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STUDY ON MEASUREMENT AND DESIGN STRATEGY OF RESIDENTIAL ROOM NATURAL VENTILATION IN CALM WIND CLIMATE ZONE -- A CASE STUDY OF HOUSEHOLD IN CHENGDU

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Abstract. It is found via the analysis of the meteorological data in Chengdu that the number of annual average calm wind days is more than 240. In the non-calm wind time, the dominant wind direction is not obvious, while the annual average wind speed is about 1.0 m/s. In consequence, problems arise as to indoor ventilation in residential buildings without mechanical ventilation in this climate zone and the way how local residential wind has adapted and improved natural ventilation for a long time. In this paper, the state of indoor ventilation in this zone is studied by measuring the concentration of carbon dioxide in the house for a long time. And the long-term adaptive improvement strategy of local residents to the ventilation of residential buildings in calm climate zone is investigated. So are strategies and experiences of local residents in improving natural ventilation in residential buildings.

Keywords: room natural ventilation, calm wind climate zone, design strategy, measurement, household

1 Introduction

Reasonable room ventilation discharges indoor heat, reduces the internal surface temperature of the room, negatively influences the life span of air conditioning, and plays an important role in improving the thermal environment and building energy saving [1]. Indoor natural ventilation depends on the outdoor wind environment and good room ventilation organization, especially for hot and wet zones [2]. However, there are two zones in China with low wind speed, among which, one is centred on Chengdu, Sichuan province, including Chongqing, southern Shaanxi, western Hubei, western Guizhou, etc. [3].Generally speaking, the wind speed in these areas is less than 1.5 m/s, considered a windless state. When it is less than 2 m/s, it becomes difficult for the atmospheric flow, regarded as a static wind state[4]. Therefore, the city with an annual average wind speed less than 2 m/s, and an annual dominant wind direction of static wind is defined as a static wind city, among which, Chengdu is the most typical [5]. Few residential buildings in China are furnished with fresh air systems, where fresh air is generally acquired through natural ventilation [6]. In consequence, it requires further reflection upon the indoor ventilation situation of residential buildings and the improvement of indoor ventilation in the calm air zone. This paper takes a residential building in Chengdu as an example, and analyzes the room temperature, humidity and carbon dioxide concentration under the annual natural ventilation condition and design strategy.

2 Introduction

Chengdu, located in the west of Sichuan Basin, the eastern edge of the Qinghai-Tibet Plateau, is classified into the hot summer and cold winter climate zone. The measurement data from 1971 to 2000 were used to analyze the outdoor climate characteristics of Chengdu. Rose chart of wind direction frequency in Chengdu was analyzed based on 30 years of data (see Figure 1). The maximum frequency is the northward wind direction at 11.5%, while the frequency with the zero wind speed in the test is 17.2%. In accordance with the measured wind speed in these 30 years, the annual average wind speed is 1.08 m/s, the wind speed less than 1.5 m/s accounts for 65%, the wind speed less than 2 m/s accounts for 82%, and the time of the wind speed more than 5 m/s is less than 5%, equipped with the characteristics of a typical static wind zone. The annual average wind speed in Chengdu varies greatly among these years, almost doubled from 0.73 m/s to 1.33 m/s (Figure 3). The question arises against the background of these meteorological parameters how the indoor environmental quality is in residential buildings relying on natural ventilation operation

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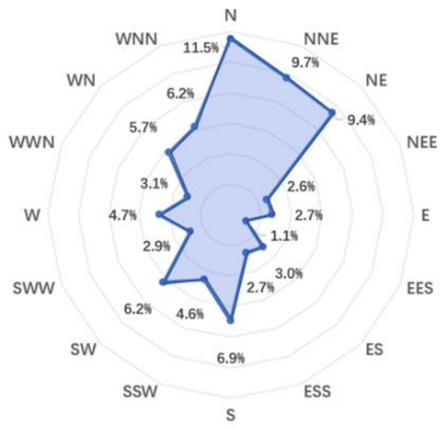

