EXPERIMENTAL STUDY ON THE BOND DESTRUCTION BETWEEEN SNOW/ICE AND ANTI-FREEZING PAVEMENTS, DEPENDING ON PROPERTIES OF SNOW/ICE AND NUMBER OF WHEEL LOAD PASSES

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ABSTRACT

The bond destruction between snow/ice and anti-freezing pavements is mainly assessed quantitatively by the relationships between bare pavement ratio (using computer image processing), the degree of scatter or stripping of snow/ice, the friction coefficient (μ), and the number of wheel load passes. Results are compared with test results from the dense-graded asphalt pavement used as a control pavement. As for the snowpack, the bond-destruction and the increase of friction coefficient (μ) are evaluated on the gum-rolled pavement that has a flexible surface texture under 100～500 passes at -5°C and 5 kN wheel load (200 kPa tire pressure). As a result of tests, the anti-freezing effects of anti-freezing pavements are evaluated and confirmed at -5°C. For the same tests and pavement but at -10°C, increased friction effects were found to be insufficient under the passenger car wheel load. Therefore, it is necessary in the future to develop a more effective hybrid type anti-freezing pavement (such as gum-rolled pavement combined with a deicing chemical in the asphalt mixture) to cause bond-destruction to all of snow/ice surfaces at -10°C.

INTRODUCTION

This study investigates the bond destruction effect and mechanism between snow/ice and anti-freezing pavements by varying the properties of snow/ice and the number of wheel load passes. The experiments are carried out in a large temperature controlled chamber equipped with four lanes of 0.6 m (width) × 10 m (length), in which car-simulation equipment is able to move repeatedly back and forth or to brake under tire-locked conditions on snowpack and ice crust surfaces formed artificially on the various anti-freezing asphalt pavements.

LABORATORY EQUIPMENT

Wheel Tracking Equipment (WTE) and Anti-freezing Pavements

The experiments are carried out in the temperature controlled big chamber equipped with four 0.6 m (width) × 10 m (length) lanes of pavement, in which car-simulated equipment, as seen in Figure 1, is able to move repeatedly back and forth or to brake under the tire-locked condition on snowpack and ice crust surfaces formed artificially on anti-freezing pavements. The temperature of the chamber can be controlled from –30°C to +60°C.

The anti-freezing pavements constructed in four lanes consist of stone mastic asphalt (SMA) mixed with de-icer, a gum-rolled asphalt in which cubes of natural gum(one side length of 15mm) are rolled into the SMA surface, a dense-graded asphalt, a rubber pavement of wasted tire-chip bound with resin, and a porous asphalt (Figure 2).

Figure 1. Wheel Tracking Equipment (WTE)

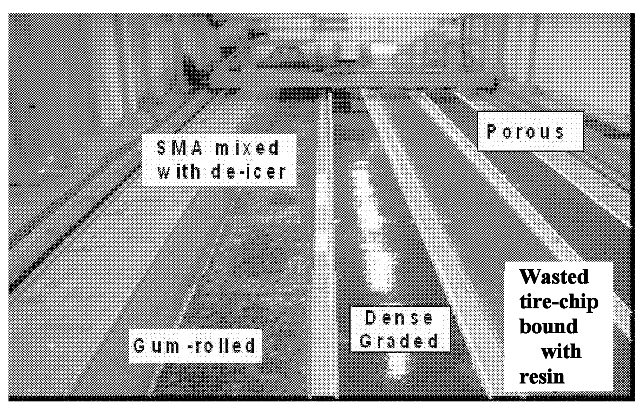

Figure 2. Anti-freezing pavements of various types

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Specification of WTE

(1) moving speed of WTE : 1 ~ 10 km/h (skid resistance test), 1 ~ 5 km/h (repeated wheel tracking test)

(2) wheel load : 1.5 ~ 5 kN, (3) tire: studless tire :165 / 80 R13 , (4) slip ratio (Anti-Brake System): 0 ~ 100 %

MAKING OF SNOWPACK AND ICE CRUST ON THE PAVEMENTS

Snowpack (Test temperatures: -5°C and-10°C)

Snow is applied in three layers on the lanes, water is sprayed on at 0°C, and the surface is compacted by the repetition of WTE so that the density of a normal snowpack (water content 10%) and a hard snowpack (water content 20%) are almost 0.50 g/cm^3 and 0.70 g/cm^3 ,respectively with 2cm thickness, as seen in Figure 3. Each snowpack is then cured at the test temperature for one day.

Ice Crust (Test temperatures: -5°C and -10°C)

An ice crust is formed in 1 mm to 2 mm thickness by spraying a water (0°C) of specified quantity on pavements cooled to the test temperature in advance, as seen in Figure 4..

