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The Influence of the Traditional Architecture Patio with Cover on the Ventilation of the Indoor Air Pressure

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Through testing the patio and indoor thermal environment of the traditional building in Huizhou and simulating test data with Airpak software, the paper analyzed indoor air environment of traditional architecture with patio in Huizhou area, and the influence of the patio cover on the wind pressure ventilation of the traditional architecture, and get the reasonable choice of the patio cover height, the opening area and the direction which provide help and reference for the traditional architectural design and reconstruction.

1. Introduction

Because of its long history, profound cultural heritage and unique architectural skills, Huizhou traditional architecture has become an important part of Chinese architectural history. With the development of the times and the improvement of living standards, Huizhou people have higher requirements for the living environment in Huizhou area. Though, the air tightness is generally weak in Huizhou traditional architecture, especially the air convection of the patio area causes the heat dissipation. In this case, it will greatly increase the building energy consumption for air conditioning system to improve the indoor comfort. It is not wise to consume a lot of energy to improve the indoor comfort of the living environment, and this is contrary to the trend of the times. In order to increase the building air tightness, and in a certain extent, control the flow of the indoor air, XY (Chen et al., 2012) put forward that under the precondition of ensuring the natural lighting and ventilation function of the patio, the patio can be covered by the glass cover, as shown in Figure 1.

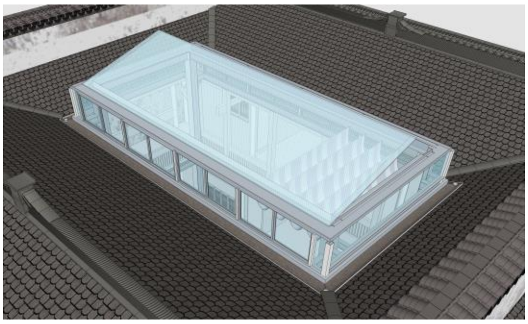

Figure 1: Patio adding cover

However, the paper analyzed (Jia and Li, 2013) article and the relevant information, and learned that it has a greater help for the Huizhou residential indoor natural ventilation to improve the transitional season indoor comfort, and may have a greater impact for the patio with cover on the indoor wind environment. On the basis of actual measurement, this paper, analyzing the wind environment of traditional architecture in Huizhou area from the overall, selecting typical layout traditional residential architecture with patio, and before and after patio with cover simulation and analysis of building ventilation by Airpak software, put forward optimization suggestions.

2. Huizhou Traditional residence patio ventilation Test

2.1 Test Method

There are hot and wind pressure to effect traditional residence patio ventilation in Huizhou. Daytime windows and doors open, it is obvious for wind pressure ventilation effect, at night, the doors and windows closed, with mainly hot pressing ventilation, and the wind speed is very small. Respectively in July 2013 and 2015 October, the paper tested inlet wind speed, patio outlet wind speed, wind speed of the main room, indoor and outdoor temperature and surface temperature of the maintenance structure of Weibianxi No. 30 and Xuhuishe inn which have typical plane layout, and obtained a complete data, as shown in Figure2,3,4.