Fig.1. Wind rose map of Chengdu

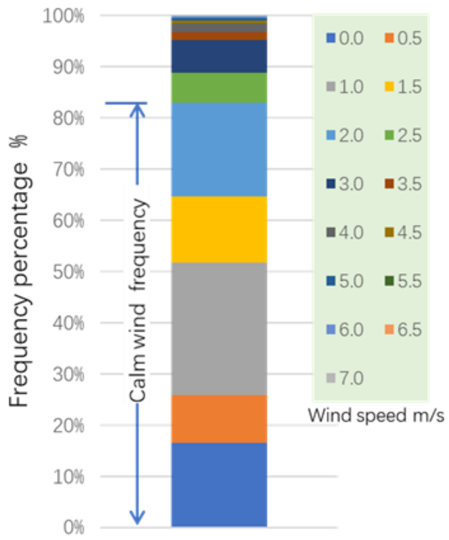

Fig.2. Bar graph of the annual cumulative wind speed frequency in Chengdu

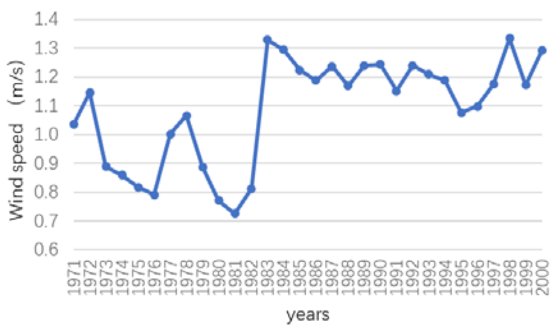

Fig.3. Annual average wind speed curve in Chengdu

3 Room environment test and data analysis

An indoor environment test was conducted on a house in Chengdu to help understand the indoor quality of houses under natural ventilation. Doors and windows of the room were open throughout the year. The test room and location are shown in Figure 4. The test tool adopted was the environment test automatic recorder produced by Tianyi instrument (Figure 5). Test parameters included temperature, relative humidity, and carbon dioxide concentration, with a test time step of 5 minutes. Test periods covered summer, winter, and excessive seasons. The specific time is from July 2021 to February 2022, with all the heating, air conditioning and transition periods involved.

3.1 Room temperature data analysis

Figure 6 shows the indoor temperature distribution in the room, where it can be seen that the indoor temperature featured a large fluctuation range between 12 and 37℃, exceeding 30℃ for parts of the summer under the natural ventilation state. In winter, the indoor temperature could be as low as 11℃, and twice exceeded 30℃ from October to November, due to the excessive solar radiation heat obtained by the large southbound window. For statistical analysis of indoor temperature shown in Figure 7, the median value of room temperature was 22℃, between 16 and 28℃ for 80% of the time and the room temperature exceeded 28℃ for about 10% of the time. Additionally, the room temperature was below 16℃ for 10% of winter, but only 1% of the time, and 12℃ was the limit temperature of human skin contraction. It can be concluded based on the test data analysis that natural ventilation can keep the room in a comfortable state for 80% of the time, with the problem of overheating or too cold for the rest of time.

