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Analysis and Research on Ventilation Strategy of the Common Forms of Windows Based on CFD Simulation

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Abstract. Based on the common forms of window opening in board hotels, PHOENICS software and CFD technology were used to simulate a variety of indoor wind environment. The open area, height of window sill, window form, position and shape of the window were varied for the simulation. The freshness of the air, relative to the appropriate wind speed, and the number of ventilation in the bathroom were adopted to evaluate the strategy analysis of the ventilation from different forms of windows. Suggestion strategy was given according to different needs for specific window.

Keywords. Indoor wind environment simulation, CFD technology, natural ventilation, ventilation strategy

1. Introduction

CFD technology is used to simulate a variety of indoor wind environments. At present, it mainly focuses on the optimization of building shapes and the spatial arrangement of building groups [1-3]. The main research is the optimization of the overall building [4]. Among the building components, the influence of the form of exterior windows on the indoor wind environment has not been found in relevant literature [5-6].

Windows are the basic components and one of the most important ways for natural ventilation of buildings [7]. In order to create a good healthy wind environment, according to the evaluation standard of human body comfort, it is urgent to analyze and study the relationship between window opening form and ventilation effect.

2. Basic Principles and Methods

Comprehensive buildings have different functions and body shapes. The actual wind pressures of the functional rooms are quite different, so they are not suitable as an overall research object [8]. Therefore, in this study, the corridor-style board-type guest rooms are selected as research object. The reasons are as follows: (1) the hotel rooms have certain requirements for indoor comfort. (2) There is little difference in the structure of guest rooms among different hotels. (3) Depth, open window area, and the

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indoor structure for each sub-unit of guest room are basically the same, which is very suitable for using Control Variable Method.

In this paper, the authors choose PHOENICS software, use CFD technology to simulate the natural ventilation of indoor wind environment in the standard guest rooms, record the intuitive air volume cloud diagram of ventilation, and finally summarize the law based on the object demand analysis, provide objective data for rational comparison, and propose the best form of building facade windows.

3. Geometric Model Construction

In this simulation study, the wind pressure difference between the front and rear windows is set to 5Pa. The size of each guest room is the same, that is, for each sub-unit, the length-to-width ratio is about 2:1 (this is also a relatively suitable size for the guest room), the depth is 6400mm, and the area of wall is 3700mm×3000mm.

According to the preliminary planning, the general floor plan of the building provided by the architectural design, and other related materials, the indoor simulation model of this project is established through the sketchup software tool.

The analysis model is aimed at the guest rooms of the hotel building (figure 1). When selecting the external field size of the model, the air flow at the boundary of the building cannot be affected. Based on the relevant engineering experience and simulated trial calculations, the calculation area setting of the model is obtained.

In this model, the target building area is set to 15.2m×62.6m×3m (length×width×height); the calculation area of the model is set to 18m×65.7m×3m. The model is set to north along the positive direction of the Y axis [9].

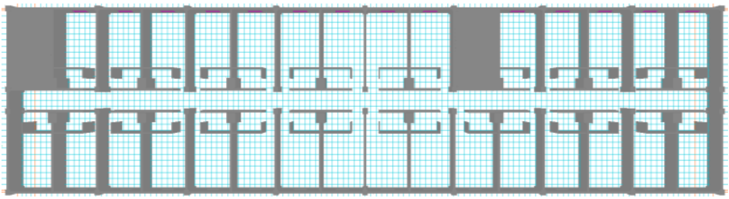


Figure 1. The floor plan of the hotel room.

4. Setting and Calculation of Working Condition Model

4.1. Window Area Change Model

The position of the center point of the window remains unchanged, and the open area is changed. Then the model working conditions are divided into 5 types. The windows are opened in the center of each wall, and the proportion is enlarged from 10% to 40%. The open area is set as 10%, 20%, 30%, 35%, and 40% respectively.

Based on the software simulation value, it can be seen that 30%, 35%, and 40% of the ventilation conditions are better, so these three working conditions are taken out for detailed comparison of the wind speed distribution.

Table 1. Statistics for changes of window area (%).

Working condition	Window open area	Low wind area	Medium wind area	Suitable area	High wind area
3	30	83.36	12.12	1.23	3.29
4	35	65.75	24.41	4.21	5.63
5	40	55.63	31.16	4.09	9.12

The proportions of mid-wind area, suitable area and high-wind area are obviously smaller in working condition 3 (table 1), and the proportion of low-wind area is the largest. Comparing condition 4 and condition 5, the middle wind area and high wind area of condition 5 account for a larger proportion, but the proportion of suitable area of working condition 4 is slightly larger, while the suitable area occupies a small proportion as a whole, so the impact is not significant.