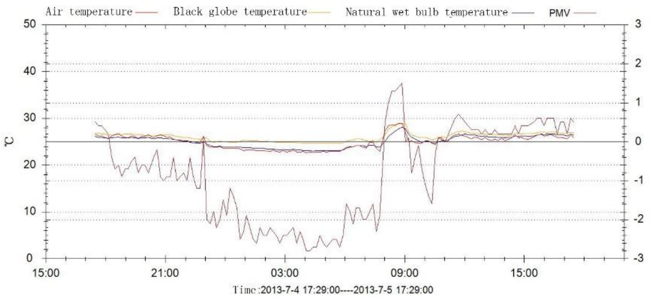

Figure 2: Comfort test index

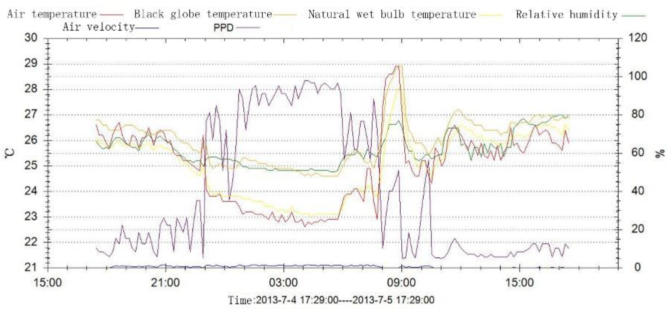

Figure 3: Comfortable satisfaction of human body

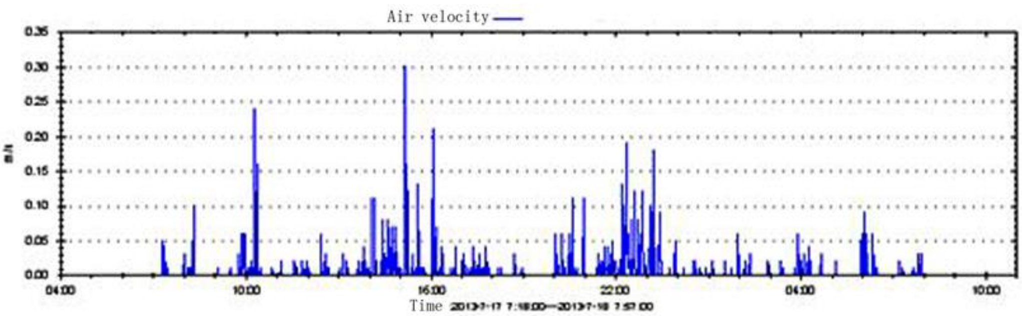

Figure 4: Wind speed at the center of the room

2.2 Data Analysis

By the test data and the related information, it is often between the 0-3m/s for the wind speed of the hot and transitional season at 10 m height of residence outdoor, generally between the 0-1.5m/s for inlet wind speed; wind speed of Indoor layer is generally between the 0-0.3m/s; air flow rate of two layers is very small which is related to the windows less and small; the wind speed of patio entrance is between the 0-0.5m/s.

3. Huizhou Traditional Residence Patio Ventilation Simulation Test

3.1 Simulation Test Method

According to typical plane layout, the paper constructed the three-dimensional model of Huizhou traditional residential building, which interior was simplified, and hot pressure was not considered, and thickness of the wall was ignored, as shown in Figure 5. Respectively set the entrance middle point of the 1.5m elevation, bottom middle point of patio area, the middle point of the main room, second floor patio center, top floor patio center for the P1, P2, P3, P4, P5. Their wind speeds were monitored, as shown in Figure 6.

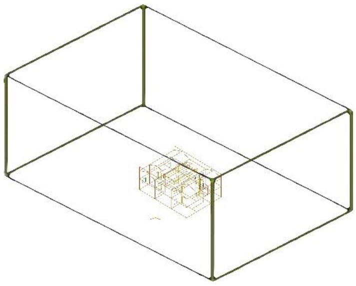

Figure 5: Verification model

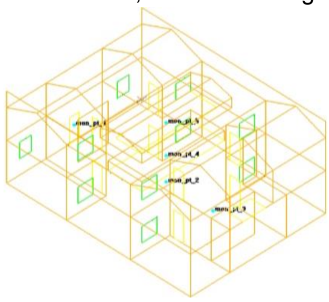

Figure 6: Monitoring point layout

3.2 Simulation Test Data Processing Model

Wind speed data would be obtained from the five monitoring points. These data can be processed by steady state method which is used to solve the flow field. In the method, it is important to construct turbulence model, Generally, it can be realized by K-ε equation, applied hexahedral unstructured grids, which computational domain size is set to 3 times the size of the model. This method was designed (Xia, 2011; Sun et al., 2014). In the boundary condition, the ground roughness index is set to 0.22.

