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Surface heat budget on green roof and high reflection roof for mitigation of urban heat island

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Abstract

In this study, the surface temperature, net radiation, water content ratio, etc., of green roofs and high reflection roofs are observed. The heat and water budget are compared to each other. In the daytime, the temperature of the cement concrete surface, the surface with highly reflective gray paint, bare soil surface, green surface and the surface with highly reflective white paint are observed to be in descending order. On a surface with highly reflective white paint, the sensible heat flux is small because of the low net radiation due to high solar reflectance. On the green surface, the sensible heat flux is small because of the large latent heat flux by evaporation, although the net radiation is large. On the cement concrete surface and the surface with a highly reflective gray paint, the sensible heat fluxes have almost the same values because their solar reflectance is approximately equal. These tendencies of the sensible heat flux accord with the pitch relation of the surface temperature. Methods to estimate the quantity of evaporation, evaporative efficiency, heat conductivity, and thermal capacity are explained, and the observation data is applied to these methods.

Keywords: Urban heat island; Surface heat budget; Green roof; High reflection roof

1. Introduction

Improvement in the surface cover of buildings and constructions that have been covered with cement and asphalt concrete is examined as one of the measures to mitigate the urban heat island phenomenon. Green roofs, high reflection roofs, wall planting, etc., are suggested from the viewpoint of building planning, and green parks, roadside trees, etc., are suggested from the viewpoint of urban planning.

The use of highly reflective paint for cool roofs and road pavements is examined by Akbari et al. [1–4] from the heat island group of the Lawrence Berkeley National Laboratory for reducing urban heat islands and energy consumption. According to their test calculation, the possibility of reduction or savings in the annual air conditioning costs was estimated to be 35 million dollars in Los Angeles, 16 million dollars in New York, and 10 million dollars in Chicago.

At the Lawrence Berkeley National Laboratory [5] and the Oak Ridge National Laboratory [6], the database of the characteristics of the roof materials (reflectivity and emissivity) available in the market is prepared and new products are developed.

The purpose of this study is as follows.

(1) From the viewpoint of urban heat island mitigation, sensible heat flux reduction for the roof surface serves as an evaluation index. Therefore, the surface heat budgets on some roof covers are examined under the same weather condition. Consequently, sensible heat flux from the surface to air is compared from the heat island mitigation effect.
(2) The estimation method of the sensible heat flux from each roof surface is investigated. The heat budget components are derived from the observation results. Finally, the sensible heat flux from each roof surface is estimated by the residue of the surface heat budget.

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2. Outline of observation

The observation period is from July 2003, to the present. It is carried out on the experimental roof of the 8-story building of the Kobe University. In this study, the observation data for August and November 2004 is used for the detailed discussion. Unit numbers 1, 2, 9, 11, and 12 in Fig. 1 are used for the detailed discussion. The unit size for the bare soil surface (unit number 1) is 1.175 m × 1.6 m; for the green (lawn) surface (unit number 2), 0.95 m × 1.6 m; and for the paint and cement concrete surfaces (unit numbers 9, 11, and 12), 0.942 m × 1.0 m. A summary of the observation unit is shown in Table 1.

Air temperature, relative humidity, solar radiation, infrared radiation, precipitation, wind direction, and velocity, are observed as weather conditions near the observation site. In each observation unit, downward and upward, short-wave and long-wave radiation (net radiation); surface temperature; internal temperature; and heat flux are observed. The water content ratio in the soil under the green surface and bare soil is observed. The observation points of temperature, heat flux, and water content ratio are shown in Fig. 2. The heat flux sensor and thermocouple are installed in the concrete slab of each unit. In addition, the air temperature in the room under the slab is controlled by an air conditioner.

