Session 5 - Contribution to sustainable development

Paper :
Eco-friendly pavements in urban areas

Author :
Masahide ITO - Japan

Eco-friendly Pavements in Urban Areas

Masahide ITO

Kanazawa River and Highway Office,

Hokuriku Regional Bureau, Ministry of Land, Infrastructure and Transport.

1. Introduction

In late years, a voice to expect mitigating environmental loads of road pavement has risen with a surging interest in environment and diversification of needs as a background. In Japan, we have been actively dealing with environmental issues in its pavement technology development, with a result of an extremely high percentage of recycling, for example. However, further development has been called for, and underway, to cope with new environmental concerns and also to contribute to lessening environmental loads brought about by various sectors other than road pavement.

In this report, the author describes the latest pavement technologies aimed at contributing to the improvement of environment, with some details on “permeable pavement for roadways” and “pavements to reduce the surface temperature”, which are currently attracting much attention in this country.

2. Technical Standards for Pavement

In Japan, pavement is designed based on the Technical Standards for Pavement structures, which were issued by the Ministry of Land, Infrastructure and Transport in 2001. The Standards call for the mitigation of environmental loads imposed by pavement structures, and encourage the use of recycled materials either from old pavement or other industrial byproducts. The only performance index stated in the Standards is “the quantity of draining water”.

3. Pavement Performance Related to Environment

An overview of environment-friendly pavement technologies currently being developed in Japan is shown in Figure 1.