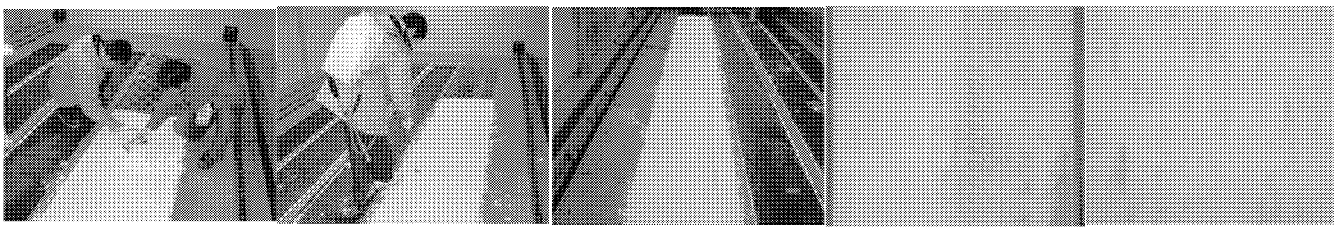


Figure 3. Making procedure of snowpack and, the surface textures of a normal snowpack and a hard snowpack.

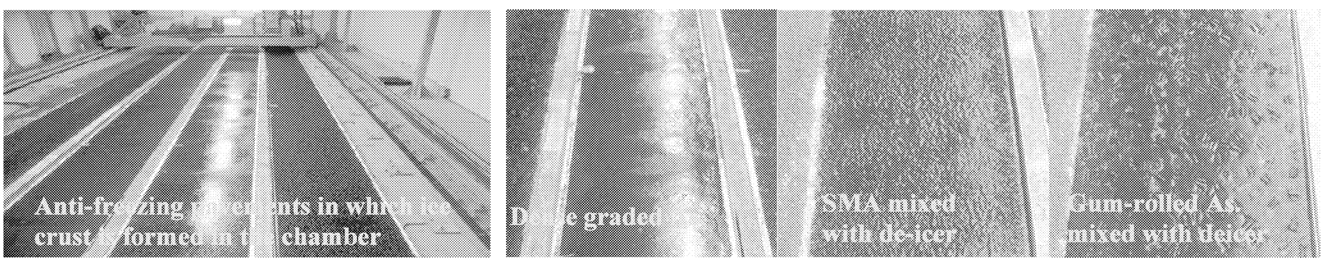


Figure 4. Whole and close-up ice crust conditions formed on anti-freezing pavements and dense graded pavement

CALCULATION OF FRICTION COEFFICIENT AND BARE-PAVEMENT RATIO

Friction Coefficient (μ)

The tire torque is measured by WTE and the average values at the specified speed section are used for the calculation of friction coefficient (μ). The formula for calculation of (μ) and the test conditions are given below. Figure 5 illustrates a typical example of test results.

Calculation of μ

μ: friction coeffficient

Mt: tire torque (m·kN)

r: radius of tire (m)

$$\mu = \frac{Mt}{r \times F}$$

Test conditions

(1) Temperature: -5°C and -10°C,
(2) Wheel load: 5 kN, (3) Speed: 10km/h,
(4)Slip ratio: 100% (tire locked)

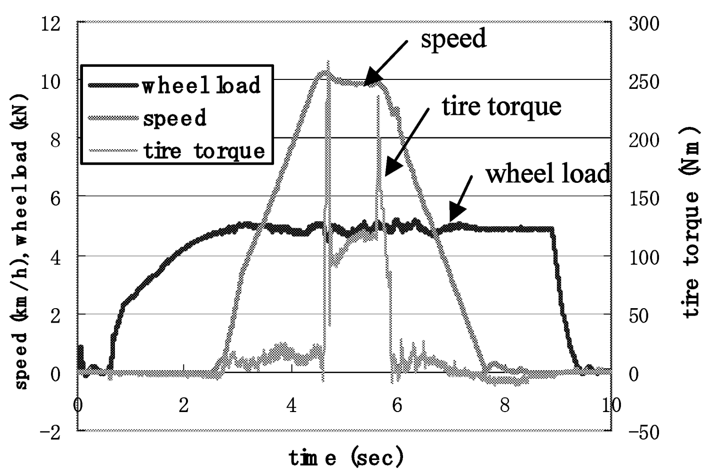


Figure 5. Illustration of the typical test results

Bare Pavement Ratio (BPR)

The snow/ice formed on anti-freezing pavements is scattered and stripped by the multiple effects of physical and chemical actions under the repetition of wheel load, and the ratio of bare pavement portion gradually increases as the test progresses. In order to quantify the effects, the snowpack surface condition photographs taken by digital camera are image processed by a binarization (snow/ice: white color, bare portion: black color) using threshold selection, as seen in the following formula. But since this method cannot be used for the ice surfaces due to a transparency of ice, the effect is assessed by a visual observation.

