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ScienceDirect

Procedia Engineering 121 (2015) 1597 – 1604

Procedia Engineering

www.elsevier.com/locate/procedia

9th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC) and the 3rd International Conference on Building Energy and Environment (COBEE)

Thermal Performance Study of Extensive Green Roof in Shanghai District: a Case Study of Lightweight Building in Winter

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Abstract

This paper aims to investigate the thermal performance of extensive green roof under free-floating and air-conditioned conditions in winter. A field experiment was conducted on two full-scale rooms from 01/12/2014 to 17/12/2014 in Shanghai, one room was covered by green roof while the other was covered by common roof. Temperature distribution along the vertical direction of both roofs was recorded, and so were heat flux through the roofs as well as soil volumetric water ratio of green roof, local weather data was collected simultaneously. The results indicated that cooling effect of green roof was significant when solar radiation was strong, and green roof showed insulation effect only at night when the indoor air temperature was about 3°C higher than that of common roof. Under free floating condition, temperature profile of green roof was like a saddle surface while common roof's profile was like a Mexican hat. And green roof's temperature profile pattern is similar to that of common roof under air-conditioned condition. Energy balance analysis shows that net solar radiation and heat convection is the major heat gain for both roofs in winter, and net long wave radiation and evapotranspiration dissipate most heat gain for green roof while net long wave radiation is the main heat dissipation for common roof.

Peer-review under responsibility of the organizing committee of ISHVAC-COBEE 2015

Keywords: Extensive Green Roof; Thermal Insulation; Evapotranspiration Cooling; Energy Balance

1. Introduction

During the past decade, green roof's thermal and energy performance has been one of the hot topics. And many field experiments have been conducted in different areas [1, 5], and it is concluded that green roof's performance is subject to many factors, which mainly can be divided into external and internal ones. External factors refer to climate

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Peer-review under responsibility of the organizing committee of ISHVAC-COBEE 2015
doi:10.1016/j.proeng.2015.09.186

conditions, including solar radiation, wind velocity, rainfall (irrigation), temperature and humidity. Internal factors include the geometrical and hydrothermal properties of plants and substrate, volumetric water ratio, thermo-physical properties of building structural layer and insulation layer. However, most of experimental studies are focused on green roofs performance in summer for their significant cooling effect, the performance in winter receives less attention. C.Y. Jim and Tasang's study in Hong Kong indicated that green roof would lead to more heat going out of the room and cause more energy consumption [3]. M. D'Orazio found that there is little difference between green roof and common roof in winter [2]. However, Karen liu's results showed that green roof acted as a good insulation and can reduce 10~30% heat loss compared with common roof in Toronto [4]. Therefore, compared with consistent point about green roofs performance in summer, there is no agreement among researchers about green roofs performance in winter. In this paper, two lightweight rooms was located in shanghai, one room was installed with green roof while the other remained common roof for comparison. A field measurement was conducted to study thermal and energy performance of extensive green roof under different conditions.

2. Methods

Shanghai(31.2N, 121.5E), a city located at the west coast of Pacific Ocean and the east rim of Asian continent, belongs to the north subtropical monsoon climate with four different seasons, plenty of sunshine and good rainfall. Summer and winter are long while spring and autumn are short. The average temperature of winter reaches 4.8°C.The experiment setup was located at Jiading Campus of Tongji University (Fig. 1). The test rooms has two conditions, one is free-floating condition (from 01/12/2014 to 07/12/2014), and the other is air-conditioned condition (from 08/12/2014 to 14/12/2014).

2.1. Roofs materials and experimental setup

As is shown in Fig, the dimensions of two test room were both 3m*3m*2.7m. The left one was common roof, while the right one was covered by green roof. The common roof was made of foam sandwich panel (75mm thick). Extensive green roof was consisted of 36 prefabricated greenery modules (Fig.2) which was connected together by buckles, and the size of every module was 50cm× 50cm×7cm (not including the canopy layer). The greenery module was artfully designed, which combined plant layer, substrate layer, filtering membrane and drainage layer together (Fig.3). The plant was sedum linear (10cm thick), which was very popular in shanghai district. The substrate was about 4cm thick and was comprised of peat soil, powdered perlite, vermiculite aggregate and organic fertilizer. The windows and doors of both rooms were locked during the experiments.

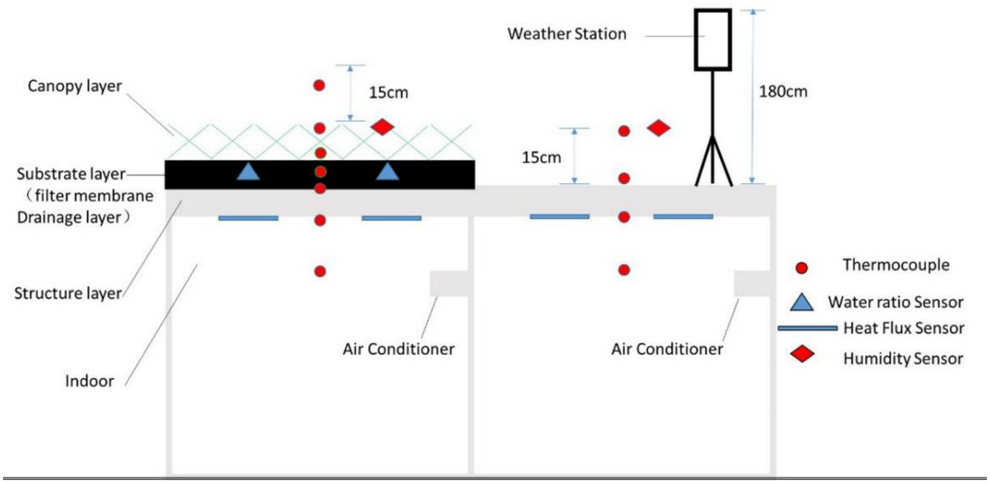

Fig. 1. Schematic drawing of experimental setup.