Analysis on night ventilation effect of buildings with different energy consumption levels in Shenyang

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Abstract. In this paper, the effects of night natural ventilation on indoor thermal environment of ultra-low energy consumption in a university in Shenyang were evaluated. The DeST software was used to establish the ultra-low energy consumption building model and the conventional building model, and the accuracy of the model is also verified experimentally. The indoor temperature, building power consumption of air conditioning system of the two models were calculated under the natural ventilation condition at night. The results show that under the optimal night natural ventilation conditions in July and August, the energy saving rate of ultra-low energy building refrigeration system is 15% and 46% respectively. The energy saving rate of conventional building refrigeration system is 14% and 44% respectively. The peak indoor temperature of the two types of buildings decreases with the increase of natural ventilation time at night. Both ultra-low energy consumption buildings and conventional energy consumption buildings adopt natural ventilation at night to help reduce indoor temperature, building power consumption of cooling system.

1 Introduction

In 2018, the total life-cycle energy consumption and carbon emission of buildings in China were 2.147 billion TCE and 49.3 t CO2, respectively, accounting for 46.5% and 51.2% of the total energy consumption in China [1-2]. Therefore, the construction sector plays an important role in achieving the goal of energy conservation and "dual carbon". At present, the building energy saving measures [3] mainly include improving thermal insulation performance and the heating efficiency of heating, air conditioning and refrigeration heating system, strengthen the building energy system operation and management, use of renewable energy, on the premise of guarantee the quality of the indoor thermal environment, thermal resistance, increase the energy exchange between indoor and outdoor to reduce the energy consumption of heating system, air conditioning refrigeration and heating, etc. The energy consumption of building HVAC system continues to rise, accounting for about half of the total energy consumption of buildings [4]. Natural ventilation at night, as an important energy-saving measure in building operation, has been widely concerned.

Night ventilation and cold storage is to send outdoor natural cold air into the room at night, so that it can conduct convection heat exchange with indoor air, envelope structure, furniture, etc., for pre-cooling and cold storage; During the day, the stored cold energy is supplied to the indoor air [5]. For most of North China, night-time refrigeration technology is a more suitable cooling measure [6]. Simulation calculations of night ventilation cooling technology conducted by Chen Shuying in Beijing show that the indoor temperature threshold of the night ventilation chamber is significantly reduced [7]. He Zhipeng et al. used EnergyPlus software to conduct a simulation calculation on the library of a university in Hunan Province, and the results showed that under the optimal conditions of night ventilation, electricity consumption could be reduced and the energy saving rate was up to 10% [8].

In this paper, taking the ultra-low energy consumption building of a university in Shenyang as the geometric model, the relevant night ventilation experiment is carried out, and the night ventilation effect of the ultra-low energy consumption building and the conventional energy building is analyzed and compared by DeST software to evaluate the energy saving effect of the night ventilation of buildings with different energy consumption levels.

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2 Method

2.1 Model

This paper takes an ultra-low energy consumption building in Shenyang as the experimental object. Figure 1 is the elevation of the ultra-low energy consumption building. It can be seen from the figure that the building has two floors, with the floors of the first and second floors being 3.3 m and 3.6 m respectively. The first floor is equipped with living room, reception room, bedroom and other rooms, mainly residential demonstration; The second floor is equipped with offices, toilets and so on. The main structure of the building is H steel frame + cast-in-place polystyrene particle foam concrete wall, and the insulation structure adopts good technical measures. The total floor area of the ultra-low energy consumption building is 302.4m², the shape coefficient is 0.47, and the ratio of window to wall is 0.09, 0.12, 0.12 and 0.05, respectively.

![Fig. 1. The appearance of the Ultra-low energy building.](image)

![Fig. 2. The model of building.](image)

![Fig. 3. Test instruments.](image)

### Table 1. Parameter setting of thermal performance for maintenance structure of ultra low energy consumption building

<table>
<thead>
<tr>
<th>Building Envelope System</th>
<th>Ultra-low energy building heat transfer coefficient (W · (m² · K)⁻¹)</th>
<th>Conventional building heat transfer coefficient (W · (m² · K)⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Outer wall</td>
<td>0.1</td>
<td>0.35</td>
</tr>
<tr>
<td>Roof</td>
<td>0.1</td>
<td>0.27</td>
</tr>
</tbody>
</table>

2.2 Experimental methods and equipment

For this night ventilation experiment, the meeting room on the first floor of the building was selected as the test room, with the size of 3.6 m × 4.6 m × 3.3 m (length × width × height). Temperature and humidity module test instrument was used to record the value of indoor temperature and humidity at each time. Fans and outdoor test instruments are placed outside the west side of the building. The power of the fan is 0.12 kW, the speed is 1400 r/min, and the air flow is 2380 m³/h. The model of infrared rangefinder is LDM-35, and the measurement accuracy is ±1.5 mm. The T/H sensor is RS485 and the temperature accuracy is ±0.5 °C. The experimental instrument is shown in Fig. 3. The time of natural ventilation at night is from 21:00 on August 7, 2019 to 7:00 on August 8, 2019, a total of 10h.

The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in Table 2 should be used.