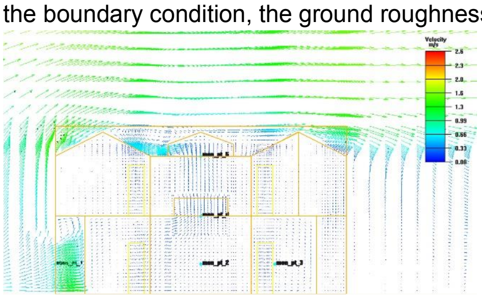

Figure 7: Wind speed vector without cover

3.3 Simulation Test Model Verification and Analysis

The wind speed is set to 0.9m/s, 2.1m/s, 2.7m/s, 3.3m/s, 1.5m/s at 10 meters height of the atmospheric boundary. Its results are shown in Table 1 by steady state method. When wind speed is 2.7m/s in the outdoor, Figure 7 shows the vector diagram of the simulated wind speed. After analysis and comparison, the simulation and measurement error must exist, there are two main reasons: first is not to consider the hot pressure ventilation, second is difficult to determine the extent of the model boundary roughness. But from Table 1 and Figure 7, the result shows that, with the increase of outdoor wind speed, the wind speed of each monitoring point has gradually become larger. The velocity of each point is in the range of measurement, and numerical simulation and experimental data is in the same order of magnitude, furthermore, the difference is very small, so that the model is effective.

Table 1: Validity verification data of wind speed model

Wind speed	Monitoring point 1	Monitoring point 2	Monitoring point 3	Monitoring point 4	Monitoring point 5
0.9	0.331	0.028	0.068	0.065	0.099
1.5	0.536	0.042	0.092	0.114	0.173
2.1	0.743	0.056	0.104	0.155	0.233
2.7	0.953	0.071	0.111	0.189	0.286
3.3	1.175	0.085	0.114	0.220	0.332

4. Study on simulation ventilation in Huizhou patio with cover

The patio cover corresponds to a barrier at the air outlet, and the patio cover is radiated by solar, increasing the temperature near the air, which will raise the temperature difference from top to bottom of patio, and have certain effect on building indoor ventilation. It has positive significance for the indoor ventilation organization to reasonable shape, proper height, opening direction and size of patio cover.

4.1 Indoor Ventilation Effect Research on Outdoor Wind Speed Change after Patio Covered

The paper took double slope symmetry, two side opening patio cover as the research object in Huizhou traditional residence, and constructed its three dimensional model. The cover overall height was set to 1.5 meters. The slope height was set to 0.6 meter. The vertical support portion opened at both sides. In the atmospheric boundary conditions, the airflow speed was set to respectively 0.9m/s, 1.5m/s, 2.7m/s, 3.3m/s at 10 meters height. Through three dimensional model constructing and data processing, Table 2 shows the simulation results.

Table 2: Wind speed simulated data in 10 meters height without cover

Wind speed	Monitoring point 1	Monitoring point 2	Monitoring point 3	Monitoring point 4	Monitoring point 5
0.9	0.33	0.03	0.07	0.07	0.10
1.5	0.54	0.04	0.09	0.11	0.17
2.1	0.74	0.06	0.10	0.15	0.23
2.7	0.95	0.07	0.11	0.19	0.29
3.3	1.17	0.09	0.11	0.22	0.33

4.2 Indoor Ventilation Effect Research on Patio Cover Height

In the atmospheric boundary conditions, the airflow speed was set to 2.7m/s at 10 meters height, and patio cover height was set to respectively 0.9 meter, 1.2 meter, 1.5 meter, 1.8 meter, 2.1 meter (the slope height was set to 0.6 meter), the three dimensional model was shown in Figure 8. Through data processing, Table 3 shows the simulation results.

Table 3. Indoor ventilation effect when outdoor wind speed change adding Patio height to 1.2 meter

Wind speed	Monitoring point 1	Monitoring point 2	Monitoring point 3	Monitoring point 4	Monitoring point 5
0.9	0.31	0.02	0.05	0.06	0.08
1.5	0.53	0.04	0.07	0.11	0.14
2.1	0.78	0.06	0.08	0.15	0.19
2.7	1.04	0.07	0.08	0.18	0.24
3.3	1.30	0.09	0.09	0.22	0.29

4.3 Indoor Ventilation Effect Research on Patio Cover Shape

The airflow speed was set to 2.7m/s at 10 meters height of the atmospheric boundary, and the patio cover overall height was set to1.5 meters. The patio cover shape was set to respectively flat roof, single slope roof (there are two kinds of opening windward and opening leeward.), double slope roof, curved roof. Figure 9 displayed those shapes. Table 4 shows the simulation results.

