Research on the Rational Proportion of Housing Window in Shanghai Based on Ventilation Comfort

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Abstract. Taking the natural ventilation process of residential buildings in Shanghai in summer as research samples, this paper aims to obtain a reasonable range of window ratio by comparing the different scenario simulations by using Thsware VENT software. The research method was to simulate ventilation process of a room with rectangular windows in the same position in order to obtain the parameters of indoor wind environment under 12 window ratios circumstances. Through quantitative comparative analysis, the results showed that the ventilation parameters change regularly with the increase of the aspect ratio of windows. Moreover, the indoor natural ventilation comfort is best when the aspect ratio equals 2.0-2.76.

1. Introduction
The window ratio of the building is affected by many factors such as function, technology and art. A reasonable window ratio should be to increase the artistic effect of the building as much as possible on the premise of meeting the function and technical requirements. However, the architects often pay too much attention to the visual art effect of the window ratio and ignore the influence of the window ratio on the rationality of the building’s function. As a result, the natural ventilation and daylighting of many buildings can’t meet people's use needs, but can only rely on the aid of air conditioning system and the artificial lighting, causing unnecessary energy waste.

Factors such as the size, proportion, number and location of the windows have a great influence on the effect of natural indoor ventilation. They are directly related to the thermal comfort of the users and the freshness of the air. Reasonable window design can make indoor air field distribute even, make the wind flow through as large an area as possible. Especially in summer, a certain indoor wind speed within the effective range of people's activities can accelerate the evaporation and heat dissipation of the human body and reduce the use of air conditioners. The window aspect ratio is an important factor affecting the indoor ventilation effect. By using Thsware VENT software, the quantitative analysis of different window ratios on the effect of indoor natural ventilation is carried out under the conditions of the same window area and position in a room. A reasonable range of window aspect ratio is obtained, which provides a scientific design basis for architects.
2. Research method

2.1. Simulation environment
Shanghai is a region with hot summer and cold winter. The average outdoor wind speed in summer is 3m/s. In areas with higher building density, the average outdoor wind speed is generally about 1m/s. The wind speed required for indoor ventilation in summer is about 0.5-1.5m/s. If the wind speed is lower than 0.5m/s, the thermal comfort of the human body is not ideal. Therefore, this research set the average wind speed of window as 1m/s and took the area and distribution of simulated indoor wind speed greater than 0.5m/s as the evaluation index of the indoor natural ventilation effect. The larger the area proportion and the greater the distribution of indoor effective wind speed, the better the indoor natural ventilation effect is. Since the wind speed map will show different distributions in different directions and different sections, in order to facilitate comparison and take into account the influence of human scale and activity range, this research adopts the wind speed distribution map in the middle longitudinal section and in the 1.2m high horizontal plane of the room as the research objects.

2.2. Model and the parameters
The object of this research is to evaluate the ventilation effect of rectangular windows with different ratios in a room. The room size is set to 5m in width, 4m in depth and 3m in height. The studied rectangular window is set to the air inlet, with an area of 2m² and a window sill height of 0.9m. Considering the possible window sizes in the actual design, the windows are respectively set to W₁ (width 1m × height 2m), W₂ (1.1m×1.82m), W₃ (1.25m×1.6m), W₄ (1.32m×1.52m), W₅ (1.41m×1.41m), W₆ (1.52m×1.32m), W₇ (1.6m×1.25m), W₈ (1.82m×1.1m), W₉ (2m×1m), W₁₀ (2.2m×0.91m), W₁₁ (2.35m×0.85m) and W₁₂ (2.5m×0.8m). The air outlet is set to 1m×1m and its sill height is 0.9m. The air inlet and outlet are in the middle of the room. (Figure 1 Room Model)

3. Simulation results and analysis
After the ventilation simulation, the wind speed distribution map of the middle longitudinal section of the room (Figure 2) and the wind speed distribution map of the room's 1.2m high horizontal plane (Figure 3) are obtained.

Figure 1. Room Model

Figure 2. Wind speed distribution map of the middle longitudinal section of the room
Figure 3. Wind speed distribution map of the room's 1.2m high horizontal plane

Importing the W1 wind speed distribution map into AutoCAD and performing vectorization processing (Figure 4 and Figure 5), the value of the area where the wind speed is greater than 0.5m/s in the W1 room can be obtained (the red area in Figure 4 and Figure 5, $S_1 = 8.08 \text{ m}^2$, $S_2 = 4.55 \text{ m}^2$). $S_1$ represents the area where the wind speed is greater than 0.5m/s in the middle longitudinal section of the room, and $S_2$ represents the area where the wind speed is greater than 0.5m/s in the 1.2m high horizontal plane of the room. In order to evaluate the uniformity of indoor effective ventilation, the ratio $P_1$ and $P_2$ are used as the evaluation index ($P_1=S_1 / (3\times4) \times 100\%=8.08/12\times100\%=67.33\%$, $P_2=S_2/(4\times5)\times100\%=4.55/20\times100\%=22.75\%$). Table 1 and Table 2 are obtained after sorting out and analyzing the indoor ventilation effect of Room W1-W12.

