Study on winter indoor thermal environment of the folk houses in Tibet Plateau

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Abstract: Lhasa is located in the middle of the Tibetan plateau, north of the Himalayas, its climatic characteristics and the form of residents are representative of the Tibetan Plateau. In order to master the indoor thermal environment of rural highland in Tibet, this paper tests the indoor and outdoor thermal environment parameters of a passive solar heating house in Lhasa, and analyzes the test results. The results show that the solar radiation intensity is high and the sunshine time is long, which is suitable for the development of passive solar energy buildings, and the interior space of the rural buildings is rationally arranged based on the use function, which can effectively improve the temperature of the main rooms. The variation law of indoor air temperature and wall temperature is approximately the same, and there is a certain phase difference between the two kinds of temperature waves; The relative humidity of the indoor air fluctuates between 18% and 32%, and the relative humidity of the indoor air is small, and the indoor humidity environment should be improved. The results of this study can provide theoretical reference for indoor thermal environment improvement in this area.

Introduction

Tibet is located in the roof of the world, high altitude, air drying, atmospheric transparency, low cloud, and the sunshine time is long, low latitude, Tibet's annual total amount of solar radiation reaching about 7000 MJ/m³, annual sunshine hours more than 3000 h, more than doubled in the eastern coastal areas in China, but is also China's most abundant solar energy resources in the region^[1]. However, the fragile ecological environment in Tibet, the economic development lags behind, the conventional fossil energy is very poor, coal, oil and natural gas reserves of nearly zero^[2]. If these conventional energy as heating energy, must rely on long-distance transport, high cost, difficult to solve the problem of residential building heating energy. The use of local rich solar energy resources to build solar houses, has a very important significance to improve the residential building indoor thermal environment quality, save energy, protect the unique ecological system in Tibet plateau.

Lhasa is located in the middle of the Tibet plateau and the north of the Himalaya mountains, the climate characteristics and the residents are all representative of the Tibet plateau^[3]. In this paper, the indoor and outdoor thermal environment of a passive solar heating residence in Lhasa was investigated, to explore the status of rural residential indoor thermal environment in the region,

and influence factors of indoor temperature analysis, in order to provide the basic research data to further improve the temperature of passive solar houses in the area in winter.

Test object

The tested object is located in Linzhou County Tie Gong Village, the indoor space is mainly composed of hall, bedroom room, living room and kitchen, indoor wall height of 2.5 m, 500 mm thick adobe walls and facades painted white paint, the roof construction practices from the top down according to the times of clay mud, gravel layer fine wood, rafters, purlin structure, thickness of about 500 mm; between the living room and kitchen with a partition, about 2.5 mm thick, the rest of the partition wall is 500 mm thick adobe walls; windows for Aluminum Alloy single glass window, all the room doors are wooden doors, south window wall area ratio of 0.42, to the East 0.2, the north is 0.1, Living room and the kitchen there are auxiliary heat source, other rooms are no auxiliary heat source, the elevation is shown in Figure 1.

Fig 1 Elevation drawing

Test plan

The test time for the December 26, 2016 8:00 to December 27th 8:00, during the test period the weather was fine, the test content includes the indoor air temperature and humidity, wall temperature, outdoor air temperature and humidity, solar radiation and scattering intensity etc..

The arrangement of measuring points in Figure 2, indoor and outdoor air greenhouse test using 175-H1 type automatic high precision temperature hygrometer, measurement accuracy of 0.2°C , the indoor temperature and humidity measurement from the ground 1.5 m, outdoor air temperature and humidity measuring points are arranged in the outdoor shade; the inner surface temperature test, the data recorder of LR5021 measurement, the inner wall the surface temperature measuring point is positioned in the middle of the wall is tested; the intensity of solar radiation by using domestic JTDL-4 type solar radiometer, solar radiation level settings and the open space around, no shelter. Indoor and outdoor parameters acquisition interval are 10min.

