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Wind Environment Simulation Based on Natural Ventilation of Traditional Large House Dwellings in Northeast Hunan Province

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Abstract: *This paper takes the traditional large house dwellings in northeast Hunan province as the research object and uses CFD technology to study the natural ventilation law of the large house dwellings. Firstly, through the field investigation of the large house dwellings in northeast Hunan province, the type analysis of the large house plane, groove door and patio is made, and the wind environment simulation research prototype is extracted. Then, CFD simulation software is used to calculate the characteristics of indoor and outdoor wind environment of traditional large house under different conditions. The results show that: 1. The indoor wind environment of slave type house is better than that of cascade type house and contiguous type house;2. The setting of the groove door is favorable to the indoor wind environment; 3. The setting of the passing hall is not conducive to the spread of indoor wind environment. This study reveals the ventilation characteristics of traditional large house in northeast Hunan province, and can provide reference for modern architectural design.*

Keywords: *Northeast Hunan Province; Traditional large house; CFD simulation; The wind environment*

1. Introduction

Residence refers to the building used for living function, and dwelling includes the residence and its extended living environment[1]. One of the most distinctive residential houses in northeast Hunan province is "Large house". These large houses spread out and gathered together, and the families were closely connected, even connecting the whole village together, forming a huge complex of buildings. People often name a large house after the surname of its occupant or the name of its founder, such as HuangJia large house[2]. At present, well-preserved large houses in northeast Hunan province include Zhangguying large house, Guanjun large house, Kanliang large house, etc. The site selection, layout and decoration of these houses all reflect the characteristics of traditional Chinese culture[3].

2. Prototype extraction of influencing factors of natural ventilation

2.1. Floor plan of the large house

The northeast of Hunan Province is located in the middle reaches of the Yangtze River Basin. This region has the characteristics of complex climate, sparsely populated, more mountains and less land. Local residents summed up a series of strategies to adapt to the environment from their daily life experience and applied them to the construction of residential houses. Under the support of these traditional experiences, the plan of large house residential buildings in northeast Hunan province presents three layout modes: cascade type, slave type and contiguous type.

2.1.1. Cascade type (tandem type)

The main rooms in the same row are arranged before and after the patio, and the wing rooms are on the left and right sides of the patio[4]. The main room and wing rooms enclose the patio from all sides, and the overall plan is generally a horizontal combination of five and three patios. The house is compact, the layout of the secondary rooms is reasonable, and the space utilization rate is high[5]. This type of large house with plane layout is the most distributed type in northeast Hunan province (see Figure 1).

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2.1.2. Slave type

On the basis of cascade style, the hall and patios on both sides are arranged vertically with the main shaft[4] to form a transverse hall. Some of the transverse halls are also arranged in parallel, and the patios are arranged in a Feng shape. If the basic unit of the transverse hall is arranged by one square and two patios, the patios are arranged in a Ri shape, such as the Guanjun Large House and Sifang Zu House, etc. (see Figure 2).

2.1.3. Contiguous type

The contiguous type of large house is formed by the staggered combination of multiple "cascade type"[6]. The difference between this form and the slave type combination is that the contiguous form takes a cross-hall combination as the axis, and the wing room is transformed into a passing room, which directly faces the patio on both sides. (see Figure 3).

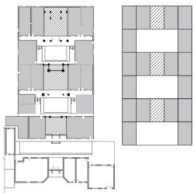

Figure 1: Simplified plane of Cascade type

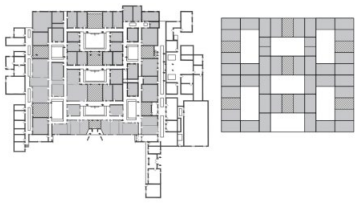

Figure 2: Simplified plane of Slave type

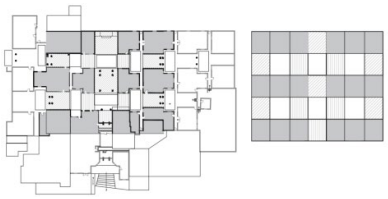

Figure 3: Simplified plane of Contiguous type

2.2. Groove Door

The groove door of the large house is usually opened in the opposite moon pond, facing the dominant summer wind direction, and is the main entrance of the building. Generally, the groove door retreats into the outer wall by 1.5-3m, forming a transitional gray space. It is not only a place for residents to enjoy the cool, but also a place to receive wealth from all sides. As a groove opening directly opposite the direction of incoming wind, the groove door can accelerate the wind blowing from the south, and is an important link in the ventilation system of traditional large houses in northeast Hunan province[7]. There are three main types of groove doors in the residential houses in northeast Hunan province, which are eaves type, splayed wall type and splayed wall concave type[8].

