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Research on the Current Situation of the Thermal Environment of the Top-story Residential Buildings in Kunming in Spring

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Abstract: With the development of social economy, people put forward higher requirements for thermal comfort of living environment, and more and more air-conditioning equipment are installed in Kunming residential building. In spring, how different is the thermal environment of the top floor of residential building compared with other floors in Kunming? In this paper, the temperature, humidity, wind speed in the main rooms of the top building and of the houses below the top floor and outdoor solar radiation are tested in the faculty District of Kunming Agricultural University. The data analysis shows that the thermal environment of the top-floor residential buildings in Kunming is worse than that of below the top floor. The temperature and humidity of the top floor are higher than those of below the top floor, but there is no significant difference in wind speed. At the same time, it is pointed out that good roof insulation design is of great significance in improving energy-saving design and thermal environment of the top floor in dwelling in Kunming.

1. Introduction

Kunming City is located in the southwest of China, Yunnan and Guizhou is higher than the central part, belongs to the low latitude plateau monsoon climate, the building climate zoning for category V areas. Kunming City, the center of 1891 meters above sea level, long hours of sunshine, solar radiation, the average annual sunshine in 2200 hours or so, the annual solar radiation of about 5500 MJ / ㎡, spring is the highest season of the year, solar radiation in March for 617.9 MJ / ㎡, April for 641.0 MJ / ㎡, May for 509.9 MJ / ㎡; the average temperature of 15 degrees, the daily temperature difference in Kunming The average temperature is 15 degrees Celsius, and the daily temperature difference in Kunming is large, and the daily temperature difference in spring can reach 12-20 degrees Celsius, which makes Kunming the famous "Spring City". [1]

In recent years, "Spring City" Kunming, with its high-quality geographic and climatic environment, has been actively building a large health city development strategy, [2] attracting more and more people to live in Kunming. With the development of social economy, to meet the requirements of different groups of people on the thermal comfort of the living environment, the family installed air conditioning equipmentMore and more, the operational energy consumption of residential buildings is also getting higher and higher.

The study shows that the climate composite index of Kunming is less comfortable in spring, with March as the uncomfortable period, and April and May as the sub-comfortable period. [3] In the past ten years, the urban heat island intensity and dry island intensity in Kunming have shown a significant increasing trend. [4] Kunming residents can reduce the indoor temperature by opening the windows for natural ventilation in summer, and most of the residents' thermal sensation is within the comfort range under non-mechanical conditions. [5] However, the space on the top floor of the residence is more directly affected by the outdoor weather environment such as precipitation, cooling and solar radiation due to the roof directly facing the outdoors, and the thermal comfort of the building is often worse compared to other floors. However, for the strongest solar radiation, the driest weather, and higher temperature of Kunming spring climate characteristics, Kunming spring residential penthouse building thermal environment has not yet been studied. In this paper, the difference between the thermal environment of the top floor and the bottom floor of the residential building is studied by comparing the test data, which reveals that it is of great practical significance to strengthen the research on the design of the roof insulation of Kunming residential buildings, to economize the operation cost of the buildings, and to improve the thermal environment of the top floor occupants [6].