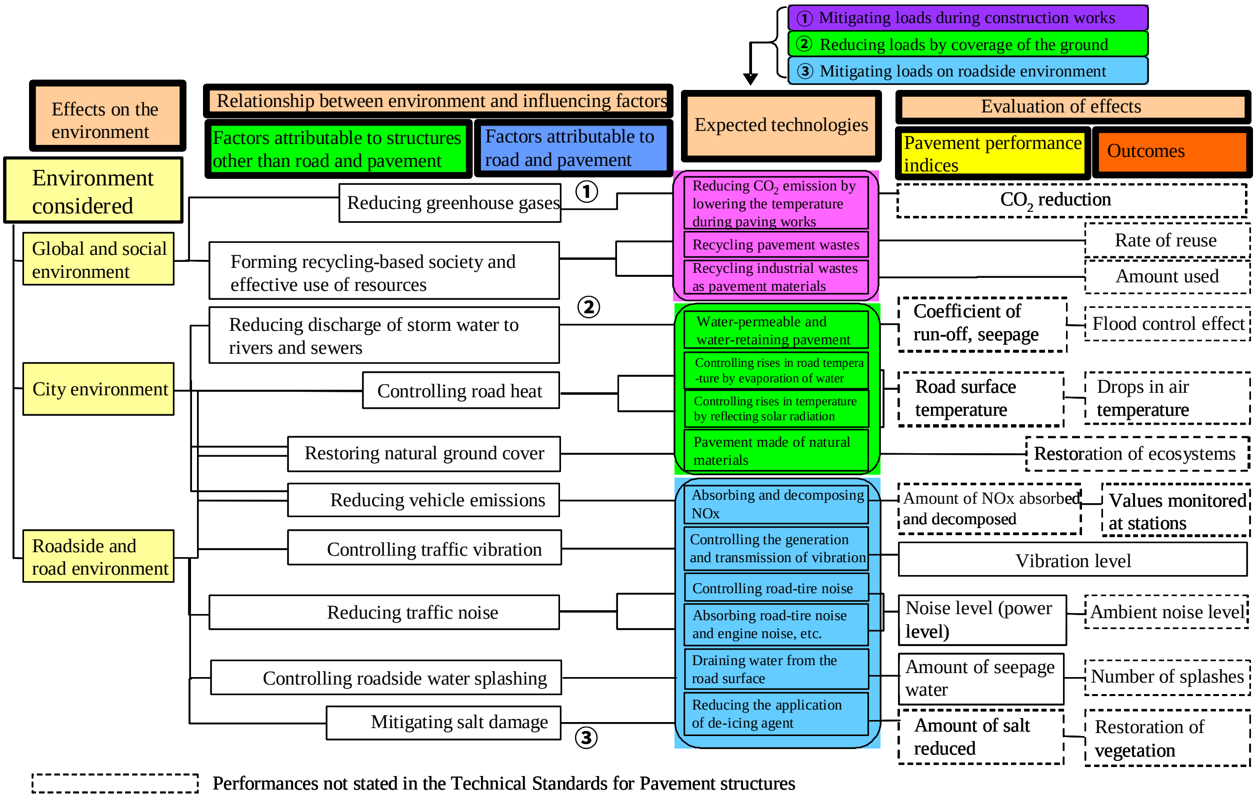


Figure 1 Involvement of pavement performances in environment

4. Current State and Evaluation of Technologies

This section outlines the technologies shown in Figure 1, and evaluates their ability to improve the environment and the issues involved.

4.1 Reducing CO_2 emission

The amount of CO_2 produced during paving works accounts for a small percentage of total CO_2 emission and contributes little to global warming compared to the transport and other industry sectors. Nevertheless, paving uses asphalt, which is a petroleum product, and energy is consumed to heat and mix asphalt in asphalt mixing plants, etc. Therefore, measures are needed to reduce CO_2 emission during paving works. Technologies to reduce CO_2 emission include: 1) cold type pavement, which is mixed and laid unheated, 2) semi hot type pavement, which is produced at temperatures not exceeding 100°C, and 3) asphalt mixing technology at lower temperature, 30°C lower than the temperature during conventional mixing.

These technologies have been recognized to reduce CO_2 emission, but their contributions in mitigating global warming have not been quantified.

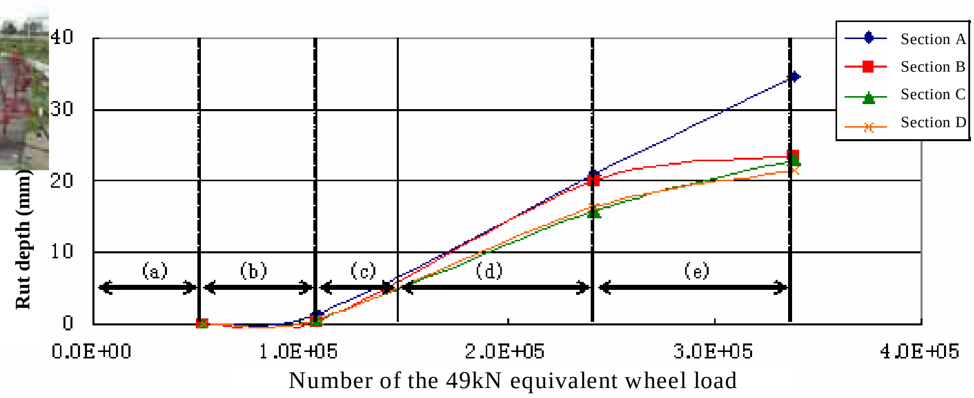
4.2 Recycling

In Japan, 99% of asphalt concrete is recycled (as of fiscal 2002). However, technologies need to be developed and established for recycling modified asphalt pavement, which is used to improve flow resistance, as well as porous asphalt pavement, which is increasingly used to reduce noise and to offer better drainage, and also for repeatedly recycling recycled pavement since the rate of reuse has increased. Durability and other performance factors of recycled pavement are being tested in various fields.

There is also an increasing demand to use incineration ash, molten slag, glass cullet and other industrial byproducts as paving materials mostly due to the lack of capacity of industrial waste disposal sites. To use them for pavement, they must 1) have the required performances as paving materials, 2) be safe to the environment, and 3) be able to be recycled again for pavement.

4.3 Controlling storm water

In 2004, the Law to Control River Floods in Specified Cities was enacted, requiring increases in storm water to be controlled when any facilities, including roads, that inhibits the existing rain water flow in excess of certain amount are constructed. Thus, permeable pavement for roadways needs to be developed.



