A Study on the Effect of Vertical Climbing Greenery on the Microenvironment of Enclosed Buildings

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Abstract. Vertical climbing greenery, as an energy-saving design tool, has a significant effect on improving the building microenvironment. The purpose of this study is to quantify the effect of vertical climbing greenery on the building microenvironment in summer, especially for a school building in Shenyang City, a cold region. In this study, a school building in Shenyang City was selected as the research object, and the ENVI-met software was used for simulation and analysis. Through simulation, the effects of vertical climbing greenery on the surface temperature of the building facade were evaluated. The simulation results show that the surface temperature of the exterior wall of the school building is significantly reduced by vertical climbing greening, in which the cooling effect of the ground brocade is better than that of the yuzan and ivy. In addition, vertical climbing greening has a positive effect on the heat and cold load of the building exterior wall, effectively reducing the energy consumption of the building. Therefore, vertical climbing greenery not only significantly improves the microenvironment of enclosed buildings, but also reduces air-conditioning utilization and building energy consumption, which is an effective natural building energy conservation method.

Keywords: Vertical climbing greenery; indoor and outdoor thermal environments; building energy efficiency; enclosed buildings

1 Introduction

With the acceleration of urbanization, cities are densely populated, buildings are erected, green areas are gradually decreasing, and urban environmental problems are becoming increasingly serious[1]. Vertical climbing greening as a new type of urban greening[2], with its unique advantages, has become an important way to solve this problem. Vertical climbing greening can not only increase the green area of the city and improve the green visibility of the city, but also improve the microclimate of the city, reduce the surface temperature of the building facade and the summer cold load inside the building[3].

However, there are relatively few studies on the impact of vertical climbing greenery on the outdoor microenvironment of buildings. The following are the conclusions obtained by some scholars on the effect of vertical climbing greenery on the

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microenvironment of buildings. For example, Santamouris et al [4] measured a building in Athens, and measured that realistic greening can reduce the surface temperature of the building by 8.4°C. Gabriel Péreza et al [5] constructed a wall and carried out vertical greening and measurements, and the results showed that the vertical greening greatly improved the humidity of the surrounding air. Yin et al [6] observed the cooling and energy-saving effect of the direct-climbing green wall on a campus in Nanjing, and found that the cooling effect of the wall was reduced in the wall. and found that the average daily temperature on the surface of the wall was 4.67°C lower than that of the reference wall. Other scholars such as Morakinyo [7], Huang [8], and Guo Chao [9] also combined ENVI-met with EnergyPlus to study the effect of outdoor microclimate changes on building energy consumption. In this paper, a local project is selected to conduct a simulation study to explore the impact of vertical climbing greening on the building microenvironment in terms of the surface temperature of the building facade and the summer cold load inside the building.

2 Project Overview

In this paper, the research object selected for a college in Shenyang City, the enclosing teaching building green space [10], the overall structure of the teaching building for the building complex, selected one of the four sides of the building are all independent of the courtyard structure, as shown in Figure 1, and there are climbing plants attached to the wall, the plant grows in summer for the lush period. The total number of floors of the school building is 5, the height of the 1st floor is 5 meters, and the height of the 2nd to 5th floors is 4 meters, with a total height of 21 meters. The first floor of the building has an elevated structure with a height of 5 meters. The courtyard is 67.6 meters long and 57 meters wide. Using ENVI-met software for modeling and simulation, the simulation selected vertical climbing green type for the software comes with two kinds of plants (ivy and yuzan) and common climbing plants in Shenyang area ground brocade.