Calculation of BPR

N1=total number of pixels in image analysis of observed section

N2=number of pixels image-processed as black by binarization

$$BPR(\%) = \frac{N2}{N1} \times 100$$

TEST RESULTS

The skid resistance tests and wheel tracking tests (by moving WTE repeatedly back and forth) are carried out to investigate the anti-freezing effects of the anti-freezing pavements. As for the hard pack snowpack surface conditions, both (μ) and BPR can be assessed quantitatively, but ice crust conditions, (μ), only can be assessed quantitatively, and BPR is roughly assessed by a visual observation of digital images, because image processing by a binarization is impossible due to the transparent property of the ice crust.

Hard Snowpack Conditions

As shown in Figures 6 and 7, BPR and friction coefficient of gum-rolled and SMA show higher values compared to dense graded, and the both values increase depending on the increase of wheel load pass at -5°C. At -10°C, these effects are also recognized to some extent for the anti-freezing pavements, but BPR of dense graded is always 0%, regardless of the increase of wheel load passes. Therefore, the anti-freezing effects of anti-freezing pavements are recognized, but the effects are not always sufficient at -10°C in the cold temperature range.

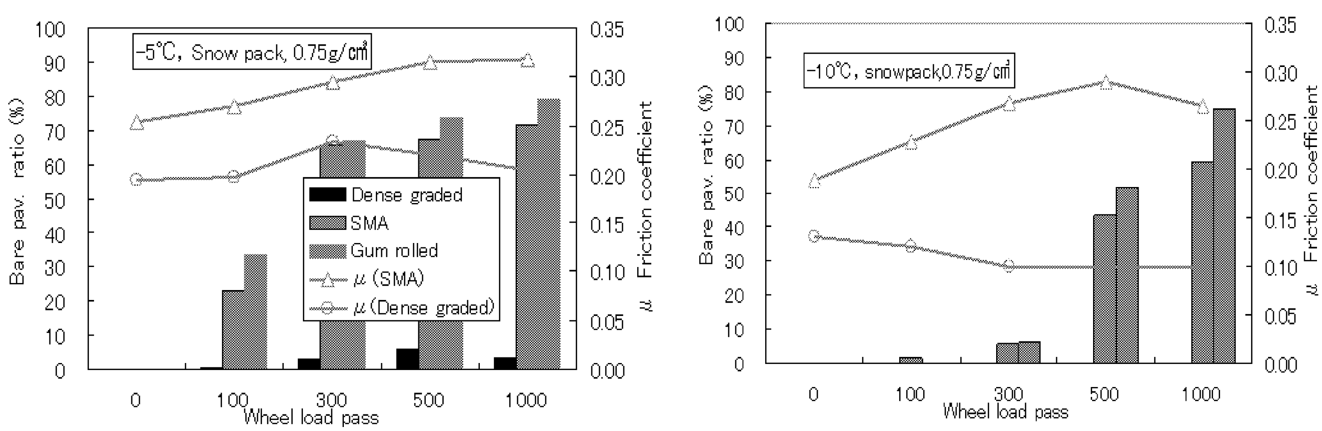


Figure 6. Changes of friction coefficient and BPR depending on the number of wheel load pass at -5°C and -10°C on dense-graded asphalt and anti-freezing pavements (SMA and gum rolled asphalt pavement)

