NEW TECHNOLOGY OF SURFACE TREATMENT TARGETING TEMPERATURE REDUCTION OF ASPHALT PAVEMENT

Tamotsu Yoshinaka & Takemi Inoue
NIPPO CORPORATION Research Laboratory, Tokyo, Japan

ABSTRACT: Reducing asphalt pavement temperature during summer season contributes to mitigate rut generation of the pavement effectively. New surface treatment materials which reflects both sunshine and infrared rays has been developed and applied on existing asphalt pavement surface. The rate of solar reflectance of the pavement is from 30 to 50 % depending on the color of the materials (black to gray). Measured surface temperature of the pavement applied with this type of surface treatment is by utmost 20 degree K lower than that of conventional asphalt pavement. Its maximum temperature reaches 60℃ and more during summer in Japan. The effect of temperature of the pavement is verified by showing a smaller rut depth generation in accelerated actual wheel load test. Rate of rut depth is approximately one third compared to conventional pavement. This surface treatment applied for pedestrian pavement offers comfortable feeling while walking. This result also brings to alleviate heat-island phenomena in urban growth area, where the rate of pavement area in large as about 20%. This paper presents outline of newly developed pavement technology which reduces surface temperature due to prevent pavement from absorbing solar radiation and its reflection properties.

This paper also shows measured pavement temperature of some colored types, durability of the asphalt pavement with and without application of this surface treatment.

KEY WORDS: Asphalt pavement, surface treatment, temperature reduction

1. INTRODUCTION

Color of asphalt pavement used for road and airfield is black. Therefore asphalt pavement has properties of absorbing solar radiation. In Japan surface temperature of the asphalt pavement reaches 60 ℃ and more in summer season. This condition will generate urban environmental problem such as heat-island phenomenon especially in the region which pavement area is high. As a countermeasure for the problem, new technology on preventing high surface temperature of the pavement is now expected. This technology could solve the heat-environmental issues of pedestrian during summer. Heat income and expenditure about a ray of light incident on the pavement and radiation from the pavement is balanced around the surface of the pavement.

Recently two new types of technology have been developed, such as water-retained pavement and solar heat-blocking pavement. Former technology is that open-graded mixture filled with water retainable cement grout evaporates the water absorbed rain water and takes the heat from the pavement itself and then reduces the temperature. However this technique

has an issue that the mechanism keeps only one day and how to provide the necessary water to the pavement [1]. Latter technology is to solve the issues by using a new developed painting technology which can reflect the solar radiation effectively [2]. Solar heat-blocking pavement is a surface treatment type that has high albedo and color selection is free and then reduces the surface temperature of the pavement [3].

In this paper, outline of new developed solar heat-blocking pavement, which the color is dark in order not to hinder the uniformity of existing pavement for traffic, is introduced including its effectiveness of the pavement.

2. DEVELOPMENT OF SOLAR RADIATION REFLECTIVE TECHNOLOGY

2.1 Manuscript

The new type pavement is developed to satisfy both high albedo and low brightness characteristics with application of the innovative surface treatment technology. The function of this pavement is based on the reflectivity for the near infrared rays and low reflectivity for the visible rays (Figure 1). This results in achieving much higher albedo instead of the dark colored pavement surface. The fine hollow ceramic particles are mixed in the treated materials to expect additional effects on reducing thermal conductivity and heating surface treated materials. As the high brightness of road surfaces by applying this material makes lower the visibility of lane markings, the target brightness of this treated materials is set to approximately 40 and under as represented by the L* value (a brightness index).

