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To cite this article: Jingbo Lei *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **527** 012014

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Study on Design Strategies About Single-sided Natural Ventilation in Residential Buildings

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Abstract. Natural ventilation is an effective measure to reduce energy consumption and improve indoor environment. The enlargement of the depth of high-rise residential buildings allows only single-sided natural ventilation, which makes the problem of poor natural ventilation itself more serious. In this study, CFD numerical analysis was used to verify the optimal design strategy of one-sided ventilation residence in a practical case, and the results showed that the design strategy could improve the ventilation effect of one-sided ventilation houses [1].

1. Introduction

In China, due to the shortage of city land and its exorbitant prices, developers pursue high intensity and high volume ratio in residential development, making high-rise residential buildings in a design tendency of deep depth. The enlargement of the depth of high-rise residential buildings allows only single-sided natural ventilation, which makes the problem of poor natural ventilation itself more serious. Poor natural ventilation not only multiplies the energy consumption of residence, but also reduces the quality of indoor air and hurts human health. Based on the analysis of several improvement strategies in the paper, the writer put forward optimal design strategies for improving the situation of single-sided natural ventilation of residence.

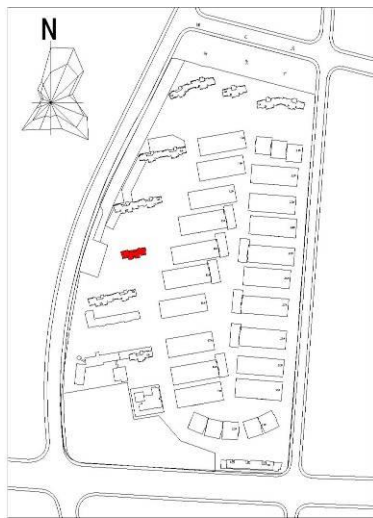
2. Analysis of actual cases

2.1 Project introduction and setting of simulated boundary conditions

The actual case in this paper is located in a residential area in Hongshan District, Wuhan .It is an independent four-family residential building with a building orientation of 10 ° south by east. (Figure1 and Figure2 in red).

In Figure 3, the two symmetrical single-side with two rooms a hall, a covered of 85.39 m² (the balcony area included in half), in the red dotted line are the research object. In the picture we can see *that*, all vents are located in the south excepts the toilet window. In the south of the living room lies half - convex and half - concave balcony with 12.4 square meters [2-3].



**Figure 1** .Actual building location map**Figure 2.** Actual building status

In this study, the simulated housing model selected lies in Wuhan, which is located in latitude $29^{\circ}58'31''$ north and longitude $113^{\circ}42'115''$ east. The dominant wind direction in summer is southeast. In this study, the wind direction was set as SE (data source: special meteorological data set for thermal environment analysis of buildings in China). In the simplified model, the shielding of surrounding buildings and the landscape of trees, the ventilation conditions of other two non-unilateral ventilated apartment types and other traffic Spaces in the building are not considered, and the influence of temperature on natural ventilation is also not considered. Therefore, this study is a steady-state simulation at a temperature of 20°C (Table 1).

Table 1. Setting of CFD simulated boundary conditions

Project	Boundary conditions
Turbulence Models	Standard k- ε model, High Reynolds Number
Inlet	$V = U_0 \times \left(\frac{Z}{Z_0}\right)^{0.25}$ $U_0=2 \text{ m/s}, Z_0=10 \text{ m/s}$ $k=1.5(I \times U_0)^2, I=0.1$ $\varepsilon = \frac{C_\mu k^{1.5}}{l}$ $l = \frac{4(C_\mu k^{0.5})Z_0 Z^{0.75}}{U_0}$
Sky	Slip, Wall Heat:Adiabatic
Outlet	Flow Split:1
Wall	No Slip

2.2 Ventilation status

For the convenience of computer simulation, the simulated wind direction is all blown from down to up by the picture surface. Therefore, when the simulated model is rotated clockwise by 32.5° , that is, the southeast wind direction is right southest, and the building faces south by east by 10° .