2.3. Patio

The patio is an important place for People's Daily life, and also an important means of regulating the indoor thermal environment of the large house[9]. In summer, when the patio is exposed to strong direct sunlight, the temperature of the roof of the patio is very high, while the interior of the patio is not directly exposed to sunlight and the temperature is low. Such temperature difference leads to the natural flow of air above and below the patio, forming natural wind[10].

2.3.1. Without Passing Hall style

In the northeast Hunan province, there is a wide range of traditional folk houses with open-hall

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patio layout. Due to the open treatment above the patio, this kind of patio is constantly separated from the house. From the foyer to the ancestral hall, the treatment of one hall and one patio, one shallow and one deep, has the effect of increasing the space depth of field. Therefore, it is one of the essential elements in the central axis sequence of courtyard residential houses.

2.3.2. With Passing Hall style

A passing hall is a four-way open space with a roof built into a patio. This type of house built between the main rooms not only better solves the problem of wind and rain protection of the patio, but also provides a more active interior space. In large houses, light and ventilation patios will be set aside between the left and right sides of the living hall and the side rooms. In this way, in residential houses, both indoor and outdoor air exchange patios can be used and indoor traffic can be facilitated[6].

3. Numerical simulation

3.1. Simulation Software

The analysis software used in this study is THSware VENT analysis software, which is built on CAD platform. The software displays computational fluid dynamics (CFD) in a visual way through integrated modeling, division of computing domain and other functions, and analyzes the flow field to generate results.

In order to clarify the wind speed and direction of each position, seven measuring points are set at the same position in each working condition, which are: 1, entrance, 2, front patio, 3, lower hall, 4, middle patio, 5, middle hall, 6, back patio, 7, ancestral hall. Measuring points are shown in Figure. 4, and measuring points are set at the same position in each simulation experiment.

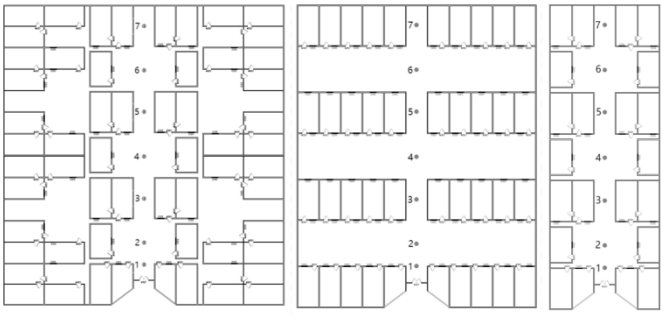

Figure 4: Location of wind speed measuring points under various working conditions

3.2. Large house plane simulation

3.2.1. Outdoor wind environment

As can be seen from Figure 5, when the natural wind passes through the sides of three different large houses, the wind speed increases at the corner. The difference is that the acceleration of the sharp Angle in working condition 2 (contiguous type) and working condition 3 (Cascade type) is more obvious than that in working condition 1 (Slave type), where the extreme value of the wind speed at the corner in working condition 2 (contiguous type) is 3.81m/s. In working condition 3, the extreme value of angular wind speed is 3.67m/s, and in working condition 1, the extreme value of angular wind speed is 3.27m/s. In addition, obvious vortexes appear on both sides of working condition 1 (Slave type).

Under the three working conditions, wind shadow area or no wind area appeared on the leeward side of the large house (Figure 5). The area of wind shadow area in working condition 1 (Slave type) was the largest, followed by working condition 2 (contiguous type), and working condition 3 (cascade type) was the smallest.

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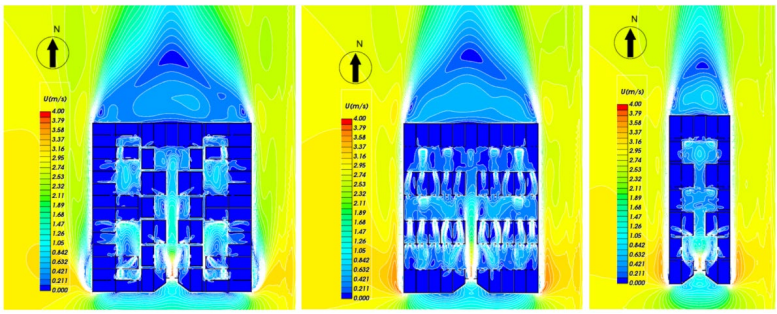

Figure 5: Wind velocity cloud at 1.5m indoor and outdoor of different plane types

3.2.2. Indoor wind environment

As can be seen from Figure 6-8, there are air flows in all parts of the large house under 3 working conditions. The natural wind on the central axis of the large house is composed of the draught from south to north and the draught from north to south. In working condition 1 (Slave type), the draught reaches farthest to the upper patio; in working condition 2 (contiguous type), the draught reaches to the middle patio; in working condition 3 (cascading type), the draught only reaches to the lower hall. This indicates that the draught effect is most obvious under working condition 1 (Slave type).