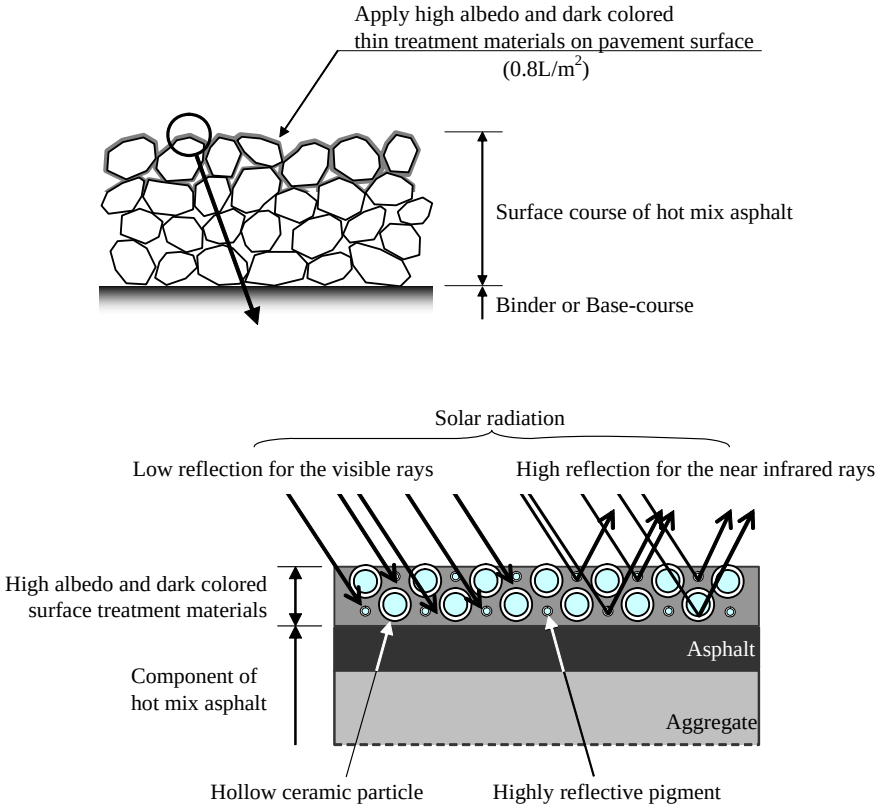


Figure 1: Schematic view of solar heat-blocking pavement

2.2 Solar Radiation Reflective Properties

Solar radiation consists of about 50% visible rays, about 50% near infrared rays and small contents of ultra violet rays. Reflective rate of visible rays decides the color. Reflective rate of solar radiation (albedo) of new surface treatment materials designed brightness of L*40, and conventional painting material with same brightness are shown in Figure 2. Apparent difference of these materials is observed. Conventional painting material has almost the same reflective ratio within whole wavelength. However in case of new surface treatment materials, reflective rate of visible rays in the wavelength is almost the same as that of conventional painting materials, but reflective rate of near infrared rays in the wavelength is very high.

The characteristics explain the temperature reduction of the surface treatment pavement instead of the same brightness. Albedo of straight asphalt used for hot mix asphalt is also shown in the same figure. Straight asphalt has small value of albedo, then has a tendency of high absorption of solar radiation and reaches high temperature. New surface treatment by using the material of above mentioned properties, could change the conventional asphalt pavement into high albedo pavement and reduce the surface temperature.

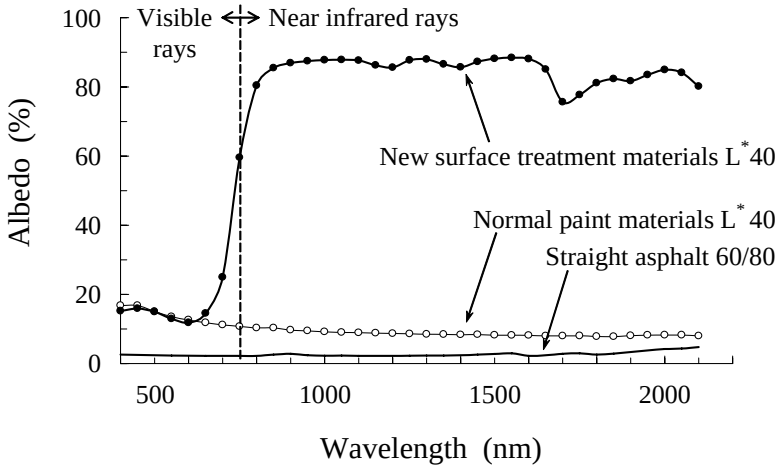


Figure 2: Albedo characteristics of treatment materials
(new surface treatment materials, normal paint materials, straight asphalt)

3. SURFACE TEMPERATURE OF SOLAR HEAT-BLOCKING PAVEMENT

Size of measured specimen is 30 x 30 x 5cm and made of dense graded hot mix asphalt and set on the existing base course. One specimen is applied by this surface treatment (brightness L*40) and the rest is not applied (leaves stand after compaction). Temperature of 0.5cm depth under specimen surface is measured by a thermocouple for 1 week in typical season.