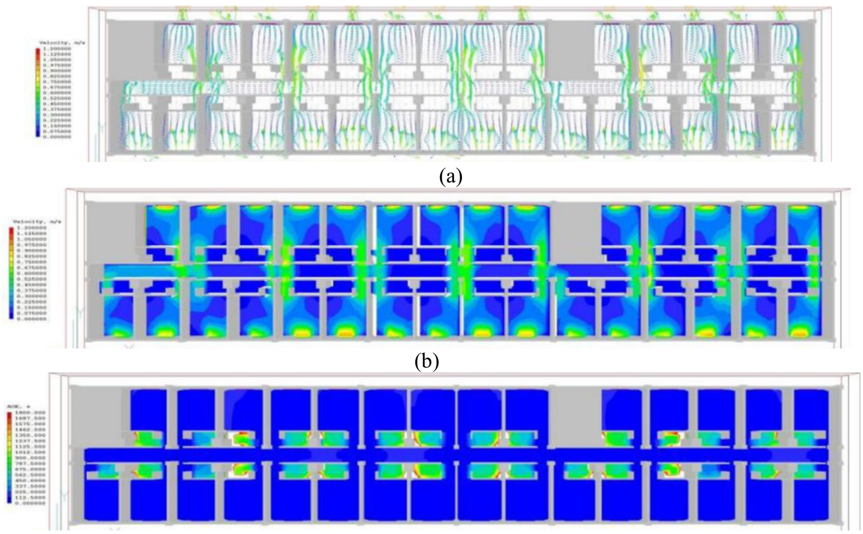
4.2. Window Sill Height Change Model

4.2.1. Model Data

The model is divided into three cases. The wall area is still 3700mm×3000mm, and the window size is 1200mm high and 1600mm wide. The height of the window sill for working conditions 1, 2 and 3 is 500mm, 900mm, and 1300mm respectively.

4.2.2. Simulation Analysis

Figure 2 shows the distribution of indoor flow field, wind speed and air age in working condition 1.This is 1.2m above the indoor ground elevation. From the analysis diagram, it can be seen that when the wind pressure is 5Pa and the window height is 500mm, the average indoor wind speed is more suitable, and there is insufficient ventilation.



(a)

(b)

(c)

Figure 2. Indoor wind speed vector diagram (a), wind speed cloud diagram (b), air age distribution diagram (c) in working condition 1.

In working condition 2 and 3, the diagrams show the distribution of indoor flow field, wind speed and air age at 1.2m from the indoor ground elevation. From the analysis diagrams, it can be seen that in working condition 2 (window sill height 900mm), the average indoor wind speed is more suitable under the condition of wind pressure of 5Pa, some parts have been improved, the ventilation condition is better than that in working condition 1, and the air age is good. On the other hand, under working condition 3 (window sill height 1300mm), the average indoor wind speed increases when the wind pressure is 5Pa, but the ventilation is not as good as that of 900mm height from the vector diagram.

4.2.3. Wind Speed Distribution Comparison

There is no obvious difference in ventilation effect in the wind speed vector diagram, that is, the difference of ventilation effect between working condition 1 and working condition 2 is very small (table 2).

Table 2. Statistics for wind speed distribution comparison (%).

Working condition	Window sill height/mm	Low wind area	Medium wind area	Suitable area	High wind area
1	500	62.09	25.25	4.95	7.71
2	900	63.11	24.54	5.34	7.01
3	1300	72.1	21.07	3.77	3.06

The proportion of high wind area in working condition 1 is higher, and the proportion of suitable area in working condition 2 is higher. In contrast, the low-wind area of working condition 3 is significantly increased, which will have a bad impact on indoor comfort, and the proportions of mid-wind, suitable, and high-wind areas are also significantly reduced [10].

4.3. Window Shape Change Model

When the window area is constant, the same basic model, window opening is divided into five forms for simulation discussion. For working condition 1, it is round, the diameter is 1700m, the area is 2.25m^2; Working condition 2, rectangle, length 2250m, width 1000m, area 2.25m^2; Working condition 3, square, length 1500m, width 1500m, area 2.25m^2; Working condition 4, strip, length 0.33m, width 2.25m, area 2.25 m^2; Working condition 5, fan ring, radius 1.45m, angle 58°, area 2.25 m^2.

4.3.1. Simulation Analysis

Figure 3 shows the distribution of indoor flow field, wind speed and air age at 1.2m from the indoor ground elevation in working condition 1. From the analysis diagram, it can be seen that the average indoor wind speed is more suitable under the working condition and the wind pressure of 5Pa,, the ventilation is good, and the air age is good. Except for a few parts of the bathroom, the air exchange can be completed within 1800s.

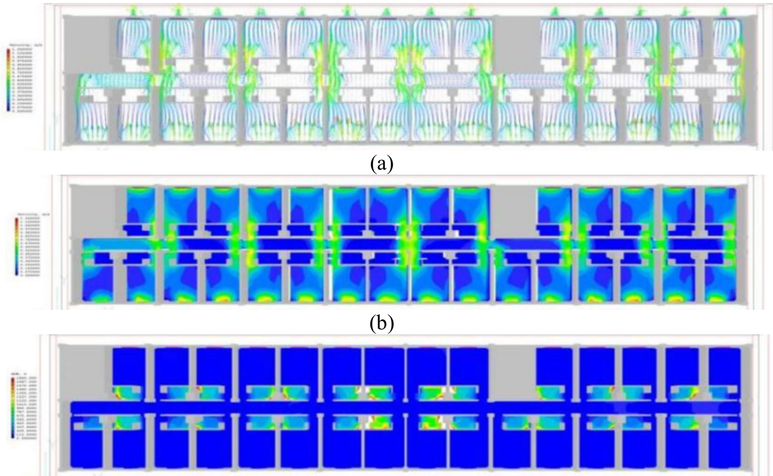


Figure 3. Indoor wind speed vector diagram (a), wind speed cloud diagram (b), air age distribution diagram (c) in working condition 1.