As shown in Table 2, the average indoor wind speed of the current case is 0.257m/s on the third floor, 0.314m/s on the 14th floor, and 0.445m/s on the 28th floor. The indoor wind speed area ratio was

76.51% on the third floor, 83.28% on the 14th floor and 93.50% on the 28th floor. The average indoor wind speed and wind speed area ratio of each floor increase with the increase of the floor. As can be seen from the scalar diagram in table 2, the indoor ventilation effect of the lower floor is poor. The difference of the ventilation effect between the east and the west floor is very obvious.

3. Analysis of improvement cases

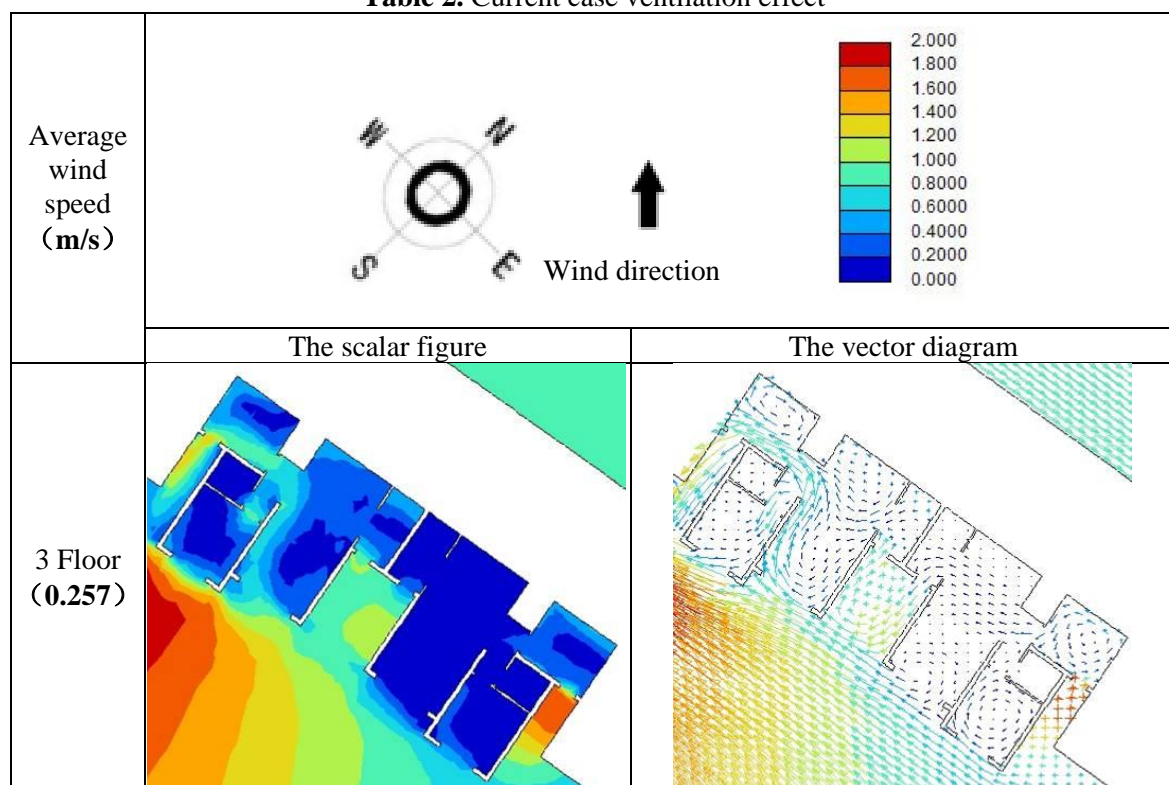
3.1 Design strategy to improve the case natural ventilation

By analyzing the ventilation effect of the previous cases, the following design strategies are proposed to improve the single-sided natural ventilation:

- 1. Change the orientation of the building from south by east 10° (32.5° clockwise compared to the wind direction) to south;
- 2. The master bedroom of the south-facing family should be added with a bay window with an included Angle of 30° with the side wall;
- 3. The balcony of the sitting room in the south-facing family should be changed to an open sunken balcony;
- 4. Since the notch between the two symmetrical houses in the south has reached 4.8m, which is deep enough, the notch depth will not be changed;
- 5. The above ventilation simulation results show that the ventilation between the living room and the master bedroom in the east-side apartment is very poor, so the partition between them should be removed to reduce the obstruction of the indoor obstacle to natural ventilation.

