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Experimental examination of solar reflectance of high-reflectance paint in Japan with natural and accelerated aging

Hideki Takebayashi[a,*], Katsuo Miki[b], Koji Sakai[c], Yasutaka Murata[d], Takafumi Matsumoto[e], Susumu Wada[f], Taizo Aoyama[g]

[a] Kobe University, Japan
[b] Miki Coating Design Office, Japan
[c] Meiji University, Japan
[d] Sojo University, Japan
[e] Nippon Paint Industrial Coating Co., Ltd., Japan
[f] Daikin Industries, Ltd., Japan
[g] Kaneka Corporation, Japan

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ABSTRACT

High-reflectance paint for building envelopes is becoming popular as an urban heat island countermeasure technology for reflecting solar radiation. Solar reflectance, which specifies the performance of the roof coated with high-reflectance paint, is reduced from its initial value in the period soon after coating. Therefore, research on the impact of aging on solar reflectance for the roof coated with high-reflectance paint is required. In this study, field measurements of solar reflectance were carried out on a building rooftop where high-reflectance paint has already been coated. Additionally, solar reflectance for white test plates was measured on building rooftops at three universities. Several accelerated aging tests were reviewed based on the literature, and an accelerated aging test was applied for test plates coated with fluorine-type and aqueous acrylic high-reflectance paints. The reduction begins several months after coating and varies over about 0.10–0.25 several years after coating. It is necessary to secure measurement data immediately after coating for reference purposes. Solar reflectance of the white test plate set on building rooftops at three universities fell by roughly 0.05–0.10 about 50 days after coating. Reduction of spectral solar reflectance is significant in the visible wavelength range. Most of the dirt components are carbon, considered to be derived from organisms and exhaust gas. Both reduction of dirt immediately after coating and coating degradation by chalking over a long period affect the temporal change of solar reflectance. An accelerated test should be developed in order to distinguish between these two effects.

1. Introduction

High-reflectance paint for building envelopes is becoming popular as an urban heat island countermeasure technology for reflecting solar radiation. Berdahl et al. [3] showed clearly that solar reflectance, which specifies the performance of the roof coated with high-reflectance paint, is reduced from its initial value in the period soon after coating. They also reported on the effects of UV exposure, elevated temperatures, moisture, and soiling. Levinson et al. [12] have investigated the effects of soiling and cleaning on the solar spectral reflectance of a light-colored roofing membrane. However, research on the impact of aging on solar reflectance for the roof coated with high-reflectance paint is required.

In Japan, the methods JIS K 5602 [7] (Determination of reflectance of solar radiation by paint film, 2008. The spectral reflectance of the sample is obtained based on the spectral reflectance of the standard white plate. Then, solar reflectance is obtained by multiplying the weight value of standard solar radiation (Column 8 in Table 1 of ISO 9845-1 (1992)) and JIS K 5675 [8] (High solar reflectant paint for roof, 2011. It is determined by the following equation. In the case of $L^* \leqq 40.0$, $\rho_{IR} \geqq 0.40$. In the case of $40.0 < L^* < 80.0$, $\rho_{IR} \geqq L^*$. In the case of $L^* \geqq 80.0$, $\rho_{IR} \geqq 0.80$. Where ρ_{IR} is solar reflectance in near-infrared wavelength (780–2500 nm), L^* is lightness.) have been established for determination of reflectance of solar radiation by paint films and high-solar-reflectance paint for roofs, respectively. The reduction

* Corresponding author at: Department of Architecture, Graduate school of Engineering, Kobe University, Rokkodai, Nada, Kobe 657-8501, Japan. Tel.: +81 78 803 6062; fax: +81 78 803 6062.
E-mail address: thideki@kobe-u.ac.jp (H. Takebayashi).

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Table 1
Field measurements of solar reflectance on a roof coated several years before with high-reflectance paint.

City	Kobe	Osaka	Osaka	Ryuo	Kato	Himeji	Osaka	Koriyama
Form	Flat	Flat	Flat	Folded	Folded	Folded	Flat	Folded
Initial value	0.87	0.73	0.73	0.87	0.87	0.87	0.73	0.87
Years after coating	0.2	0.4	2.5	4	4	4	6	7
Measurement point 1	0.65	0.66	0.67	0.60	0.79	0.64	0.71	0.72
Measurement point 2	0.88	0.65	0.69	0.59	0.74	0.66	0.76	0.71
Measurement point 3	0.86	0.66	0.69	0.61	0.70	0.66	0.72	0.74
Averaged value	0.79	0.66	0.68	0.60	0.74	0.65	0.73	0.72
Initial – averaged value	0.08	0.08	0.05	0.27	0.13	0.22	0.00	0.15
After wiping	–	–	0.67	0.69	0.88	0.71	0.72	0.81
After wiping – point 1	–	–	0.00	0.09	0.09	0.07	0.01	0.09

of solar reflectance for the roof coated with high-reflectance paint a short time after coating has been found in several field measurements [4,5].