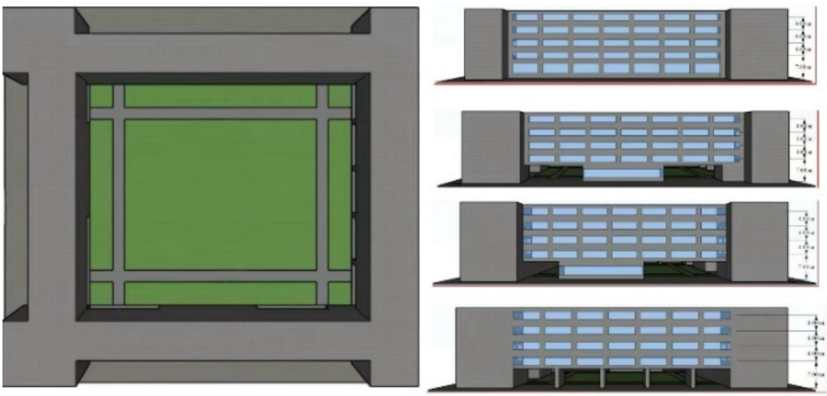

Fig. 1. Top view and elevation of enclosed building

3 Simulation Studies

The time chosen for this simulation is June 21, 2023 at 14:00, the summer solstice. The points selected for the study are the heights of the four walls from the ground at 6m, 12m, 16m, and 19m, which are the heights of the walls between the windows on different floors of the building, and there are 10 points on each of the four walls in this way from the left to the right at each height. B3 (eastward), A2 (westward), D1 (southward), C2 (northward) represent the four walls of the enclosed building facade. The following analysis takes A2 (westward) as an example, and the simulation results of the remaining three walls are similar and will not be described too much in this paper.

3.1 Modeling and Parameter Setting

For this simulation, the ENVI-met software was chosen for the simulation study, which is able to simulate and analyze the distribution of climatic parameters and thermal comfort states in outdoor environments using a fine mesh. This is a specialized hydrodynamic simulation software for microenvironments. This simulation study uses a 1 m x 1 m grid for meshing, as shown in Figure 2 for the three-dimensional drawing of the building. Then the local meteorological parameters and plant parameters are set and imported into the model for iterative calculations, and the visualization results are exported through Leonardo visualize module, as shown in Fig. 3 for the temperature distribution of the external wall of the ground brocade.

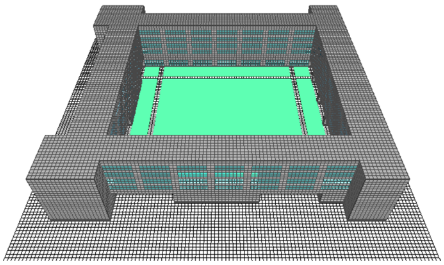

Fig. 2. Enclosed building meshing diagram

The simulation results show that when vertical climbing greenery is present, the temperature of the enclosing building façade decreases in all directions. Take A2 (west direction) as an example. The average temperature is 36.19°C when there is no greenery; 29.17°C when there is ground brocade; 31.70°C when there is ivy; and 29.62°C when there is yuzan. It can be seen that the three kinds of vertical climbing greenery obviously reduced the temperature of the exterior wall of the enclosed building, on the other hand, the temperature change of the exterior wall of the three kinds of vertical climbing greenery at different heights was not obvious.