Relationship between rut depth (OWP) and number of the 49kN equivalent wheel load

Section	(a)	(b)	(c)	(d)	(e)
Type of loading vehicle (number of passes converted by 49 kN / number of vehicles)	3.76	4.90	0.62	13.14	4.13
Season of driving the loading vehicles	Mid December to early January	Early January to end January	Mid February to May	May	Early July to early August
Mean temperature of the section (℃)	6.2	3.5	14.4	20.9	30.1
Mean precipitation of the section (mm/days driven)	1.0	0.0	3.1	5.2	1.9

Figure 2 Evaluating the durability of test pavement and results

Permeable pavement is widely used for pedestrian paths, but has little been laid on roadways except on some test road sections since permeating water was considered to adversely affect the durability of pavement and subgrade. Methods for preserving the durability of pavement and estimating the effects in controlling storm water are being investigated by laboratory as well as full-scale tests at the Public Works Research Institute (Figure 2) and by paving test sections on national highways.

The investigations revealed the following facts and possibilities, based on which the Public Works Research Institute compiled the Design/Construction Manual on Permeable Pavement for Roadways in June 2005:

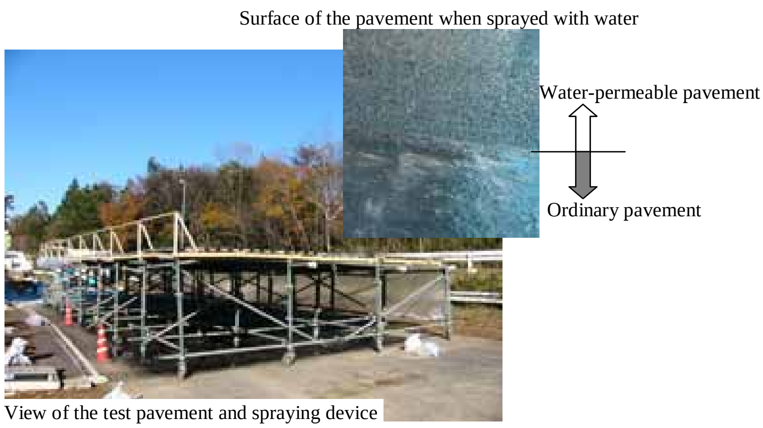
(1) Permeable pavement can be broadly classified into the following two:

a) a pavement through which water permeates to the ground down to the subgrade, and

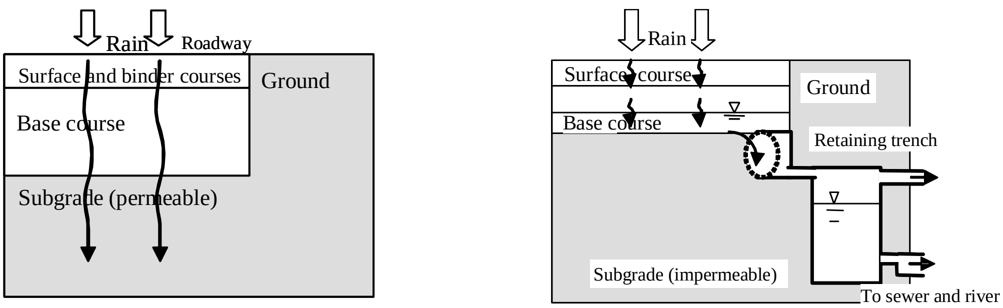
b) a pavement that temporarily stores water and discharges it afterwards.

Of these, pavement should be selected appropriately for the permeability of the ground and traffic conditions (Figure 3).

Photograph 1 Damage by softening of the subgrade



Photograph 2 Spraying test on full-scale water-permeable pavement



Water is discharged directly from the subgrade to the ground.

【When the ground is sandy and permeable】

Water is temporarily stored in pavement and then discharged through trenches, etc.

【When the ground is impermeable】

Figure 3 The conceptual scheme of the type of roadway permeable pavement based on permeability property of the ground

(2) The durability of pavement drops when the subgrade is clayey (Figure 2). This decrease can be prevented by increasing the thickness of the pavement and constructing structures to discharge water from the pavement through the subgrade.

(3) The capacity to discharge storm water from the road surface at various rain intensities can be calculated using a simple method with measured permeability coefficients of the materials (Figure 4).