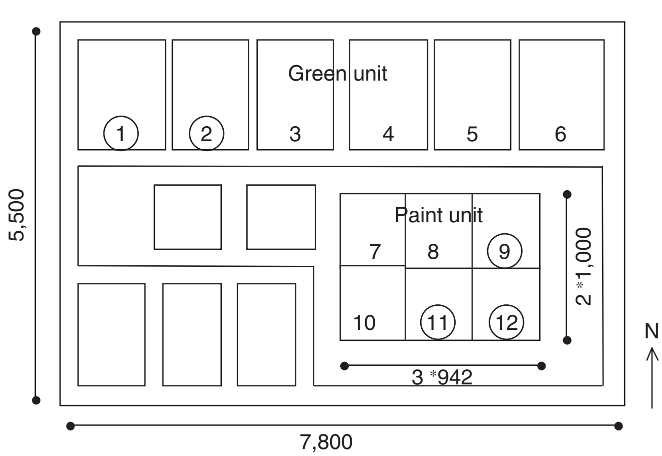

Fig. 1. Experimental roof plan.

Table 1
Outline of the experimental roof

Unit number	Experimental object
1	Bare soil
2	Green (lawn)
9	(Cement) Concrete
11	Highly reflective white paint
12	Highly reflective gray paint

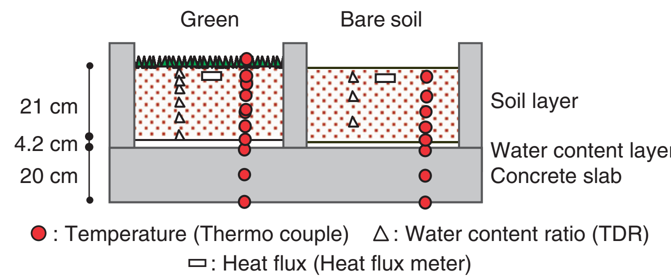

Fig. 2. Observation points of temperature, water content ratio, and heat flux. Temperature observation points under the green surface are at 2, 4, 6, 10, 11, 16, and 21 cm from the surface. Temperature observation point under the bare soil surface is 2, 6, 10, 16, and 21 cm from the surface. Water content ratio observation point under the green surface is 2, 4, 6, 11, 16, and 20 cm from the surface. The water content ratio observation point under the bare soil surface is 2, 6, and 16 cm from the surface. Heat flux observation point under the green and bare soil surface is 2 cm from the surface.

3. Observation result

3.1. Observation result of the surface temperature

Weather condition in August and November 2004 are shown in Figs. 3 and 4. Observation results of the surface temperature in August and November 2004 are shown in Figs. 5 and 6. Although the leaf surfaces and the region around the roots in a lawn are expected to have different temperatures, only the result of the leaf surface temperature is shown, which is observed continually by a radiation thermometer.

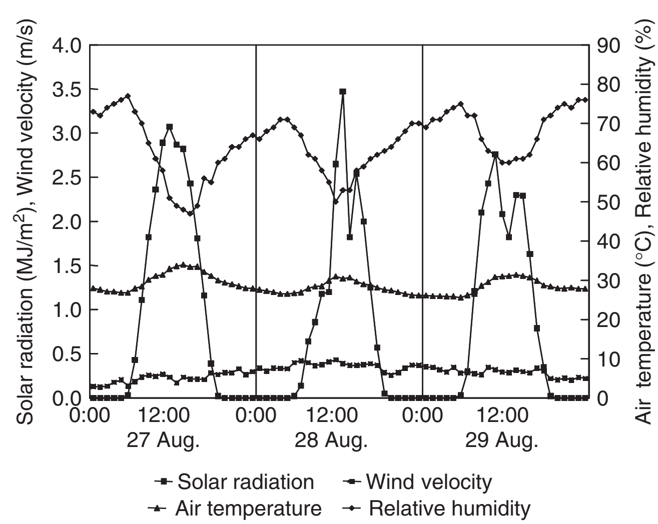

Fig. 3. Weather condition on August 27–29, 2004.

In August, the surface temperature of the (cement) concrete slab and the highly reflective gray paint is almost the same and higher by about 10 °C than that on surfaces with highly reflective white and green paints. The surface temperature on the green surface is several degrees lower than that on bare soil, and it is several degrees higher than that on the highly reflective white paint.