3.1 Summer Season

Weather condition that affects surface temperature of the pavement and surface temperature in summer season is shown in Figure 3 and 4 respectively. Maximum air temperature is approximately 35℃, with no rains. From those figures, surface temperature of conventional pavement reaches 60℃ except third day from starting measurement, however surface temperature of surface treated solar heat-blocking pavement is about 39℃.

The maximum temperature difference between the specimen with and without surface treatment is about 20 degree K. This result shows effective advantage of reducing pavement temperature by applying surface treatment using new materials in summer season when solar radiation induces high pavement temperature. And also good effect of temperature reduction is kept during measurement. This result indicates that the mechanism of temperature reduction is derived from high reflective rate of new materials.

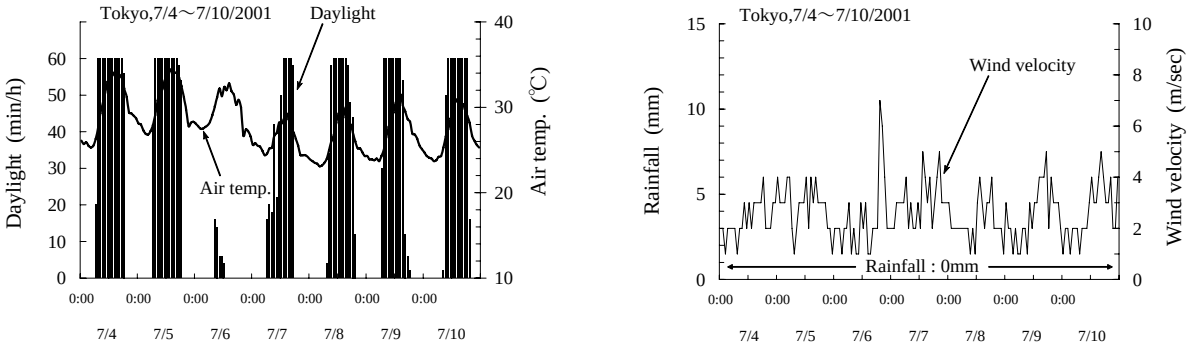


Figure 3: Weather condition

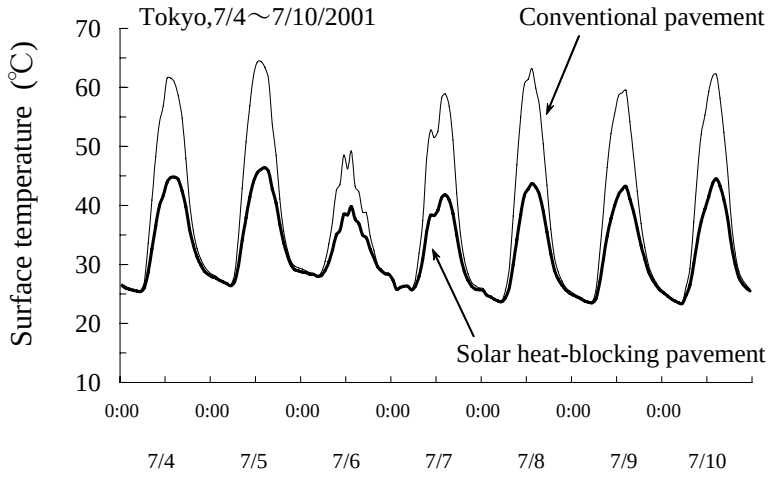


Figure 4: Surface temperature of solar heat-blocking pavement
and conventional pavement (in summer)

3.2 Cloudy and Rainy Season

Effectiveness of the new surface treatment on surface temperature reduction in cloudy and rainy season in conducted by the same method in case of summer season.