2. Experimental Content

2.1 Purpose of the experiment

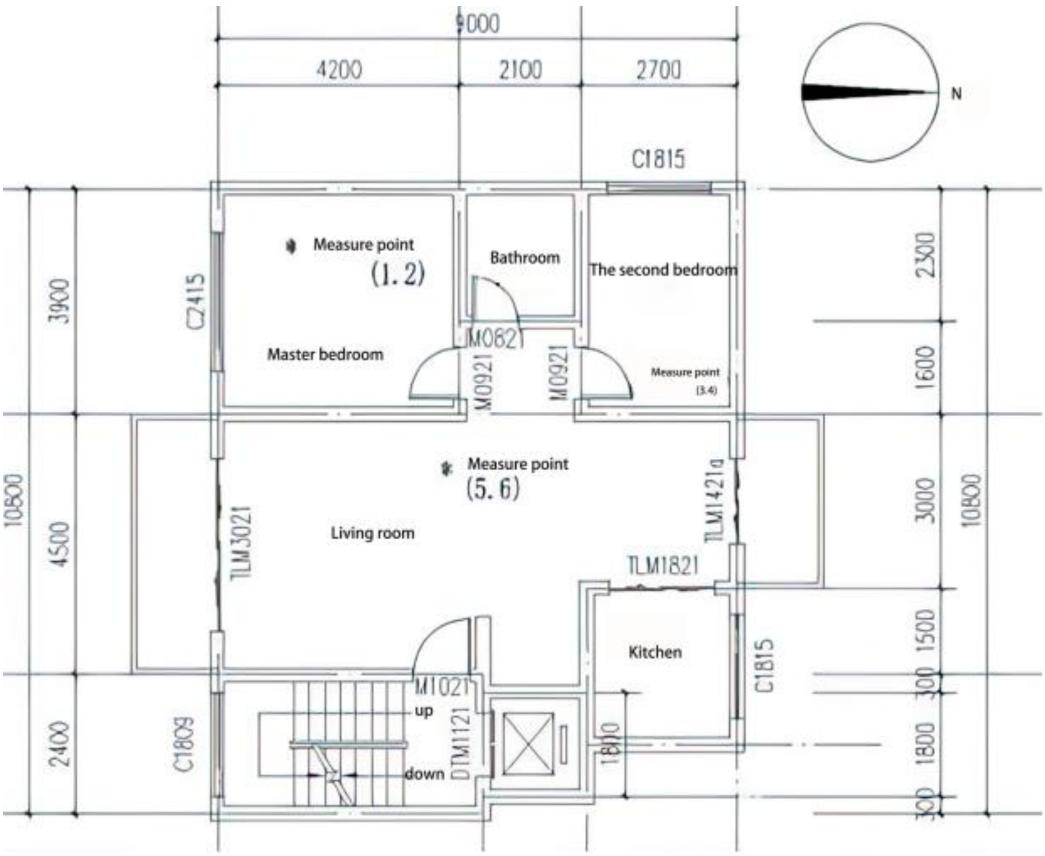

Figure 1: Building plan

In order to analyze and study the absorption of solar radiation on the roof of a residential building in Kunming in the spring affecting the thermal environment of the top floor building, to ensure that the test object is the same external environment in addition to the roof is subjected to solar radiation factors. This experiment selected a residential building in Kunming Agricultural University faculty residential area of the top floor residents (seventh floor) and the sixth floor residents as the test object (Figure 1), and data comparison and analysis. Experimental test research object situation: living room and master bedroom for the south, the second bedroom for the west, the building structure for the concrete frame structure, the building exterior wall for 240mm thick hollow clay brick, no insulation measures, the building window to floor ratio of 1:6, the roof is reinforced concrete flat roof, inside the 50mm thick polystyrene foam board insulation, for the non-superior roofing, in the upper roof of the master bedroom has solar collector panels. Experiments on the two households at the same time for temperature, humidity, wind speed and the intensity of outdoor solar radiation to test, compare and analyze the differences in the thermal environment of the building between the two, to summarize the amount of solar radiation absorbed by the roof affects the degree of influence of the thermal environment of the building on the top floor.

2.2 Experimental apparatus and experimental methods

2.2.1 Experimental equipment

The main instruments used in this experiment are: ① JTR08 temperature and humidity meter 7, test range 0 - 100% RH / - 40 - 85 ℃; measurement accuracy: ±1.5% RH / ±0.3 ℃ resolution: 0.1% / 0.1 ℃. ②TESTO425 thermal anemometer tachometer 3, measurement range 0 ~ 20m / s; resolution: 0.01m / s. ③ JTR05 solar radiometer 1, test range 0 ~ 2000w / ㎡, stability: < ±2%.

2.2.2 Experimental method

Temperature and humidity meter through the setting, every 30 minutes to record, 24 hours uninterrupted data collection, continuous testing for 7 days; solar radiometer through the setting, every hour to record every 7:00 am to 7:00 pm, continuous recording for 3 days, indoor wind speed test for manual testing of indoor wind speed every 1 hour to record for 3 days.

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3. Experimental data and data analysis

The amount of data collected in this experiment is relatively large, and considering that the purpose of this study is to determine the impact of solar radiation on the indoor thermal environment of the building, the impact of solar radiation on the results is particularly prominent in the test process. Through the comparison of the test data, it is concluded that the test results on May 23 objectively reflect the difference of thermal environment between the residents on the top floor and the following floors of the building.

3.1 Solar radiation data and analysis

In the test process, the weather is mainly sunny, solar radiation is relatively large, the average intensity of total solar radiation is 552W / ㎡, the peak intensity of solar radiation appeared at 13:30 on May 22 as 862W / ㎡, Figure 2 shows the solar radiation time-to-time change curve.