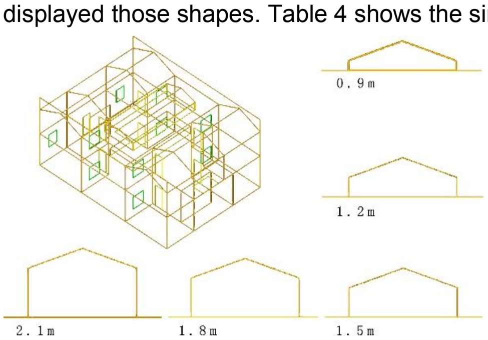

Figure 8: Patio Height design

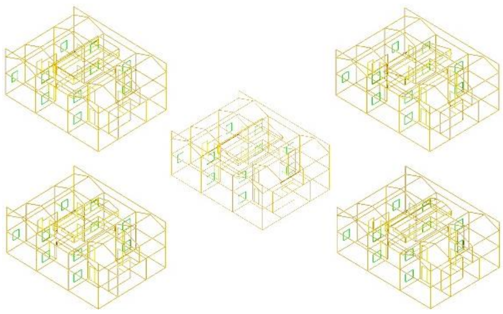

Figure 9: Patio shape design

Table 4: Indoor ventilation effect when Patio height change keeping a certain outdoor wind speed (2.7m/s)

Wind speed	Monitoring point 1	Monitoring point 2	Monitoring point 3	Monitoring point 4	Monitoring point 5
0.9	0.91	0.06	0.08	0.16	0.19
1.2	1.04	0.07	0.08	0.18	0.24
1.5	1.08	0.08	0.08	0.19	0.26
1.8	1.07	0.08	0.08	0.20	0.27
2.1	1.07	0.08	0.08	0.20	0.28

4.4 Indoor Ventilation Effect Research on Patio Cover Size

The airflow speed was set to 2.7m/s at 10 meters height of the atmospheric boundary, and the patio cover overall height was set to1.5 meters, the cover shape selected double slope roof. The patio cover opening size was set to respectively 100%, 75%, 50%, 25%, 0%. The simulation results are showed in Table 5.

Table 5: Indoor ventilation effect when Patio shape change keeping a certain outdoor wind speed (2.7m/s) and cover height (1.5 meter)

	Monitoring point 1	Monitoring point 2	Monitoring point 3	Monitoring point 4	Monitoring point 5
Flat roof	1.06	0.08	0.08	0.18	0.27
Single slope (Tail wind)	1.15	0.07	0.10	0.18	0.27
Single slope (Lee)	1.01	0.08	0.09	0.18	0.24
Double slope	1.08	0.08	0.08	0.19	0.26
Arc top	1.00	0.08	0.08	0.20	0.26

5. Simulation Results Comparison and Analysis

The results simulation from 2.3 section and 3.1 section show that the wind speed is basically constant in the one or two storey patio area after the patio was covered, and the wind speed is somewhat reduced at the main room area; and the wind velocity is obviously reduced in the center of the patio top. Found from the wind speed vector Figure 10, the wind speed difference is larger on both sides of the patio cover opening. And it was significantly higher for the wind speed of the opening windward side than that on the opening leeward side, which inevitably leads to the uneven distribution of wind speed in the patio opening area. Figure 11 shows when the outdoor wind speed is smaller the patio covered has a small effect on the inlet ventilation. But with outdoor wind speed increasing, it has a significant effect on the inlet ventilation. In addition, from Figure 10, after the patio was covered the pressure is not balanced on both sides of the cover, which makes the wind pressure decreasing on the cover opening windward side. It increases the pressure difference between the patio upper and the lower. Thus the wind pressure ventilation effect is strengthened.