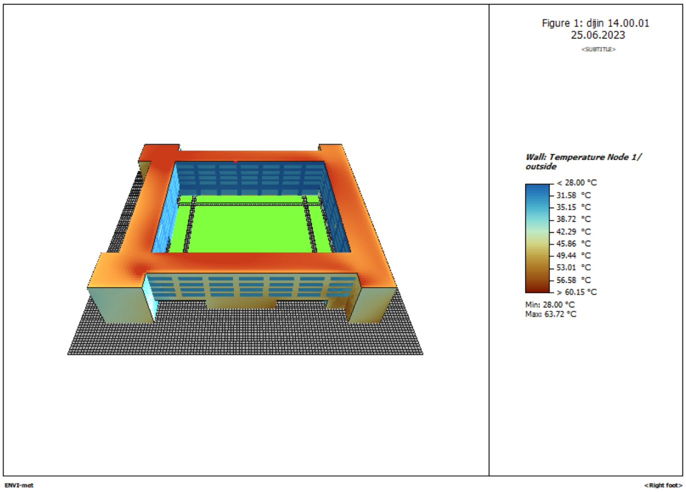

Fig. 3. Temperature distribution of the outer wall of the ground brocade

3.2 Comparison of the Effects of Different Vertical Climbing Greenery on the Temperature of Enclosing Building Facades

Take A2 (west facing) wall at 6m as an example. The temperature change graphs without greening and with greening (ivy, yuzan, and ground brocade) are shown in Figure 4. The average temperature without greening was 36.07°C; among the three types of greening, the average temperature of ivy was 31.49°C; the average temperature of yuzan was 29.79°C; and the average temperature of ground brocade was 29.07°C. From the temperature change Figure 4, it can be seen that the vertical climbing greening makes the temperature of the building facade significantly reduced and the cooling effect: ground brocade > yuzhan > ivy.

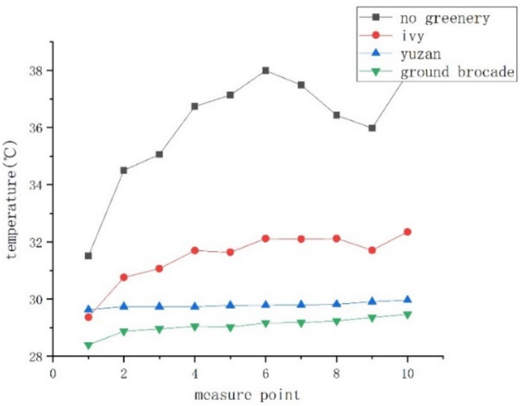

Fig. 4. Temperature variation at 6m from wall A2 (west facing)

4 Analysis of the Impact of Vertical Climbing Greenery on Energy Consumption of Enclosed Buildings

4.1 Theory of Air Conditioning Load Calculation in Summer

(1) Calculation formula for heat transfer and cold load of external walls

$$Q_C(\tau) = AK(t_{C(\tau)} - t_R)$$

Style:

K—Heat transfer coefficient of external wall, W/(m²·°C);

A—Calculated area of external walls, m²;

t_R—Indoor Calculated Temperature, °C;

$t_{C(\tau)}$—Calculated time-by-time cold load temperature for external walls or roofs, °C.

4.2 Analysis of the Results of the Impact of Vertical Climbing Greenery on the Energy Consumption of Enclosed Buildings

Take A2 (west-facing) wall as an example. The heat transfer cold loads from the building formation to the external walls were calculated. When there is no greening, the cold load generated by A2 (westward) wall is 2649.4W; among the three types of greening, the cold load generated by ground brocade through A2 (westward) wall is 824.2W; the cold load generated by ivy through A2 (westward) wall is 1482W; and the cold load generated by yuzan through A2 (westward) wall is 941.2W. From the above data, the three kinds of vertical climbing greenery all reduce the heat and cold load of the building, and the effect of reducing consumption: ground brocade > yuzan > ivy. Vertical climbing greenery positively affects the heat and cold load of the building facade, thus reducing the energy consumption of the building and achieving the purpose of energy saving.

5 Conclusions

(1) Vertical climbing greenery system is an effective natural shading device, and the temperature of the wall with vertical climbing greenery was significantly lower than that of the wall without greenery. The average temperature without greenery was 36.19°C, 29.17°C with ground brocade, 31.70°C with ivy, and 29.62°C with yuzan.

(2) Different vertical climbing greening species have different effects on the wall temperature due to different parameters such as plant leaf area index, and the cooling effect: ground brocade > yuzan > ivy. The average temperature is 36.07°C when there is no greening, 29.07°C when there is ground brocade, 29.79°C when there is yuzan, and 31.49°C when there is ivy.

(3) There is no obvious pattern in the temperature distribution of the three vertical climbing greens at different heights, and the effect of vertical climbing greens at different heights is neglected in this simulation study.

(4) In this simulation study the heat transfer and cold load of the exterior wall is directly proportional to the temperature of the exterior wall, and the effect of reducing consumption: ground brocade > yuzan > ivy.

Vertical climbing greenery increases the thermal inertness of the wall envelope, avoids large changes in indoor temperature, and improves the thermal comfort of the indoor environment. It has a positive impact on reducing air-conditioning energy consumption and improving building energy utilization in summer.

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