Fig. 2 the size of the building and the layout of the measuring points

Can be seen from Figure 2, the existing rural residential area has been the integration of some of the solar thermal utilization of ideas and methods, such as the interior space of a reasonable division of the north and south, two-way layout, will mainly use the room as the living room and bedroom are arranged in the south, and the auxiliary room such as kitchen, grocery room layout in the north.

Test results and analysis

Outdoor thermal environment test

The daily variation of solar radiation intensity and outdoor air temperature during the test are shown in Figure 3, figure 4.

Fig.3 Diurnal variation of solar radiation intensity

Figure 4 outdoor air temperature

It can be seen from Fig. 3 that the sunshine time is about 9 hours. The maximum radiation value of the sun appears at 14:00 pm, the radiation intensity is high, the maximum is $788 \text{ W} / \text{m}^2$, the average is $436 \text{ W} / \text{m}^2$, The proportion of scattered radiation to total radiation is very small, about 35%. As can be seen from Figure 4, the average air temperature during the test is about $-1.7 \text{ }^{\circ}\text{C}$, the maximum air temperature is $4.9 \text{ }^{\circ}\text{C}$, the lowest temperature is $-9.8 \text{ }^{\circ}\text{C}$, the temperature fluctuates greatly.

The data show that the region's high intensity of solar radiation, long sunshine, high outdoor air temperature fluctuations, but the average temperature is not low, this unique outdoor weather conditions suitable for building passive use of solar energy to solve the problem of winter heating ^[4]

Indoor thermal environment test

Indoor air temperature

The indoor air temperature of each room is shown in figure 5.

Fig 5 indoor room hourly temperature

From Figure 5, the data can be seen, the higher temperature of living room and kitchen, and about 18:00 temperature increased, the reason is the living room and the kitchen are auxiliary heat source, other rooms without auxiliary heat source, so we focus on the changes of temperature and humidity in the other room.

It can be seen from the change of temperature in other rooms that the indoor temperature of the south to the room is higher than that of the north. The bedroom and the hall the average temperature is about 8.1°C , and the storage room (middle) and storage (West) the average temperature is only 4.2°C and 2.8°C . The main reason is that the bedroom is in the middle position of the building, the hall and living room is located on both sides, On the north side of the storage room (middle) constitutes the bedroom "temperature transition zone" On the north side of the storage room (middle) constitutes the bedroom "temperature transition zone"^[5], effectively reduce the heat loss of the bedroom, the temple. Room temperature fluctuation is larger than the north room, storage room (middle) and storage (West) temperature difference is about 1.8°C and 2.6°C , the temperature difference between the bedroom and the hall is about 4.7°C and 4.4°C . The main reason is that the south window wall area ratio is relatively large, resulting in increased heat loss at night, resulting in increased temperature fluctuations.

The above data show that the south of the building room to get more heat, and the heat loss is small, which can make the indoor air temperature is maintained at a high level, For the Lhasa area with abundant solar energy resources, indoor space of residential building based on the reasonable layout of the use function, to optimize the use of solar energy to create a comfortable indoor thermal environment is very necessary and effective.

Indoor air humidity

The indoor air humidity of each room is shown in figure 6.

Fig 6 room humidity changes in the room

As can be seen from Figure 6, the average relative humidity of each room is low, between 18% ~ 32% fluctuations, while the human body comfort humidity range between 30%-60%^[3], the indoor air is very dry. Therefore, the construction of the area should be moderately improved indoor humidity environment to meet the needs of people's thermal comfort. Indoor air humidity decreases with the increase of air temperature, The humidity value of the living room is very volatile, the amplitude is about 17%, the main reason is that the living room for the people the main activities of the room, the activity increased the content of indoor water vapor ^[6].

Room wall temperature

The temperature of the inner wall and the indoor air temperature between the bedroom and the storage room are shown in Figure 7, figure 8.