Fig.3 is the schematic diagram of the application location of the improvement strategy, and Fig. 4 is the improved house plan.

Table 2. Current case ventilation effect



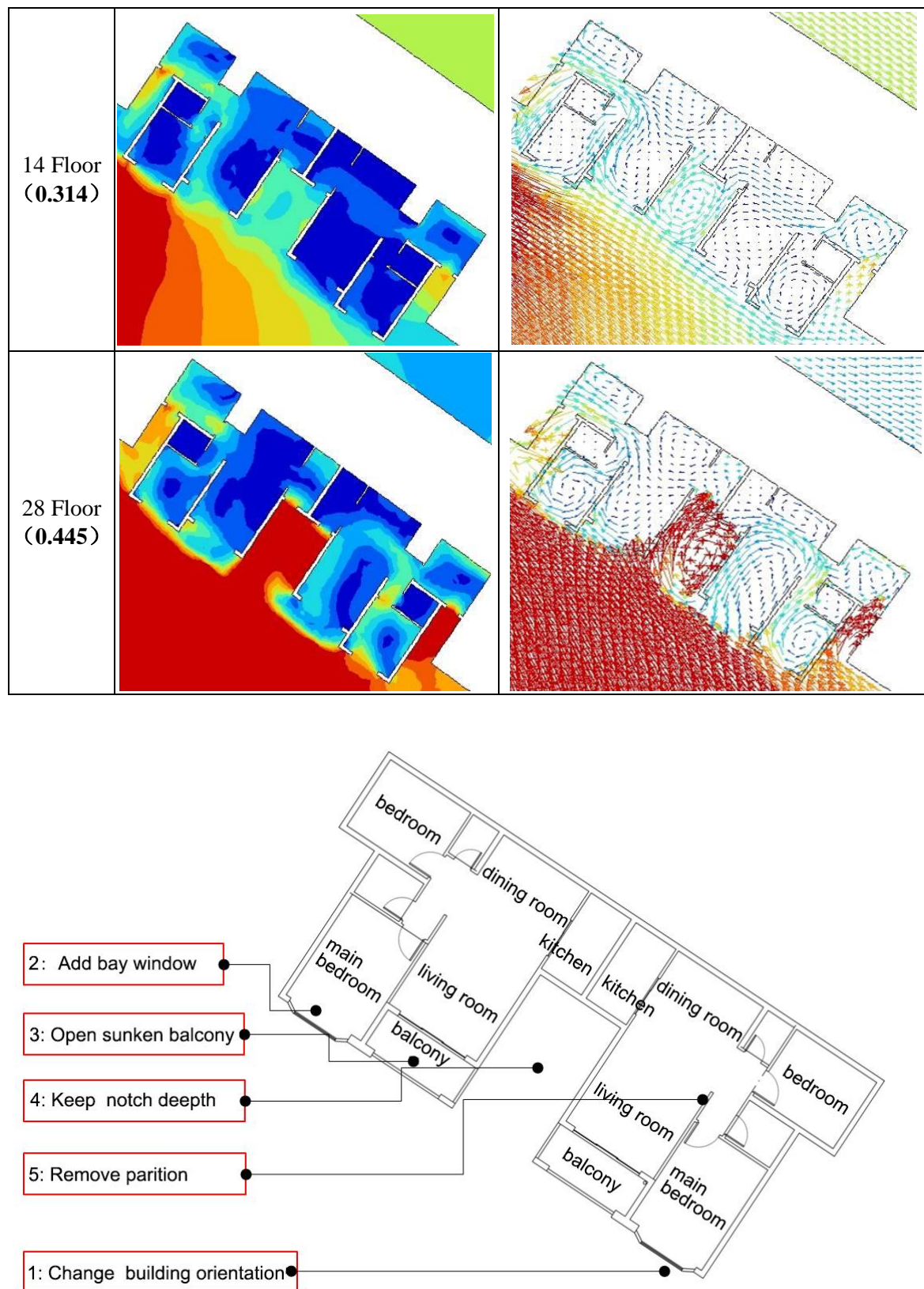