In this study, field measurements of solar reflectance were carried out on a building rooftop where high-reflectance paint has already been coated. Additionally, solar reflectance for white test plates was measured on building rooftops at three universities. Several accelerated aging tests were reviewed based on the literature, and an accelerated aging test was applied for test plates coated with fluorine-type and aqueous acrylic high-reflectance paints.

2. Measured variation with age of roof solar reflectance in six Japanese cities

In order to address the real scenario for effects of aging on the solar reflectance of the roof coated with high-reflectance paint, we measured solar reflectance on several building roofs where two kinds of high-reflectance paints were coated several years prior to measurement. Their initial reflectance was measured only in the laboratory according to JIS K 5602 (2008) and could not be measured in the field owing to the constraint imposed by the installation of the paint. Following ASTM E1918A (a pyranometer-based method of measuring solar reflectance, as in [1]) and JSTM J6151 (a method for measuring solar reflectance of flat roofs in the field, as specified by the [10]. Solar reflectance of the target surface after removing the influence of the surrounding is calculated, by using the paranometer and standard plates that solar reflectance is known.), solar reflectance on the target surface was calculated using black and white masking sheets. The masking area was 1200 mm × 1200 mm (specified as more than 1000 mm × 1000 mm in JSTM J6151 (2014)). Objective buildings were located in the vicinity of Osaka and Kobe. All roof surfaces were coated by the high-reflectance paint in the field; consequently, the installation accuracy is unclear. The coating process was as follows: underlying adjustment, undercoating, and top-coating according to the manufacturer's manual. Solar reflectance was measured at three points on each building roof surface. Variation of solar reflectance measured at three points on the building roof was observed due to differences in dirt at each point, influenced by the drainage slope.

Field measurements of solar reflectance on the roof where high-reflectance paint was applied several years earlier are shown in Table 1. The arrangement for solar reflectance field measurements by pyranometer (Kipp & Zonen CNR-1, CM3 ISO-class) set to 50 cm above the target surface with a white masking sheet is shown in Fig. 1. Reduction of solar reflectance is confirmed for samples several months after coating, and varies over about 0.10–0.25 several years after coating, depending on dirt deposition conditions. Solar reflectance after wiping the target surface with a wet cloth is recovered less than 0.10. However, on most surfaces recovery did not reach the initial value. It is considered that the cause is dirt adhering to irregularities in the coated surface. Dirt tended to be concentrated in the valley of the folded roof, but a quantitative evaluation of this has not been performed.

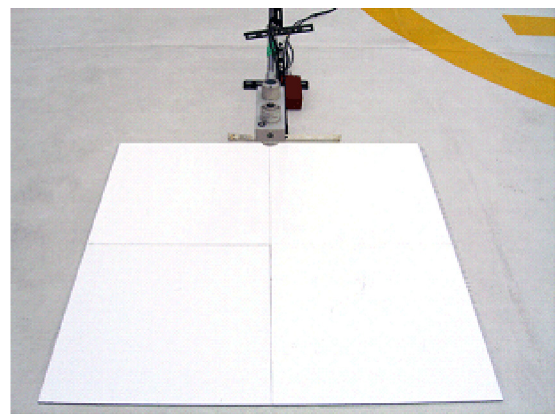

Fig. 1. Field measurement of solar reflectance by pyranometer with a white masking sheet.

Field measurements of solar reflectance were periodically carried out by using pyranometer (Kipp & Zonen CNR-1, CM3 ISO-class) on the roofs of the buildings at Kobe University and Kaneka Osaka factory, where high-reflectance paint was coated on the roof surface. High-reflectance paint was coated on the waterproof sheet of the building roof at Kobe University and on the metal surface of the building roof at Kaneka Osaka factory. Both self-cleaning-type (Kaneka 1) and general-type (Kaneka 2) paints were coated on the roof at Kaneka Osaka factory. Measurements of solar reflectance on the roofs of these buildings are shown in Fig. 2. After coating, measurements were initially carried out almost every week up until 100 days had passed, after which the interval of measurement was

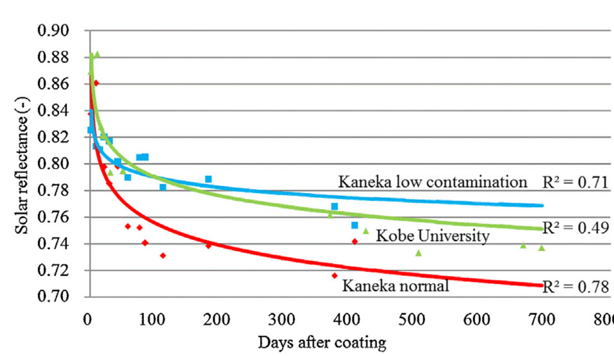

Fig. 2. Periodic solar reflectance field measurement results on the roofs of buildings at Kobe University (green line) and at the Kaneka Osaka factory (blue and red lines).