Weather condition (air temperature, sunshine duration time, rainfall, wind velocity) and measured surface temperature of the specimens are shown in Figure 5 and 6 respectively. Figure 6 shows that surface temperature difference between with and without application of new surface treatment is 3K in intermittent rainfalls in June 6th and 10K in cloudy day in June 10th.

Surface temperature of the specimen applied with new surface treatment is also kept lower by 3～10K in rainy and cloudy day instead of affecting temperature due to rainfall and air temperature.

This result indicates that surface treated solar heat-blocking pavement demonstrate its ability of reflecting solar radiation, even in rainy and cloudy day.

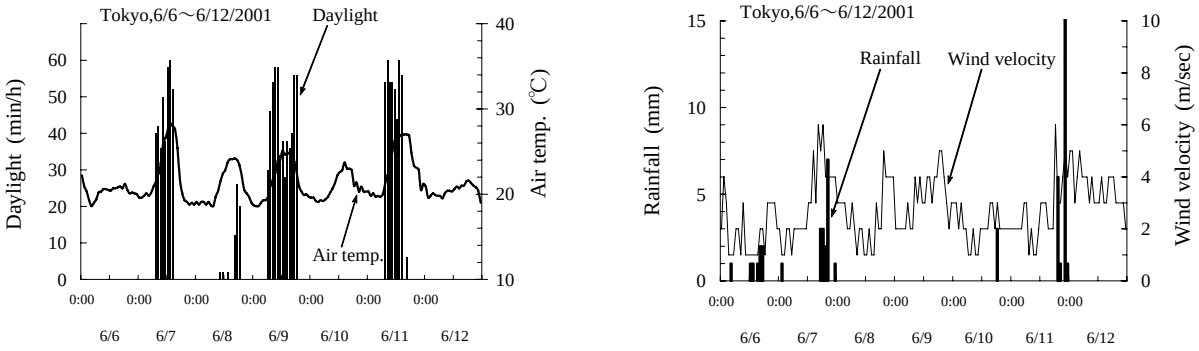


Figure 5: Weather condition

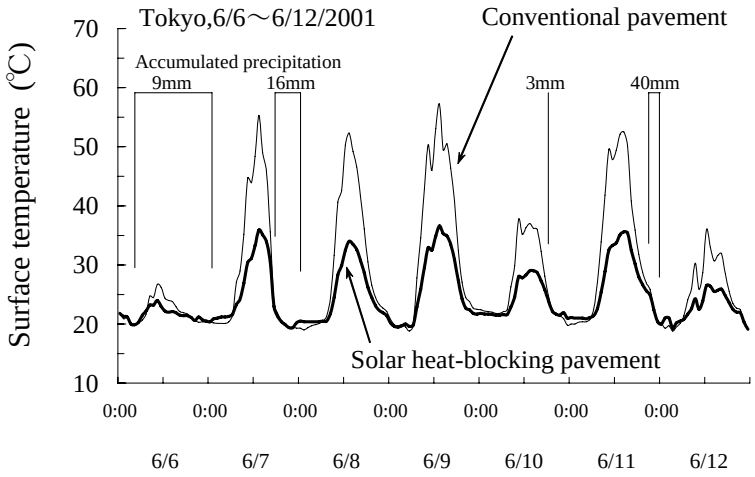


Figure 6: Surface temperature of solar heat-blocking pavement and conventional pavement (in cloudy and rainy)

3.3 Winter Season

There is an anxiety that the new surface treatment will like to generate ice layer on its surface due to the reduction of surface temperature. The same measurement are curried out in winter season (air temperature decrease below 0℃ at night) in order to check this condition. Weather condition and measured surface temperature are shown in Figure 7 and 8 respectively.

In case of that both the surface temperatures in over 0℃ and sunshine exists, specimen applied with new surface treatment materials shows the same tendency of reducing surface temperature. However, this tendency can not be found during night and almost the same surface temperatures are measured on both specimens. And snow removal time is observed that there needs a little bit longer on the new surface treatment specimen. This phenomenon is

attributed to the reflective rate of solar radiation of the treated materials. Surface temperature of solar heat-blocking pavement changes with that of conventional pavement from evening to early morning, it might be thought that there would be no risk to freeze the pavement surface with ease and fast.