Figure 3. Schematic diagram of application location of improvement strategy

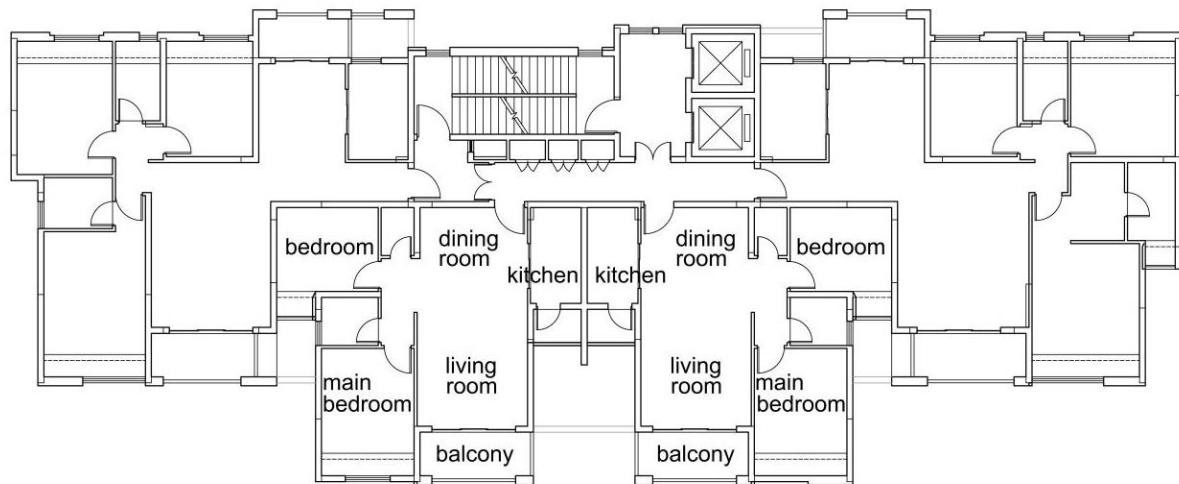
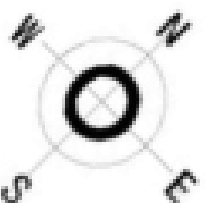

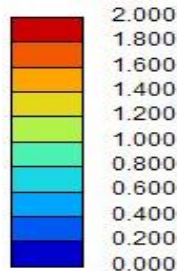
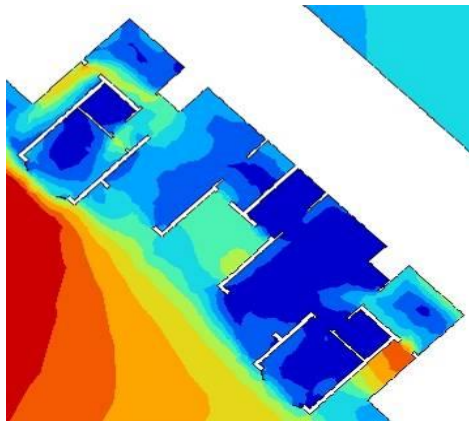
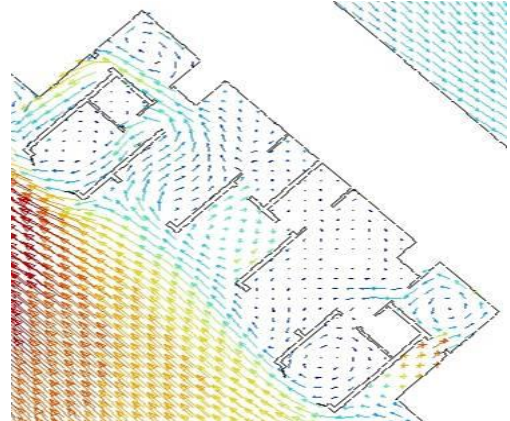