4.4 Heat controlling technologies

The heat island phenomenon has been observed in many cities around the world, and in Japan the mean air temperature has increased by about 3°C in Tokyo and other large cities for the past 100 years. Aiming to mitigate the heat island phenomenon, technologies to reduce the temperature of pavement are being developed by private companies and tested by municipal governments.

The technologies are classified into the following two pavements by the mechanism used to control heat: 1) water retentive pavement stores water in the pavement and the evaporation heat cools the pavement as the water evaporates,

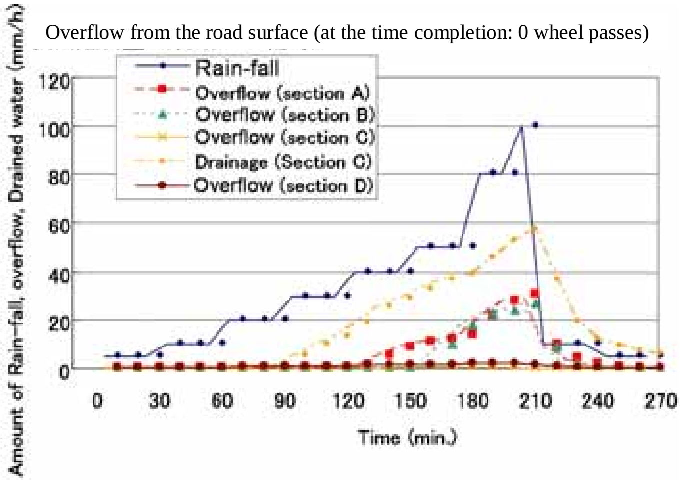


Figure 4 Calculation of storm water control effect

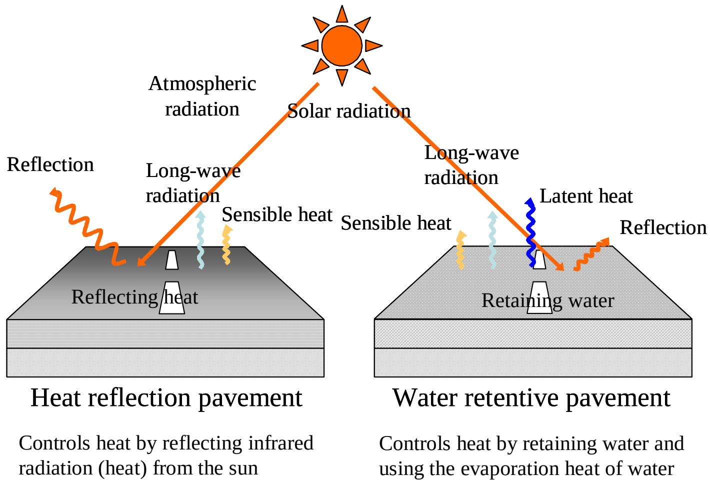


Figure 5 Schematic diagram of heat-controlling pavement

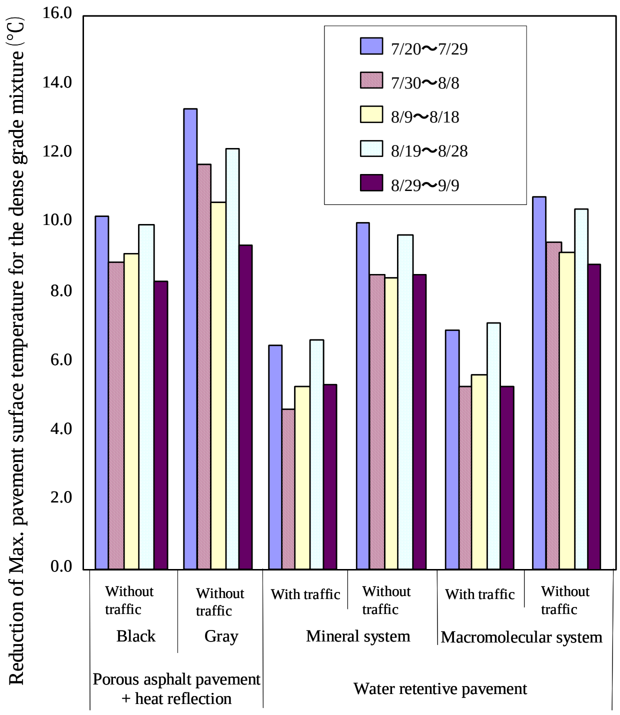


Figure 6 Reduction of Max. pavement surface temperature

and 2) heat reflective pavement has a surface coat of special paint that reflects solar radiation (Figure 5).