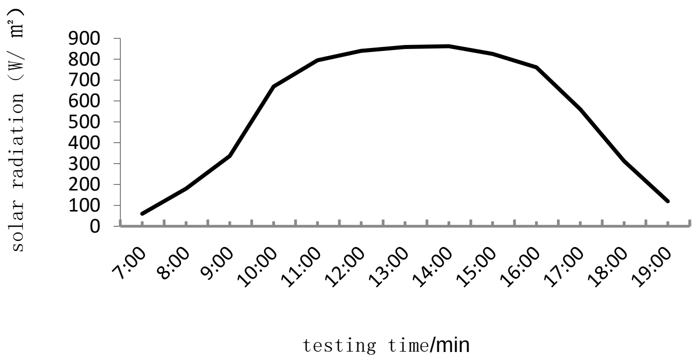

Figure 2: Time-by-time variation curve of solar radiation

3.2 Temperature data analysis

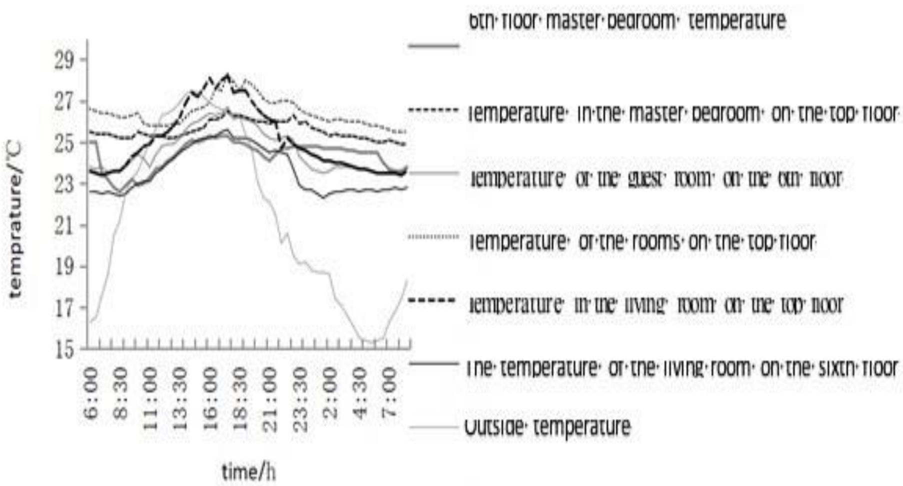

Figure 3: Time-by-time variation curve of solar radiation

As shown in Figure 3, it can be seen that the maximum outdoor temperature was 27.5℃ and the minimum temperature was 15.3 ℃, with a temperature difference of 12.2℃, which is a large temperature difference. The highest temperature appeared around 14:30 and the lowest temperature appeared around 6 o'clock. During the daytime, the temperature shows a gradual increase with the rising of the sun, peaking in the afternoon, decreasing with the setting of the sun in the west, and gradually decreasing at night due to the strengthening of air convection and the influence of atmospheric radiation. Compared with the change of outdoor temperature, the change of temperature inside the building is small, the highest temperature of all test points appeared around 17:30, which is 3 hours later than the highest point of outdoor temperature; the lowest temperature of all test points appeared between 7:00 and 8:30, and the change of temperature of all test points between 7:00 and 8:30 was within 0.2 degrees.

Table 1: Room temperature related data

Room Name	highest temperature	minimum temperature	Temperature	Average temperature	The temperature changes Rate	Up and down floors Average temperature difference	remark
Master bedroom on the top floor	26.7	24.9	1.8	25.6	7.0	1.3	——
6th floor master bedroom	25.7	22.6	3.1	24.3	12.7		Solar collector panels shade the sun
Second bedroom on the top floor	28.3	25.2	3.1	26.4	13	1.8	No shading
Second bedroom on the 6th floor	26.7	23.5	3.2	24.6	11.7		——
Top-floor living room	27.9	23.4	4.5	25.1	14	1.5	No shading
Living room on the 6th floor	25.6	22.3	3.3	23.6	17.9		——
outside	27.5	15.3	12.2	21.4	57	——	——