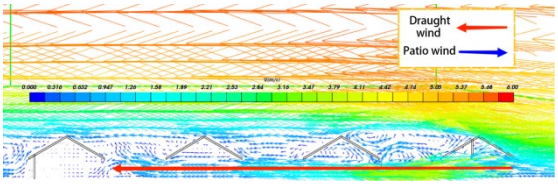

Figure 6: Working condition 1: Section wind Velocity vector on the central axis of the Slave type house

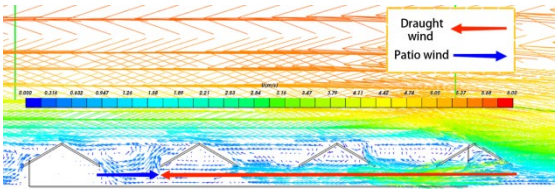

Figure 7: Working condition 2: Section wind velocity vector on the central axis of the contiguous type house

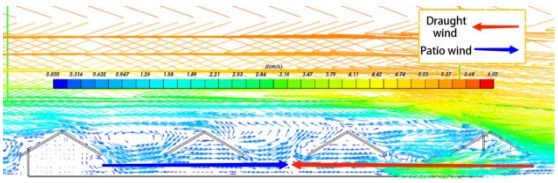

Figure 8: Working condition 3: Section wind velocity vector on the central axis of the cascading type house

As can be seen from Table 1, the average wind speed of each measuring point under the three working conditions is as follows: working condition 1 (Slave type) : 1.46m/s; working condition 2 (contiguous type) : 1.43m/s; working condition 3 (cascade type) : 0.98m/s. As a whole, the indoor wind environment of working condition 1 is better than that of working condition 2. The indoor wind environment of working condition 2(contiguous type) is better than that of working condition 3.

Table 1: Wind speed at each measuring point under different plane conditions (m/s)

measuring point	1	2	3	4	5	6	7
Working condition1	3.69	2.54	1.28	1.29	0.67	0.71	0.03
Working condition2	3.54	2.83	1.64	1.24	0.35	0.38	0.03
Working condition3	3.39	1.42	0.54	0.46	0.29	0.77	0.02

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3.3. Simulation of groove door

In this experiment, to understand the influence of groove door shape on indoor and outdoor wind speed, set the scale of groove door as: 2.7m*1.8m. Four working conditions are set: no groove door in working condition 1, eaves type groove door in working condition 2, splayed wall type groove door in working condition 3 and splayed wall concave type groove door in working condition 4 (as shown in Figure. 9).

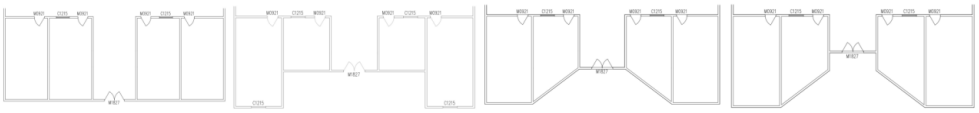

Figure 9: Groove door shape diagram

According to the wind velocity vector diagram at the vertical section of the central axis of the large house, the indoor wind environment of working condition 2 (eaves type), working condition 3 (splayed wall type) and working condition 4 (splayed wall concave type) in which the groove door is set is roughly the same. Natural air only offsets with the patio wind at the central patio after entering through the groove door, while the acceleration at the entrance of working condition 1 (no groove door) is not obvious. This reduces the wind speed of the ventilation in the lower patio and then escapes from the patio, indicating that the groove door does have an accelerating effect on the ventilation.

The research shows that the setting of the groove door accelerates the incoming air and is conducive to indoor ventilation, while the different groove door forms have little influence on the indoor air environment.