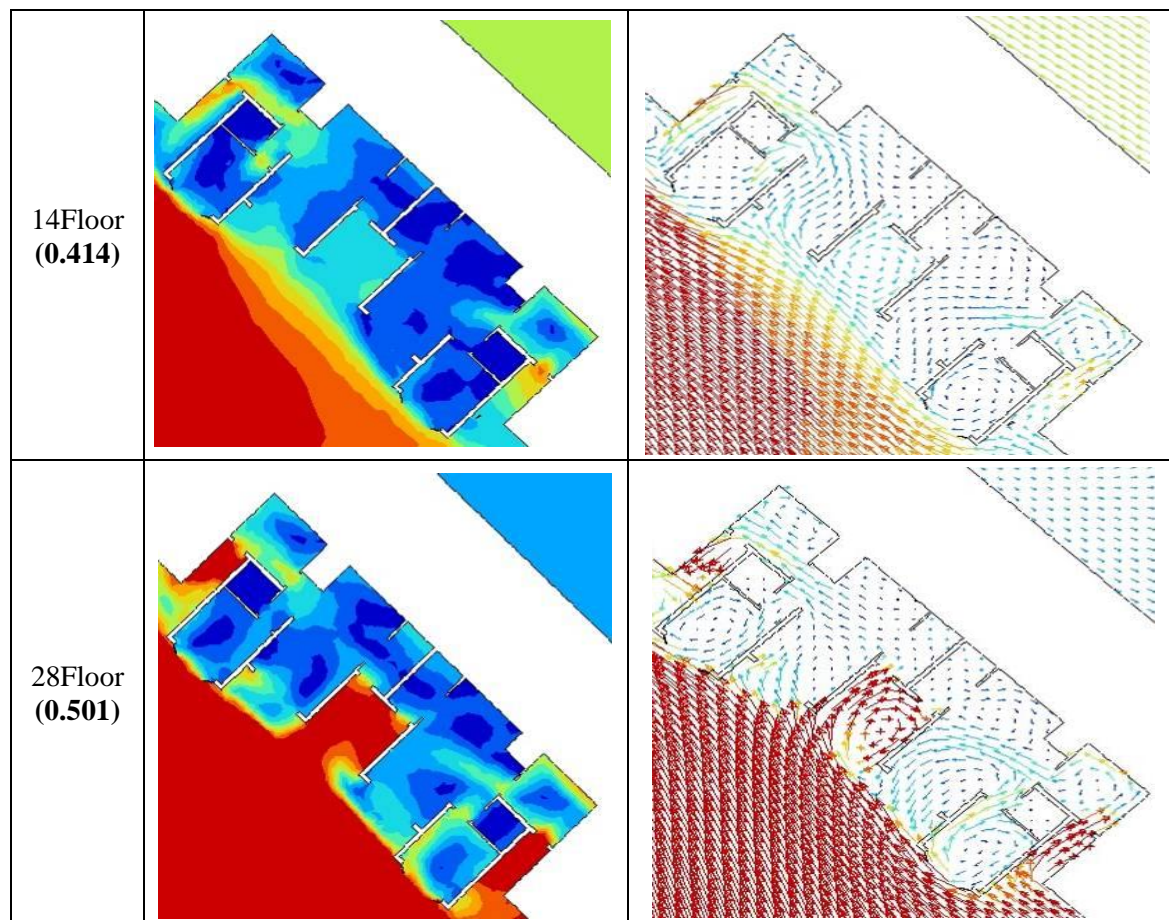
Figure 4. Improved house plan

3.2 Ventilation simulation results

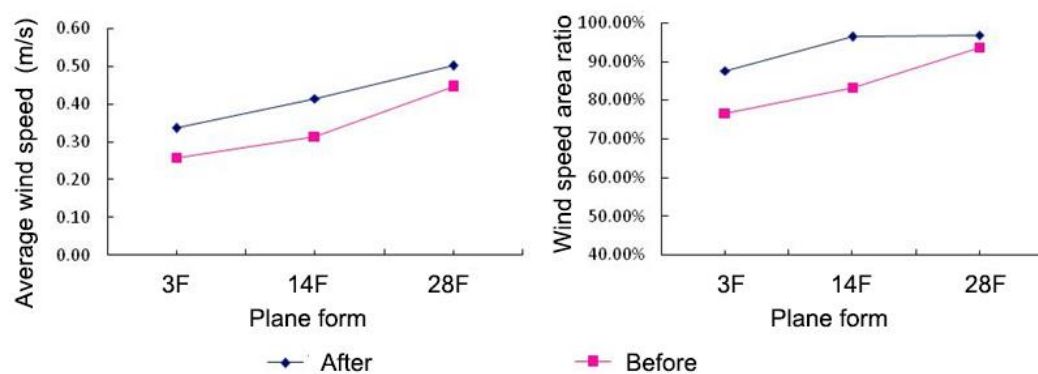
As shown in Table 3, the average indoor wind speed in the third floor of the improvement case was 0.336m/s, 0.414m/s in the 14th floor, and 0.501m/s in the 28th floor. As shown in Table 4, the area ratio of indoor wind speed was 87.59% in the floor 3, 96.27% in the floor 14, and 96.81% in the floor 28. The average indoor wind speed and wind speed area ratio of each floor increased with the increase of the floor. Compared with the indoor wind speed in table 2, it can be clearly seen that the area of dark blue part in the scalar diagram is significantly reduced, and the indoor ventilation effect of the east door model is significantly improved.