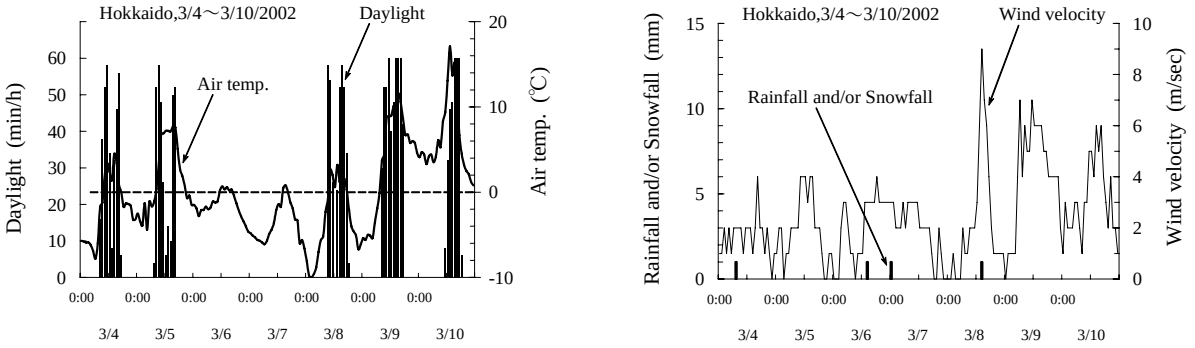


Figure 7: Weather condition

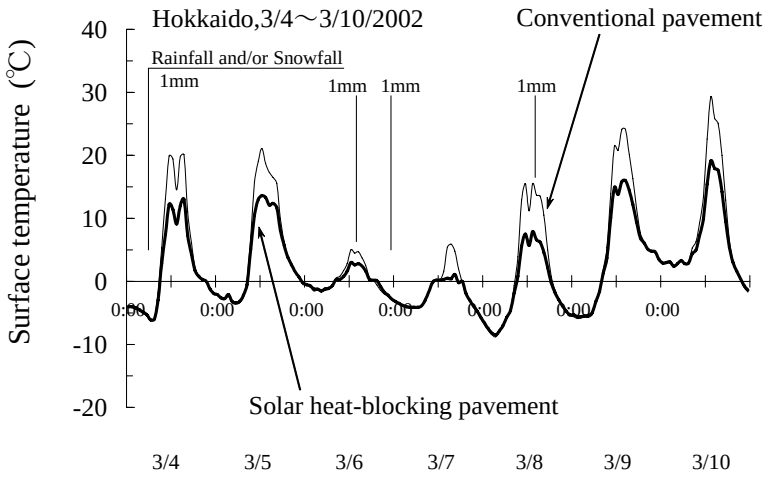


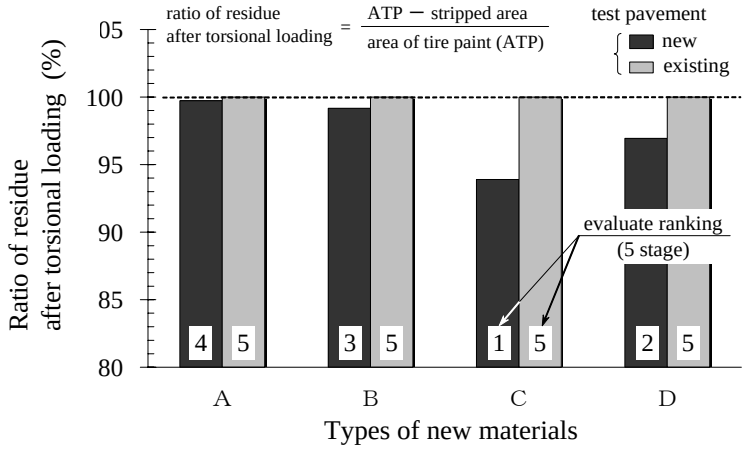
Figure 8: Surface temperature of solar heat-blocking pavement
and conventional pavement (in winter)

4. DURABILITY OF NEW DEVELOPED TECHNOLOGY

4.1 Torsional Resistance

It is necessary for technology to keep a good adhesive proportion to conventional pavement in order to maintain surface temperature reduction. Durability of adhesive proportion is curried out on surface treated pavement by torsional load of front wheel (7.4kN) of commercial van-type car. 4 types of new surface treated materials (variable: applied resin) are applied on 8 test pavement sections which are new and existing pervious pavement. Testing situation and one example of test surface condition are shown in Photos 1 and 2. Torsional load is applied by steering right and then left direction totaled 10 times and evaluated by visual observation according to the criteria shown in Figure 9.

