[Original Paper]

Evaluation of Air Temperature measured at the Site established in Rooftop Gardening

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The air temperature was measured to examine the mitigation effects of rooftop gardening on air temperature by using buildings with different surface coatings of rooftops. The air temperature measured at the site with a rooftop garden (Site C) was lower than those measured at other sites where there was no rooftop gardening. Site C showed a lower air temperature than other sites from early-evening to early-morning (15:00 - 6:00) in the summer season and in the afternoon and at night (14:00 - 8:00) in the winter season.

I INTRODUCTION

The urban heat island phenomenon has been intensively studied with the objective of limiting thermal pollution in urban areas all over the world [1-9]. Alteration of the earth's surface property as well as anthropogenic waste heat is the main causes of urban heat island phenomena. Rooftop gardening is considered one of the effective countermeasures to this urban heat island phenomenon. Some examinations of the effects of rooftop gardening have been carried out[10-12] and heat balance has been also studied[13,14]. Furthermore, numerical simulations have been carried out[15]. Air temperature was measured to examine the mitigation effects of rooftop gardening on air temperature by using buildings with different surface coatings on the roof in the study.

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II MATERIALS AND METHODS

1 Monitoring sites

1.1 Monitoring site

Air temperature was measured at four sites on the roof of three buildings of the Hyogo Prefectural Government: No.1, No.2, and No.3. The distance of each building is as follows: No.1-No.2: 100 m, No.1-No.3: 200 m, and No.2-No.3: 100 m. The conditions of the sites such as the height of the buildings are summarized in Table 1. The flowering grasses were planted on the roof of the No.2 building, and replanted twice a year. A solar photovoltaic system is installed on the roof of the No.1 building; therefore air temperature was measured at two sites on the roof of the No.1 building: near the solar photovoltaic system and 25 m away from the solar photovoltaic system. Air temperature measured on the roof of the No.3 building was used as the control of the other sites. Outlines of the roofs of each building are illustrated in Fig. 1 and summarized in Table 1.

Table 1 Outline of roof each building

	Elevation above sea level m	Height above ground level m	Total area m²	Material of foundation bed	Area of solar photovoltaic system m²	Area of gardening m²
No.1 building	55	53.6	2032	concrete	81.3	–
No.2 building	55	53.4	1149	concrete	–	260
No.3 building	55	59.9	1578	concrete	–	–

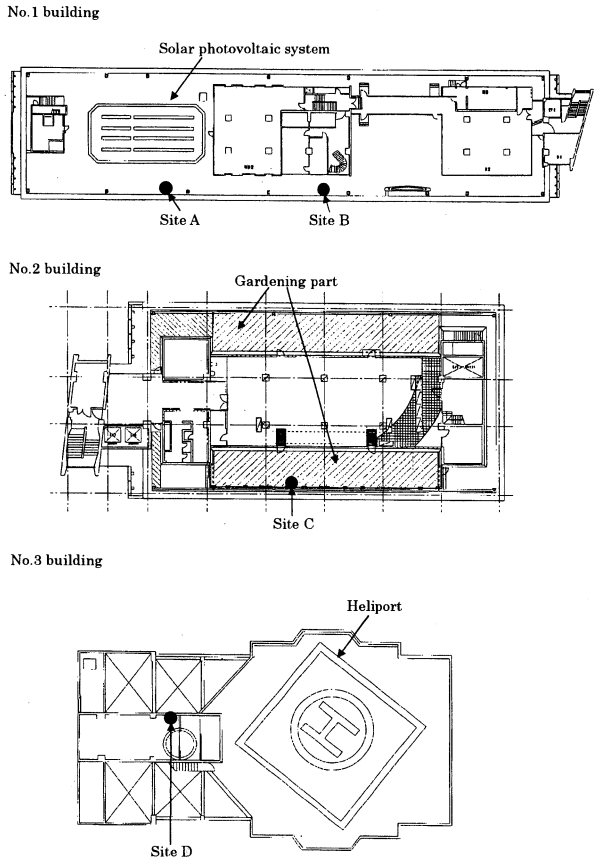

Fig. 1 Outline of roof of each building and monitoring sites.