Fig 7 bedroom hourly wall temperature and air temperature

Fig. 8 Storage room hourly wall temperature and air temperature

Can be seen from figure 7, the higher value of the average south wall surface temperature, higher temperature fluctuations, the average value is about 8.9 °C, the fluctuation value of 6 °C; the north wall of the average wall temperature is low, the temperature fluctuation is small, the average value is about 8.6 °C the fluctuation value of 3 °C. The average wall temperature of the west wall is basically the same as that of the south, the main reason lies in the bedroom on both sides of the "temperature transition zone" to effectively reduce the heat loss to the wall; east wall temperature is higher, the main reason is the living room with intermittent heating, the auxiliary effect on the east wall of the wall temperature improve. The temperature of the inner surface of the outer wall is affected by two aspects: one is the influence of the outside temperature wave on the wall, and the other is the influence of the indoor air temperature. The attenuation effect of wall on

the outdoor temperature is far greater than the indoor temperature, so the change rule and the indoor temperature change within the external wall surface temperature test value is roughly the same, but different parts of building envelope heat capacity difference, is caused by the internal surface temperature fluctuation was the main reason of the difference.

Can be seen from Figure 8, the storage room (middle) the change trend of the surface temperature of the wall is basically the same, but there are differences in the wall temperature, the average wall temperature of the south wall is higher than that of the north wall, but the temperature fluctuation value is basically the same as about 1.1°C , and the average temperature of the southern

wall surface is about 6.1°C , and the average wall temperature of the north wall is about 4.6°C .

The main reason is that the heat gained from the main rooms of the south is transferred to the room by the inner partition wall, firstly, the south wall temperature of the north room is increased, and then the convection heat exchange with the air causes the temperature of the north room to rise, In addition, the north does not have direct solar heat caused by the northern wall outdoor air temperature is the lowest, making the largest loss of heat to the north wall.

The variation law of air temperature and wall temperature is approximately the same, but there is a certain phase difference between the two kinds of temperature waves, there is a certain complementary effect between the two kinds of temperature waves, which is helpful to improve the stability of indoor thermal environment.

Conclusions

(1) In Lhasa, the solar radiation intensity is high, the sunshine time is long, and the outdoor air temperature fluctuates greatly, but the average temperature is not low, this unique outdoor weather conditions suitable for the use of passive solar building to solve the heating problems in winter.

(2) The south room of the building is obviously hot, and the heat loss is small, which can make the indoor air temperature is maintained at a high level, For the Lhasa area with abundant solar energy resources, indoor space of residential building based on the reasonable layout of the use function, to optimize the use of solar energy to create a comfortable indoor thermal environment is very necessary and effective.

(3) The indoor air is very dry in winter, indoor air relative humidity is only between $18\% \sim 32\%$. Therefore, the construction of the area should be moderately improved indoor humidity environment to meet the needs of people's thermal comfort.

(4) The variation law of air temperature and wall temperature is approximately the same, but there is a certain phase difference between the two kinds of temperature waves, there is a certain complementary effect between the two kinds of temperature waves, which is helpful to improve the stability of indoor thermal environment.

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References

- [1] Wang Yuqun, Wang Junle. Tibet solar energy development existing problem and several suggestions[J]. Tibet's Science&Technology, 2007, (02): 26-28.

- [2] Sang Guochen, Study on Construction System of Low Energy consumption Residential Building in Tibet Plateau[D]. Xi'an: Journal of Xi'an University of Architecture & Technology, 2009.
- [3] Yang Liu. Building climatology [M] . Beijing: China Architecture & Building Press, 1986.
- [4] Xie Linna, Climate Division for passive solar buildings[D]. Xi'an: Journal of Xi'an University of Architecture & Technology, 2006..
- [5] Sang Guochen, Chen Deyong, Han Yan, et al. Measuring study of passive solar house for dwelling building In Ningxia Zhongwei Area [J]. Journal of Xi'an University of Technology, 2015, 31(3): 273-276.
- [6] Hu Rongrong, Li Wanpeng, He Wenfang, et al. Study on winter indoor thermal environment of the folk houses in qinling mountains[J]. ACTA ENERGIAE SOLARIS SINICA, 2011, 32(2): 171-174.