Figure 9 showed that every kind of surface treatment materials has a good adhesive properties (ratio of adhesive strength to initial condition is over 90%). Type A is the best materials in this trials, however, existing pavement whose bitumen coating is off and/or oil proportion is less are preferable for this materials.



evaluate ranking		criteria
excellent	5	no stripping, excellent adhesion
	4	a little stripping, good adhesion
	3	little stripping, fair adhesion
	2	visible stripping, improved adhesion is necessary
worse	1	visible stripping, worse adhesion

Figure 9: Evaluation results on adhesive properties of new surface treatment materials and pavement

Photo 1: Torsion test by car front-wheels

Photo 2: Surface condition of solar heat-blocking pavement after torsion test (type A)

4.2 Weather Resistance of Solar Reflection

Weather resistance of solar reflection of new surface treatment materials is conduced by the method of accelerated ultra violet test (QUV) for 3,000 hours. QUV for 3,000 hours is equal to exposure time of the 12 years and its weather resistance keeps approximately 94% of initial condition (Table 1). In case of actual application, surface treatment materials have been polluted by actual traffic loading and then weather resistance has been recognize by 80～90%

of initial condition, depending on the service life. From these test results, weather resistance of the new surface treatment materials keep good for long duration.

Table 1: Weather resistance of new surface treatment materials

	Test Time (h)	Solar reflective ratio (%)	Ratio of weather resistance (%)	Remarks
QUV	0	51.2	—	Initial condition
	3,000	48.1	93.9	After required exposure

Note: QUV is in conformity to ASTM G-53
Solar reflective ratio is based on JIS A 5759

4.3 Execution of Surface Treatment

Effective execution process of surface treatment in given time is as follows;

- Clean the existing or newly paved surface.
- Spray the new surface treatment materials by about 0.4L/m^2.
- Spray ceramic ball on first sprayed surface.
- Finished spray of the new surface treatment material by about 0.4L/m^2.

Curing time for traffic opening depends on in general a characteristics of resin binder used for surface treatment. Hardening time of the new surface treatment is approximately 15 minutes and curing time is from half to 1 hour depends on weather condition after finished.

4.4 Surface Characteristics

Test pavement conducted in experimental loop yard of Public Works Research Institute shows good result of rut depth by 1/3 of without surface treatment after 150,000 loading of 49kN wheel load [4]. Skid resistance keeps almost the same value 95% as that of first condition. And also, human feelings walking on the pavement are observed that over two thirds of cooler than another finished pavement.

Total area of actual execution of the new surface treatment for taxiway in airport and road (from heavy duty road to pedestrian) pavement has reached 42,000m^2 (51 projects) and above mentioned performance have been recognized in every place.

5. CONCLUSIONS

Following results are derived and confirmed from this study mentioned above;

(1) Reduction of surface temperature with application of new surface treatment is confirmed all the year around, especially in summer season by 20 degree K lower than that of conventional pavement due to preventing of solar radiation especially reflecting abort 50% of near infrared rays.
(2) Reduction of surface temperature effect both little rut depth of road pavement and cool feeling of pedestrian walk. This result might expect the long durability of the pavement.
(3) This type of new surface treatment materials could be applied on every kind of pavement and good performance could be expected in the near future.

The developed technology has to be improved, enhanced, and contributed to lessen the heat island phenomena.

At present mixed type new materials has been developed and overlaid with 5mm thick on the existing pavement in order to get a long durability, and same performance as surface treatment.

Main issue is to evaluate the cost-effectiveness of this technology, then we have to profile the actual data and plan of the survey in the future.

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