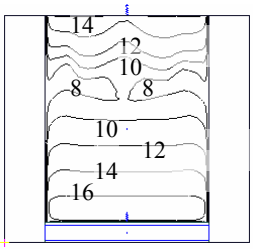

Fig.8 Temperature distribution with air barrier (supply air volume is 300 m^3/h, power is 300W)

4.2 Discussions on Controlling Method

Fig.9 and Fig.10 are the surface temperature distributions under different air-supply parameters. Fig.9 shows the surface temperature distribution in the condition that supply air volume is 350 m3/h, Fig.10 shows the surface temperature distribution in the condition that supply air has heated by a 400W power . Both of the lowest temperature is higher than the dew point temperature 7.8□. What kind of the controlling method should be chosen will depend on the other factors that you are concern.

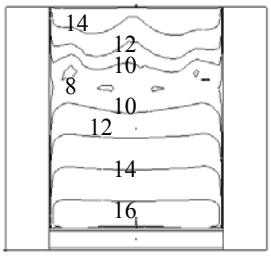

Fig.9 Temperature distribution with air barrier (supply air volume is 350 m^3/h, power is 300W)

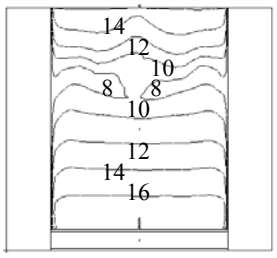

Fig.10 Temperature distribution with air barrier (supply air volume is 300 m^3/h, power is 400 W)

5. ANALYSIS OF SYSTEM AND ECONOMY

5.1 Analysis of System Technical

The air barrier system studied in this paper apply hot airflow through window fan to decrease the load of window surface, to avoid dewfall in winter and decrease heat radiation of window surface in summer to improve the thermal comfort. The advantages of air barrier system are as follows:

1) It can simplify the air-conditioning system of office building and make the management more convenient;

2) It can deal with the load near the source, decease the equipment load, the investment of the air-conditioning system and the operation cost;

3) It can improve the local discomfort caused by cold radiation from outside-zone.

5.2 Analysis of System Economy

How to deal with the air-conditioning system of outside-zone is the major concern on improving the environment of window side area. No matter whether there is an air-conditioning system for the outside-zone itself, the economy and effect must be taken into account.

Though the air barrier system is simple and can save the cost of AHU and ducts, the operation cost of it also needs to be considered. The economy of this system should be considered synthetically. Further more, as was pointed by Fan et al[2], though the air barrier technology may charges less, people may feel a little cold in window side area if we use this system. We need a further study to determine the economy of the air barrier system.

6. CONCLUSION

Compared with the system without air barrier technology, using air barrier system can not 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 between the comfort, economy and energy saving.

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