1.2 Survey area

The buildings of the Hyogo Prefectural Government -- No.1, No.2, and No.3 -- are located in Kobe City, Hyogo Prefecture, Japan (Fig. 2). Population and industrial activities are concentrated in this area, and there are many commercial facilities and roads with heavy traffic, resulting in one of the most urbanized areas in Japan.

2 Data acquisition and data correction

2.1 Data acquisition

Air temperature was measured on a 30-minute basis, and the air temperature measured on the hour every hour was used for analyses. The 30-minute base air temperature was measured by a thermometer (TR-72U, T&D Corp., Nagano, Japan) calibrated with a thermostat and installed in a simple naturally ventilated thermometer shelter (CO-RS1, CLIMATEC Inc., Tokyo, Japan) positioned about 1.5 m above the rooftop.

Air temperature has been measured since December 2005. The data from December 2005 to January 2007 was analyzed in the present study.

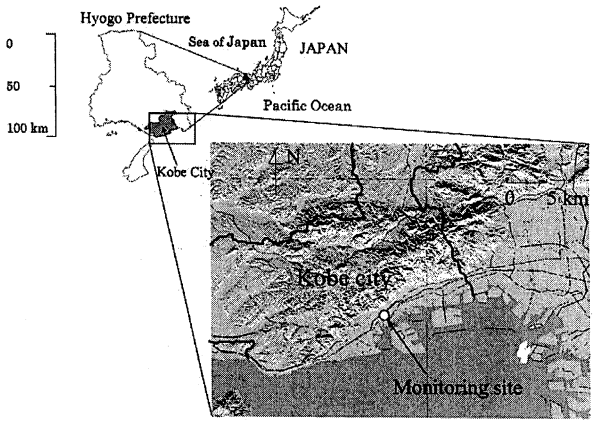

Fig. 2 Location of Kobe City, Hyogo Prefecture, and Japan.

2.2 Data correction

As summarized in Table 1, the elevation of the sites was different, thus the air temperature data was corrected by a moist-adiabatic lapse rate (0.6 ℃/100 m) when the data was compared.

3 Rooftop gardening

A brief description of rooftop gardening employing is summarized in Table 2.

Ⅲ RESULTS AND DISCUSSION

1 Monthly mean air temperature

Fig. 3 shows a time series of the monthly mean

Table 2 Brief description of rooftop gardening

	Vegetation	Depth of growth	Condition of watering					
			Method	Frequency			Amount a watering / m^3	
		cm		Summer	Spring, Autumn	Winter	Summer	Spring, Autumn	Winter
South-facing side	Flowering grasses	7	Manual	4 times a week	2 times a week	once every 2 weeks	7-8	4-5	Less than 5
North-facing side	Sedum	2-3	Manual	-	-	-	-	-	-

air temperature at each site. Some differences can be observed in each month although the air temperatures seem to be similar values. In addition, the differences appear to show seasonal variations in that the air temperature at site D was higher than those at other sites in the summer season (June, July and August) and the air temperature at site C was lower than those at other sites in the winter season (December, January and February).

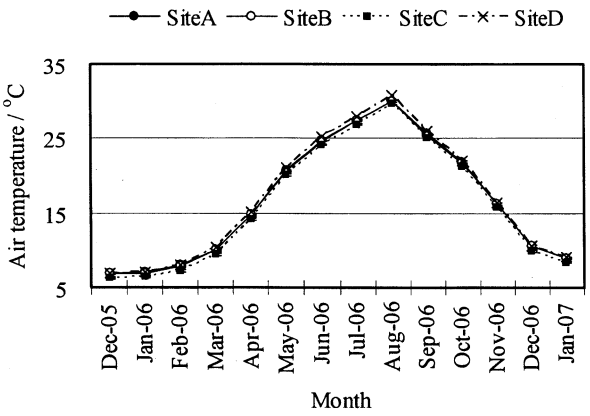

Fig. 3 Time series of the monthly mean air temperature at each site.

2 Difference in air temperature

Fig. 4 shows a time series of the difference in monthly mean air temperature between sites A, B, C and site D. The difference in air temperature showed a negative value, meaning that the air temperature at site D was higher than those at other sites. The reason for the higher air temperature at site D is unidentified. In addition, the difference in air temperature between site A and site D was close to that between site B and site D, furthermore the difference in air temperature between sites A, B and site D was smaller than that between site C and site D, showing that the air temperature at site C was the lowest among the four sites.

