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Case study

Field measurements of road surface temperature of several asphalt pavements with temperature rise reducing function

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ABSTRACT

In the urban area, the heat island phenomenon and hot nights when the temperature does not fall below 25 °C outdoors are becoming environmental problems. Pavements cover a high percentage of the urban area and largely affect the development of the urban heat island phenomenon. The authors have developed water retaining pavements with several cement-based grouting materials poured into voids of open graded asphalt pavements (porous asphalt pavements) to reduce the surface temperature in the hot summer climate. The cement-based grouting materials consist of cement, ceramic waste powder, and fly ash or natural zeolite. In field measurements conducted in the summer season, all of the water retaining pavements reduced the surface temperature by 10 °C and more, when the porous asphalt pavement reached over 60 °C. Especially, one of the water retaining pavements, which uses ultra-rapid hardening cement, ceramic waste powder, and natural zeolite, reduced the surface temperature by about 20 °C. In this paper, the details of the cement-based grouting materials used in the field tests are described. Also, the field test results on the thermal performance of the water retaining pavements are reported.

1. Introduction

In the urban area, the heat island phenomenon and hot nights when the temperature does not fall below 25 °C outdoors are becoming environmental problems. Pavements cover a high percentage of the urban area and largely affect the development of the urban heat island phenomenon. There are many reports on cooling pavements to improve the thermal conditions in the urban environment and to reduce the energy consumption [10,8,11,1]. As countermeasures in the field of road engineering, water retaining pavements and solar radiation reflective pavements with the surface temperature rise reducing function (STRRF) have been developed. Especially, a water retaining pavement consists of open graded asphalt pavement (porous asphalt pavement: PoAs) and a cement-based material grouted into voids in the PoAs. In general, the cement-based grouting material (CBGM) has a high water absorption of, for example, 40–80% by mass, and the water retaining pavements reduce the surface temperature by 10 °C and more, as compared with a conventional asphalt pavement,

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which reaches over 60 °C in the hot summer climate. Kinouchi et al. [8] have developed an asphalt pavement with high albedo (reflection coefficient) and low brightness using an innovative paint coating. Their field measurements show that the maximum surface temperature of the paint-coated asphalt pavement is lower than that of the conventional asphalt pavement. Synnefa et al. [11] have developed colored thin lay asphalt pavements with higher solar reflectance. The results of their field measurements show that an off-white asphalt sample having the highest solar reflectance has the greatest difference from the conventional asphalt sample.

On the other hand, the infinite use of resources to meet consumer demand in the growing economic will cause continual increase in the industrial waste. Material recycling is an attractive solution in industrial wastes disposal, because the availability of landfill is limited. Ceramic porcelain insulators discarded from electric power industries can also be industrial wastes. The ceramic porcelain insulators are chemically stable and have high quality. Their particles after the crushing process have sharp and knife-like edges, which can be dangerous to use as constructional aggregates. Sano et al. [9] have proposed a recycling method for producing safe and round ceramic waste aggregates through crushing and grinding processes. Subsequently, the authors have investigated the utilization of ceramic waste aggregates for construction materials [2–4]. In the above processes, ceramic waste powder, which is collected by a dust chamber, also constitutes about 20% of the total mass of the ceramic waste.

In this study, the utilization of ceramic waste powder as a part of components in water retaining pavements is investigated and the STRRF of several CBGMs developed is evaluated to measure the surface temperature of pavements through field measurements conducted in the summer season. The CBGMs, which each consist of cement, ceramic waste powder, and fly ash or natural zeolite, are developed to apply for roadways, sidewalks, and parking lots considering the economic efficiency of the materials. In this paper, the thermal performance of the water retaining pavements in fields is reported.

2. Cement-based grouting materials

2.1. Materials and mixtures

The CBGMs developed for the PoAs with the STRRF fundamentally consist of cement (C), ceramic waste powder (CWP) (supplied from The Kanden L&A Co., Ltd., Japan), and fly ash (FA) (supplied from Nippon Steel & Sumikin Slag Products Co., Ltd., Japan) or natural zeolite (NZ) (produced in Izumo, Shimane, Japan). For the CWP, improvement of fluidity and strength gain is expected, and the FA and the NZ are selected as supplementary cementitious materials. The physical and chemical properties of these powder materials are shown in Table 1. Two types of cement (produced by Sumitomo Osaka Cement Co., Ltd., Japan), i.e., normal Portland cement (NPC) and ultra-rapid hardening cement (URHC), were used in this study. The specific gravity and the specific surface area in Blaine of the FA were 2.10 and 3494 cm^2/g. The particle size of the NZ used was less than 200 μm. The specific gravity and the specific surface area in Blaine were 2.30 and 6770 cm^2/g. The URHC and the NZ have creamy color. Each CBGM and the combination of those powder materials are shown in Table 2.

For a water retaining pavement, the required abilities of the CBGM poured into the PoAs are principally fluidity and water absorption. From the previous study [5]. the mixture proportion using the URHC and the FA was determined as C:CWP: FA = 0.5:0.35:0.15 by mass. In the case of using the NZ instead of the FA, the mixture proportion was the same as that. The

Table 1
Physical and chemical properties.

Properties	NPC	URHC	CWP	FA	NZ
Chemical compositions (wt.%)					
SiO_2	20.68	NA	70.90	50.50	70.15
Al_2O_3	5.28	NA	21.10	26.10	12.28
Fe_2O_3	2.91	NA	0.81	–	1.16
CaO	64.25	NA	0.76	2.90	1.98
MgO	1.40	NA	0.24	1.13	0.53
SO_3	2.10	NA	–	–	–
Na_2O	0.28	NA	1.47	–	1.93
K_2O	0.40	NA	3.57	–	2.38
TiO_2	0.28	NA	0.33	–	0.17
P_2O_5	0.25	NA	–	–	–
MnO	0.09	NA	–	–	0.06
SrO	0.06	NA	–	–	–
Fe	–	NA	–	3.57	–
S	–	NA	–	0.18	–
Cl	0.015	NA	–	–	–
Physical properties					
Loss on ignition (%)	1.80	0.80	NA	NA	9.25
Specific gravity	3.15	3.05	2.43	2.10	2.30
Specific surface area in Blaine (cm^2/g)	3360	5230	1810	3494	6770