3.4. Patio simulation

In this experiment, the influence of passing hall on the indoor wind environment of the large house was studied. Two groups of working conditions were set, as shown in Figure 10. As can be seen from the wind speed vector on the central axis of the large house, the dominant wind direction in the large house under working condition 1 (with passing hall) and working condition 2 (without passing hall) is the same. The leading wind direction in the foyer and lower hall is the draught wind; the leading wind direction in the middle and upper hall is the patio wind; the draught wind and the patio wind converge in front of the central hall; the presence of passing hall has little influence on the draught wind. It has great influence on the formation of patio wind.

The wind speed at each measuring point under the two working conditions is studied. The average wind speed under working condition 1 (with passing hall) is 0.90m/s, and the average wind speed under working condition 2 (without passing hall) is 1.08m/s. On the whole, the indoor wind environment of the large house without passing hall is better than that of the large house with passing hall.

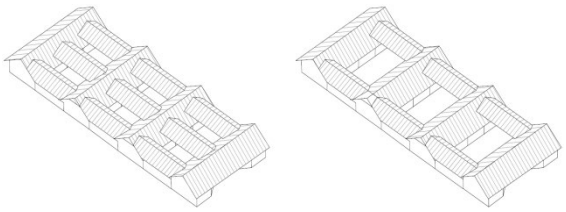

Figure 10: Working condition 1 with passing hall and working condition 2 without passing hall

4. Conclusion

This paper takes the traditional large houses in northeast Hunan province as the research object, extracts the prototype of typical large houses, restores its original layout, and then carries out software numerical simulation, and studies its ventilation performance by comparing the data of different measurement points. The following conclusions are drawn:

(1)There are three main types of large house planes in northeast Hunan province: cascade type, contiguous type and slave type. The simulation study of wind environment shows that the indoor wind environment of a large house is mainly composed of the outdoor ventilation and the patio wind generated by pressure. The stronger the ventilation is, the indoor wind environment is dominated by the

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south-north ventilation, and the stronger the patio wind is, the indoor wind environment is dominated by the north-south patio wind. On the whole, because of the numerous and complex internal patios and lane-way, the indoor wind environment of the slave type large house is better than that of the contiguous type large house and the cascade type large house.

(2)The groove door of large house has three forms: eaves type, splayed wall type and splayed wall concave type. In addition to the decorative function, the setting of groove door also greatly strengthens the wind speed of the house indoor draught, and the lower hall and the middle hall have better ventilation effect. There is no significant difference in indoor ventilation of large houses with different groove door forms.

(3) In some large houses, a passage hall is built between the front and back halls, which divides the patio into two parts, which not only ensures lighting and air exchange to the outside world, but also protects the sun and rain, and facilitates the passage of residents. However, the hall itself has no promoting effect on the indoor wind speed of the building, but blocks the air outlet of the house patio, which has an adverse effect on the indoor wind environment.

Acknowledgements

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References

[1] Xu Cong. Research on Rural Residential Renovation Design in Functional Renewal [D]. Southwest Jiaotong University, 2019.
[2] Zhang Bei. Spatial expression of civil order: A Study on the space of large houses in Southeast Hubei [D]. Huazhong University of Science and Technology, 2018.
[3] Xu Yongzhan, Guo Weimin. Zhang Jian's Architectural Views on the Western Application of Chinese Literature [J]. Journal of Nantong University (Social Science Edition), 2017, 33(05):140-143.
[4] Liu Shenglan. A Comparative study on the spatial pattern of traditional residential houses in Northern Siheyuan and South Patio Courtyard [D]. Hunan University, 2014.
[5] Sun Y F. A comparative study on the residential buildings of Hubei and Hunan under the influence of the "Hubei, Hunan and Guangdong Filling by Jiangxi" immigrants in Ming and Qing Dynasties [D]. Huazhong University of Science and Technology, 2008.
[6] Pan Y. Interpretation of the planar pattern of traditional dwellings in Jiangxi [J]. Agricultural Archaeology, 2009(03):197-199.
[7] Liu Xueqing, Liu Shichen, Liu Han, Ai Yong, Chen Qiuyu. Study on Ventilation Performance of traditional houses in Northeast Hubei [J]. Journal of Architecture, 2020(S1):33-37.
[8] Dan Jinsong. Survey of traditional dwellings in Chibi [J]. Chinese Dwellings, 2013(07):106-107.
[9] Liu Jin. Design Research on Improving the Indoor Thermal Environment of Rural Residential Houses in Chongqing [D]. Chongqing University, 2010.
[10] Liu Xueqing. Study on Ventilation Performance of Traditional Residential Houses in Northeast Hubei [D]. Huazhong University of Science and Technology, 2018.