Temperatures measured on test pavement sections at the Public Works Research Institute are shown in Figure 6. The effects differed by the time of the year and the types of pavement, but the temperature of the heat controlling pavements were almost 10°C lower than that of conventional pavement and sometimes as much as 12 to 14°C lower.

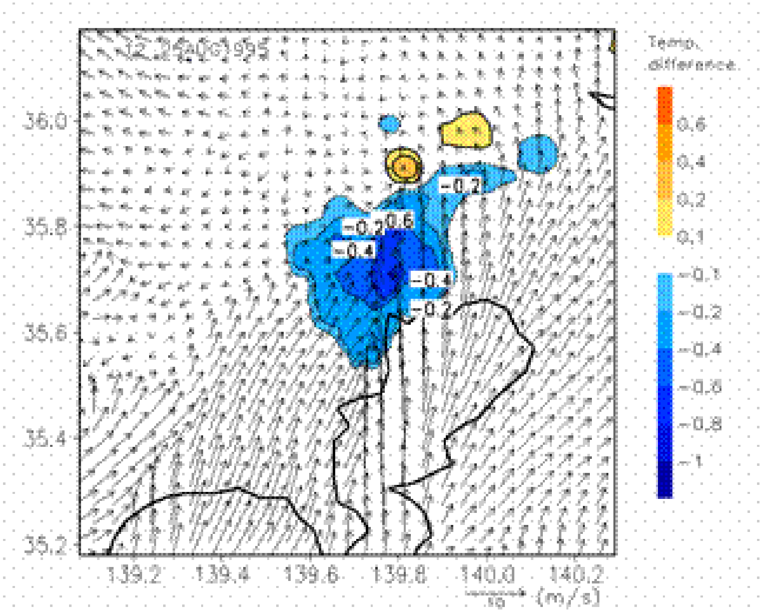


Figure 7 Simulation of mitigating the heat island phenomenon

Figure 7 shows calculated drops in temperature at noon in the summer in Tokyo by assuming that all roadways of the central Tokyo (total area: 621 km^2, pavement area: 114 km^2) were paved with water retentive pavement. In some downtown districts, the temperature drops of about 0.6°C are shown. This effect is almost the same as the temperature reduction by greening 40% (23% at present) of the roof area. Paving the entire road area of 114 km^2 with water retentive pavement would cost at least 196 billion yen annually. Since the durability of the heat controlling effect and its meteorological effects in large areas are not clarified, it is not yet certain whether these very costly technologies are an appropriate countermeasure against the heat island phenomenon.

