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Effect of Green Roofs Combined with Ventilation on Indoor Cooling and Energy Consumption

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Abstract

With the increase in building energy consumption and the improvement of the thermal environment requirements of the residents, it is very important to find a way to adjust the thermal environment for the residents and to save energy. In this paper, an experimental building in Shanghai, China, was chosen, and used DesignBuilder software to simulate the cooling and energy-saving potential of green roof combined with intermittent ventilation in hot summer and cold winter zone. The results show that the use of intermittent ventilation is more conducive to indoor cooling than the all-day ventilation, and the green roof combined with intermittent ventilation is better. During the entire air-conditioning season, the proportion of the time which under the upper limit of acceptable temperature reduced by 20% compared the insulation roof with all-day ventilation. In the case of intermittent ventilation, the energy consumption of the two roofs is reduced by about 10% compared with that without ventilation, while the energy-saving rate of green roof with ventilation is 26.7%.

Keywords: Green roof; Ventilation; Passive cooling; Energy saving;

1. Introduction

With the rapid development of urbanization in China, building energy consumption increased significantly. In 2013, the building energy consumption accounted for about 19.5% of the annual total energy consumption, and the ratio of urban and rural energy consumption of total commercial energy is increased, which has reached 48.1% [1]. Therefore, saving energy and protecting the environment, greatly reducing building energy consumption, vigorously carrying out energy-saving emission reduction, promoting building energy conservation has become the goals of economic development in China.

In order to implement the provisions on energy conservation, the building energy efficiency standards have been introduced in recent years to improve the indoor thermal environment and the energy efficiency of heating and air conditioning. However, the current energy-saving design standards in the construction envelope thermal

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performance requirements are in accordance with the provisions of the air conditioning mode. For example, the "Design standard for energy efficiency of residential building in hot summer and cold winter zone" (JGJ 134-2010) [2] (hereinafter referred to as "standard") in the provisions of the air conditioning temperature is 26℃ in summer, and it is operated full time. It is not consistent with the fact that the residents' indoor thermal environment regulation. In addition, the use of natural resources has been neglected.

Many surveys show that residents prefer ventilation to cooling in summer[3,4], but the architects and residents always use the natural full time ventilation as one of the main measures to improve the residential thermal environment in summer. Due to the special climate of the hot summer and cold winter in China, the wind speed is high when the outdoor temperature is high in the daytime, which is not conducive to improving the indoor thermal environment [5]. So， intermittent ventilation will be a method to meet the needs of residents and reached the goal of saving energy at the same time.

In addition, as an efficient technology encompasses many benefits in terms of environmental sustainability, green roofs has attracted more and more researchers' attention all over the world. The survey and experiment in Hong Kong, Greece and Singapore have shown that the use of green roof effectively decreased the indoor temperature [6, 7, 8], and reduced the cooling load of the space by 17-79% [9].

However, in the case of that the doors and windows were closed, the indoor temperature of green roofs is higher than that of common roofs at night with non-air-conditioning[10]. And many of the current researches are a separate study on green roofs which is about indoor energy consumption. An experimental study in summer by Roche and Berardi [11] demonstrated that the green roofs used as thermal mass combined with night-time ventilation is beneficial to the indoor thermal environment.

Obviously, green roofs and ventilation are the way to improve the indoor thermal environment and to reduce the energy consumption, and combine them will be greater energy-saving potential. In this paper, the cooling and energy saving potentials of green roofs and ventilation in hot summer and cold winter zone in China are simulated and analyzed by using DesignBuilder software.

2. Method

2.1. Experimental building and model

The experimental building is a warehouse in Shanghai, which is oriented to the south and no shelter from other nearby facilities. The structure type is transverse bearing brick masonry wall systems, and it is an one-story building which divided into four rooms, no window. The area of each room is about 23 square meters. The middle two rooms were elected as experimental object to measure for the subsequent comparison, and one of them is under green roof, and another is under bare roof. The plant used in this experiment is Sedum lineare, which is a plant genus of the Crassulaceae family, and is about 10-15 cm high. The substrate under plant is about 8 cm thick. And the door was closed and no inner heat gain in the room.

And then, the experimental building was used as the original model to have a simulation in DesignBuilder. The structures and size of the model were the same as the experimental building`s.

2.2. Model validation

In order to assure the reliability and validity of the simulation results of DesignBuilder software, the developed simulation model was validated with the actual data of the selected building. The simulated indoor temperature, internal surface temperature of roofs, were compared with the measurements of the building. The ratio of them are depicted in Fig. 1.

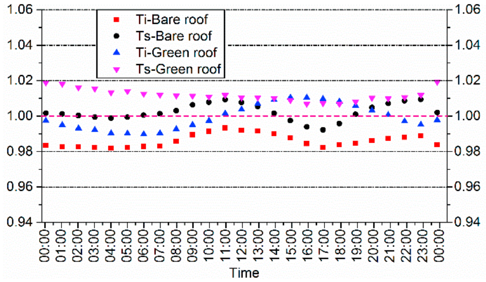

Fig.1 The ratio of the simulated temperature to the measured temperature. (Ti is the indoor air temperature, Ts is the internal surface temperature)

It can be concluded that the simulation results largely match with the actual temperature of the studied building.