Figure 4. The wind speed greater than 0.5m/s in the middle longitudinal section

Figure 5. The wind speed greater than 0.5m/s in the 1.2m high horizontal plane
Table 1. Comparative analysis of indoor ventilation effect of W1-W6

| Window | Middle longitudinal wind speed map | 1.2m high horizontal wind speed map | Window | Middle longitudinal wind speed map | 1.2m high horizontal wind speed map |
|--------|-----------------------------------|-----------------------------------|--------|-----------------------------------|-----------------------------------|
| W1     | ![Image](image1.png)               | ![Image](image2.png)             | W2     | ![Image](image3.png)               | ![Image](image4.png)             |
| Width: 1m | High:2.1m | Aspect ratio:0.5 | S1=8.0 | S2=4.5 | P1=8.08/12x100%=67.3% | P2=4.55/20x100%=2.75% |
| W3     | ![Image](image5.png)               | ![Image](image6.png)             | W4     | ![Image](image7.png)               | ![Image](image8.png)             |
| Width: 1.25m | High:1.6m | Aspect ratio:0.78 | S1=6.2 | S2=4.3 | P1=6.25/12x100%=52.08% | P2=4.3/20x100%=21.5% |
| W5     | ![Image](image9.png)               | ![Image](image10.png)            | W6     | ![Image](image11.png)              | ![Image](image12.png)            |
| Width: 1.41m | High:1.41m | Aspect ratio:1.0 | S1=5.2 | S2=4.6 | P1=5.27/12x100%=43.92% | P2=4.69/20x100%=2.345% |

Table 2. Comparative analysis of indoor ventilation effect of W7-W12

| Window | Middle longitudinal wind speed map | 1.2m high horizontal wind speed map | Window | Middle longitudinal wind speed map | 1.2m high horizontal wind speed map |
|--------|-----------------------------------|-----------------------------------|--------|-----------------------------------|-----------------------------------|
| W7     | ![Image](image13.png)              | ![Image](image14.png)             | W8     | ![Image](image15.png)              | ![Image](image16.png)             |
| Width: 1.6m | High:1.25m | Aspect ratio:1.28 | S1=4.86 | S2=5.58 | P1=4.86/12x100%=40.5% | P2=5.58/20x100%=7.9% |
| W9     | ![Image](image17.png)               | ![Image](image18.png)             | W10    | ![Image](image19.png)              | ![Image](image20.png)             |
| Width: 1.82m | High:1.1m | Aspect ratio:1.65 | S1=4.35 | S2=5.68 | P1=4.35/12x100%=36.25% | P2=5.68/20x100%=28.4% |
According to the graphic changes in Table 1 and Table 2, it can be seen that with the increase of the window aspect ratio, the area distribution in the middle longitudinal section where the wind speed is greater than 0.5 m/s shows a decreasing trend, while the area distribution of the 1.2 m high horizontal plane shows an increasing trend. The reason is that from W1 to W12 the window width gradually increases and the window height decreases, which causes the wind speed in the room to change from vertical distribution to horizontal distribution. It can be seen from Table 1 and Table 2 that the maximum wind speed value in the room W1-W12 is located at the inlet and outlet. The minimum wind speed value in the longitudinal section is located at the bottom and top of the room, and the minimum wind speed value in the horizontal plane is located in the vortex area. In addition, it can be seen from Table 1 and Table 2 that the area where the wind speed is greater than 0.5 m/s changes regularly with the increase of the window aspect ratio. The values of S1, S2, P1 and P2 of W1-W12 are listed in Table 3.

| Window 9 | Width: 2 m | High: 1 m | Aspect ratio: 2.0 | S1 = 4.21 | S2 = 6.45 | P1 = 4.21/12 × 100% = 35.08% | P2 = 6.45/20 × 100% = 32.25% |
|----------|------------|-----------|------------------|----------|----------|--------------------------|--------------------------|
| Window 10 | Width: 2.2 m | High: 0.91 m | Aspect ratio: 2.42 | S1 = 3.64 | S2 = 6.3 | P1 = 3.64/12 × 100% = 30.33% | P2 = 6.3/20 × 100% = 31.5% |
| Window 11 | Width: 2.35 m | High: 0.85 m | Aspect ratio: 2.76 | S1 = 3.37 | S2 = 6.8 | P1 = 3.37/12 × 100% = 28.08% | P2 = 6.8/20 × 100% = 34.00% |
| Window 12 | Width: 2.5 m | High: 0.8 m | Aspect ratio: 3.13 | S1 = 3.01 | S2 = 6.98 | P1 = 3.01/12 × 100% = 25.08% | P2 = 6.98/20 × 100% = 34.9% |

The curves of S1 and S2 value changing with the aspect ratio is shown in Figure 6. It can be seen that with the increase of the aspect ratio, S1 shows a decreasing trend and S2 shows an increasing trend.
because that the width of the window gradually increases from $W_1$ to $W_{12}$ and the height gradually decreases, resulting in a significant improvement in the horizontal ventilation effect while a relatively reduce in the vertical ventilation effect. When the aspect ratio is about 1.2, the effective ventilation area in the longitudinal section and the horizontal plane is equal and its value is about 5.4m². Figure 7 also reflects the same change trend. Because $P_1$ and $P_2$ in figure 7 adopt relative values, the intersection of two curves represents the same situation in which the vertical and horizontal ventilation effects are equal. When the aspect ratio is about 2.3, the effective ventilation proportion of the room in the vertical and horizontal directions is equal and its value is about 32%. At this time, the uniformity of effective ventilation distribution in the room is the highest and the ventilation effect is best. Considering that the evaluation of ventilation effect should have a certain degree of flexibility in practice, the aspect ratio 2.0-2.76 corresponding to the effective ventilation proportion between 30%-36% is taken as the reasonable range of window aspect ratio.

4. Conclusion
In the ideal wind environment simulation, the wind speed distribution map obtained is completely symmetrical. With the increase of the window aspect ratio, $S_1$, $S_2$, $P_1$ and $P_2$ in the room all show a regular trend of change, indicating that the aspect ratio has a direct influence on the ventilation effect of the room. In the same environment, the rationality of housing window form is: horizontal rectangular window > square window > vertical rectangular window. When the window aspect ratio is 2.0-2.76, the indoor natural ventilation comfort is best.
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