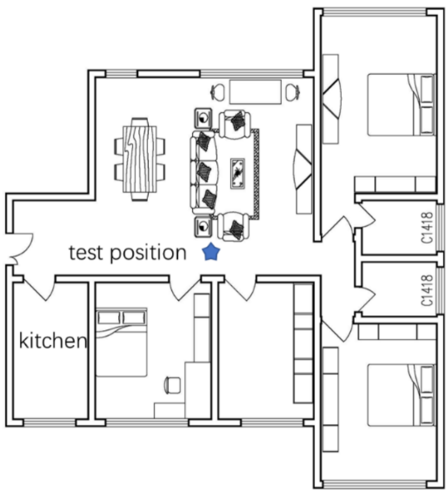

Fig.4. Test position and diagram sketch of the rooms plan

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Fig.5 The instrument

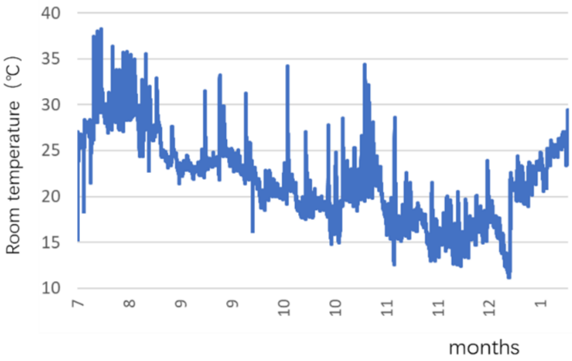

Fig.6. Room temperature curve（from 7/2021-2/2022）

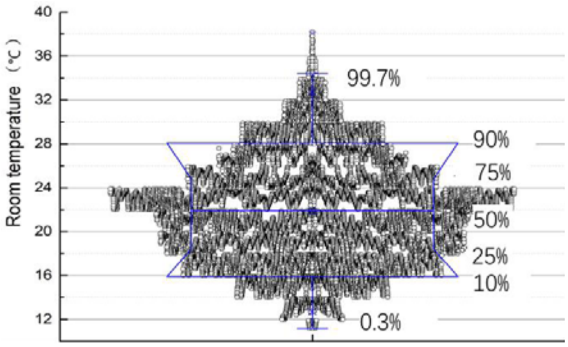

Fig.7. Box chart of room temperature（from 7/2021-2/2022）

3.2 Indoor relative humidity problems

Relative analysis of the room finds that the annual relative humidity is at a high level, and the annual floating range is between 45% and 95% (Figure 8).

It is found in the statistical analysis that humidity for 80% of the time is between 60% and 80%, the median value of relative humidity is 72%, and the relative humidity is higher than 50% (Figure 9).

Related studies show that different from people in thermal environment sensitive to humidity changes, people in neutral or cold environment are not sensitive to humidity changes [7].

Comparing Figure 8 and Figure 9, it can be found that high humidity always occurs with high temperature, when the outdoor temperature is higher than the indoor temperature, increasing the ventilation volume fails to reduce the indoor humidity.

Fig.8. Room relative humidity curve（from 7/2021-2/2022）

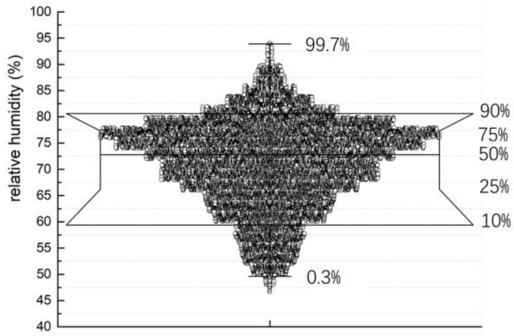

Fig.9. Box chart of relative humidity（from 7/2021-2/2022）

3.3 Indoor carbon dioxide concentration measurement

Limited by the instrument measurement, the step length of the chamber carbon dioxide concentration test is still 5 minutes. As can be seen from Figure 10, there is no correlation between the indoor carbon dioxide concentration and the season, which indicates that there is no seasonal difference in the volume of natural indoor ventilation. According to relevant studies, carbon dioxide concentration below 1000 ppm, in particular, the detection criteria for CO 2 concentration is the average concentration over a period rather than the control of transient values. As shown in Figure 11, the carbon dioxide concentration in the room is less than 450 ppm for 90% of the time, and does not exceed 500 ppm for 99% of the time. It can be reasonably concluded that insufficient ventilation can be achieved in residential rooms in hot summer and winter, not to mention good, or even excessive ventilation. The next step is to consider reduce in the natural ventilation volume and the building energy consumption for air conditioning and heating seasons.