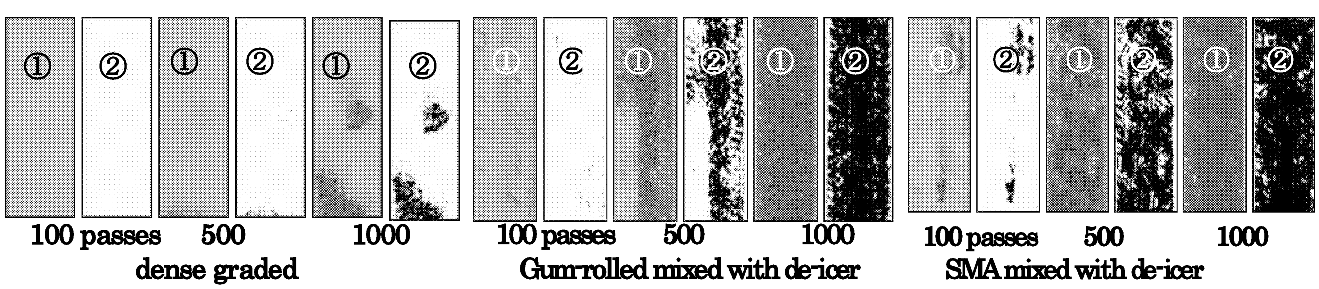
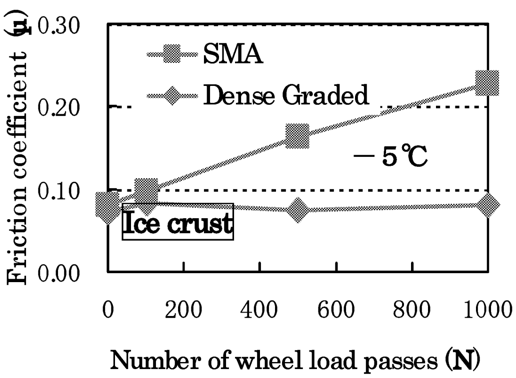


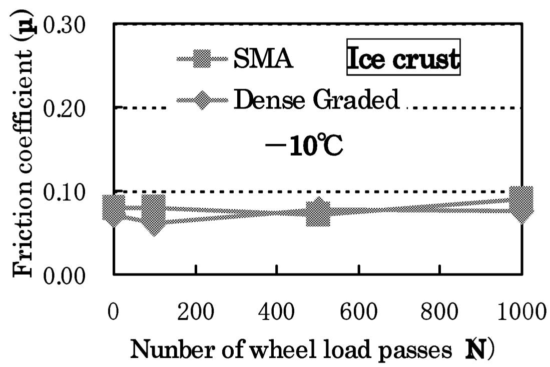
Figure 7. Snowpack surface images of before ①(real image) & after ②an image processing by binarization.

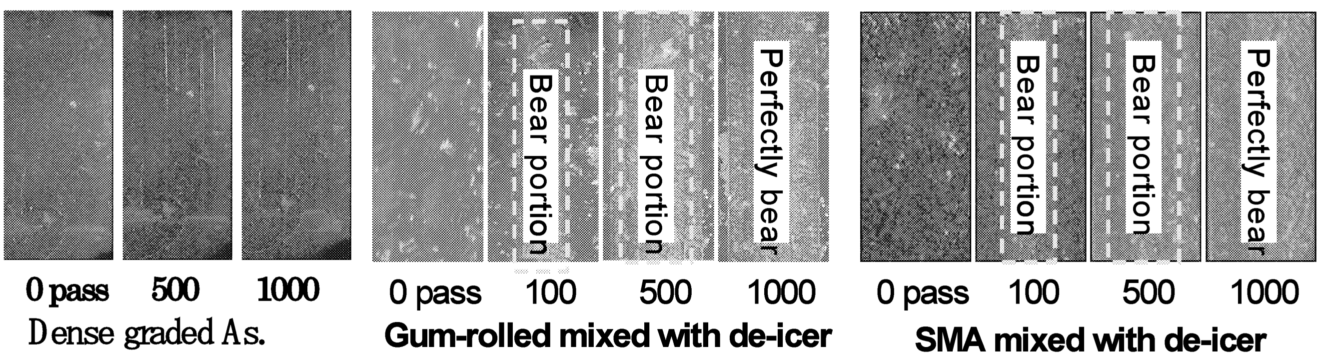
Ice Crust Conditions

Figure 8 shows changes of friction coefficient of the ice crust (1mm thickness) formed on dense-graded asphalt and SMA, depending on the number of wheel load passes. SMA has an effect on the anti-freeing pavement at -5°C, comparing with dense graded asphalt, but no effect at -10°C. This effect is caused by formation of a hard bond between the ice crust and SMA, and very little elusion of de-icer from the SMA mixture at -10°.

Figure 9 shows that dense-graded asphalt keeps the transparent ice crust surfaced conditions, regardless of the increase of wheel load passes, and on the other hand, SMA shows an increases of bare portion ratio by a scatter or stripping of ice crust, depending on the increase of wheel load passes at -5°C.







CONCLUSIONS

The bond-destruction between snowpack /ice crust and anti-freezing pavements are recognized, due to the anti-freezing effects of the hybrid properties (flexible gum cubes and de-icer) of gum-rolled pavement and SMA added with de-icing chemical into the asphalt mixture at -5°C. However, at -10°C, anti-freezing pavements are not always sufficiently effective. Further study is needed because it is necessary to develop the anti-freezing pavements which can generate the anti-freezing effects in the colder temperature range.

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