Table 3. Improvement case ventilation effect

Average wind speed (m/s)	  
	<div data-bbox="486 1496 694 1534">The scalar figure</div> <div data-bbox="989 1496 1228 1534">The vector diagram</div>
3Floor (0.336)	 

**Table 4.** Results of the Average wind speed and Wind speed area ratio(unit: m/s)

	Average wind speed		Wind speed area ratio	
	Improvement area	Actual cases	Improvement area	Actual cases
3 Floor	0.336	0.257	87.59%	76.51%
14 Floor	0.414	0.314	96.27%	83.28%
28 Floor	0.501	0.445	96.81%	93.50%

**Figure 5.** Comparative analysis of Average wind speed and Wind speed area ratio

As can be seen from table 5 and figure 5, the average wind speed and the wind speed area above 0.1m/s in the improved house model are significantly increased compared with the current cases. It can be seen from the previous ventilation results that the natural ventilation of the east house is weaker than that the west house. In order to narrow the difference in ventilation effect between the two houses, the ventilation strategy (5) suggests removing the wall A between the living room and the master bedroom of the east house to reduce the resistance on the indoor ventilation path. The results of average wind speed and wind speed area ratio of the east house are presented in table 5.

Table 5. The results of average wind speed and wind speed area ratio of the east house (unit: m/s)

	Average wind speed		Wind speed area ratio	
	Bfore	After	Bfore	After
3 Floor	0.230	0.147	81.47%	57.25%
14 Floor	0.349	0.218	94.35%	72.39%
28 Floor	0.550	0.484	98.22%	99.71%

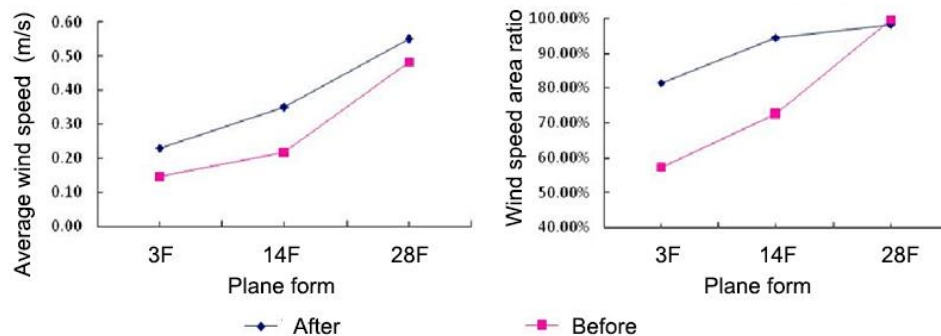


Figure 6. Comparative analysis of average wind speed and wind speed area ratio of the east house

As can be seen from figure 6, the natural ventilation of the improved east house is significantly improved, and the effect on the east house is more obvious, because of removing wall A from the interior of the house in strategy 5.

4. Conclusion

Based on indoor ventilation effect analysis and comparison of the single-sided residence, the study puts forward the corresponding design improvement strategies, including changing and increasing the model plane form and architectural structure. The results show that unilateral ventilation effect is better after application of improved strategies. Besides the wave and changed balcony window to the flat not only improves the unilateral ventilation effect, but also provides more flexible spaces for the house. At the same time it also verifies the effectiveness of improving the single-sided ventilation strategies.

5. References

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