![Ventilator](image)

![Infrared distancer](image)

![T/H sensor](image)
2.3 Simulation experimental

According to the geometrical structure of the experimental building, the DeST simulation software was used to establish the ultra-low energy consumption building model and the conventional building model. The external geometric dimensions, internal structure and exterior facade of the building model of the two energy consumption levels were consistent with the experimental building data (Fig. 2). The thermal parameters of the building were shown in Table 1. Wind pressure is the main driving force of natural ventilation, and obtaining accurate wind pressure coefficient is the key to calculate the construction of natural ventilation [9]. The distribution of wind pressure on the surface of a building is related to the wind direction, the surrounding environment and the orientation of the building. Therefore, CFD software is required to simulate and calculate the wind pressure coefficient of the model in 28 windows in 16 wind directions. The window wind pressure coefficient is set in DeST software, and the window opening time period is 21:00-7:00 and 1:00-7:00, respectively, to simulate the natural ventilation of the two levels of energy consumption buildings at night.

3 Result

3.1 Experimental Verification

On the test day, the outdoor temperature ranged from 20.00 °C to 35.25 °C, with a variation range of 15.25 °C, and the average temperature of the day was 26.28 °C Under the natural ventilation scheme, the indoor temperature of ultra-low energy consumption buildings fluctuates between 25.13 °C and 25.94 °C, with a range of 0.81 °C and an average temperature of 25.41 °C.

Based on relevant experimental data, the simulation of natural ventilation in ultra-low energy buildings at night was built in DeST. Under the natural ventilation scheme, the indoor temperature of ultra-low energy buildings fluctuates between 24.12 °C and 25.66 °C, ranging from 1.54 °C and the average temperature is 24.7 °C. Comparing and analyzing the two groups of data, the standard error of experimental data and DeST simulation data is 0.6, and the average relative error is 6.2% under the condition of similar outdoor meteorological parameters. The final data of night ventilation technology in the two research methods are basically consistent with the overall trend, indicating that the experimental results are highly consistent with the DeST simulation results. DeST software can be used to analyse and study the night ventilation technology of buildings in cold regions.

3.2 Simulation result

Fig. 4a and Fig. 4b respectively show the indoor temperature change curves of ultra-low energy consumption buildings and conventional buildings under the two ventilation schemes. It can be seen from the figure that the indoor temperature change trend of the two energy consumption grade buildings is almost the same under the two ventilation schemes. The indoor temperature change curve of the scheme with the ventilation period from 21:00 to 7:00 the next day is slightly lower than that of the scheme with the ventilation period from 1:00 to 7:00 the next day.

The ventilation volume of the scheme with the ventilation period from 21:00 to 7:00 the next day is larger than that of the scheme with the ventilation period from 1:00 to 7:00, that is, more outdoor cold air enters the room to reduce the indoor temperature.

Therefore, the indoor temperature of the two energy consumption grade buildings is lower under the scheme of ventilation period from 21:00 to 7:00 the next day. Ultra-low energy consumption buildings have better thermal insulation effect, and have better ability to maintain indoor low temperature when the night ventilation is sufficient. When night ventilation is insufficient, its good heat insulation prevents heat exchange with outdoor cold air. Therefore, under the condition of long night ventilation, the indoor temperature of ultra-low energy consumption buildings is lower than that of conventional buildings, while under the condition of short night ventilation, the indoor temperature of ultra-low energy consumption buildings is higher than that of conventional buildings.
Fig. 5 shows the power consumption and energy saving rate of the refrigeration system of ultra-low energy consumption buildings and conventional buildings under the scheme that the ventilation period is 21:00 to next day 7:00. The refrigeration system of ultra-low energy consumption buildings consumes 7.48 kWh/m² and 4.45 kWh/m², with energy saving rates of 15% and 41%. The power consumption of conventional building cooling system is 7.53 kWh/m² and 4.47 kWh/m², and the energy saving rate is 14% and 44%.

At 21:00 to the next day 7:00 between natural ventilation at night, two kinds of energy consumption level of the refrigeration system power consumption and energy saving rate is smaller, conventional refrigeration system power consumption is slightly lower than low energy consumption building good heat insulation and heat preservation effect. Cold at night, can effectively prevent outdoor hot air during the day, so reducing the power consumption of the building's refrigeration system. The calculation of energy saving rate is related to the power consumption of the refrigeration system under the two working conditions of building airtight and night ventilation, and the power consumption of the refrigeration system under the two working conditions is related to the outdoor air temperature. Therefore, the energy saving rate of the building with the same energy level is different in different months. In the same month, the energy-saving rate of buildings with different energy consumption grades also varies.

4 Conclusion

In this paper, night ventilation research is conducted on buildings with two different energy consumption levels, and the summary is as follows:

(1) The variation curves of indoor temperature in ultra-low energy consumption buildings and conventional buildings are consistent under different ventilation periods. The longer the ventilation time, the better the effect of both indoor temperature and cooling load reduction.

(2) When the night ventilation time is sufficient, the indoor peak temperature is lower than that of conventional buildings; Otherwise, the indoor peak temperature is higher than those of conventional buildings.

(3) In July and August, natural ventilation should be carried out at night between 21:00 to the next day 7:00 for ultra-low energy consumption buildings and conventional buildings. The refrigeration system consumption of both buildings has a better energy saving rate. It is suggested to use natural ventilation at night under suitable outdoor conditions.

References