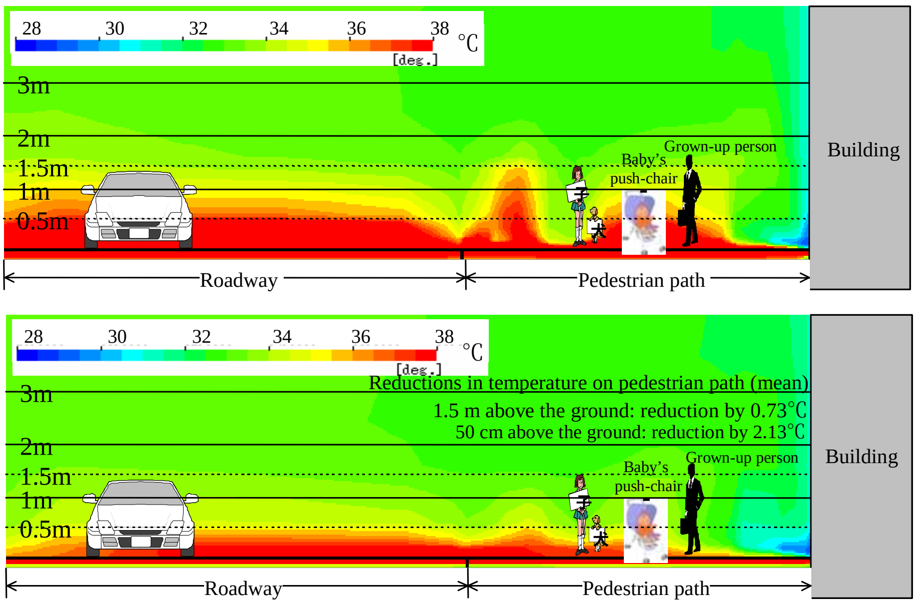


Figure 8 Simulation of improving the heat environment of pedestrian paths

On the other hand, these pavement technologies effectively improve the heat environment for pedestrians and neighborhood. Simulated heat control effects are shown in Figure 8. The pavement reduced the air temperature by 1°C at the height of an adult’s head and 2°C at the height of a child’s head in daytime during the summer. To verify the effect on actual roads, the Ministry of Land, Infrastructure and Transport will start constructing test pavements totaling 100,000 m^2 in various parts of the country in 2005.

4.5 Restoring natural ground cover

A pavement on which plants can grow and another pavement that uses soil are technologies to restore natural ground cover. In the former type, lawn grass is planted on porous concrete blocks, and in the latter type a surface is constructed as such that resembles the natural ground in terms of water seepage, among others, by stabilizing soil with cement. These properties should be more appropriate for parking lots and light-traffic roads than for ordinary roadways.

4.6 Absorbing and decomposing nitrogen oxides

One particular technology aims to remove nitrogen oxides from the atmosphere by fixing titanium oxide, which is a photo catalyst, on the road surface to result in oxidizing and turning them into nitrate ions. The method was reported to be highly effective in a closed space, but the effects have not been clarified on conventional roads. It has neither been quantified the contribution to preventing air pollution nor been clarified the durability of the effect yet. Besides investigating these issues, we also need to compare the effects with those of measures for eliminating pollution sources.

4.7 Controlling generation and transmission of vibration

Vibration can be controlled primarily by constructing smooth road surfaces and also by preventing the transmission of vibration by strengthening soft subgrade and ground. A relatively small-scale and effective measure is vibration reducing pavement.

Several pavement structures are being tested including: 1) special sheets are laid between the surface course and binder course, 2) heavy aggregates are used to increase the weight of the binder course, and 3) rubber plates are installed on the slab structured surface course. One of the disadvantages of these approaches is the high cost, which is almost double that of conventional pavement.

4.8 Reducing tire/road noise and draining surface water

Porous asphalt pavement, which reduces road noise, is widely used today in cities. Methods are now being developed for preventing the deterioration of noise reducing effect and restoring the performance, and materials and structures having higher noise reducing performance are being investigated (use of small particles, coating, or Twin-layers for surface course).

Porous elastic pavement, which consists of rubber chips and urethane resin, is also being investigated to reduce noise even further (the ordinary porous asphalt pavement reduces noise by 3 dB, whereas the porous elastic pavement is expected to reduce noise by 10 dB). The safety against skidding, durability and high cost are issues that need to be addressed.

4.9 Controlling icing

Icing control pavement is expected to improve the roadside environment since it reduces the amount of de-icing agent resulting in lesser roadside salt concentration. However, the effects have not been quantified.

5. Future topics and summary

Topics for developing and promoting pavement technologies that improve the environment are summarized below:

1) Quantifying and organizing the roles of pavement for mitigating environmental loads,

2) Balancing the environment improvement effects with the original roles of pavement,

3) Developing technologies to improve the effects and to reduce the cost (without reducing the original performance of pavement such as resistance against plastic deformation),

4) Establishing methods for evaluating the effects of improving the environment,

5) Identifying the target effects (establishing performance standards),

6) Introducing procurement methods that can appropriately reflect the technological levels of constructors, and

7) Constructing a system for disseminating the technologies.

New pavement technologies are not yet widely used in Japan, but the importance of developing and using pavement technologies to improve the environment is increasingly recognized. Some technologies are being tested in test pavement, and once analyzed, the results will be published.