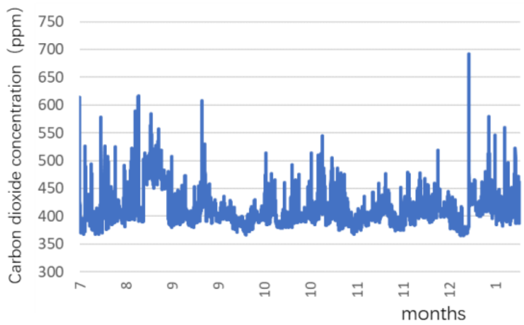

Fig.10. Room carbon dioxide concentration curve

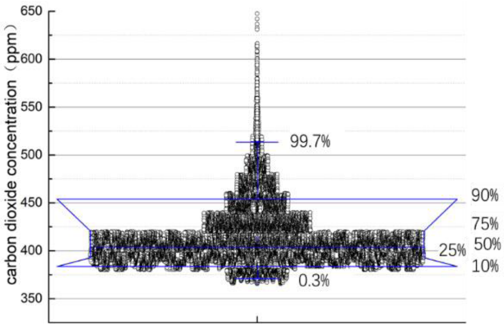

Fig.11.Box chart of r carbon dioxide concentration

4 Ventilation design strategy in residential buildings

Residential buildings are the result of local residents adapting to local climate for a long time, and they embody the wisdom to adapt to local climate and improve the quality of residential environment. The long-term adaptation also leads to changes in the habit of using the building. The living habit of the users of the test room in this project is to open the window all the year round, and refuse to close the doors and windows even if the room temperature changes. Through research, the following biological climate design strategies for residential buildings are adopted by people in Chengdu, so as to get themselves adapted to the local climate characteristics of calm wind.

4.1 Long-term opening of the window

In cities where the climate is similar to that in Chengdu, cities in the calm wind zone at the same time, there is almost no indoor blowing, forming the habit of residents using windows throughout the year, even at the expense of thermal comfort.

4.2 Cold roof tiles for the roof

Given their relatively mild climate, cold tiles are generally applied to the roof of residential buildings in these areas, which are directly laid on the wood strip, without plaster bonding, thus forming "trickle wind" by virtue of the gaps between the roof and the indoor.

4.3 The outer wall made of bamboo weaving, plastering or wooden board wall

The wooden structure houses in the residential houses, with strong plastering or wooden walls and a wall thickness of 2~3cm, is also ventilated. Even if the wall body is established with bricks, there is a gap in the purlins and the wall junction, which is not closed. These practices may be provided with economic considerations, but in the final analysis, no air tightness requirements are proven necessary for the room given the limited outdoor wind speed as well as the limited indoor and outdoor temperature difference.

4.4 The adoption of the indoor "bed account" room for the hot environment in winter

The environment in winter is not agreeable, since the residential houses are too "transparent" . Beds in the residential houses are enclosed to form the room and a relatively warm small space. It should be highlighted that "the comfort refers the comfort of people, not that of the house", especially at night. "Indoor hot environment" with human body heat can be achieved in winter via the adoption of enclosed beds inside the room.

5 5. Conclusion

Chengdu is a typical calm wind zone, with an outdoor wind speed less than 2 m/s for 82% of the year. Given the fact that it is difficult for buildings in the calm wind zone to form a sense of blowing, the residents have developed the habit of opening the window all year round, but through which, insufficient ventilation can be achieved in residential rooms in hot summer and winter, not to mention good, or even excessive ventilation.

The annual indoor air humidity is more than 50% for 90% of the time, when natural ventilation is required to reduce the indoor humidity and ineffective. In consequence, both the roof and outer wall of residential houses in Chengdu adopt the engineering practice of large gaps, which makes the hot pressure ventilation and air pressure ventilation relatively smooth. Considering the mild climate and low wind speed in Chengdu, coupled with the living habits or local residents, the indoor temperature is between 16 and 28℃ for about 80% of the whole year without air conditioning or heating equipmentt, and for about 10% of the year when intermittent air conditioning and heating methods are adopted.

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