As can be seen from Table 1, the temperature change in the master bedroom located in the south direction is small, and the maximum temperature in the master bedroom of the sixth-floor occupants is 25.3℃ and the minimum temperature is 23.6℃, with a temperature difference of 1.7℃, and the temperature change rate is 12.7%, and the formula for the temperature change rate is $P = \frac{t_{max} - t_{min}}{t_0} \times 100\%$: where: t_{max} is the maximum temperature℃; t_{min} is the minimum temperature t_{min} ℃; and t_0 is the average temperature℃. The temperature change rate is the rate of temperature change of a given time. The rate of temperature change indicates the magnitude of temperature change within a certain period of time. The maximum temperature of the master bedroom of the occupant on the top floor is 26.76℃ and the minimum temperature is 24.96℃. The temperature change rate is 7%, and the average temperature difference between the master bedroom of the occupant on the top floor and the master bedroom of the occupant on the sixth floor is 1.22℃. The maximum temperature in the west-facing second bedroom on the top floor was 28.3℃ and the minimum temperature was 25.2℃, with a temperature difference of 3.1℃ and a rate of change of 11.7%. The maximum temperature in the west-facing second bedroom on the sixth floor was 26.7℃ and the minimum temperature was 24.9℃, with a temperature difference of 1.8℃ and a rate of change of 7%, and the average temperature difference between the second bedroom on the top floor and the second bedroom on the sixth floor was 0.89℃. The highest temperature in the living room on the top floor was 27.9℃, The minimum temperature is 23.4℃, the temperature difference is 4.5℃, the average temperature is 25.1℃, and the temperature change rate is 14%.The maximum temperature of the living room on the sixth floor is 25.6℃, the minimum temperature is 22.3℃, the temperature difference is 3.3℃, the average temperature is 23.6℃, and the temperature change rate is 17.9%. The average temperature difference between the living room of the top-floor occupant and the living room of the sixth-floor occupant is 1.5℃.

The temperature difference between residential buildings in Kunming is smaller than the outdoor temperature difference, 12.2℃ outdoors and 1.8℃-4.5℃ indoors. The magnitude of outdoor temperature change is greater than that of indoor, the rate of change of outdoor temperature is 57%, the rate of change of indoor temperature is 7%, -17.9℃, the rate of change of temperature difference is 50%—39.3%. Outdoor temperatures were above the average temperature for 9 hours, and residential rooms were above the average temperature for 9-16 hours. Temperatures at all test points were above the average temperature at each test point for the period from 0900 to 2130 hours. The temperature in each room of the top floor residence was 1.3-1.8℃ higher than the average temperature in the corresponding room of the sixth floor residence, where the maximum temperature in the second bedroom and the living room of the top floor was higher than the maximum outdoor temperature by 0.4℃-0.8℃ for a duration of 4.5 hours and 4 hours. Due to the installation of solar collector panels on the roof of the master bedroom on the top floor, the solar collector panels have a certain shading effect, which is helpful for indoor cooling, and the master bedroom with shading measures, also located in the top floor of the household, has a lower average temperature of 1.2℃ than the second bedroom without shading measures. And the living room on the top floor, which is also without shading measures, has a lower temperature than the second bedroom on the top floor, with an average temperature difference of 1.3℃. This is mainly due to the fact that the natural ventilation in the living room is better than that in the second bedroom, which can be known from Figure 5.