The difference in air temperature demonstrated a clear seasonal variation: smaller in the winter season and larger in the summer season.

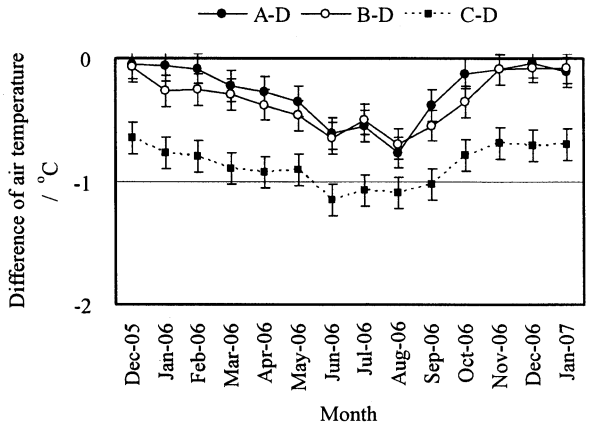

Fig. 4 Time series of the difference of the monthly mean air temperature between the site A, B, C and the site D.

3 Diurnal variation

Fig. 5 shows the diurnal variation in air temperature at each site in August and December 2006.

In the diurnal variation in August, the air temperature at site D was always higher than those at other sites all through the day, particularly in the midday. On the other hand, the air temperatures at sites A, B and C were similar from 7:00 to 14:00, while the air temperature at site C was lower than those at sites A and B from 15:00 to 6:00.

In the diurnal variation in December, the air temperatures at all sites were close to each other from 9:00 to 13:00. Furthermore, the air temperatures at sites A, B and D were similar all through the day. On the other hand, the air temperature at site C was lower than those at other three sites from 14:00 to 8:00.

The diurnal variation can be summarized as follows.

1. Site D showed a higher air temperature all through the day in the summer season.
2. Site C showed a lower air temperature from

early-evening to early-morning (15:00 - 6:00) in the summer season.

3. All sites showed a similar air temperature in the morning (9:00 - 13:00) in the winter season.
4. Site C showed a lower air temperature in the afternoon and at night (14:00 - 8:00) in the winter season.

The summary on the diurnal variation in air temperature likely indicates that the effect of the rooftop gardening easily appeared in the air temperature at night not only in the summer season but also in the winter season.

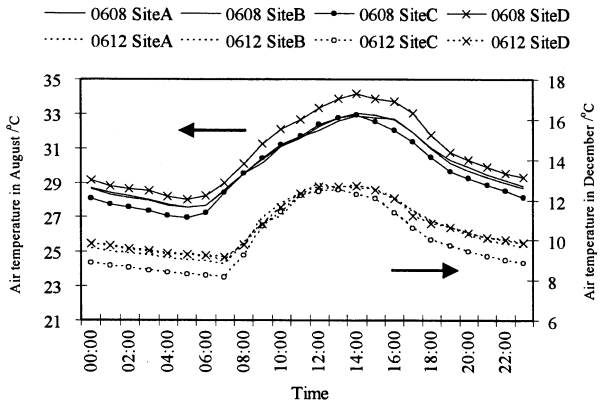

Fig. 5 Diurnal variation of the air temperature at each site in August and December 2006.

IV CONCLUSION

Air temperature was measured to examine the mitigation effects of rooftop gardening on air temperature by using buildings with different surface coatings of the roof. The monthly mean air temperature measured at the site established in the rooftop garden (Site C) was lower than those measured at other sites where there was no rooftop gardening (Sites A, B and D) all through the year. The difference in air temperature between site C and sites A, B, and D was larger at night than in the daytime not only in the summer season but also in the winter season.

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[原著]

屋上緑化された地点で測定された気温の評価

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要　約

屋上緑化による気温低減効果を検証するため，屋上表面被覆の異なる建物で気温を測定した．屋上緑化された地点（地点C）で測定された気温は屋上緑化されていない地点で測定された気温よりも低かった．地点Cでは他の地点よりも，夏季には夕方から早朝(15:00 - 6:00)にかけて、冬季には午後及び夜間(14:00 - 8:00)において気温が低かった．