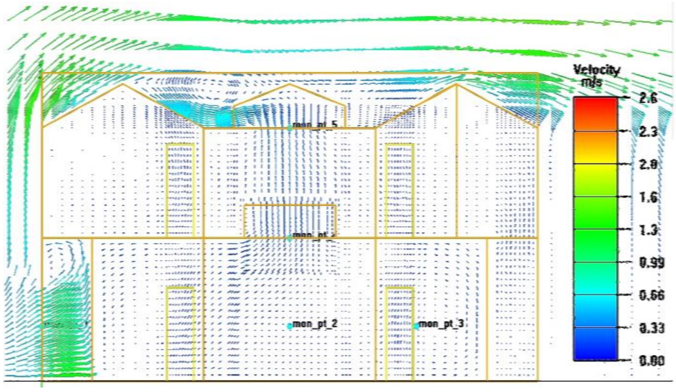

Figure 10: Patio wind velocity vector with cover

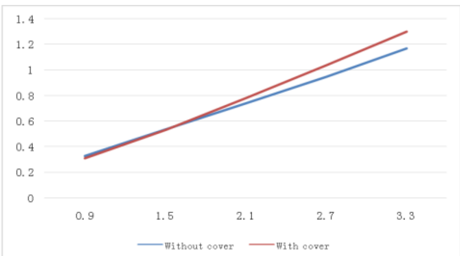

Figure 11: Indoor ventilation effect when outdoor wind speed change adding cover before and after

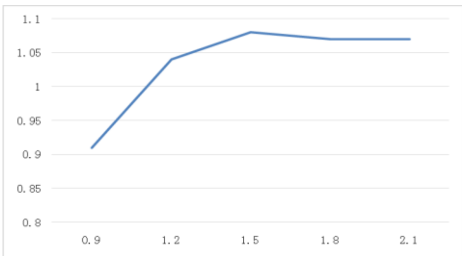

Figure 12: Indoor ventilation effect when patio cover height adjustment keeping a certain outdoor wind speed

From 2.3 and 3.2 section, increasing the patio cover height and opening size, the indoor ventilation can be promoted. On the contrary, the indoor ventilation will be suppressed. With the increase of the cover height, the inlet air velocity increases rapidly at the beginning, and then decreases slowly. When it is about 1.5 meters for the patio cover height, it will weaken the indoor ventilation effect to increase the cover height on the basis of 1.5 meters, as shown in Figure 12. In addition, after changing the patio cover height, in a certain range, the wind speed increases in the one or two storey patio area, when the height is increased again the wind speed basically remains unchanged in patio area and main room, however, the wind speed in the center area of the patio top was gradually increased.
From 2.3 and 3.3 section, when the patio is not covered the wind speed vector distribution is uniform, all kinds of the patio cover shape have a certain influence on the indoor wind pressure ventilation. Their influence is about the same to flat roof, double slope roof, curve roof. Compared the orientation of single slope roof cover opening, the paper finds the windward opening has maximum effect to indoor wind pressure ventilation, on the contrary, the leeward is least. In the double slope roof cover, the wind speed on the windward side is larger than the leeward side. It is slightly worse for curve roof cover to the indoor ventilation because the streamline shape will weaken wind pressure difference between the two sides of the patio cover.
Analyzed the simulation results of 3.4 and 2.3 section, the paper knew when the opening size of the patio cover was reduced the indoor air pressure ventilation can be suppressed. So, Reasonable control of the cover opening size can realize controlling artificially the air flow in the patio area.

6. Conclusions

In this paper, through the test simulation and analysis, it is concluded that the reasonable choice of the patio cover height, the opening area and the direction. These results play an important role in the practice of the patio renovation, indoor physical environment improvement which has also been recognized by the local residents, and provide help and reference for the traditional architectural design and reconstruction. It has a very positive meaning for transformation and utilization of traditional architecture in Huizhou area. In the future, through a large number of test and engineering practice and effective software, the paper further improves the adaptability and the quality of the traditional architecture in Huizhou area, which improves quality of traditional architecture livability and the people lives.

Acknowledgments

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