3.3 Humidity data analysis

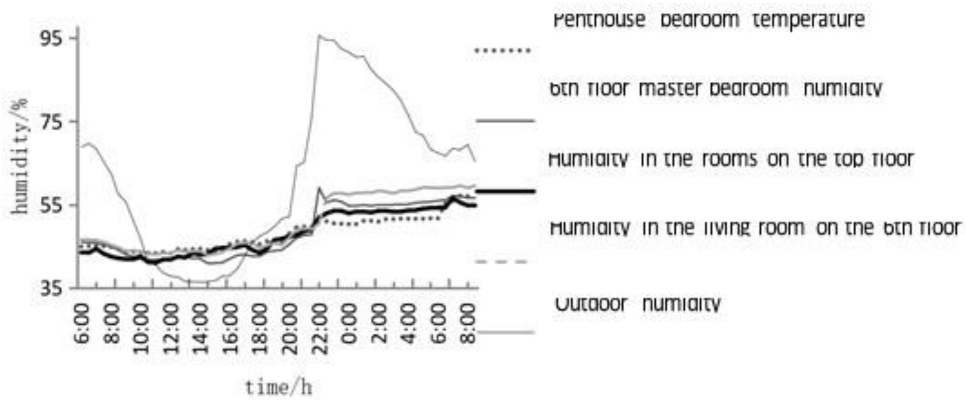

Figure 4: Indoor and outdoor relative humidity change curve hour by hour

As shown in Figure 4, both outdoor and indoor, the relative humidity change exists in the opposite trend to the temperature change, the temperature increases, the humidity decreases, but the outdoor humidity is greatly affected by the weather change. At about 22:00, it rained in showers, and the outdoor humidity rose suddenly. Similarly, the indoor humidity of the building showed a sudden rise influenced by the outdoor humidity, but the change was small in comparison. There is also a difference in humidity between the top floor and sixth floor occupants. The humidity at each test point in the top floor occupants is smaller than that at each test point in the sixth floor occupants, but the magnitude is not large, with a difference of only 1.1% to 2.4%. The range of humidity change at each humidity test point in the household is 14.5%—16.7%, but under the influence of outdoor showers, the humidity will also increase more substantially, by 10%—15%.

3.4 Analysis of wind speed data

As the two households being tested are up and down the floor relationship, i.e., the 7th and 8th floors, the building facade and window opening form are the same, while the external airflow environment is basically no difference, from the test results, it also proves that there is no change in the wind speed between floors. Therefore, the wind speed test point data of the top floor occupants will be analyzed and illustrated.

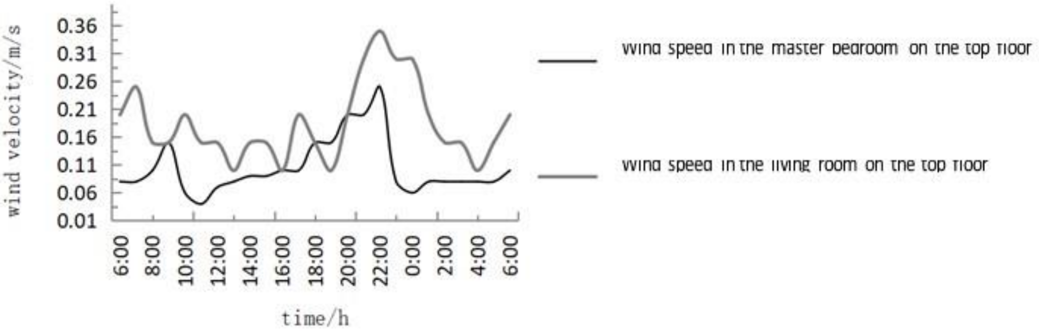

Figure 5: Wind speed variation graph

As shown in Figure 5, it can be seen that the internal ventilation conditions of the building are relatively good, except for the evening rest time of the master bedroom, the living room and the master bedroom have high wind speeds in the morning and evening, and in the middle and lower part of the day, and the wind speeds in the afternoon are small. At the same time, the top floor living room has a penetrating wind, the ventilation effect is better than the top floor master bedroom, which is conducive to indoor cooling and improves the comfort of human thermal sensation. The average wind speed of the top floor living room is 1.8 m/s, the highest frequency of 0.15 m/s wind speed occurs, accounting for 41.6%, the lowest wind speed is 0.1 m/s, the wind speed changes are relatively large, and the highest wind speed is 0.35 m/s, which occurs before and after the showers around 22:00. The average wind speed in the top master bedroom was 0.11 m/s, 0.008 m/s had the highest frequency of occurrence, accounting for 37.5%, the lowest wind speed was 0.04 m/s, the highest wind speed was 0.25, and the wind speed varied less.

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4. Conclusion

By testing the building thermal environment of the top floor and the sixth floor of the tenants in the faculty residential area of Kunming Agricultural University, including solar radiation, indoor and outdoor temperature, humidity and wind speed, the data were analyzed above, and the following conclusions were drawn:

(1) The spring in Kunming is dry, high temperature and little rain, the indoor temperature of the tenants on the top floor is significantly higher than that on the sixth floor, the temperature is higher than the average temperature for a longer period of time, and the maximum temperature is higher than that of the outdoor maximum temperature; the change in humidity decreases with the increase in temperature, and the magnitude of the change is slightly greater than that of the sixth-floor tenants; there is no obvious difference in the wind speed between floors, and the role of ventilation is obvious in the decrease in temperature. Overall, the thermal comfort of the occupants on the top floor of Kunming residences in spring is much worse than that of other floors, presenting a building indoor environment characterized by dry heat.

(2) Comparing the roofs with shading measures with those without, the roofs with shading have better effects on indoor cooling; the effects of various roof shading measures on the thermal environment of the buildings mainly based on passive building technologies have a good research value in the further study of the thermal environment of Kunming residences.

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