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Study on the urban heat island mitigation effect achieved by converting to grass-covered parking

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Abstract

The urban heat island mitigation effect of conversion from asphalt-covered parking areas to grass-covered ones is estimated by observation and calculation. The mean surface temperature in a parking lot is calculated from a thermal image captured by an infrared camera. The sensible heat flux in each parking space is calculated based on the surface heat budget. The reduction in the sensible heat flux is estimated to be approximately 100–150 W m^{-2} during the day and approximately 50 W m^{-2} during the night, in comparison with an asphalt surface. The air temperature reduction by the spread of grass-covered parking areas is calculated to be about 0.1 °C. Furthermore, consideration is given to the appearance of the parking lot, the growth of grass, the effects of the weight of a car and the heat radiated from its engine, the costs of construction and maintenance, etc.

Keywords: Urban heat island; Grass; Parking

1. Introduction

The following factors have been established as causes of the urban heat island effect: the decrease in the evaporative cooling ability that results from the natural ground surface being changed to an artificial surface and the increase in the amount of heat stored by this artificial surface, the increase in anthropogenic heat release with the increased air conditioning load for maintaining the comfort of indoor environments, ventilation obstruction caused by the high density of buildings, and restricted long-wave radiant losses at night due to the reduced sky view factor etc. The purpose of this study is to investigate the urban heat island mitigation effect achieved by conversion from asphalt-covered parking lots to grass-covered parking lots as a ground surface improvement, which is an urban heat island mitigation technique. This investigation involved an analysis of surface temperature and surface heat budget. Other factors related to grass-covered parking lots are also discussed, for example, the appearance of this type of parking lot, the growth of grass, the effects of a car's weight and the heat radiated from its engine, and the costs of lot construction and maintenance. Green roofs have been studied for thermal benefits to both buildings and their surrounding environments by several researchers, e.g. Teemusk and Mander (2009), Takebayashi and Moriyama (2007), Wong et al. (2003), Onmura et al. (2001), Eumorfopoulou and Aravantinos (1998), Hoyano (1988). Effects of green park have been also studied by several researchers, e.g. Yu and Hien (2006), Ca et al. (1998), Honjo and Takakura (1990–1991), Saito et al. (1990–1991), Kawashima (1990–1991). The urban heat island mitigation effect by green planting was pointed out by several researchers, e.g. Avisaar (1996), Taha et al. (1999). In the urban canyon temperature decreases by the effect of covering the building envelope with vegetation are estimated by Alexandri and Jones (2008). However, these studies assume the general

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plants and they don't pay attention to the parking lot. This study takes up a parking lot and performs the several examinations.

With regard to grass-covered parking lots, certain types have been used for nearly 10 years, but they have never been evaluated from the viewpoint of the urban heat island mitigation effect. In this regard, an investigation was conducted Osaka Prefecture (2005). From the Osaka Prefecture report, a maximum surface temperature reduction of 14.7 °C was observed from asphalt surfaces to grass-covered parking lots during sunny conditions in the summertime. These parking lots with a large proportion of grass had a superior surface temperature reduction effect. However, in this investigation, the surface temperature observations were performed only at representative points for each parking space. To evaluate a parking lot composed of various materials, it is necessary to obtain the mean surface temperature of the entire parking lot.

Therefore, in this study, surface temperature changes were measured using thermocouples placed on the representative constituent materials in each parking space; thermal images were captured using an infrared radiation camera, and the mean surface temperature of the entire parking lot was calculated from these thermal images. In addition, the net radiation from each parking space and the underground temperatures were also measured. The surface heat budget for each parking lot and the sensible heat flux from each parking lot were then estimated.

2. Outline of observation

2.1. Outline of the site

The examination site is a public parking space managed by Hyogo Prefecture. It is located near Kobe City Center. Thirty-six parking lots are built by the different private companies, and each parking lot is maintained by each company. Characteristics of each parking lot are shown in Table 1. The period for execution and maintenance of grass is from June 10 to July 27; our observation began

Table 1
Characteristics of each parking lot.

Parking lot number	Cover	Supporting part	Green cover area (%)	Thickness (mm)	Observed solar reflectance[a]
19	Japanese (korai) turf	Plastic protector	57.5	250	0.175
20	Japanese (korai) turf	Plastic protector	74.0	250	0.225
21	Bermuda grass	Plastic, concrete and wood protector	35.6	250	0.209
22	Japanese turf	Water keeping block	84.3	250	0.208
23	Japanese turf	Concrete block	75.2	250	0.208
24	Ophiopogon japonicus	Water keeping concrete	55.8	250	0.184
25	Ophiopogon japonicus	Water keeping concrete	55.8	250	0.200
26	Japanese turf	Steel mesh	83.4	250	0.192
27	Bermuda grass, Centipede grass	Wooden log	66.1	250	0.200
28	Japanese (korai) turf	Plastic protector	100.0	250	0.215
29	Japanese turf	Steel mesh	88.1	225	0.227
30	Fescues, Ryegrasses, Bluegrass	Water permeability block	47.3	225	0.214
31	Japanese turf	Water keeping block	47.0	200	0.240
32	Bermuda grass, Bluegrass, Japanese turf	Plastic protector	90.0	175	0.202
33	Japanese (korai) turf	Water keeping block	47.0	150	0.201
34	Japanese (korai) turf	Water keeping plate	53.0	150	0.246
35	Bermuda grass	Wooden log	64.1	150	0.211
36	Centipede grass	Concrete block	75.0	150	0.189
37	Japanese (korai) turf, Moss	Brick and block	57.7	140	0.219
38	Japanese turf	Water keeping plate	53.0	120	0.259
39	Japanese (korai) turf	Concrete plate	65.7	110	0.239
40	Japanese turf	Water keeping block and recycle brick	58.7	100	0.189
41	Japanese turf	Water keeping block	39.0	280	0.214
43	Japanese turf	Wooden railroad tie	50.5	250	0.208
44	Ophiopogon japonicus	Water keeping block	48.0	250	0.180
45	Japanese (korai) turf	Plastic protector	100.0	250	0.189
46	Japanese (korai) turf, Ophiopogon japonicus, Hedera, Canariensis	Metal and wooden railroad tie	21.2	250	0.165
47	Bermuda grass	Water permeability block	82.6	250	0.205
48	Japanese turf	Water permeability block	54.7	250	0.214
49	Japanese (korai) turf	Bamboo	66.0	250	0.197
50	Japanese turf	Plastic protector	100.0	250	0.206
51	Bermuda grass, Japanese turf, Ryegrasses	Wood and recycle rubber mat	60.5	250	0.213
52	Japanese (korai) turf	Plastic protector	100.0	225	0.198
53	Fescues, Ryegrasses, Bluegrass	Water permeability block	62.8	225	0.231
54	Japanese (korai) turf	Recycle wooden material	38.3	200	0.244
55	Japanese (korai) turf	Wood skin	58.0	200	0.208

[a] Solar reflectance is mean value observed on July 30, August 20 and September 23, 2006.