In working condition 2, the diagram shows the distribution of indoor flow field, wind speed and air age at 1.2m from the indoor ground elevation. From the analysis diagram, it can be seen that under the working condition 2 and the wind pressure of 5Pa, the indoor average wind speed is more suitable, the ventilation is good, and the air age is better, which is slightly worse than that of working condition 1, and there are more toilets that do not meet the air exchange in 1800s.

Similar to this is in working condition 3, the diagram shows the distribution of indoor flow field, wind speed and air age at 1.2m from the indoor ground elevation. From the analysis diagram, the average indoor wind speed is more suitable, the ventilation is good, and the air age is better when the wind pressure is 5Pa in the working condition 3, which is slightly worse than that of the working condition 1, and slightly better than that of the working condition 2.

In working condition 4 and 5, the diagrams also show the distribution of indoor flow field, wind speed and air age at 1.2m from the indoor ground elevation. From the analysis diagrams, when the wind pressure is 5Pa, for working condition 4, the ventilation is good, and the average indoor wind speed is obviously reduced, but the air age is good, which can ensure the freshness of the air. While for working condition 5, the ventilation is good and suitable, the air age is also good, and the air freshness can be guaranteed.

4.3.2. Wind Speed Distribution Comparison

It can be seen from the graphs of wind speed and air age that the air ages of working conditions 4 and 5 are better. However, from the perspective of wind speed distribution, the wind speed of working condition 5 in each area is obviously the best; the difference of air age in working conditions 1, 2, and 3 is not big, from the perspective of wind speed, working condition 2 has more advantages (table 3), because it has fewer low-wind areas and a greater proportion of stroke, suitable, and high-zone areas [11].

Table 3. Statistics for wind speed distribution comparison (%).

Working condition	Window shape	Low wind area	Medium wind area	Suitable area	High wind area
1	Round	62.5	22.28	4.92	10.3
2	Rectangle	58.97	25.48	5.25	10.3
3	Square	63.1	23.63	4.51	8.76
4	Strip	76.73	16.96	3.29	3.02
5	Fan ring	64.68	21.22	4.93	9.17

4.3.3. Same side and Different Side Models of Doors and Windows

The same basic model, the window size is 1200×800mm, and the study is divided into two working conditions, working condition 1 is on the same side of doors and windows, and working condition 2 is on different sides of doors and windows. Through software simulation, the difference of indoor ventilation between working conditions 1 and 2 is not obvious.

5. Analysis and Recommendations

5.1. Window Opening Area and Ventilation Strategy

In general, when other variables are more appropriate and unchanged, if the open area of the window is less than 20%, it is recommended to increase the open area to effectively improve the indoor wind environment; if the open area of the window is greater than 35%, the status quo can be maintained, and the window area can also be appropriately increased to increase the air flow rate. However, if it is greater than 40%, considering thermal insulation, it is recommended to appropriately reduce the window area.

5.2. Window Sill Height and Ventilation Strategy

Regarding the influence of the height of the window sill on the ventilation effect, relatively high windows have a greater influence on the ventilation situation. High windows generally have an adverse effect. When the height of the windows is 900mm, the ventilation effect is good, and the wind speed is suitable. If there is a special design, lowering the window sill will not have much impact; but if you want to increase the height of window sill, it is recommended to consider carefully. If the situation is special, you can appropriately raise it while considering multiple comprehensive factors.

5.3. Window Shape and Ventilation Strategy

Under normal circumstances, if priority is given to the freshness of the air, and more attention is paid to the number of ventilation changes in the toilet compared to the appropriate wind speed, the fan ring will be given priority when conditions permit; if the wind speed is appropriate, the ventilation effect of the toilet is not strictly required, Or use mechanical ventilation to solve the problem, the rectangle is the most suitable.

5.4. Orientation of Windows and Ventilation Strategy

Whether the doors and windows of the building are on the same side has little effect on the indoor ventilation environment, so it will not have a significant impact on human comfort.

6. Conclusions

Aiming at the influence of the window opening form of the hotel or office building on the ventilation effect, using the CFD analysis of PHOENICS software, the results are as follows:

(1) The window area should not be greater than 40% and less than 20%, 35% may be the best.

(2) The height of the window sill is best when it is 900mm from the ground.

(3) The overall shape of the window is preferably a fan ring or rectangle.

(4) Whether the doors and windows are on the same side has little effect on the indoor ventilation effect.

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